UNIVERSITY OF KWAZULU NATAL

CLIMATE CHANGE AND VARIABILITY IMPACTS ON CROP PRODUCTION IN THE LOW POTENTIAL SMALLHOLDER FARMING REGIONS OF ZIMBABWE

OBERT JIRI

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CLIMATE CHANGE AND VARIABILITY IMPACTS ON CROP PRODUCTION IN THE LOW POTENTIAL SMALLHOLDER FARMING REGIONS OF ZIMBABWE

by

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PREFACE

The research contained in this thesis was completed while based in the discipline of Crop Science, School of Agricultural, Earth and Environmental Sciences of the College of Agriculture, Engineering and Science, University of KwaZulu Natal, Pietermaritzburg Campus, South Africa. The research was supported by the National Research Foundation of South Africa.

The content of this work has not been submitted in any form to any other university and, except where the work of others is acknowledged in the text, the results reported are due to investigations by the candidate.

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Signed: Professor Paramu Mafongoya (Main supervisor)

Date: …………………………………………………….

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Signed: Dr Pauline Chivenge (co-supervisor)

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DECLARATION

I, Obert Jiri, declare that:

i. The research reported in this thesis, except where otherwise indicated or acknowledged, is my original work;
ii. The thesis has not been submitted in full or in part for any degree for examination at any other university;
iii. This dissertation does not contain other peoples' data, pictures, graphs or other information unless specifically acknowledged as being sourced from other persons;
iv. This dissertation does not contain other persons' writing unless specifically acknowledged as being sourced from other researchers. Where other written sources have been quoted, then
    a. their words have been re-written but the general information attributed to them has been referenced;
    b. where their exact words have been used, their words have been placed inside quotation marks, and referenced;
v. Where I have used materials for which publications followed, I have indicated in detail, my role in the work;
vi. This dissertation is primarily a collection of materials prepared by myself, published as journal articles or presented as a poster and oral presentation at conferences. In some cases additional information has been included;
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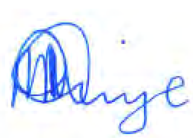
Obert Jiri____

Date___________________________________

As research supervisor I agree to submission of this thesis for examination

Professor P. Mafongoya (Main supervisor) ____

Date______________________



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Signed: Dr Pauline Chivenge (co-supervisor)

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ABSTRACT

Climate change and variability is one of the most serious global problems affecting many sectors in the world. It is considered to be one of the most serious threats to sustainable development with adverse impact on environment, human health, food security, economic activities, natural resources and physical infrastructure. Southern Africa is one of the most vulnerable regions to climate change in the world, particularly because of widespread poverty, recurrent droughts, inequitable land distribution, over-dependence on rain-fed agriculture and low adaptive capacity. Yet rural farmers in southern Africa have managed to survive the vagaries of climate change over the years. The central argument in this study was that coping and adaptation strategies to climate change by local smallholder farming communities in Zimbabwe who traditionally relied on indigenous knowledge systems are at risk and less effective because the use of indigenous knowledge systems is becoming unreliable due to climate change and variability.

The main objective of this study was to identify local smallholder farmers' perceptions to climate change and variability and the influence of indigenous knowledge systems in deciding and adopting coping and adaptation strategies. This study used a combination of participatory and field data collection tools in Chiredzi District, one of the areas affected by climate change impacts in Zimbabwe. Household surveys, focus group discussions and key informant interviews were done in selected wards in the district. Field trials were done to identify climate smart cropping options to assist farmers in coping and adapting to climate change and variability.

The results indicate that farmers use a variety of local indicators for weather forecasting and climate prediction, for adapting to climate change and variability. Integrating indigenous knowledge systems with climate scientists' efforts can contribute to effective on-farm adaptation initiatives. One objective of this research was to identify IKS used by farmers to predict seasonal weather patterns, and the subsequent adaptation strategies. The information was collected using focus group discussions, household survey, and ethnographic interviews. Most farmers (72.2%) indicated that low rainfall is the major limitation to agricultural production. Without reliable local scientific weather forecasts the farmers use tree phenology, animal behaviour and atmospheric circulation as sources of local knowledge to predict the onset and quality of the season. These

forecasts are then used for designing crop choices, planting dates and agronomic practices. Study results obtained show that the use of IKS in local farming communities is an effective way of building coping and adaptation strategies. The results revealed that IKS are being eroded and becoming less accurate in seasonal weather prediction. Therefore, future studies on IKS should use multiple methods that combine indigenous knowledge and scientific weather data in order to obtain more complete and accurate information for local area season quality prediction.

Another study objective was to examine farmer perceptions on climate variability, current adaptive strategies and establish factors influencing smallholder farmers' adaptation to climate change. The results showed that farmers perceived that there has been a decrease in annual rainfall and an increase in average temperatures. A linear trend analysis of rainfall and temperature data from 1980 to 2011 corroborated the farmers' perceptions. Farmers' adaptation options included adjusting planting dates and crop diversification. Off-farm income has reduced the dependence of the farmers on agriculture. A multinomial regression analysis showed that socio-economic factors such as gender, age, number of cattle owned, land size and average crop yields influenced farmer adaptation strategies. We conclude that although farmers are diverse in their socio-economic attributes, they exhibit homogeneous perceptions on changes in climate, which are consistent with observations of empirical climate data. These perceptions help to shape smallholder farmer coping and adaptation strategies.

The variability of climate demands the use of a variety of agronomic strategies and crop choices in order to reduce vulnerability and increase resilience and adaptive capacity to climate change and variability. Traditional drought tolerant crops such as sorghum are often chosen when drought seasons are anticipated. However, there are certain crops, originating elsewhere, that could help the smallholder farmers increase diversity of crops that can be grown in changed climates. One such crop is tepary bean (*Phaseolus acutifolias*). Resource poor farmers, affected by drought effects of climate change, can adopt climate smart crops to achieve food, nutritional and heath security from combinations of cereals and legumes.

This study revealed that these rural farmers are highly vulnerable and resilient, largely using indigenous knowledge systems to cope and adapt to climate change. Availability and access to scientific weather information to make cropping and other decisions at the local level remain key issues to usage of climatic data by rural farmers. One the other hand, indigenous knowledge is what they have been using but is also becoming unreliable due to climate change, increasing vulnerability and demanding more resilience. Integration of indigenous knowledge and scientific seasonal forecast seems to be a key possible thrust to reduce vulnerability, enhance resilience of rural farmers and increase their adaptive capacity.

This study concludes that farmers can use indigenous knowledge systems to make adaptation decisions. However, there is need to integrate indigenous knowledge systems and scientific knowledge to reduce vulnerability and increase adaptive capacity of smallholder farmers. Climate smart crops provide a useful option for farmers affected by climate change and variability to improve food and nutritional security and livelihoods.

CHAPTER 1

INTRODUCTION

1.1 Rationale of the study

The impacts of climate change and variability will require management at different levels, namely, mitigation strategies adopted by governments and environmental bodies (specifically to address greenhouse gas emissions) (Vicente-Serrano et al., 2012), increasing adaptive capacity of smallholder farmers, diversifying coping mechanisms and improving the reliability of information for managing climate risks (Stringer et al., 2010).

Although substantial research has been undertaken to improve the understanding of complex and interwoven spheres of climate change, there are significant knowledge gaps regarding the "understanding of impacts likely to result from significant changes to present patterns of climate" (Brassard et al., 2008; Fiebig-wittmaack et al., 2011). Knowledge gaps continue to exist at the level of impact analysis despite a growing number of country-level case studies (Smith & Tol, 1998). Knowledge on local impacts is considered to be uneven and incomplete. This is the case because the bulk of research funding and human resources has been channeled towards developing and improving models of atmospheric climate change and this has deflected attention away from research on crop production and socio-economic impacts (Lobell et al., 2008).

Large scale farmers have several practices that help them overcome the vagaries of the harsh environment and allow them to sustain their livelihoods and actively manage their environment (Nhemachena & Hassan, 2010). The situation is different and more precarious for small-scale farmers who have to earn their livelihoods from subsistence farming but lack adaptive capacity (Speranza, 2010; Stringer et al., 2012). Given these scenarios, how do the rural poor farmers cope with the immediate challenges of climate variability and adapt their farming systems to future threats of further climate change?

There has been extensive research on the impacts of climate change in Africa, but little has been done on the impacts on agriculture in Zimbabwe (Mano & Nhemachena, 2007). This provides a context for this study to investigate the impacts of climate change on agriculture in Zimbabwe, considering that agriculture remains the backbone of the country's economy. The agricultural sector contributes about 17% to the country's Gross Domestic Product (GDP) (FAO, 2009).

Agriculture is also an important source of raw materials, providing about 60% of raw materials for the manufacturing sector in the country (Veronica Makuvaro & Crimp, 2014). Drought years that are depicted by negative rainfall deviation correspond with the declining and low growth rate in GDP contribution from the agricultural sector, implying that rainfall patterns have a significant effect on this contribution over the years. Since 1901, 51.4% of the seasons had less than the long-term average rainfall. Six warmest years on record for Zimbabwe have occurred since 1987 and there have been eleven drought seasons since 1990, causing massive crop yield losses (Met. Department, November 2011). During these drought years temperature increased and the rainfall was poor, and this had a significant effect on agricultural performance and hence the growth rate of GDP contribution from the sector (Mano & Nhemachena, 2007).

1.2 Conceptual framework

Figure 1.1 outlines the conceptual framework of this study. It is pinned on the critical role that IKS can play in farmers' perception and understanding climate change and variability. It also shows the need for adaptation measures that can influence increase resilience and improve livelihoods. The use of IKS to understand climate change and variability should ultimately lead to decrease in vulnerability and, if IKS is integrated with scientific knowledge, increase adaptive capacity.

Literature documents that humankind has struggled to secure livelihoods by making use of accumulated experiences and knowledge. This battle is still continuing but modern sciences have succeeded to some extent in making some adjustments that enabled man to control his surrounding environment. Warren (1991) described indigenous knowledge (IKS) as: "local knowledge that is unique to a given culture or society. It contrasts with international knowledge system generated by universities, research institutions and private firms. It is the basis for local level decision making in agriculture, health care, food preparation, education, natural-resources management and a host of other activities in rural communities". Flavier et al (1995) put IKS in the following context "Indigenous knowledge is the information base for a society, which facilitates communication and decision-making. Indigenous information systems are dynamic and are continually influenced by internal creativity and experimentation as well as by contact with external systems". The UNESCO and Netherlands Organization for International Cooperation in Higher Education have made their contribution to the definition of IKS as follows: "local and IKS refer to understanding skills and philosophies developed by societies with long histories of interaction with their natural surroundings. For rural indigenous people, IKS informs decision-making about fundamental aspects of day to day life." Van der Velden (2013) treats traditional knowledge, indigenous knowledge and local knowledge as synonymous terms and generally refer to knowledge system embedded in the cultural traditions of regional, indigenous or local communities. UNESCO and the Netherlands Organization for International Cooperation in Higher Education have summarized the main characteristics of IKS as follows:

- Locally bound, indigenous to specific area;
- Culture-and-context-specific;
- Non-formal knowledge, orally transmitted and generally not documented;
- Dynamic and adaptive; and
- Holistic in nature and closely related to survival and subsistence for many people worldwide.

Recognition of the significance of IKS for climate change has only begun to emerge at the international level in the last few years. The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), published in 2007, triggered an enhanced focus climate change adaptation. The shift towards adaptation has been accompanied by an increase in the attention paid to impacts and responses at the national, subnational and local levels, including an increasing appreciation of the observations and actions of local communities that are rooted in IKS.

In analysing available practices and tools relevant to IKS for adaptation, it is important to distinguish between the tools that focus mainly on vulnerability and impact and those that address adaptation. Some ascribe to adaptation a character of “change of state” (Adger, 1996). The emphasis on a change of state in order to reduce vulnerability has certain implications for how IKS is perceived by designers and users of various tools. If transformation underpins the objectives of adaptation action, then, for many local communities, adaptation action may run the risk of undermining their adaptive capacity rather than reinforcing their resilience. That risk is further magnified if such knowledge is perceived as only ‘traditional’, which is subject to limits, especially in changing environments.

Some of the tools make explicit reference to IKS and report that they focus on local perceptions and integrate local knowledge. They include: (a) Climate Vulnerability and Capacity Analysis (CVCA), a tool developed by CARE to prioritize "local knowledge on climate risk and adaptation strategies in the data gathering and analysis process" (Dazé, Ambrose and Ehrhart, 2009), and (b) From Vulnerability to Resilience, a tool designed by Practical Action as a framework for analysis and action to reduce vulnerability and strengthen the resilience of individuals, households and communities (Pasteur, 2011).

There is now a growing awareness that IKS has significant contributions to make within the climate change adaptation process, from observation and assessment to planning and implementation. This entire area of work, however, is new and only beginning to become the focus of dedicated efforts. New, both because climate change adaptation itself is a rapidly developing field of theories and practice, and also because the articulation of IKS and adaptation was only initiated in the last decade and only began in earnest in the last five years. For that reason, the domain of IKS and climate change adaptation, even though it holds great promise, requires as yet considerable investigation and experimentation.

Owing to the emerging nature of the area of work, major gaps persist and need to be addressed in order to benefit from the added value of bringing IKS into climate change adaptation processes. The initial development of guidelines on the mobilization of IKS across all components of adaptation could provide decision makers and practitioners with modalities and tools for linking IKS with scientific knowledge and using IKS in adaptation decision-making, recognizing the role of relevant policies and best practices. With the increased attention paid to resilience in climate change adaptation initiatives, there is a need for the development of frameworks for resilience assessments and the development of indicators. The frameworks should be explicitly IKS sensitive.

While there is general agreement on the importance of IKS and its relevance to understanding how local communities are affected by and adapt to climate change, it is a newly emerging focus area of research and policy. While there is recognition of the role of IKS in adaptation, its role is mainly concentrated in the early stages of the adaptation process, primarily observation and assessment. More understanding of the nature of IKS itself, and how it interlinks with climate change impacts and adaptation, needs to be developed before appropriate approaches and tools can be strengthened. A special challenge for most development efforts is the need for robust information systems, for planning as well as for monitoring and evaluating adaptation. However, information systems are generally weak in terms of disaggregated, timely and scale-relevant data. This has a clear implication for any planning and monitoring of the use of IKS climate change adaptation initiatives.

Climate change will affect rainfall, temperature and water availability for agriculture in vulnerable areas and this will undermine efforts to cut rural poverty. Changes in growing seasons can be adapted to by redeploying existing improved crop varieties that can cope with a wide range of climatic conditions. Short duration crop varieties which can escape terminal drought at later stages of growth can be adopted. What is needed now is a better understanding of the physiological mechanisms underlying heat tolerance such that more effective screening techniques for desired traits can be developed; wider gene pools to develop climate-smart crops should also be identified. However, lack of information can be a barrier to better climate change adaptation. Many smallholder farmers can benefit from the existing drought resistant climate smart crops. Many farmers prefer the use of indigenous grains such as millets and sorghums that are more drought - resistant than maize and also produce high yields with very little rain. Farmers also prefer specific crop varieties for drought seasons, such as an indigenous finger millet variety as it ripens fast, and an early maturing cowpea *(Vigna unguiculata)* variety. Generally, in areas with little moisture, farmers prefer drought - tolerant crops (like *Cajanus cajan*, sweet potato, cassava, millet, and sorghum), and management techniques emphasize soil cover (such as mulching) to reduce moisture evaporation and soil runoff. These varieties that exhibit high genetic variability have a huge untapped potential to be grown in many marginal environments of Africa and elsewhere threatened by climate change. These examples are of great significance because they help the resource - poor farmers living in marginal environments, providing the basis for adaptive natural resource management strategies that provides the opportunity for diversification of cropping systems which lead to greater stability and ecological resiliency under climatic extremes.

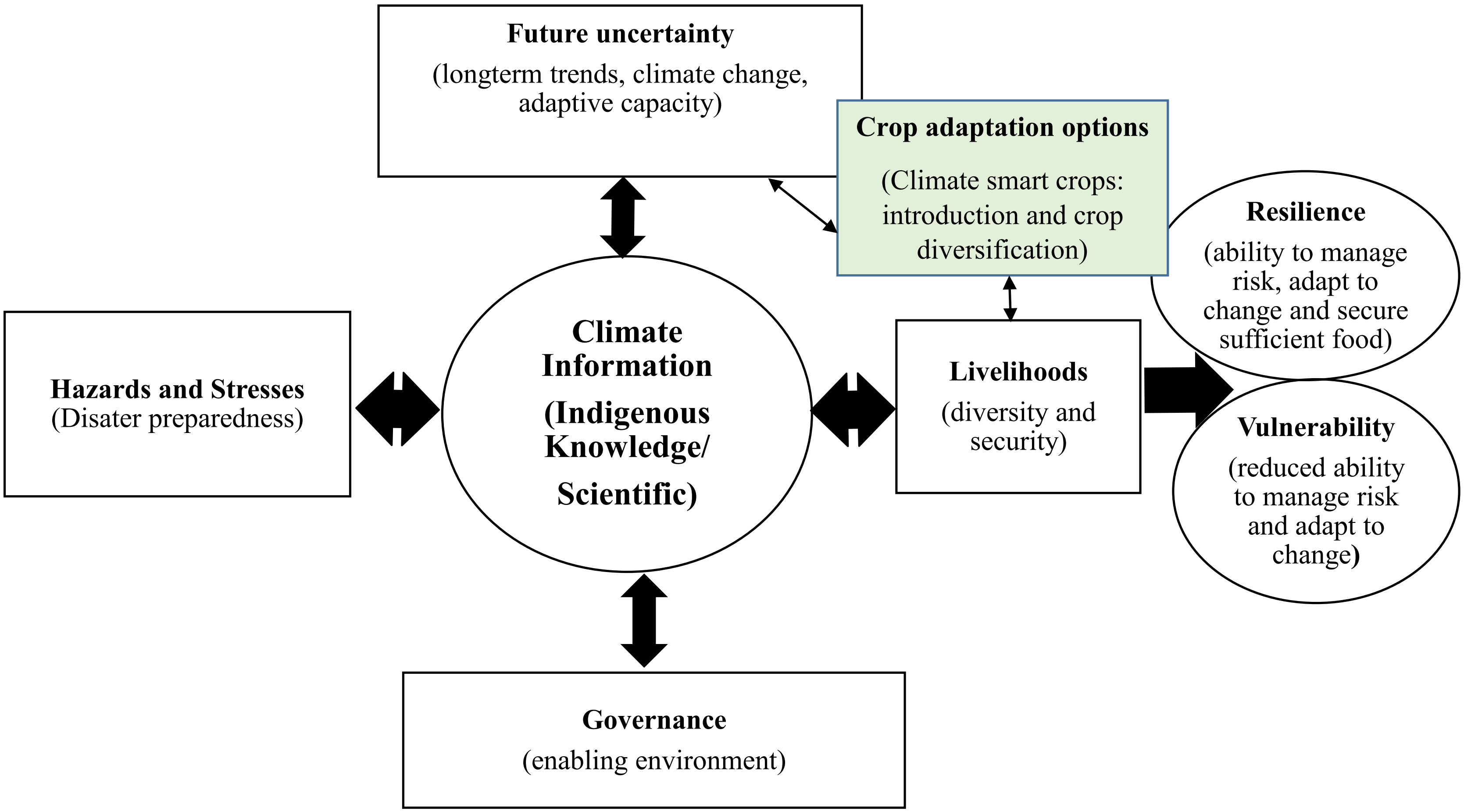

Figure 1. 1: Conceptual framework for the study, centered on the role played by IKS to understand and adapt to climate change and variability (modified from Pasteur, 2011)

1.3 Importance of the study

By 2050, average temperatures over Zimbabwe are projected to be 2 – 4°C higher and rainfall 10–20% less than the 1961- 1990 baselines (Lobell et al., 2008; Schlenker & Lobell, 2010). Simulation models show annual rainfall declining by 5 – 20% of the 1961 - 90 average by 2080 in all Zimbabwe's major river basins (Lobell et al., 2008). Agriculture, an important sector in Zimbabwe, has been identified as the sector most vulnerable to these climate changes. Given these predictions of climate change, the smallholder farmer in the marginal areas needs to adapt to climate change and variability through informed crop and variety choices, and strategic crop management regimes. It is critical to investigate how these adaptive strategies are affected by the different soil types and fertility levels in these marginal areas. It is also important to investigate how the farmer will be affected by future climate change impacts and the subsequent adaptation processes.

Climate change will intensify the already adverse conditions of crop production in the drylands (Knox et al., 2011). Considering the socio-economic and political contexts of climate change in sub-Saharan Africa, a central argument is that adaptations to climate change need to be resilient, that is, to have the ability to deal with stresses and disturbances as a result of change, while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to learn and adapt to change.

Smallholder farmers, that is, those operating a farm sizes of 2 hectares or less were chosen as the focus of analysis. They constitute the majority of the rural poor, practice rain-fed agriculture, and account for most food production in southern Africa (Bauer & Scholz, 2010). They are also among the worst hit by climate change due to their dependency on rain-fed agriculture.

Evidence show that sub Saharan Africa will mainly experience adverse impacts but a major challenge is to deal with the uncertainties in climate predictions. Considering the uncertainties, the widespread poverty and lack of capacities, resilience concepts offer a superior entry point to analyze adaptations to climate change under conditions of uncertainty compared to vulnerability (Katharine, 2010). A central argument is thus that adaptations to climate change need to be resilient, by building buffer capacities, enhancing self-organization as well as being able to learn and adapt (Pasteur, 2011).

Thus, this study sought to identify vulnerability, resilience and adaptive capacity of smallholder farmers as influenced by their perceptions to climate change and variability. The research would also test some 'climate smart' crop options for the smallholder farmers in the lower potential regions of Zimbabwe. Analysis of indigenous knowledge systems, vulnerability and adaptive capacity would allow for drawing of recommendations for adaptation processes for smallholder farmers in future climate change and variability scenarios.

1.4 Hypothesis

1. Local farmers adaptation options are shaped by their perceptions to climate change and variability
2. Local farmers use indigenous knowledge to cope and adapt to climate change and variability
3. Local farmers have local adaptive strategies to climate change and variability
4. Introduction of climate smart crops will increase resilience of smallholder farmers to climate change and variability

1.5 Objectives

The overall aim of the study was to identify local smallholder farmers' perceptions to climate change and variability and how they were affected by indigenous knowledge systems. The study also investigated local level contextual vulnerability and how adaptive capacity and resilience to current and future climate change could be developed at the local level, using climate smart crops.

The specific objectives were:

1. To investigate indigenous farmers knowledge and perceptions on climate change and variability and indigenous weather forecasting systems
2. To investigate local vulnerabilities and development of adaptive capacity and resilience to climate change and variability.

3. To evaluate climate smart crop options for the vulnerable smallholder farmers in drought prone areas.

1.6 General methodology and study approach

The study used participatory research approach in semi-arid region in southern Zimbabwe. Structured questionnaires, focus group discussions and key informant interviews were used to obtain information on the different objectives. Field trials were conducted to obtain information on climate smart options. Data was subjected to statistical analyses using Statistical Package for Social Sciences (SPSS), logit regression and analysis of variances.

1.7 Organization of the Thesis

This Thesis is written in paper format. Each Chapter is a standalone paper. Chapter 1 provides the rationale for the study and points out the significant knowledge gaps that arise due to significant changes in climate. Chapter 2 reviews and gives and insight on the use of knowledge by rural farmers to cope and adapt to climate change and variability. The review concludes by pointing out the need to integrate scientific knowledge and indigenous knowledge systems to enhance local farmers' adaptive capacity. Chapter 3 identifies indigenous predictors used by farmers to predict seasonal weather patterns and subsequent adaptation strategies. This Chapter notes that indigenous knowledge systems are being eroded and were becoming less accurate in predicting seasonal weather variation. There is need for further studies to use multiple methods that combine indigenous knowledge and scientific weather data. Chapter 4 examines farmer perceptions on climate variability, current adaptive strategies and factors influencing smallholder farmers' adaptation to climate change. These perceptions help shape farmers coping and adaptation strategies. Chapter 5 assessed smallholder farmers' vulnerability to climate change and variability based on socio-economic and biophysical characteristics. The results identified the need to define and map local area vulnerability as a basis for recommending coping and adaptation strategies to counter climate change hazards. Chapter 6 analyzed factors that influence household decisions to adapt to climate change in Chiredzi district. The results showed that resource levels, age and access to information are important in defining the resilience buildup of smallholder farmers. Chapter 7 showed that resource poor farmers can adopt climate smart crops including cereals and legumes in order to create food and nutritional security in the face of climate change and variability. Chapter 8 integrates the major findings of the Thesis and identifies topical issues that may inform future research.

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CHAPTER 2[1]

LITERATURE REVIEW

Indigenous knowledge systems for seasonal climate prediction, resilience building and adaptation in agriculture systems in southern Africa

Abstract

Climate change and variability is rapidly emerging as one of the most serious global problems affecting many sectors in the world. It is considered to be one of the most serious threats to sustainable development with adverse impact on environment, human health, food security, economic activities, natural resources and physical infrastructure. Southern Africa is one of the most vulnerable regions to climate change in the world, particularly because of widespread poverty, recurrent droughts, inequitable land distribution, over-dependence on rain-fed agriculture and low adaptive capacity. Yet rural farmers in southern Africa have managed to survive the vagaries of climate change over the years. This review reveals that these rural farmers can use indigenous knowledge to cope and adapt to climate change. Availability and access to scientific weather information to make cropping and other decisions at the local level remain key issues to usage of climatic data by rural farmers. One the other hand, indigenous knowledge is what they have been using but is also becoming unreliable due to climate change. Integration of indigenous knowledge and scientific seasonal forecast seems to be a key possible thrust to reduce vulnerability, enhance resilience of rural farmers and increase their adaptive capacity.

Key words: Climate change, indigenous knowledge, seasonal weather prediction, adaptation

[1] This chapter has been accepted by *Journal of Agricultural Sciences.* Obert Jiri, Paramu L. Mafongoya, Chipo Mubaya and Owen Mafongoya. 2016. Seasonal Climate Prediction and Adaptation Using Indigenous Knowledge Systems in Agriculture Systems in Southern Africa: A Review. *Journal of Agricultural Science*, Vol. 8, No. 5. ISSN 1916-9752 E-ISSN 1916-9760. Published by Canadian Center of Science and Education (accepted)

2.1. Introduction

Climate change exerts multiple stresses on the biophysical as well as the social and institutional environments that underpin agricultural production (IPCC, 2007). Khanal (2009) classified the patterns of impact of climate change on agriculture into biophysical and socio-economic impacts. Mark *et al*. (2008) highlighted some of the direct impacts of climate change on agricultural systems as: (a) seasonal changes in rainfall and temperature, which could impact agro-climatic conditions, altering growing seasons, planting and harvesting calendars, water availability, pest, weed and disease populations; (b) alteration in evapotranspiration, photosynthesis and biomass production; and (c) alteration in land suitability for agricultural production.

An important feature of drylands is the low seasonal rainfall amounts and the high rainfall variability (Khanal, 2009). High rainfall variability as manifested in variable onsets and rainfall amounts, dry spells, recurrent droughts and floods are intrinsic characteristics of many sub Saharan Africa (SSA) regions (Ifejika, 2010). This implies that rain-fed agriculture already has to account for these various characteristics. Yet, the widespread impacts of droughts and floods often force national governments to declare a state of emergency and appeal for external aid (WFP, 2006), indicating that smallholders are yet to meet the challenge of crop and livestock production under such climatic conditions.

Ifejika (2010) indicated that, at the level of practices, there are several ways to adapt to climate change at the farm-level. These different ways are mainly complementary as they address different components of the smallholder farming system. Adaptation is a continuum of practices which ranges from activities that are predominantly developmental to those that focus on reducing climate change impacts. No one single measure is sufficient to adapt to climate change. Rather, a mix of measures is needed which targets the various farm variables – water, soil, micro-climate, seeds and crops as well as labour and capital.

Most smallholder crops are highly sensitive to climate and ecosystems will shift over space in response to climate change. For instance, research done in various countries in southern Africa has demonstrated that a 2ºC rise in ambient temperature and a rise of mean temperature by 4ºC would significantly lower crop yields (Agoumi, 2003). Potential effects of climate change on maize, a staple crop, using a general circulation model and the dynamic crop growth model CERES-maize in Zimbabwe, showed that maize production was expected to significantly decrease by approximately 11–17%, under conditions of both irrigation and non-irrigation (Agoumi, 2003; Magadza, 1994; Makadho, 1996; Mano and Nhemachena, 2006; Muchena, 1994 and Stige *et al*., 2006).

This sensitivity of agriculture in southern Africa, obtained through exposure to climatic hazards and stresses, could lead to increased vulnerability in the absence of adequate coping, adaptation and policy mechanisms, underpinned by access and use of climate information (Figure 1). How smallholder farmers respond to climate change and variability depends on the information they obtain and use to decipher appropriate coping and adaptation strategies (Gukurume, 2014). Such information can be derived from indigenous knowledge systems (IKS) or meteorological weather data or both. On the other hand, reduced vulnerability, encompassed by access and effective utilisation of climate weather forecast data, is shown by improved livelihoods and increased resilience to climate change (Figure 2.1).

This review covers research that has been done in Africa, particularly southern Africa, and examine the importance of climate forecasts, challenges that have been faced in southern Africa through scientific forecasts, the role played by indigenous forecasting and challenges that indigenous knowledge faces in development interventions, including opportunities in integrating scientific and indigenous forecasts in informing adaptation and increase resilience of smallhilder farmeing systems. This study is solely based on in-depth literature review of studies that have been done on Sub-Saharan Africa, with particular focus on southern Africa, regarding climate change adaptation and indigenous and scientific forecasting.

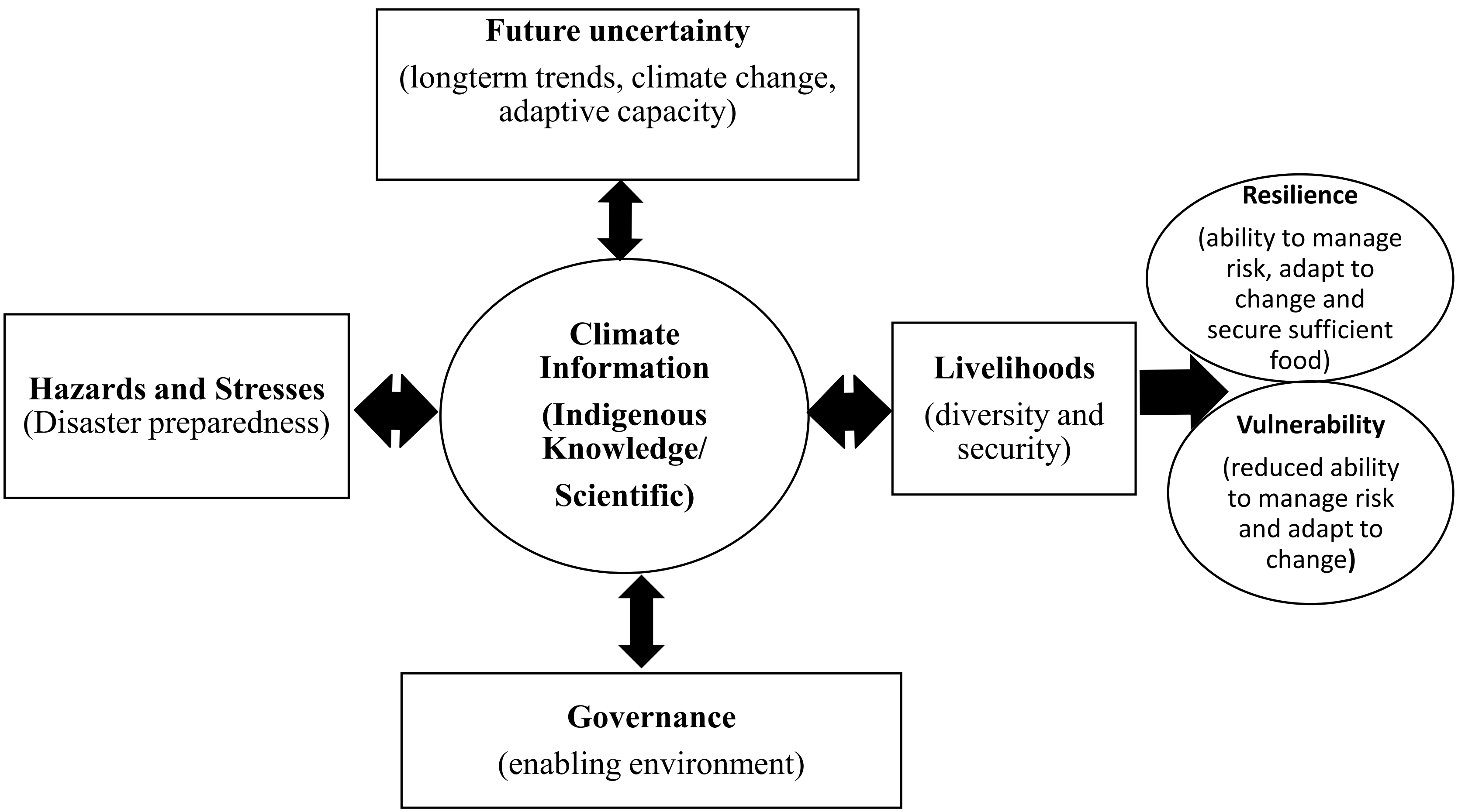

Figure 2.1: Framework of vulnerability and resilience based on access and usage of climate information (modified from Pasteur, 2011)

Sustainable smallholder agricultural production cannot be achieved in the absence of local coping and adaptation capacity to current variability and change and adaptive capacities for future climate changes (Finnigan, 2009; Ogallo, 2010). Failure to adapt to climate change may lead to adverse impacts on major food crops at the farm level and in the region (Lobell et al., 2008). Climate information (including observations, research, predictions and projections) has a central role to play in both adaptation and mitigation of climate change (Zillman, 2009). In SSA, however, there is limited access to climate information and relatively low capacity to meaningfully utilize the provided information that farmers have access to (Dutta, 2009; Odendo et al., 2006). Farmers, therefore, tend to rely on indigenous knowledge and information from local social networks to make decisions and manage technology related risks and climate variability (Nyong et al., 2007; Pawluk et al., 1992).

The concept of indigenous knowledge has increasingly become topical and been embraced by academics and development practitioners as integral to addressing multiple livelihood challenges faced by rural communities in developing countries and as a basis for locally driven adaptation strategies that transcend the planning stage and can begin to be implemented (Mapfumo et al., 2015; Moonga and Chitambo, 2010; Saitabau, 2014). More recent studies have shown that resilience building for smallholder farmers in Africa is a process that starts with the ability to anticipate change and accordingly adjust farming practices and set the base for sound food security, particularly in the context of climate variability and change (Kolawole et al., 2014).

2.2. Sources of seasonal climate forecast information

There is an inevitable demand for seasonal and medium- to long-term climate forecasts to support farmers in decision making. Farmers tend to use a combination of meteorological information and indigenous knowledge in their seasonal forecasting, as they primarily rely on indigenous knowledge but are also open to receiving scientific forecasts (Mapfumo et al., 2015; Orlove et al., 2010; Roudier et al., 2014). While smallholder farmers approach a season with a wealth of prior experience in empirical observation and traditional knowledge regarding forecasts, these farmers also adjust their practices as they seek further local information and also as scientific real-time forecasts become available (Furman et al., 2011; Frimpong, 2013; Orlove et al., 2010). It becomes difficult in some cases to ascertain which source of information influences what decision in the same season. It may, therefore, be prudent to assert that it is a combination of the types of forecasts that influences farmers' decision making. The trajectory of change highlights how farmers in a study conducted in West Africa more than a decade ago entirely relied on their experience and intuition to make decisions on their farms in a given season (Hansen, 2002) to currently where they make use of a combination of indigenous and modern forecasts in parts of southern Africa (Mapfumo et al., 2015).

Climate information appears to be particularly important and in many cases a prerequisite for coping and adapting to the negative impacts of climate variability and change, given that most of the rural livelihoods in southern Africa depend on climate and environmental dynamics (Hans et al., 1996; Goddard et al., 2010). What is emerging from a number of studies is that farmers tend to make decisions on farming practices based on potential evidence of climate occurrences, particularly in relation to rainfall patterns (Goddard et al., 2010; Mapfumo et al., 2015; Roudier et al., 2014). Studies further highlight that farmer crop management strategies (planting time, weeding, fertilizing, application of pesticides) are shaped by predictive climate information, particularly rainfall related forecasts (Moeletsi et al., 2013; Roudier et al., 2014). Environmental observables tend to guide farmers actions, among them soil moisture and expected weather conditions (Goddard et al., 2010; Moeletsi et al., 2013). Decision making is not restricted to modifications of these decisions but also by reinforcing what a farmer has already decided on, thereby having a psychosocial effect through encouragement to maintain good practices (Roncoli et al., 2009). Farmers have the capacity to use climate forecasts to maximize benefits from anticipated favourable conditions and governments in Africa have increasingly invested in climate services to enhance farmers' adaptive capacity (Roudier et al., 2014). However, farmers may not plan for an average season but for a poor season to ensure survival. Failure to plan for a good season but only for a poor one makes farmers miss out on profits in a good year (Goddard et al., 2010).

Studies show that climate information is instrumental in improving agricultural production and ultimately dealing with food insecurity (Friesland and Lo¨pmeier, 2006; Moeletsi et al., 2013; Patt et al., 2005; Phillips et al., 2001; Roncoli et al., 2009). There is an increasing realization that agro-climatological information, particularly that which provides details on climate extremes and recommendations for actions to be taken, is crucial to improve on agricultural production and responsible use of agricultural resources and managing agricultural risk (Fig 1; Andre et al., 2007; Friesland and Lo¨pmeier 2006; Moeletsi et al., 2013). Agricultural productivity can be increased and costs of production minimized through informed use of weather/climate information, which makes it very important to ensure wide dissemination of this information (Balaghi et al., 2010; Basco, undated cited in Moeletsi et al., 2013). However, some scholars hasten to throw caution on over generalisation of the importance of climate change based on these studies given the small-scale nature of the sample size and exclusion of other important categories of society such as gender, among other factors (Roudier at al., 2014).

2.3 Problems of scientific forecasts

Climate information has increasingly become important and available in the last decade and Regional Climate Outlook Forums have enhanced dialogue on seasonal forecasts among producers of information, researchers and different categories of decision-makers (Goddard et al., 2010). Moreover, studies demonstrate that there is potential value in incorporating seasonal forecasts into the decision-making of different sectors (Cabrera et al., 2007; Hammer et al., 2001; Hansen, 2002; Hansen et al., 2009; McIntosh et al., 2007; Thonson et al., 2006). However, many studies that have been done on scientific climate and weather information in Africa cite gaps that still exist between information provided and information desired, including challenges such as inaccurate forecasts, inadequate access to information as a barrier to utilization of internet data, lack of climate data, little meaningful use of the information (policies, planning, decision making at a higher level), products not well developed (some data have not been digitized) low skills, and lack of adequate timing for information dissemination (Frimpong, 2013).

Inaccurate forecasts remain a major challenge to effective use of seasonal forecasts by farmers and other users in southern Africa. Forecasts accuracy tends to decrease with smaller regions and locally specific information tends to be more uncertain and making this information more accurate requires sufficient observational records in order to be meaningful (Goddard et al., 2010; Gong et al., 2003). Inaccurate forecasts have been implicated in negative yield impacts and the opportunity costs for uncertain forecast is substantial and compromises profitability (Kolawole et al., 2014; Roudier et al., 2014). Farmers in Zimbabwe, and in eastern Africa, have demonstrated that, with some help, they are able to understand and incorporate probabilistic forecast information into their decision making processes (Ingram et al., 2002; Luseno et al., 2003; Lybbert et al., 2007; Patt, 2001; Suarez and Patt, 2004). Therefore, much more work needs to be done in engaging farmers directly on interpreting seasonal climate forecasts correctly.

Limited and inequitable access to forecast information by farmers compounds the problems of efficiency of seasonal forecasts in smallholder farming systems is a barrier to utilization (Kolawole et al., 2014; Mapfumo et al., 2015; Mberehgo and Sanga-Ngoie, 2012; Roncoli et al., 2002; Roncoli et al., 2009; Roudier et al., 2014). Therefore, there is need to improve the effectiveness of communication of climate information through multiple channels and deliberately partnering with the media for this cause since widespread communication failures constrain access to and therefore widespread uptake of information (Goddard et al., 2010; Hansen et al., 2011; Tarhule and Lamb, 2003). Access to climate information is to a large extent a function of the density of meteorological stations in an area (Ogallo, 2010).

There is little evidence to show that seasonal climate forecast information is being meaningfully put to use and embedded in policies, planning or decision-making within the socio-economic sectors, even in cases where these sectors received vast amounts of information resulting from the seasonal forecasts (Goddard et al., 2010; Tarhule and Lamb 2003). There is need to generate useful climate information and predictions and translate that information into usable forms for decision makers through continued dialogues among users of the information periodically. Information tends to be applicable to relatively large areas and lacks specificity, including the fact that information is disseminated late and in unfriendly languages, with technical jargon that makes it limit the effectiveness of uptake (Goddard et al., 2010; Hansen et al., 2011; Kolawole et al., 2014;

Van Aalst et al., 2008 cited in Mapfumo et al., 2015; Mberego and Sanga-Ngoie, 2012; Patt and Gwata, 2002). There is also lack of specific information about timing of rainfall and season onset or length, including the late dissemination of the information (Hansen et al., 2011; Kolawole et al., 2014).

Some of the available forecasts of extremes are not well developed, are not digitalized and are presented as typical probabilities rather than risk of these extremes, a challenge presented by the embryonic state of seasonal forecast systems at many centres (Goddard et al., 2010; Ogallo, 2010). Up to date, forecasters have not accounted for shortcomings such as models not currently representing important modes of intra-seasonal-to-interannual variability, in addition to ENSO predictions that have been encouraging to this point (Goddard et al., 2010). In certain situations, misinterpretation may lead to model predictions conflicting with official consolidated forecasts and the lack of easily available data and overestimated probabilities tend to reduce the actual use of many of these predictions and the usefulness of applications (Chidzambwa and Mason, 2008; Goddard et al., 2010). Although there is evidence of increasing skill in seasonal forecasting in Africa, availability of seasonal forecast on the internet is likely to include statements that may be construed through inexpert interpretation of limited inputs (Goddard et al., 2010), indicating that there is need to better channel climate information. Essentially, a low relevant skills base still makes it difficult to simulate convective precipitation that produces torrential rainfall, leading to the difficulties faced by climate scientists.

The major point regarding most of the problems highlighted in this section is that these problems are symptomatic of inadequate policies and institutional process, and are therefore amenable to intervention (Hansen et al., 2011; Mberehgo and Sanga-Ngoie, 2012). Three key elements are identified as crucial for influencing action; technical quality of the information, relevance of this information to the needs of decision makers and perception that the information suits users' interests (Cash and Buizer, 2005; Cash et al., 2006).

2.4 Indigenous knowledge systems seasonal forecasts

Given the significant gaps in scientific knowledge, ethno-meteorological knowledge plays a key role in farmers' ability to devise climate variability and change adaptation measures. There is evidence to show that naturally, farmers have an inclination towards indigenous forecasts as opposed to scientific forecasts as they value their experiences over the years (Kolawole et al., 2014; Roudier et al., 2012). Farmers rely on historical patterns, weather observations and signs to formulate expectations on weather and climate (Orlove et al., 2010).

There are advantages that seem to emerge in studies done in South Africa, Zimbabwe and Botswana regarding indigenous forecasts; reliance on indigenous prediction indicators and, developing agricultural strategies in response to predictions (choice of crop varieties, land management strategies, and livestock species and management strategies), sometimes without consulting any other sources of predictions (Brooks et al., 2011; Orlove and Kabugo, 2005; Speranza et al., 2009). Indigenous knowledge has a strong practical emphasis that is oriented towards planning, and exhibits dynamism that allows for incorporation of new elements (Flavier et al., 1995; Kolawole et al., 2014; Orlove et al., 2010). These studies in Malawi, Botswana, and Uganda highlight the social nature of indigenous knowledge and shows that indigenous knowledge on forecast tends to be more accessible given that elders, who are predominantly custodians of this knowledge command respect in their communities and their stock of personal experience is considered to be valuable (Briggs and Moyo, 2012; Kolawole et al., 2014; Orlove et al., 2010; Roncoli et al., 2001). Moreover, farmers tend to share their experiences and knowledge on forecasts with others at a larger scale and give them a sense of the arrival and progress of the rains (Orlove et al., 2010). Farmers in Malawi and Botswana highlight that indigenous forecasts tend to be more accurate and simple to understand to farmers as opposed to the complex nature of scientific forecasts that require sophisticated equipment and formal education and training and financial investment (Briggs and Moyo 2012; Kolawole et al., 2014; Onyango, 2009; Ouma, 2009).

Farmers use tree phenology, animal behaviour, wind circulation, cloud cover and other social indicators to predict rains and season quality. Farmers are particularly interested in when the rainy season will start so they make preparations. They are also concerned with the quality of the season so they make decisions of what to grow.

Tree phenology indicators

Table 2.1 shows some of the vegetation indicators used in southern Africa to predict rainfall. Studies have for the past decade started to show that there are already shifts in the flowering patterns of trees to El Niño events (Curran et al., 1999). This brings to mind the implications of shifting tree patterns to traditional indicators that are critical for seasonal forecasting (see Table 2.1). Studies done in southern Africa highlight that if certain trees bear fruit at certain periods of time then this indicates either a good or poor rainfall season, for instance, in Botswana, a certain shrub called Moretlhwa and known in English as Brandy bush/Raisin bush (*Grewia flava*) bears fruits twice a year. Early fruiting (November to early December) indicates low rainfall and late fruiting (February/March) indicates a good season and no fruit at all indicates a serious drought (Kolawole et al., 2014). In Zimbabwe the disappearance and delayed fruiting of trees such as Maroro, Tsambatsi and Hute and on the other hand the profuse fruiting of the Muhacha tree, including the delayed regrowth of grasses from August to Octobers have for a long time indicated droughts to come (Mapfumo et al., 2015). Coffee cultivation in Uganda was not common until the 1940s, and so the habit of observing the flowering of the coffee tree as a sign for the onset of the rain must have developed after this time (Orlove et al., 2010). Signs that there will be rains in a few weeks include the flowering of trees, especially coffee trees in Uganda (Orlove et al., 2010). Hence, the shifting of tree fruiting patterns is likely to render this indicator less reliable. The reliability of the indicators that have been highlighted in reviewed studies is critical since indigenous forecasts are a significant part of the prediction of climate parameters for smallholder farming systems. It is also important to understand the significance of the indigenous forecasts for planning purposes at this level.

It is also important to note the robustness of indigenous indicators across the region (Table 2.1, 2.2 and 2.3). The commonality of these indicators across ecozones from Tanzania in the east to South

Africa in the south is critical with regard to preservation of certain ecosystems. The use of these robust indicators alludes to the necessity to preserve and protect the trees and animals bearing these indicators.

Table 2.1: Indigenous indicators for weather and climate in southern Africa - tree phenology

Indicator	Country	Significance	Reference
Onset of the rains			
Flowering of the peach tree (*Prunus persica*), apricot (*Prunus armeniaca*), budding of acacia species,	Botswana Malawi Zambia Zimbabwe South Africa	Beginning of rainy season	Kolawole et al., 2014 Joshua et al. 2011; Mugabe et al. 2010; Risiro et al. 2012; Mapfumo et al., 2015 Zuma-Netshiukhwi et al. 2013
Season Quality			
Behavior of certain plants: sprouting of *Aloe ferox*; Germination of new leaves on baobab and tamarind trees	Bostwana Malawi South Africa Swaziland Zimbabwe Zambia	Indication of good rains; Abundance of wild fruits such as *Vangueria infausta*, *Englerophytum natalense* and *Sclerocarya caffra* during the months of December to February signify an imminent challenging farming season	Mogotsi et al. 2011 Joshua et al. 2011 Zuma-Netshiukhwi et al. 2013 Mugabe et al. 2010 UNEP, 2008; Dube and Musi, 2002
Mango tree (*Mangifera indica*); Nandi Flame tree (*Delonix regia*)	Malawi Tanzania Zimbabwe	Heavy flowering of the mango trees indicate a potential drought season	Joshua et al. 2011 Risiro et al. 2012 Kijazi et al. 2012; UNEP, 2008
Parinari curatellifolia (muchakata), *Lannea discolor* (gan'acha), *Uapaca kirkiana* (mushuku); *Boscia albitrunca*; *Adansonia digitata*	Botswana Malawi Zambia Zimbabwe	Heavy flowering of the trees indicate a potential drought season	Mogotsi et al. 2011 Joshua et al. 2011 Mugabe et al. 2010 Muguti and Maposa, 2012
Dormancy breaking in certain trees species e.g. *Brachystegia boehmii* (mupfuti)	Malawi Zambia Zimbabwe	Indicates plenty of rain in a few days	Joshua et al. 2011 Mugabe et al. 2010 Muguti and Maposa, 2012
Dropping off of young avocado fruits	Swaziland	Challenging farming season	UNEP, 2008; Dube and Musi, 2002

Animal behavior indicators

The singing, nesting and chirping of certain birds appears to be a useful indicator for the onset of the rains in southern Africa (UNEP, 2008). In addition, there are signs that there will be a lot of rains through the arrival of migratory birds, particularly the southern hornbill (*Bucorvus abyssinicus*) in Zimbabwe, Zambia and northern parts of South Africa (Orlove et al., 2010) with use of the movements of fronts to provide them with tailwinds (Liechti, 2006). Sounds from certain insects that emerge from overwintering/hibernation (Mapfumo et al., 2015) tend to signal the start of a season and planning by farmers in Bostwana and Zimbabwe. Table 2.2 shows some of the indicators based on animal behaviour. It should be noted that there are indicators that are common in most southern Africa countries. This assists in preservation of various animals across the region.

Table 2.2: Indigenous indicators for weather and climate in southern Africa - animal behaviour

Indicator	Country	Significance	Reference
Onset of the rains			
Appearance of red ants, rapidly increasing size of anthills, moist anthills (October – November)	South Africa Malawi Tanzania Zambia Zimbabwe	Good rains are coming	Zuma-Netshiukhwi et al. 2013 Mugabe et al. 2010 Kijazi et al. 2012; UNEP, 2008 Joshua et al. 2011 Risiro et al. 2012
First appearance of sparrows; flock of swallows (*Psalidoprocne pristoptera*) preceding dark clouds	Botswana Malawi South Africa Swaziland Tanzania Zambia Zimbabwe	Rainy is at hand and farmers should prepare for above normal rains	Mogotsi et al. 2011 Joshua et al. 2011 Zuma-Netshiukhwi et al. 2013 Mugabe et al. 2010 Risiro et al. 2012 Kijazi et al. 2012; UNEP, 2008; Dube and Musi, 2002
Appearance of certain birds e.g. stock, *Quelia* Singing, nesting and chirping of certain birds	Malawi Zimbabwe Botswana Zambia Tanzania	Rainy is at hand and farmers should prepare for above normal rains	Joshua et al. 2011 Muguti and Maposa, 2012 Risiro et al. 2012 Mogotsi et al. 2011 Mugabe et al. 2010 Kijazi et al. 2012; UNEP, 2008
Cry of the phezukwemkhono (*Cuculus solitarius*) bird	Swaziland	This signals the start of the wet season in August-November.	UNEP, 2008
Termite appearance (*Ancistrotermes* spp and *Macrotermes* spp)	Botswana Malawi Zambia Zimbabwe	Appearance of many termites indicate near rainfall onset	Mogotsi et al. 2011 Joshua et al. 2011 Mugabe et al. 2010 Muguti and Maposa, 2012

Frogs in swampy areas croaking at night	Swaziland Zambia Zimbabwe	Indicator for onset of rains	UNEP, 2008; Dube and Musi, 2002 Mugabe et al. 2010 Muguti and Maposa, 2012
Rock rabbit	Zimbabwe	Its unusual squeaking indicates imminent rainfall	Muguti and Maposa, 2012 Risiro et al. 2012
Cicadas (nyenze), day flying chafers (mandere), dragon flies (mikonikoni)	Malawi Zambia Zimbabwe	Appearance of these signifies imminent rainfall	Joshua et al. 2011 Mugabe et al. 2010 Muguti and Maposa, 2012 Risiro et al. 2012
Season Quality			
Grunting of pigs and behaviour of peacocks, doves and ducks, indicate low humidity	Tanzania Swaziland South Africa	Rains are near	Kijazi et al. 2012 UNEP, 2008; Dube and Musi, 2002 Zuma-Netshiukhwi et al. 2013
Calves jumping happily	Swaziland South Africa	Good rain season	UNEP, 2008; Dube and Musi, 2002 Zuma-Netshiukhwi et al. 2013
Certain snakes moving down the mountain	Zambia South Africa	Good rain season	Mugabe et al. 2010 Zuma-Netshiukhwi et al. 2013
Frequent appearance of tortoises	South Africa	Good rain season	Zuma-Netshiukhwi et al. 2013
Appearance of certain insects e.g. millipedes, spiders	Malawi Zimbabwe	Indicates coming of heavy rains	Joshua et al. 2011 Risiro et al. 2012; Mapfumo et al. 2015
Increased appearance of elephants (*Loxodonta africana*) near watering points meant for livestock	Botswana	Indicator of low rainfall	Mogotsi et al. 2011
Nesting of the emahlokohloko bird (*Ploceus* spp)	Swaziland	If nesting is done high up in the trees next to the river, floods are anticipated, and vice versa	UNEP, 2008; Dube and Musi, 2002

When the umfuku (*Centropus burchellie*) bird chirps during the farming season (October to April)	Swaziland	This is a sign of a thunderstorm approaching.	UNEP, 2008
Increase in swarms of bees	Tanzania	Sign of a wet season	Kijazi et al. 2012 UNEP, 2008
Abundance of butterflies (*Danaus plexippus*) during the farming season, presence of army worms (*Spodoptera exempta*)	Swaziland	Indicate imminent mid-season drought and possible famine	UNEP, 2008
Goat intestines	Tanzania	If the goat intestines are empty at slaughter it indicates drought or famine ahead, and vice versa	Kijazi et al. 2012 UNEP, 2008
Libido of donkeys	Tanzania	Increased libido of donkeys (August – October) indicate below normal rain and drought in the coming season	Kijazi et al. 2012 UNEP, 2008
Mating of goats	Tanzania	Increased mating of goats (August – September) indicate more rain in the coming season	Kijazi et al. 2012 UNEP, 2008

Atmospheric indicators and indigenous forecasting

Table 2.3 shows some of the indicators based on atmospheric air circulation. Farmers in southern Africa believe that there is significant merit in the sequencing of seasons as an indicator for what the coming season will be like (Orlove et al., 2010; Mapfumo et al., 2015). Essentially, indigenous forecasting is not solely based on personal experience but also on trend analysis (Kolawole et al., 2014; Mapfumo et al., 2015). Mapfumo et al (2015) cite a case of farmers in Zimbabwe who have traced the changes in five rainfall regimes that had for ages indicated the specific stages of rainfall such as the onset of the winter season at the end of May, rains coming in August after the processing of grains, late September marking the end of wild fires, hastening growth of new tree leaves in October and marking the beginning of the rainy season in October/November. These case studies show that the traditional indicators have also been affected by changes in rainfall patterns to an extent that they may mislead farmers and not be as reliable as they used to be. Farmers rely on these indicators for farming practices including securing marketing and trade arrangements for food security (Mapfumo et al., 2015).

The onset of rains from a few days to a few weeks is indicated by an increase in night-time temperatures, shifts in direction of prevailing winds, particular phases of the moon and the appearance of strong whirlwinds, changes in smell of the environment, all highlighted as happening just before the rains (Ajibade and Shokemi, 2003; Orlove et al., 2010; Kolawole et al., 2014; Mapfumo et al., 2015). However, there are certain inconsistencies in one community in Uganda on the exact indications of onset of rains through wind direction as some farmers look for a change in wind direction from easterlies to westerlies while others look for a shift from southerlies to northerlies (Orlove et al., 2010). In terms of the moon, there are inconsistencies on whether it is the dark phase of the moon or the waning of the moon that indicates the onset of the rain. Although many farmers have expressed a high level of confidence in traditional indicators for a rainfall season (Orlove et al., 2010; Roudier et al., 2012), the highlighted inconsistencies give pointers to a degree of inaccuracy of some of these indigenous indicators. However, there still exists a significant level in some of these indicators that have been explained in scientific terms, for instance the Inter-tropical Convergence Zone [ITCZ] in March in the same area explains the nighttime temperature shifts and other scientific forecast (Kolawole et al., 2014; Roncoli et al. 2002 cited in Tarhule and Lamb 2003). These temperature fluctuations are also used in West Africa as an indication of the occurrence of a rain event within days (Roudier, 2012).

Table 2.3: Indigenous indicators for weather and climate in southern Africa - atmospheric circulation

Indicator	Country	Significance	Reference
Onset of the rains			
Moon phases	South Africa Malawi Zambia Zimbabwe	moon crescent facing upwards indicates upholding water and when facing downwards is releasing water in the next three days	Zuma-Netshiukhwi et al. 2013 Joshua et al. 2011 Mugabe et al. 2010 Shoko and Shoko, 2013
Star constellation	Botswana Malawi Swaziland Zambia Zimbabwe South Africa	Star pattern and movement from west to east at night under clear skies means rain will fall in 3 days	Mogotsi et al. 2011 Joshua et al. 2011 Mugabe et al. 2010 Shoko and Shoko, 2013 Zuma-Netshiukhwi et al. 2013 UNEP, 2008; Dube and Musi, 2002
Season Quality			
Moon profuse halo	South Africa Malawi Tanzania Zambia Zimbabwe	Good rains Disposition of the new moon indicates more disease and erratic rainfall	Zuma-Netshiukhwi et al. 2013 Joshua et al. 2011 Kijazi et al. 2012 Mugabe et al. 2010 Shoko and Shoko, 2013 Risiro et al. 2012
Wind swirls	Botswana Malawi Swaziland Tanzania Zambia Zimbabwe South Africa	Frequent appearance is a sign of good rains	Mogotsi et al. 2011 Joshua et al. 2011; Mugabe et al. 2010 Kijazi et al. 2012 UNEP, 2008; Dube and Musi, 2002 Muguti and Maposa, 2012 Zuma-Netshiukhwi et al. 2013 Risiro et al. 2012

Mist-covered mountains	South Africa	Signal of good rains	Zuma-Netshiukhwi et al. 2013
Temperature	Botswana Malawi Tanzania Zambia Zimbabwe	Heat in low areas in August indicate there will be more rainfall in the coming season; high temperature in October and November signifies near onset and a good rain season.	Mogotsi et al. 2011 Joshua et al. 2011 Kijazi et al. 2012 UNEP, 2008 Mugabe et al. 2010 Shoko and Shoko, 2013 Risiro et al. 2012
Appearance of many nimbus clouds; appearance of red clouds in the morning	Malawi Swaziland Tanzania Zambia Zimbabwe	Indicators for rain in 1 – 3 days	Joshua et al. 2011 Mugabe et al. 2010 Kijazi et al. 2012 UNEP, 2008; Dube and Musi, 2002 Risiro et al. 2012
Appearance of fog/haze in the morning	Malawi Zambia Zimbabwe	Indicator for no rain	Joshua et al. 2011 Mugabe et al. 2010Risiro et al. 2012

Other natural resources indicators

Although natural resource based indicators featured in reviewed studies, these indicators are not as common as the others in terms of predicting the coming season. However, it is noted that the natural resource based indicators still play a significant role in predicting the seasons (Kolawole et al., 2014; Mapfumo et al., 2015; Roncoli et al., 2001). The nature of major rivers, springs and streams and changes in behavior of major resource pools remains important in indicating what the coming season will be (Mapfumo et al., 2015). A one-directional free flow of the river indicates an abundant rains season while rivers flowing in a spiral-like manner tends to indicate a season of limited rainfall (Kolawole et al., 2014). A justification for these river flow behaviours are couched in the logic that free flow indicates plenty of rains upstream while a spiral movement of river flow emanating from a rivers gradually drying up when they receive less rainfall (Kolawole et al., 2014). Table 2.4 shows other natural resources indigenous knowledge indicators.

Other indigenous indicators

Table 2.4: Other indigenous indicators for weather and climate in southern Africa

Indicator	Country	Significance	Reference
Rainmaking ceremonies	Botswana Zimbabwe	Praying and traditional healers consulting the gods	Mogotsi et al. 2011 Vijfhuizen, 1997
Body feels increased or excessive heat during the night and day; a feeling of body pain (headache, flu, backaches)	Zimbabwe	Indicator for rain in 1-3 days	Risiro et al. 2012
Asthmatic attack, painful operations	Zimbabwe	Imminent cold weather and humid conditions	Risiro et al. 2012

2.5 Potential for integration of indigenous knowledge with climate science

While there are differences in criteria used to define seasonal phenomena by both farmers and scientists, there is a significant overlap between indigenous and scientific knowledge regarding weather and climate forecasts (Hinkel et al. 2007; Kolawole et al., 2014; Laidler and Ikummaq, 2008), making indigenous knowledge potentially useful for scientific forecasting, particularly in tracking change. Moreover, both local and scientific knowledge in weather forecasting are produced through observation, experimentation and validation, suggesting that there is a meeting point between the two forms of knowledge, although there is an acknowledgement that indigenous knowledge is devoid of any regimentation and regulations and entails a measure of spirituality that is absent in scientific forecast (Kolawole et al., 2014). Therefore, there is need for a suitable platform where farmers and scientists can work together and to enable them devise adaptation strategies against climate change and variability.

Studies show that generally, farmers are open and willing to integrate new information into their traditional forecasting methods as demonstrated by these farmers readiness to engage, discuss and use modern scientific forecasts (Orlove et al., 2010). This openness and interest could work well for climate scientists as this could allow them design forecasts that would be in sync with farmers' priorities and more acceptable to these farmers (Nyong et al., 2007). For instance, climate scientists' current system rests on a coarse spatial analysis that does not address the risks in drier sub-regions within relatively moist regions, providing an opportunity for incorporation of indigenous knowledge of spatial variability in climate patterns for the identification of areas at risk for drought (Orlove et al., 2010).

Scientific forecasting information is not embraced by the smallholder farmers due to a number of reasons. Lack of a sense of ownership by farmers and decision makers alike has contributed to the limited uptake of the disseminated meteorological information. For this and other reasons, climate scientists are increasingly under pressure to transcend their disciplinary confines and engage in a process of joint, continued and participatory learning with users of the information and encourage effective outreach programmes for the information to realise its full potential (Glatnz, 2003; Glantz, 2005; Goddard et al., 2010).

A tripartite arrangement between users, scientists (cross disciplinary) and policy makers is important to create partnerships that maximize use of available climate information through the near-universal use of indigenous climate indicators, and building culturally relevant analogies of decisions under uncertainty into the climate communication process (Kolawole et al., 2014; Ogallo 2010; Phillips and Orlove, 2004; Sivakumar, 2006; Suarez and Patt, 2004). This can be done through contact workshops, public lectures and through the mass media (Kolawole et al., 2014). This is a more viable alternative model to that which casts climate scientists in an active role as "sources of knowledge" and the farmers in a passive role as "recipients of forecasts" (Orlove et al., 2010). The social nature of indigenous knowledge presents an opportunity for national meteorological services to develop new means of communication for their forecast products where farmers can participate as agents as well as consumers as well as for farmers themselves to understand and develop an interest to act on forecast information (Orlove et al., 2010; Roncoli et al., 2005; Roncoli et al., 2009; Suarez and Patt, 2007).

2.6 Challenges facing IKS and potential integration with scientific knowledge

It is important to highlight that it would be naïve to believe that indigenous knowledge forecasting is without its challenges. Three areas in which indigenous knowledge for weather and climate forecasting faces challenges are: negative perceptions regarding indigenous knowledge, erosion due to modernization and disruption of the traditional indicators by changes in weather and climate. There is a tendency to perceive local knowledge and practices as impediments to the success of externally funded projects related to agriculture and imposed on the poor communities. In addition, policymakers on the continent tend to view reliance on indigenous knowledge for climate forecasting with skepticism (Briggs and Moyo 2012; Saitabau 2014). And for this and other reasons, countries in southern Africa are still at knowledge stage rather than at a conceptual stage where there is implementation or use of this knowledge for smallholder farmer productivity (Saitabau, 2014). Essentially, there is need for serious engagement with communities before implementation of development intervention to take into account local knowledge for enhanced productivity, particularly deriving response farming approaches with both the extension office and farmers participating (Berkes and Berkes, 2009; Briggs and Moyo 2012; Mberego and Sanga-Ngoie, 2012; Sillitoe and Marzano, 2008).

The local systems have come under threat from modernization with local custodians of knowledge now viewed as 'backward charlatans' (Onyango, 2009; Ouma, 2009). On the other hand, scientific knowledge for climate forecasting is considered to be superior and currently enjoys a dominant position as a privileged knowledge as opposed to the 'conservative' and 'backward' knowledge that farmers rely on (Davis, 2005). This explains the suggestion that there is need to document indigenous knowledge in the context of weather and climate forecasting (Goddard et al., 2010; Ouma, 2009) in order to maintain its relevance in the face of accelerated modernization. Individuals and societies tend to have short-term memories, yet they have to rely on these memories for climate forecasting (Glantz, 2003; Mberego and Sanga-Ngoie, 2012). Documentation of local knowledge in both local languages and English becomes vital for adequate information sharing and for the preservation of traditional indicators that have proven to be useful for smallholder farmers, given that few people's indigenous knowledge is in-depth and the elders as the custodians of this knowledge are dying out without passing down the knowledge as was the case in the past (Kolawole et al., 2014; Speranza et al., 2009).

Documentation becomes even more critical given that climate variability and change has affected some of the indigenous indicators, placing limits on the scope of these indicators as a basis for decision making (Mapfumo et al., 2015). This emerging thinking of the disruption of traditional indicators by climate change is also based on the waning of the natural resource base upon which the knowledge is built, which is worrisome given the increasing demands for adaptation to climate variability and change (Mapfumo et al., 2015). For instance, biotic resources have adapted themselves to changing climatic conditions and abrupt changes in weather patterns, modifying themselves in the process and making it increasingly difficult to anticipate certain patterns in their behavior (Boko et al., 2007; Mapfumo et al., 2015; Ouma, 2009).

Scientific knowledge had over the past decades increasingly taken priority over local knowledge and practice in agricultural systems research and development (Walker et al., 1999). For instance, early warning systems on disasters and climate related hazards were traditionally channeled through religious and cultural methods such as oral literatures, poems and songs, which had unfortunately lost recognition and utilization in the context of climate change adaptation in the same period. However, in recent years, particularly in the past decade, there is an emerging and dominant view that places emphasis on local knowledge as a key component of an agricultural system and the view that instead, scientific knowledge must enhance local knowledge, rather than displace it (Jain, 2014; Joshua et al., 2011; Maconachie, 2012; Osbahr and Allan, 2003). Despite this shift towards recognition of IKS in climate change adaptation in agriculture systems, there is evidence to show that increased rainfall variability and temperatures have reduced smallholder farmers' confidence in indigenous knowledge, hence reducing these farmers' adaptive capacity and increasing their vulnerability to climate change (Joshua et al., 2011). In addition, skewed use of scientific knowledge and weather and climate predictions has proven to be a major constraint for farm level decision making as they do not incorporate IK, which farmers already live with. In the same context, farmers are more willing to use seasonal climate forecasts when these forecasts are presented with and compared to the local indigenous climate forecasts (Gana, 2003; Patt and Gwata, 2002). This would increase resilience and adaptive capacity (Figure 2.1).

2.7 Social capital and indigenous knowledge adaptation systems

In southern Africa, spiritual rainmaking ceremonies have been at the heart of many smallholder traditional societies and their interaction with nature when inducing rain and blessings in the agricultural enterprise (Vijfhuizen, 1997). Ritual performers would conduct prayers, use medicine portions, brew and drink traditional beer, dance under trees among other activities in manipulating the falling of rain. These acts were known for yielding positive results to the autochthonous people. The success of the performed rituals was guaranteed because they were conducted in a deeply rooted and synchronised cosmological condition with an intricate connection between moral geography, the whole environment and the spirits surrounding them (Vijfhuizen, 1997). Current calls by traditionalists in conjunction with politicians and social scientists to rejuvenate spiritual rainmaking as one of the panacea to current weather and climate hazards affecting modern societies have received intensive criticism from bio-physical (pro-scientific) and Christian based standpoints (Memmott, 2010). Bio-physical scientists jettison the rituals as anachronistic and redundant practices with no tangible results. Their argument is premised on the assumption that there is no a symbiotic relationship between brewing traditional beer, dancing under trees and use of medicine objects and the falling of rain. The bio-physical views are deeply rooted on the premise of science to predict and manipulate both short term and long term climate. In other instances they have the power to influence weather patterns through artificial practices like cloud seeding among others.

There is need for further research especially in providing empirical evidence to support traditionalists and farmers' current claims of changes in seasonality and the role of spiritual ceremonies in reducing vulnerability (Mapfumo et al., 2015). This is an area in which climate (biophysical and social) scientists can collaborate with traditional farmers to provide integration of science and social capital. In addition, to date, less progress has been made in assessments of the extent and impact of forecast use, particularly among vulnerable populations, such as smallholder farmers in Africa. This becomes an interesting area for study that needs further explanation of how forecasts are used by smallholder farmers and to what extent this is really the case. Another area that needs further research and in which scientists can partner with farmers is in connecting the physical climate system to environmental indicators that farmers have highlighted in a number of documented studies (Goddard et al., 2010), integrated with use of indigenous knowledge and spiritual ceremonies. This will enable climate scientists to capitalize on the possible connections.

2.8 Adaptation strategies

Adaptation strategies employed by farmers are different depending on climatic stimuli and intervening conditions or non-climatic stimuli. The different stimuli influence the sensitivity of a particular system and the nature of adjustments or adaptation required. As a result adaptation measures need to consider socio-economic and institutional arrangements at a particular locality. Impacts of climate change are quite different depending on the socio-economic disposition of the farmers, and may require different adaptive responsive, both in the short and in the long term. The appropriateness of a particular adaptation strategy is highly dependent on time and place as they are influenced by key cultural and indigenous observations and indicators at the local level. These indigenous observations, while sometimes robust, are usually peculiar to a local area or region.

There are generally two approaches to adaptation. The first is an approach that advocates for actions that reduce existing vulnerability. The use of early warning systems, for instance, means individuals and communities are able to employ anticipatory adaptation. The second approach is to mainstream climate change into existing activities. Mainstreaming ensures that future vulnerability to climate change is countered by considering climate change in decision making.

This is the trend in most developing countries where development is a priority. This approach is particularly useful where climate change may increase the risk of failure of assets.

It is vital, therefore, to increase resilience, coping and adaptive capacity of natural and human systems, so as to prepare them for future variability and extremes due to climate change.

2.9 Conclusions

Scientific forecasts have to some extent failed to make an intended impact on smallholder farmers due to the inaccessibility and inequitable distribution of this information to smallholder farmers as the primary users of the information. The issue of injustices in the context of the dominance of scientific forms of forecasting against indigenous indicators that tend to be regarded as backward. While indigenous forecasting is not without its challenges, a lot more can be learned and used to implement adaptation strategies that are long lasting by building scientific forecasts on indigenous knowledge. This will likely lend legitimacy of these forecasts in the eyes of smallholder farmers. Certain inconsistencies in indigenous indicators, including shifts in phenological patterns and changes in indigenous indicators due to changes in rainfall patterns, all point to negative implications for traditional forecasting as a reliable method of forecasting. However, indigenous forecasting remains a sound entry point given its social nature and acceptability by smallholder farmers. Moreover, indigenous knowledge has a strong practical emphasis that is oriented towards planning, and exhibits dynamism that allows for incorporation of new elements; where scientific forecasts can then come in to complement and add credence to indigenous knowledge.

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CHAPTER 3[2]

The use of indigenous knowledge systems to predict seasonal quality for climate change adaptation

Abstract

Farmers use a variety of local indicators for weather forecasting and climate prediction, for adapting to climate change and variability. Integrating indigenous knowledge systems (IKS) with climate scientists' efforts can contribute to effective on-farm adaptation initiatives. The objective of this research was to identify IKS used by farmers to predict seasonal weather patterns, and the subsequent adaptation strategies. The information was collected using focus group discussions, household survey, and ethnographic interviews. Most farmers (72.2%) indicated that low rainfall is the major limitation to agricultural production. Without reliable local scientific weather forecasts the farmers use tree phenology, animal behaviour and atmospheric circulation as sources of local knowledge to predict the onset and quality of the season. These forecasts are then used for designing crop choices, planting dates and agronomic practices. Study results obtained show that the use of IKS in local farming communities is an effective way of building coping and adaptation strategies. The results revealed that IKS are being eroded and becoming less accurate in seasonal weather prediction. Therefore, future studies on IKS should use multiple methods that combine indigenous knowledge and scientific weather data in order to obtain more complete and accurate information for local area season quality prediction.

Key words: Indigenous knowledge, smallholder farmers, weather forecasting,

3.1 Introduction

The IPCC (2007) emphasized that many developing countries, especially in Africa, will be much more exposed to climate change impacts in the future. This is as a consequence of the widespread low adaptive capacity, low resilience and susceptibility to climate and environmental shocks in these countries. By 2050, average temperatures over southern Africa are projected to be 2–4°C higher and rainfall 10–20% less than the 1961- 1990 baselines (Unganai, 2006; Lobell et al.

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2008, Nyong et al. 2007). Sub-Saharan Africa is already being severely and disproportionately affected by climate change and vulnerable to future variability, and yet has the least capacity to respond (Boko et al. 2007). This is because of the large number of communal and smallholder subsistence populations living in the rural areas. Indeed, the low resources and poor technology characterizing the rural populations result in limited options for adapting to climate change (Mendelsohn et al. 2000). Development of adaptation strategies has a huge potential of reversing the adverse impacts on agricultural productivity hence food security.

In Southern Africa, agriculture is a complex and challenging operation due to a number of factors, among them low-fertility soils, changing social and political situations, unfavourable economic environment and a variable climate (Osbahr & Allan, 2003). Literature highlights efforts by farmers to address these challenges and use of indigenous knowledge systems (IKS) is a key component in this context. One of the key uses of IKS includes using various forms of traditional indicators to predict weather and climate and also to respond to climate risk (Joshua et al. 2011).

Indigenous knowledge or local knowledge is generally defined as understanding of the local environment by local communities and the practices, techniques and technologies they use to ensure coping and adaptation to climate change and variability (Ajibade, 2003). Most climatic models lack localised climate data and scenarios. Climate scientists can benefit from the local observations of weather (Kirkland, 2012). Understanding the basis of indigenous peoples coping and adaptation strategies is critical if climate change research and development efforts aimed at these communities are to be successful. Considering local IKS will enhance decision-making at local levels as well as influence policy processes and policy choices at the national level (Adger et al. 2007). Indigenous people have ways of predicting weather within a season and from season to season. These predictions help them to know what and when to plant for a particular season as well as when to do certain operations within a season.

Scientific knowledge had, over the past decades, increasingly taken priority over local knowledge and practice in agricultural systems research and development (Walker et al. 1999). Early warning systems on disasters and climate-related shocks were traditionally channelled through religious and cultural methods such as oral literatures, poems and songs, which had unfortunately lost recognition and utilization in the context of climate change adaptation in the same period. However, in recent years, particularly in the past decade, there is an emerging and dominant view that places emphasis on local knowledge as a key component of an agricultural system and the view that instead, scientific knowledge must enhance local knowledge, rather than displace it (Jain 2014; Joshua et al. 2011; Maconachie, 2012; Osbahr & Allan, 2003; Walker et al. 1999). Despite this shift towards recognition of IKS in climate change adaptation in agriculture systems, there is evidence to show that increased rainfall variability and temperatures have reduced smallholder farmers' confidence in indigenous knowledge, hence reducing these farmers' adaptive capacity and increasing their vulnerability to climate change (Joshua et al. 2011). In addition, skewed use of scientific knowledge and weather and climate predictions has proven to be a major constraint for farm level decision making as they do not incorporate IKS, which farmers already live with. In the same context, farmers are more willing to use seasonal climate forecasts when these forecasts are presented with and compared to the local indigenous climate forecasts (Gana, 2003; Patt & Gwata, 2002).

Season quality forecasting is complex and imperfect. The majority of communal farmers cannot access scientific weather information. Where the weather information has been accessed, it is at a scale that is not usable by the local indigenous peoples. Weather information is given for a whole province but certainly distribution and amount of rainfall vary at a much small scale. However, indigenous peoples in these communities have been able to adjust cropping and livestock systems without much access to scientific information of weather forecasting. This has made indigenous people continue to rely on IKS for whether prediction and forecasting. This indigenous knowledge is based on long term observation and experiment (Kirkland, 2012). Practitioners of indigenous knowledge draw deductive inferences from phenomena, which are deliberately and systematically verified in relation to experience (Scott, 2011).

The objective of this study is to explore the use of indigenous knowledge systems by communal farmers to predict season quality and subsequent adaptation in the face climate variability and change.

3.2 Materials and Methods

Study site

The study was carried out in Chiredzi District in Masvingo Province, Zimbabwe (18°55'S and 29°49'E) (Figure 3.1). The district falls within the semi-arid areas, lying entirely under agro-ecological region 5 of Zimbabwe where there are frequent food shortages due to uncertainty of rainfall (Vincent &Thomas, 1960). The rainfall in this region is often erratic, with widespread drought in most years. The mean annual rainfall ranges from 300 mm in the southern parts of the district to 400 mm in the north eastern parts. The annual mean, maximum and minimum monthly mean daily temperatures in the district are 24.8°C, 27.4°C (November) and 22.3°C (July), respectively (Vincent & Thomas, 1960).

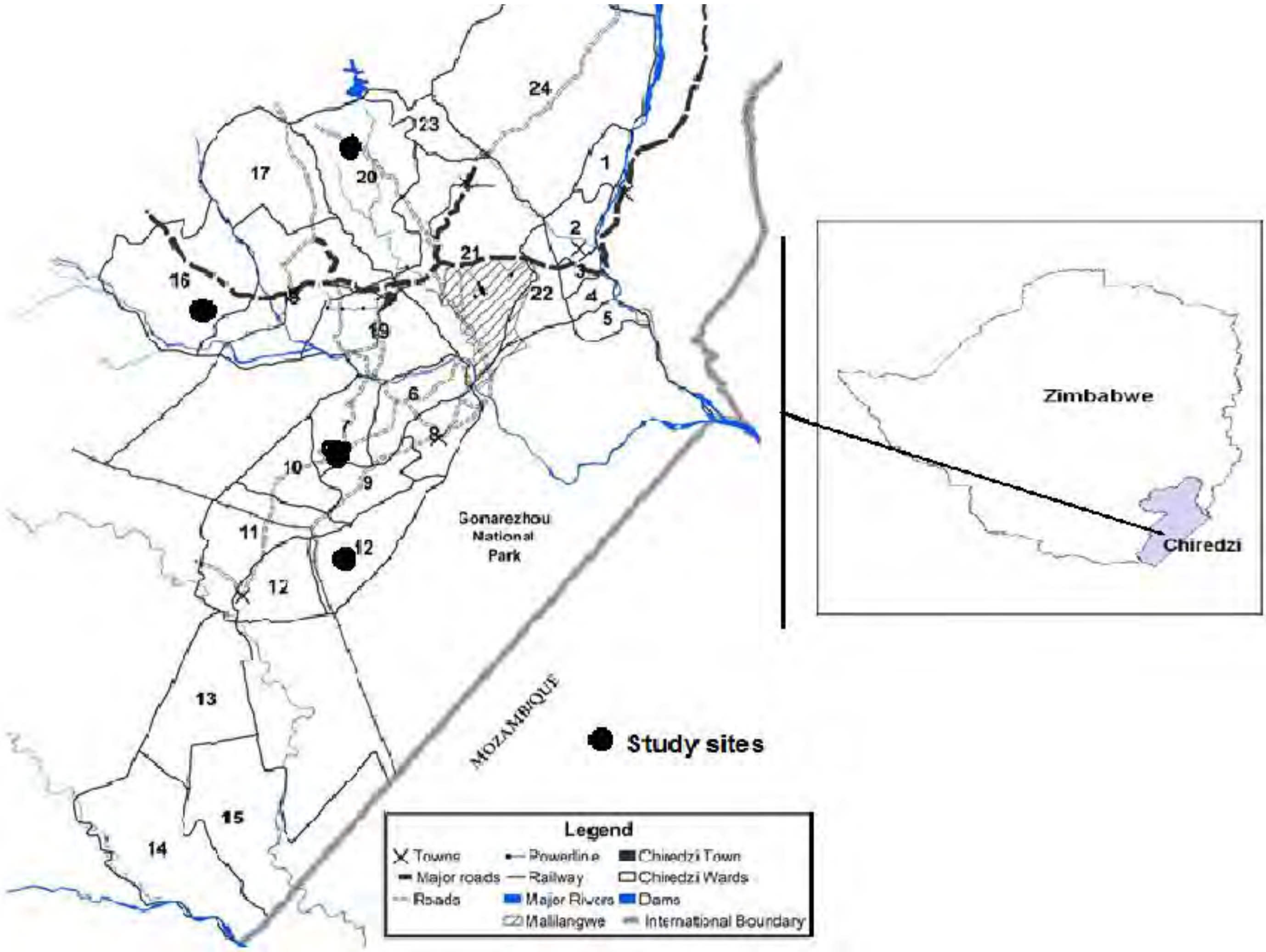

Figure 3. 1: Location of study sites

Data collection

Farming households were sampled to collect both primary and secondary data. Data were collected using a structured questionnaire, focus group discussions, key informant interviews and literature surveys. Sampling of the study area was achieved through the help of government agricultural extension (AGRITEX) officials in the area who assisted in the identification of suitable wards to carry out the study. Four wards, two on either side of the Runde River, were chosen for this study. Farmer lists were produced by village by the respective AGRITEX officers for each ward. Five villages were the randomly chosen from each ward so as to have a sample representing the whole ward. Within the randomly selected villages, five farmers were also randomly selected using the farmer lists in each village to give 25 respondents per ward. The respondents identified for this study was all dry land smallholder farmers. A total of 100 respondents were used for the study.

Key informant interviews were done with key district personnel as well as village heads and the elderly. Quantitative data collected was analysed using the Statistical Package for Social Sciences (SPSS) (SPSS, 2009)

3.3. Results

3.3.1 Socioeconomic characteristics of the respondents

The mean age of the respondents was 49 years. These were people who were born and grew up in the district of Chiredzi. About 68% of the respondents had some level of education (Table 3.1).

Table 3.1: Level of education of respondents

Level of education	Percentage (%) of respondents
Primary	38.1
Secondary	26.8
Tertiary	2.1
No formal education	33.0
Total	100.0

Almost a third (28.9%) of the households had no other sources of income outside the subsistence agricultural activities. Less than 10% of the household received more than USD350 per month from sources outside the farm (Figure 3.2). Most households depended on farming activities with no access to credit facilities (73.2%).

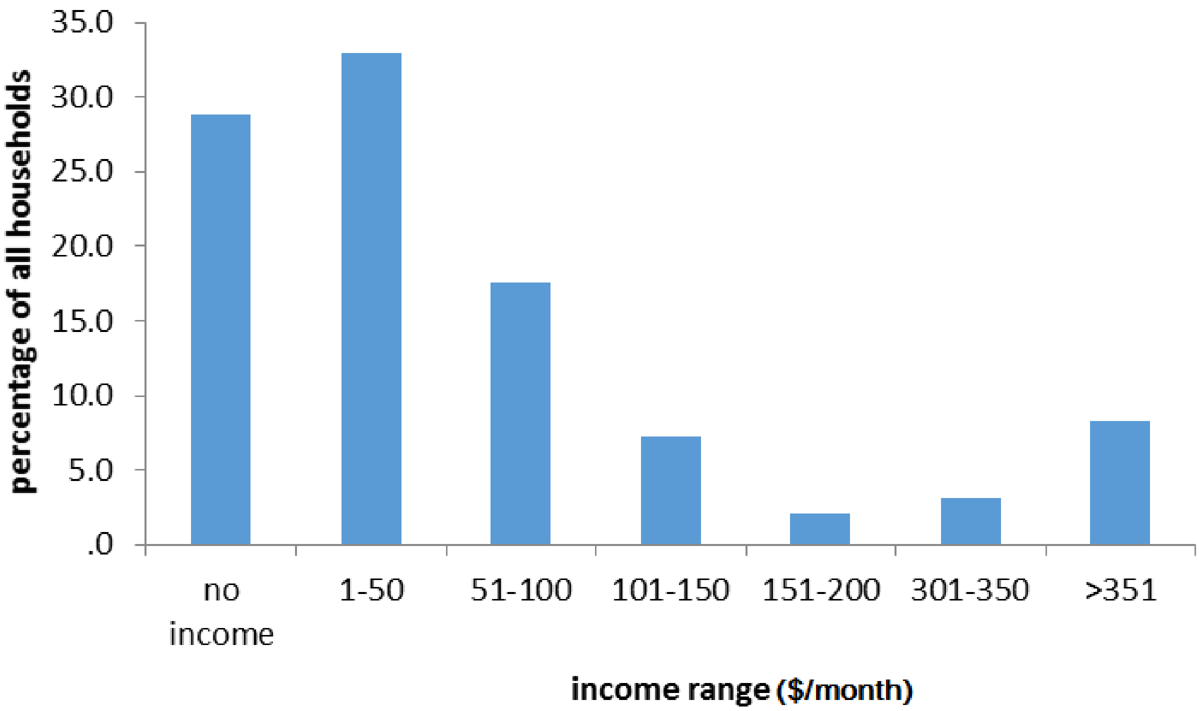

Figure 3. 2: Level of income from sources other than household agricultural activities

3.3.2 Indigenous people observations of climate change and variability

The results show that 86.6 % of the respondents were of the opinion that there have been some changes in the climate over the 20 years (Figure 3.3 and 3.4). The majority of the farmers indicated that there has been an increase in temperature over the last 20 years (Figure 3.3). Focus group discussants all concurred that it has become hotter in Chiredzi over the last years. Contrary to temperature perceptions, farmers indicated that rainfall amount has decreased over the past 20 years (Figure 3.4). Although the farmers were aware of the meteorological weather forecasts, they have not linked them to climate change and variability.

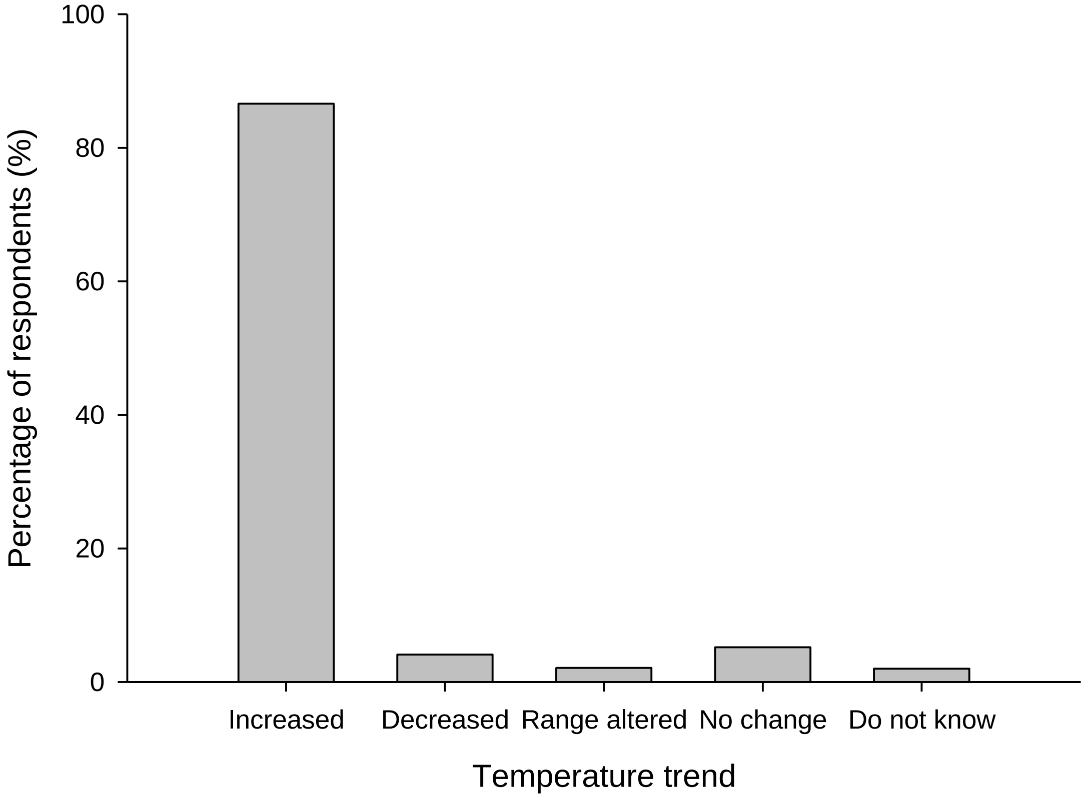

Figure 3. 3: Perceived temperature trends in the last 20 years in Chiredzi district

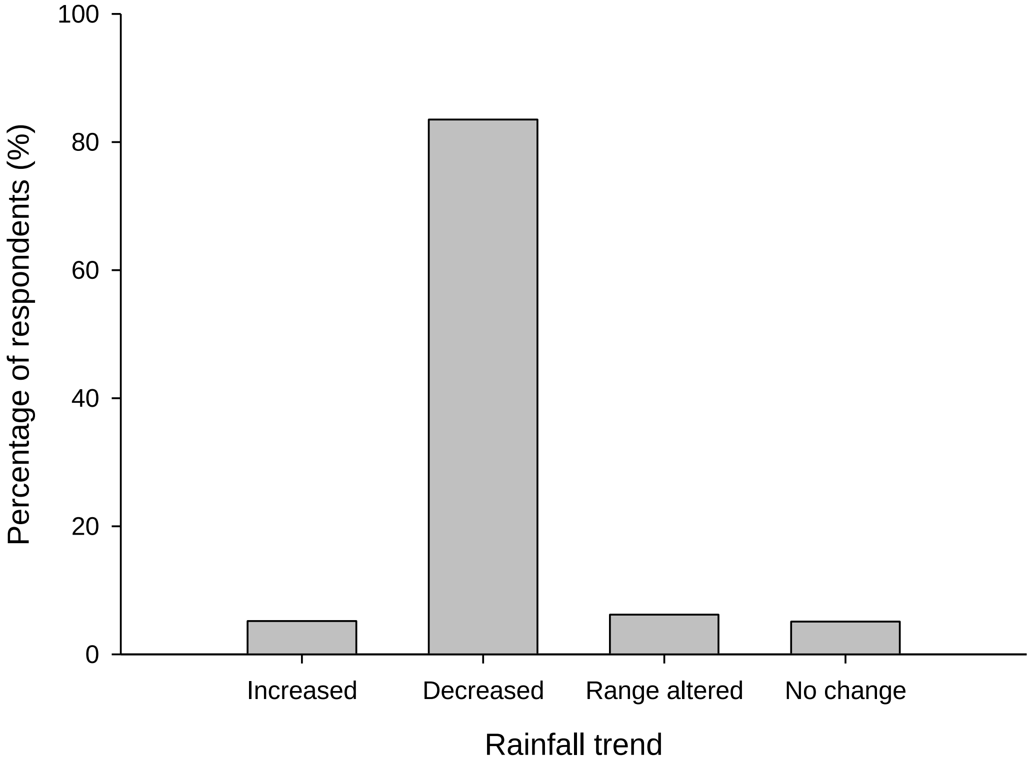

Figure 3. 4: Perceived rainfall trends in the last 20 years in Chiredzi district

3.3.3 Limitation to agricultural production

Farming in Chiredzi district is mostly rainfed. Only 3.1% of the households indicated that they had access to some form of irrigation, mainly for market gardening in the dry season. The farmers are mainly subsistence farmers who use animal drawn implements (71.1%) and hand implement (25.8%). Farmers perceive low rainfall as the greatest challenge to agricultural production over the past 10 years. The majority (72.2%) cited low rainfall as a challenge to their farming, followed by lack of inputs (17.5%). A lesser number (5.2%) cited high temperature as limiting agricultural production. Probed as to the main challenge to maize cropping, almost all respondents (92.8%) highlighted low rainfall. The rest were not aware of the reasons for crop failure.

More than 50% of the farmers indicated that lack of grazing and low rainfall affects livestock production (Figure 3.5).

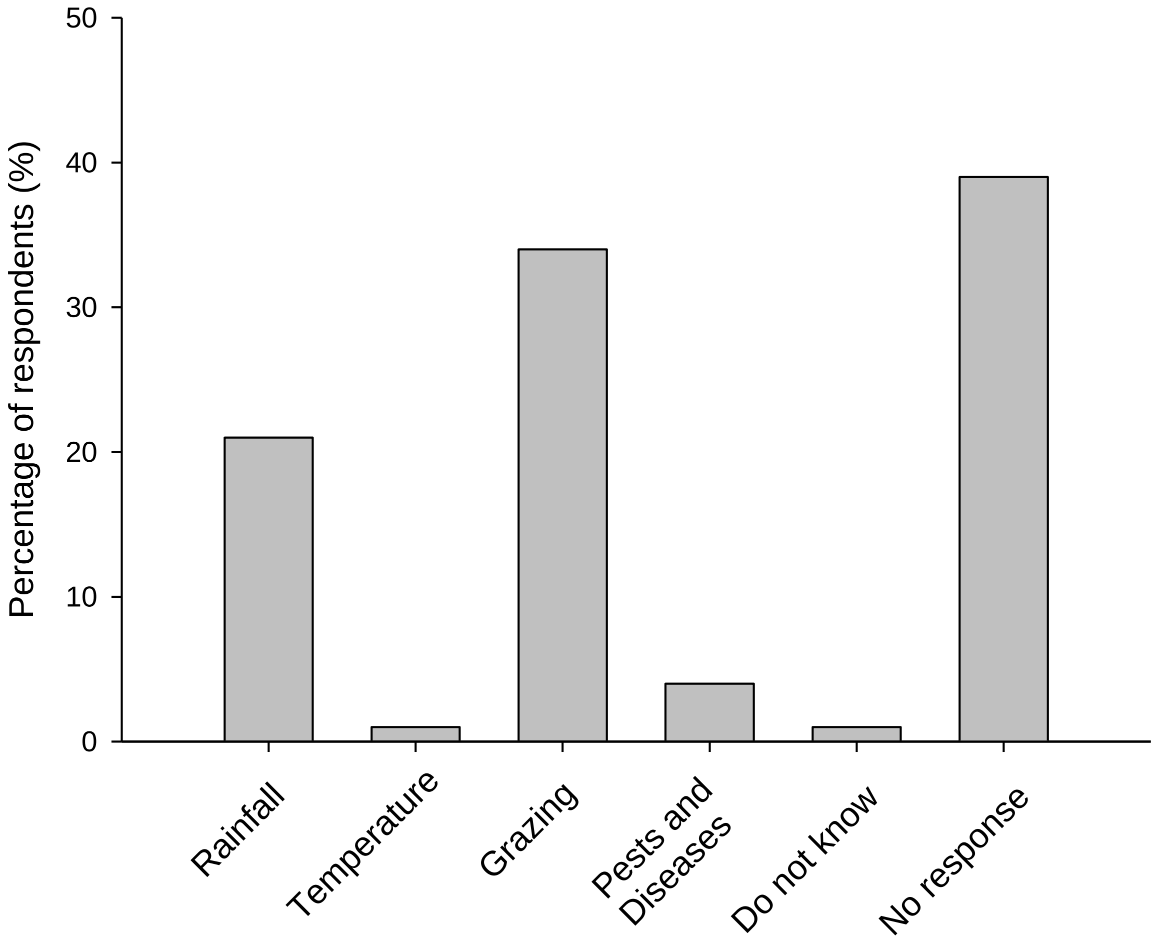

Figure 3. 5: Challenges faced in cattle production

A summary analysis indicate that the most limiting factors to smallholder agricultural production are low rainfall and lack of inputs (88.8%) while a small percentage of the respondents cited high temperature (3.4%) and lack of draught power (7.9%) as limiting factors also (Table 3.2).

Table 3.2: Factors limiting agricultural production

Factors affecting farmer production	Percentage (%) of respondents
Low rainfall	75.3
High temperature	3.4
Lack of draught power	7.9
Lack of money to buy inputs	13.5

These results show that the indigenous farmers in Chiredzi understand that there is variability and change in climate. Cropping and adaptation decisions have been based certain indicators that they have used over the years.

3.3.4 Season quality prediction by the indigenous people

While seasonal forecasts are important, farmers require short term local area forecasts for making cropping decisions. Farmers indicated that they need to be able to know when the season would start to enable them to prepare for planting. They also need information on when rainfall will occur at their local area. This survey (from individual farmer respondents, key informants and focus group discussions) showed that indigenous knowledge was used both for long and short term rainfall predictions (Table 3.3; 3.4 and 3.5). These indigenous knowledge indicators can be classified into tree phenology, animal behaviour and atmospheric observations. The long-term predictors are used in conjunction with short-term, within season predictors.

Environmental indicators that famers use to predict the coming rainy season are available for observation at different times of the year. Observations on which farmers rely on most are fruit production of certain trees and the behaviour of birds and insects throughout the year. They also observe the intensity and direction of winds.

Whole season forecasts and predictions

Table 3.3 shows indicators that are used by indigenous farmers to predict the quality of the coming season.

Table 3.3. IKS indicators for whole season quality (rainy or drought)

Name	**Characteristics**	**Importance**
Colophospermum ***mopane*** **(**mopani) sprouting	Level of sprouting and colour of leaves during spring months; initial heavy flowering indicates good rains, subsequent heavy flowering indicates poor rains	Long term rainfall predictions
Sclerocarya birrea (mupfura) fruiting	Heavy fruiting	Imminent drought
Chochomela birds	When these are seen in summer, it is a sign of a good rainy season	Long term prediction
Kwarakwara birds	If this bird is seen in summer, it is a sign of a good season	Long term prediction
Madzetse (big frogs)	If these are heard in dry streams in summer	Good rainy season
Ciconia ciconia (stork)	Appearance of these birds indicate a good rainy season	Short-term rainfall prediction
Time of winds	If at the end of October there is too much wind, it indicates a poor rainy season to come	Season prediction
Moon	Profuse halo around the moon	Good rain season
Grasshoppers	Abundances and hatching of grasshoppers in mid-season indicates a good rainy season	Season prediction

Beginning of the rainy season

The communal indigenous farmers are able to predict when the rains are about to start. Table 3.4 shows to of the indicators used by farmers.

Table 3.4: IKS indicators of the start of the rainy season

Name	**Characteristics**	**Importance**
Lone baboon	If a lone baboon crosses the area in early summer, it indicates onset of the rains.	Short-term rainfall prediction
Millipedes	Big millipedes producing sounds in the soil indicate onset of the rains	Short-term rainfall prediction

In-season predictions

Table 3.5 shows predictors used to forecast the rains with a short period of time.

Table 3.5: IKS indicators of very short predictions (within season)

Name	**Characteristics**	**Importance**
Cuckoo bird (kohwera bird)	Whenever this bird produces its crying sound, rains will fall within 2 days	Short-term rainfall prediction
Bucorvus leadbeateri (Southern ground-Hornbill) - Dendera bird	When a sound of this bird is heard, it rains the following day	Very short-term rainfall prediction
White frog	This small frog stays on trees. If it croaks in summer, rains will fall within a day.	Short-term rainfall prediction
Wind direction	Winds that come from the south eastern indicated it would rain that week	Short-term rainfall prediction
Cloud types	Dark clouds preceding strong winds means rainfall in a few hours	Short-term rainfall prediction

3.3.5 Coping and adaptation to climate change using IKS

Farming is the primary occupation for all of the sampled households although some combine a small level of non-farming activities. The high degree of dependence on farming activities calls for major adaptation to happen in the farming sector as this sector is directly affected by climate change. Based partly on their perceptions and local indigenous knowledge of climate variability, the farmers have adopted different strategies to cope with the consequences of climate change and to manage future climate variability.

Farmers indicated that they will employ different strategies at crop, field, farm and community level to adapt their cropping to climate variability and change. Table 3.6 summarizes the adaptations at different levels of the community in Chiredzi district.

Table 3.6: Coping and adaptation strategies used by farmers

Scale	**Timing**		
	Before the season	**During the season**	**After the season**
Crop	Variety selection for stress tolerance	Replanting with early maturing varieties	
Field	Staggered planting dates	Changing crops when replanting	Grazing of failed field for animal maintenance
	Low density planting	Increasing plant density when replanting	
	Intercropping		
	Soil and water management strategies		
	Delayed fertilizer use	Split application of topdressing fertilizer	Spreading of anthill soil to fields
Farm	Diversified cropping	Shifting crops between land types	
	Plot fragmentation		
Community level	Social networks	Matching weeding labour inputs to expectations of the season	Asset sales for cereal purchases
	Off-farm employment networks		Food transfers
	Increase livestock assets		Migration employment
	Assess cereal stocks		

3.4 Discussion

This study noted that indigenous knowledge was a preserve of the elderly and traditional leaders. Younger people and women were hesitant to confirm their indigenous knowledge. This may mean that indigenous knowledge is not widely shared in these communities. This concurs with the findings of Easton & Roland (2000) and Ramphele (2004) who found that women are often side-lined in indigenous knowledge systems in communities. Most elders and village heads acknowledge traditional knowledge as an important source of weather pattern information for the area. From focus groups, it was evident that indigenous knowledge is traditional knowledge passed from generation to generation. The elderly usually responded to explain the weather indicators. The younger generation and women were less confident in outlining the indicators. The younger people were also not able to give names of the trees and birds used in weather prediction. This agrees with Pilgrim et al. (2008) who found significant differences between the young and older people's knowledge of local species in indigenous communities in India. However, all farmers, women, children and the elderly, pointed to changing climate and increased vulnerability. This has increased social challenges as the farmers depend on farming for livelihoods (Soh et al. 2012).

When asked whether a change in climate has occurred in their lifetime, most farmers interviewed responded that climate variability has increased (Figure 3.4). In their view, it rains less than before, rains begin late or end prematurely and dry spells are more frequent. These perceptions of farmers show high level of understating of climate change occurrence, while still a small proportion failed to do so. This small proportion should be considered positively as a target for the extension system to be provide with information on climate change related issues (Leautier, 2004). Perceived changes in temperature have significant influence in the choice of climate change coping and adaptation strategies (Figure 3.3; Mbilinyi et al. 2005; Nkoma et al. 2014). Perceived change in average temperatures did seem to explain the cultivation of more crop varieties, use of short growing crop varieties and use of soil and water conservation measures (Table 3.6). This is supported by Eriksen (2005) and Yesuf et al. (2008) who concluded that adoption of cropping adaptation strategies is largely influenced by current perception and levels of climatic variables.

The rainfall has also become erratic in Chiredzi. It has become difficult to plan when to plant crops and to do other agricultural operations. Farmers indicated that the rainfall season now starts late, but some years it could be different. This concurs well with scientific climate studies which indicates that rainfall would become more erratic and shift in seasons would also result from climate change (Lobell et al. 2011; Mavhura et al. 2013)

Temperature increases and decline in rainfall will increase environmental stresses (Robinson and Herbert, 2001). The impacts of increasing temperatures and decline in rainfall call for continuous coping and adaptation (Mavhura et al. 2013). The magnitude of these impacts in the local communities will be influenced by their level of vulnerability to climate change (UNDP, 2010; Hiwasaki et al. 2014). Despite increased climate variability, these marginal people have managed their farming and resources effectively over the years. They have observed the changing tree phenology and animal behaviours over the years to help them cope and adapt to climate change and variability (Table 3.3; 3.4; and 3.5). As a result they hold knowledge of how wildlife and plants behave and reproduce as an indicator of certain weather patterns (Pilgrim et al. 2008).

Increased climate variability, however, has weakened the farmers' confidence in the local forecasts of rainfall patterns based on tree phenology and animal behaviour. Some elders recalled the times, in the past, when they were able to predict the onset of the rains accurately. Now, they are open to alternative sources of rainfall information. They do not resist the use of scientific information or regard it as threatening local IKS. This is because local IKS is robust and dynamic (Roncoli et al. 2002; Davis, 2005). Farmers pragmatically mix indigenous knowledge with extension advice and meteorological forecasts. Even in using their indigenous knowledge, farmers often combine a variety of environmental and spiritual traditions. The farmers' observations are related to movement of weather systems that have a bearing on the rainfall pattern over the area. In South Africa, for instance, the farmers' perceptions were that IKS were usually right, but not always (Zievogel, 2001). Generating useful forecasts, therefore, calls for a deep understanding of the needs of specific user groups, more-so those in agriculture, and the benefits and challenges forecasts may present to these users (Zievogel, 2001; Zurayk et al. 2001). Farmers concurred that, just as meteorological weather forecast have become too generalised and unreliable, their indigenous knowledge has also become less reliable.

Local communities have developed coping mechanisms and adaptation strategies which include a mix of crops, selection of more drought tolerant crop varieties and sites, staggering planting of crops and adjusting land and crop management to suit the prevailing conditions. This is also reported in other studies (Yesuf et al. 2008; Mavhura et al. 2013; Hiwasaki et al. 2014). These strategies are reached at partly through consideration of IKS predictions. More than 90 percent of the 100 rural households sampled reported having faced severe food shortages, especially during the months of November to January. Local people in Chiredzi district, and indeed southern Africa, are no strangers to climatic risks and have developed some useful mechanisms to cope with them (GoZ-UNDP/GEF: Coping with Drought and Climate Change Project, 2009). Like in other regions of Africa, southern African farmers monitor a number of indicators to predict rainfall including plant and animal behaviour and can adjust labour and allocate resources accordingly (Munyua & Stilwell, 2013; Zuma-Netshiukhwi et al. 2013).

The use of IKS in climate change adaptation requires consideration of timescale. It also means setting climate-specific adaptation in the broader context of changing livelihoods (Kirkland, 2012). Understanding existing adaptation strategies utilised at household and community level is important especially when introducing new options. Farmers are aware of the changes in their environment (Rao, 2006). Whenever a bad rainfall season was anticipated, the farmers preferred to grow short season maize varieties, small grains like sorghum. Livelihood systems shifted to focus more on market gardening and casual labour and gathering wild fruits and rearing of livestock (Patt & Gwata, 2002). When good rainfall season was expected the farmers grew mostly long season maize variety on large areas.

It, therefore, requires a look at the worsening climate change impacts outlook and the extent to which diversification into off-farm activities could assist in building resilience. The predictions of an increase in average temperatures and a decrease in rainfall in southern Africa (Thornton et al. 2011), projects an increase in the frequency of occurrence of crop failures. For this reason, recommending farming as a continued livelihood activity would be appropriate in the short to medium term. This is where bringing IKS to local adaption strategies and policies would be important. However, in the long term, a diversification of livelihoods into climate insensitive activities would be a more appropriate adaptation pathway (Newsham & Thomas, 2009).

Traditional coping methods are based on experience accumulated over the years and transmitted from generation to generation. Prior to the 1970s, climate extremes such as strong El Niño events occurred every 10 to 20 years. This rhythm enabled the local communities in southern Africa to deal with these problems either at the household level or through well-established social networks. Climate change is eroding these coping mechanisms by causing climatic extremes with a frequency and intensity never seen in the past. The recurrent droughts in Africa have led to the degradation of the resource base and forced many farmers to sell their assets and migrate to cities or neighbouring countries.

However, as reported by IPCC (2007), indigenous knowledge systems are steadily being eroded the world over. These could become extinct in the next decade (IPCC, 2007). When this happens, outside actors need to ensure that this traditional knowledge is preserved and protected (Kirkland, 2012).

3.5 Conclusion

The role of traditional knowledge in smallholder agriculture cannot be understated. This research has proved that mostly the traditional leaders and the elderly fully understand the use of indigenous knowledge in forecasting season quality. However, even these have noticed the erosion of local knowledge. Despite this, the farmers still use indigenous knowledge to make certain coping and adaptation decisions. Climate change may bring about a new set of weather patterns and extreme events that are well beyond what the local communities are capable of dealing with. External help is necessary to enhance the social and ecological resilience among rural communities. Indigenous coping mechanisms, albeit not enough on their own to respond to climate change, can serve as a useful entry point for interventions by governments, relief organizations and development agencies. It should be noted that, despite the inclusion of indigenous knowledge in the design and implementation of sustainable development projects, little has been done to document and incorporate this into formal climate change adaptation strategies. Further research is needed to better understand the usefulness of these traditional indicators and to see how they can be used as an entry point to operationalize science-based climate forecasting at local community level. This will enhance resilience to climate stresses and buttress copping and adaptation strategies.

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CHAPTER 4[3]

Smallholder farmer perceptions on climate change and variability: a predisposition for their subsequent adaptation strategies

Abstract

Smallholder farmers are facing several climate-related challenges. Projected changes in climate are expected to aggravate the existing challenges. This study was conducted in Chiredzi district, Masvingo, Zimbabwe. The study objective was to examine farmer perceptions on climate variability, current adaptive strategies and establish factors influencing smallholder farmers' adaptation to climate change. A survey was conducted with 100 randomly selected respondents from four wards. Additionally, data was collected through focus group discussions and key informant interviews. The results showed that farmers perceived that there has been a decrease in annual rainfall and an increase in average temperatures. A linear trend analysis of rainfall and temperature data from 1980 to 2011 corroborated the farmers' perceptions. Farmers' adaptation options included adjusting planting dates and crop diversification. Off-farm income has reduced the dependence of the farmers on agriculture. A multinomial regression analysis showed that socio-economic factors such as gender, age, number of cattle owned, land size and average crop yields influenced farmer adaptation strategies. The study concludes that although farmers are diverse in their socio-economic attributes, they exhibit homogeneous perceptions on changes in climate, which are consistent with observations of empirical climate data. These perceptions help to shape smallholder farmer coping and adaptation strategies.

Key words: Climate change and variability, farmer perception, adaptation, adaptive capacity

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4.1 Introduction

Climate change and variability is one of the biggest global agricultural production threats for the current and future generations. There is evidence that climate change has greatly modified the hydrological cycles, rainfall and temperature patterns in many parts of the world (IPCC, 2007). The effects of climate change and variability, however, vary across regions, farming systems, households and individuals. The combined effects of all these occurrences put a strain on the livelihoods of smallholder farmers, especially in developing countries. This vulnerability of developing countries to the climate risks is based on the observations that developing countries heavily depend on rainfed agriculture (IPCC, 2007). Without any adaptation, climate change and variability would cause a decline in annual gross domestic product of 4% in Africa (World Bank, 2010). The situation is of even greater concern in Sub-Saharan Africa where per capita food production has been declining.

The vulnerability, resilience, coping and adaptive capacity of farmers to climate change and variability in semi-arid systems could be addressed through different adaptation strategies. However, farmers' adaptation decisions are guided by their perception to climate change and variability, and climate related risks. Smallholder farmers need to be able to identify the changes already taking place in their areas and institute appropriate coping and adaptation strategies. A farmer's ability to perceive climate is a pre-requisite for their choice to cope and adapt (Moyo et al. 2012; Kihupi et al. 2015). The coping and adaptation strategies of smallholder farmers depend, to a large extent, on their perception knowledge level (Kihupi et al. 2015). In essence, adaptation to climate change and variability requires farmers to first notice that the climate has changed, and then need to identify and implement potential useful adaptations (Adger et al. 2005).

Consequently, without adaptation, the vulnerability of communal households that depend on agriculture would increase with climate variability and change. However, these smallholder farming communities have coped and adapted to the effects of climate change and variability over the years (Li, Tang, Luo, Di, & Zhang, 2013). This creates the need for understanding the perception of the smallholder farmer to the impacts of climate change and variability at the local level (Shemdoe, 2011, Kassie et al., 2013).

Over the years, smallholder farmers in Zimbabwe and other parts of Southern Africa have devised adaptation strategies to climate change and variability. These include crop diversification, planting different crop varieties, complementing farm activities with non-farm activities (such as curio sales), changing planting dates, increasing the use of irrigation, and increasing the use of water and soil conservation techniques (Hassan and Nhemachena, 2007). However, smallholder farmers' decisions to implement any meaningful agricultural adaptation strategies is largely influenced by their perceptions of the weather, among other factors (Patt and Gwata, 2002; Patt et al. 2005). The farmers' perception of climate change influences their propensity to respond to the strength of a climate signal and subsequent adaptation (Bryan et al. 2009). The impacts of climate change and variability cannot be understood without considering farmer perceptions, economic policy and environmental forces that influence how climate signals are felt and how they impact on farm level decisions.

The objective of this study was to infer the perceptions of smallholder farmers on climate change and variability, and its influence on subsequent adaptation strategies in Chiredzi District, Zimbabwe.

4.2 Materials and methods

Description of the study area

The study was conducted in Chiredzi District in Masvingo Province, Zimbabwe, which lies between 18°55'S and 29°49'E. Chiredzi District was chosen as it falls within the arid and semi-arid areas. It lies largely in Natural Region V, a region that experiences the lowest amount of rainfall of less than 400 mm $year^{-1}$ in most years (Moyo, 2000; Vincent and Thomas, 1960). The rainfall is often erratic, with widespread droughts in most years. Temperatures are always quite high in summer (day temperatures often over 39ºC in summer) causing evaporation losses of 10-13mm per day. The annual mean, maximum and minimum mean monthly temperatures in the district are 24.8°C, 27.4°C (November) and 22.3°C (July), respectively.

Data collection and analysis

Four out of the 24 wards in rural Chiredzi district, two on either side of the Runde River, were chosen for this study. Five villages were randomly chosen from each ward and farmer lists for each village were supplied by the agricultural extension officers. Within the randomly selected villages, five farmers were randomly selected using the farmer lists in each village to give 25 respondents per ward. Quantitative and qualitative data was collected using a variety of participatory methods: structured questionnaire, focus group discussions and key informant interviews (Bryman, 2008). Seven key informant interviews were done with key district personnel as well as village heads and the elderly. A focus group discussion was done in each ward. A total of 100 households were interviewed using the questionnaire. Quantitative data collected through the structured questionnaire was analysed using the Statistical Package for Social Sciences (SPSS) (SPSS, 2009). Linear trend analyses of climate time series data was done on climate and multinomial logit regression analysis of determinants of adaptation options was also done. The multinomial logit analysis model for climate adaptation strategy specifies the following relationship between the probability of choosing option A_i and the set of explanatory variables X as:

$$Prob\ (A_i = j) = \frac{e^{\beta_j' x_i}}{\sum_{k=0}^{j} e^{\beta_k' x_i}}, j = 0,1 \dots . J$$

Where β_j is a vector of coefficients on each of the independent variables x. The variables used for the multinomial logit regression analysis are as follows:

a. Gender of household head
b. Age of household head
c. Total area of dry land being used
d. Average maize yields
e. Average cotton yields
f. Total number of cattle owned
g. Total number of members fit to work
h. Employment status
i. Perception on climate change

4.3 Results

4.3.1 Household and demographic information

Male household decision makers made up 65% of the respondents while 35% were female. Sixty seven percent of the respondent farmers were married with 10%, 22% and 1% being widowed, single and divorced, respectively. The average age of the respondent farmers was about 49 years, with a range of between 17 and 80 years (Table 4.1). The results also revealed that a high proportion of the farmers (38.2%) had primary education while 26.8% had up to secondary education. Only about 3% of the farmers had some tertiary education. However, 32% of the farmers did not have any formal education.

Table 4.1: Age of household head

	Age of head of household (years)
Mean	48.84
Std. Error of Mean	1.44
Median	50
Std. Deviation	14.14
Minimum	17
Maximum	80

The average household size was seven persons, an average of three males and four females per household. However, each household had an average of four members being fit to work in the fields and members who were either too young or chronically ill to work explain the difference. A significant proportion, 77.3%, of the household heads were full time farmers while the remainder were involved in formal employment (5.15%) or self-employment (6.19%). The remainder, 11.36%, were not part of any of the categories indicated. Seventy nine percent of the farmers have income of less than $100 per month with 28% of these having no reliable source of this income. The major sources of income were crop (average $51 per month) and livestock (mainly goats averaging $48 per month) sales, as well as part-time work (averaging $45 month income).

4.3.2 Farmer perceptions on long-term climatic changes

Figure 4.1 shows the respondent farmers' perception on long-term temperature trends in Choredzi district. More than 87% of the respondents perceive that there has been an increase in average temperatures in the past 10-20 years.

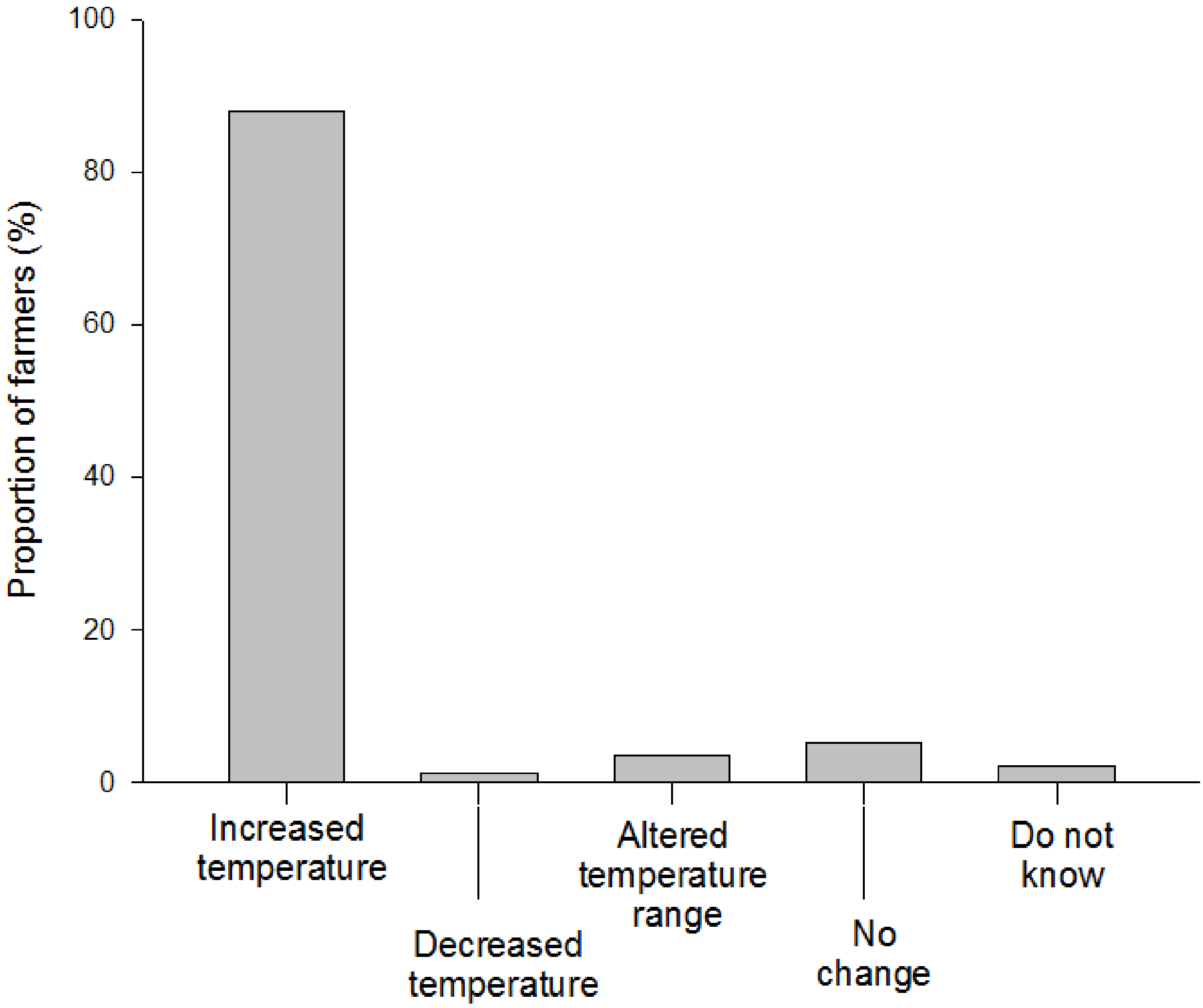

Figure 4. 1: Farmer perceptions on long-term temperature changes in Chiredzi district

The results also indicated that most farmers (85.7%) perceive that precipitation has been declining in the past 10-20 years. This implies that the district is becoming more and more prone to droughts due to declining rainfall as perceived by the farmers. About 9.2% of the farmers perceive that, in the past 10-20 years, there has been a noticeable change in the onset and duration of the rains, while 4.1% and 1% either perceive no change or do not know whether there were any changes in rainfall, respectively.

These results agree with trend analysis of the observed rainfall and temperature data obtained at Chiredzi (Figures 4.2, 4.3 and 4.4). The trend analysis for rainfall in Chiredzi district is shown in Figure 2. The analysis shows a negative trend in total rainfall in the district. The decrease in rainfall is 2.59 mm/year. The trend analysis for rainy days (Figure 4.3) shows that there is also a negative trend of 0.43 days/year (1980 – 2011). Figure 4.4 shows an increase in average temperatures for Chiredzi district of 0.03ºC/year from 1980 to 2011.

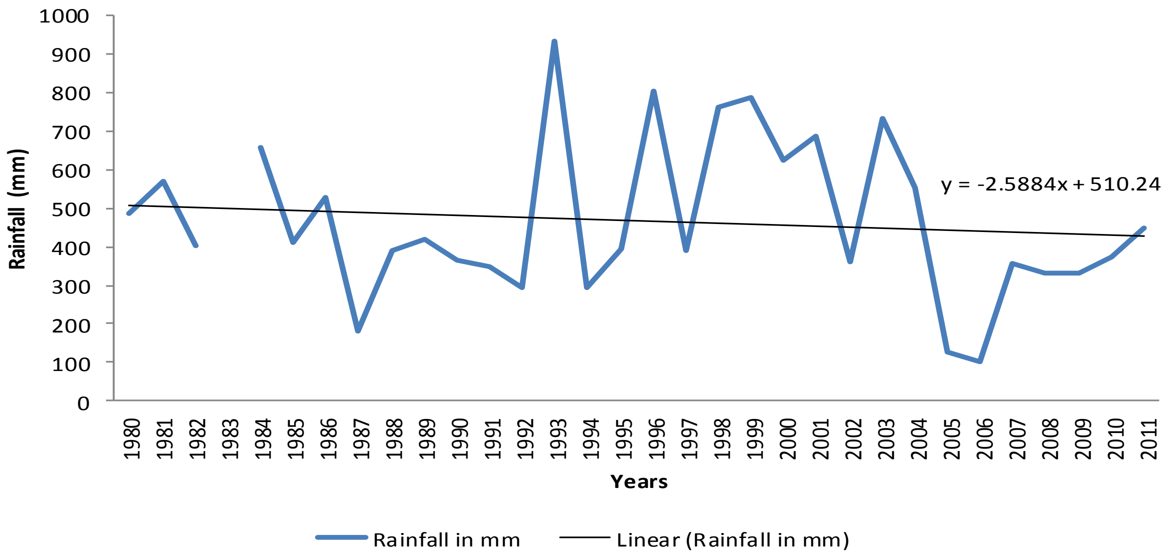

Figure 4. 2: Rainfall trends for Chiredzi district from 1980 – 2011
Source: Chiredzi Research Station Climate Records, 2013

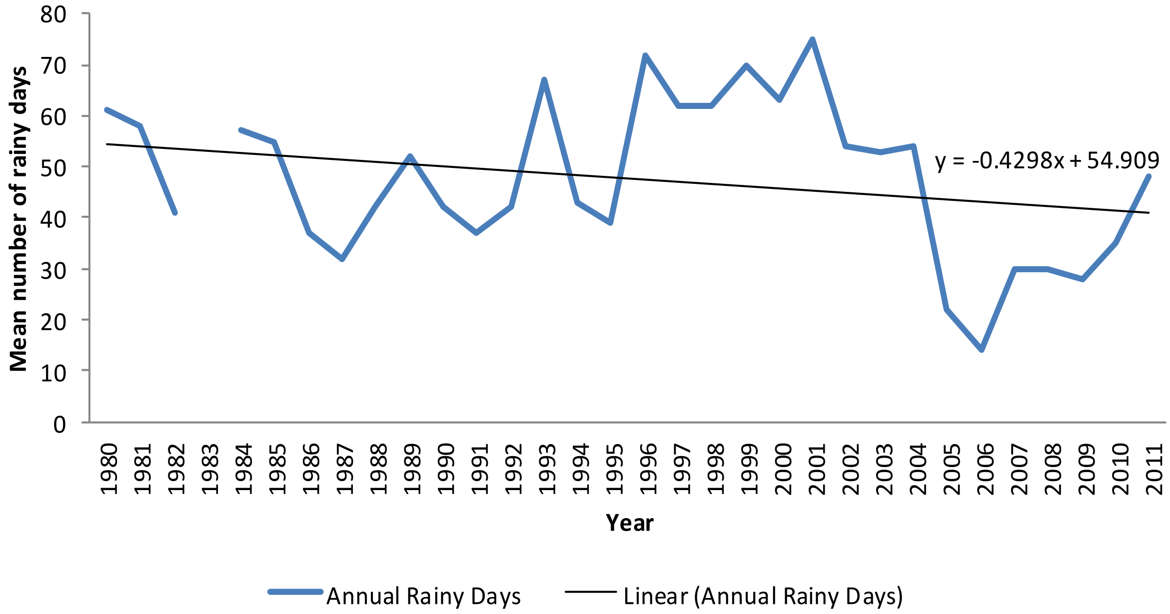

Figure 4. 3: Rainy days trend for Chiredzi district from 1980 - 2011
Source: Chiredzi Research Station Climate Records, 2013

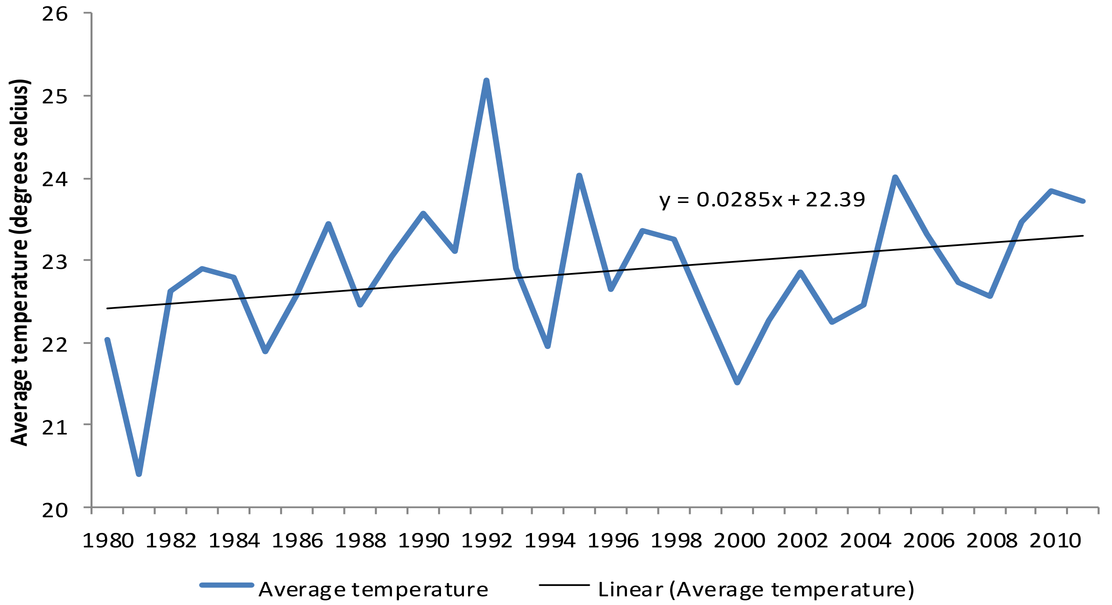

Figure 4. 4: Temperature trend for Chiredzi district from 1980 - 2011
Source: Chiredzi Research Station Climate Records, 2013

4.3.3 Farmer perceptions on crop yields

The results indicated that 76% of the farmers believed that maize yields have been declining over the past 20 years. Twenty-four percent either observed no changes or thought the maize yields had remained static. Analysis of average yield per hectare and total maize total maize output for Chiredzi district confirmed the farmers' perceptions (Figure 4.6). While the area under maize and sorghum has been constant, the average area put to cotton per household has been marginally increasing over the years (0.25ha in 2009, 0.31ha in 2010 and 0.35ha in 2011). An analysis of the main cereal crop yields showed prevalence of farmers obtaining very low average yields of less than one tonne per hectare over three years in Chiredzi district for maize (Figure 4.6) and sorghum (Figure 4.7).

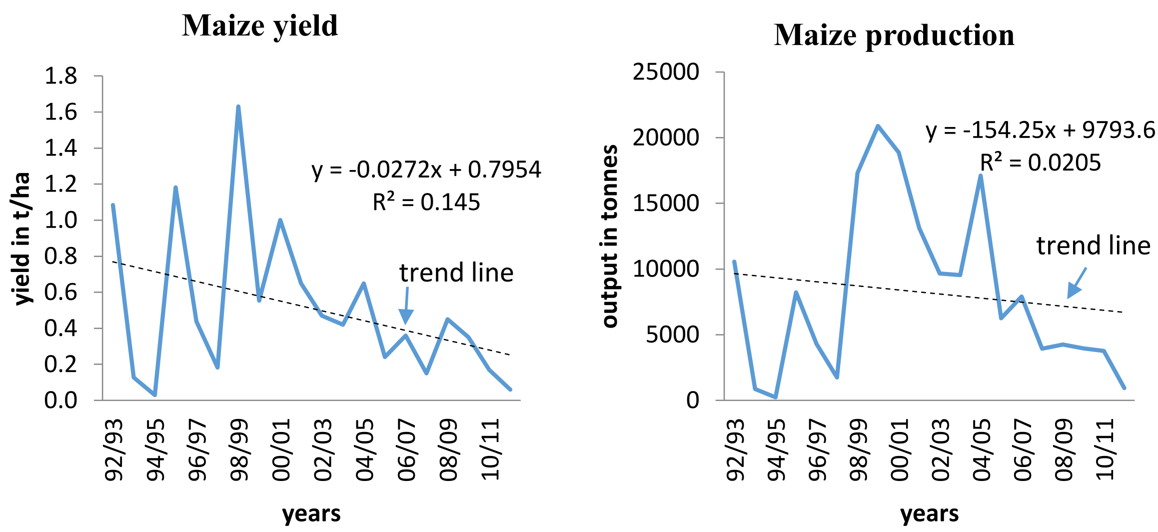

Figure 4. 5: Chiredzi district maize yield and production trends

Source: Ministry of Agriculture, Mechanization and Irrigation Development (Chiredzi), 2013

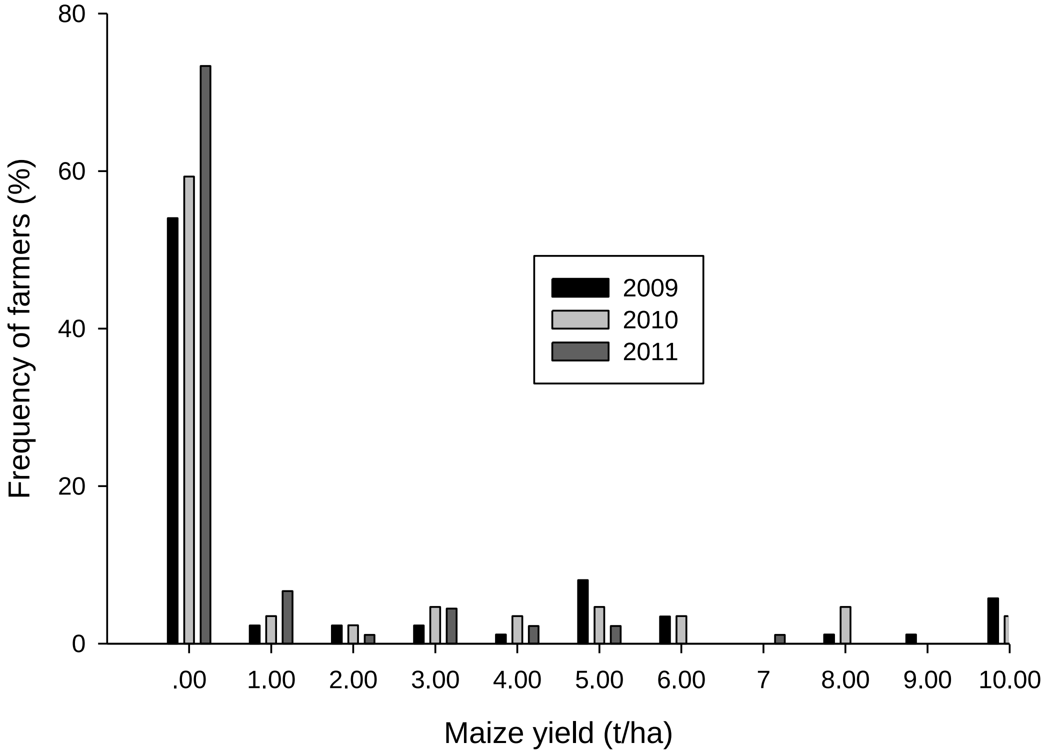

Figure 4. 6: Frequency of farmers obtaining different maize yields in Chiredzi district in 2009, 2010 and 2011 (Source: Survey data)

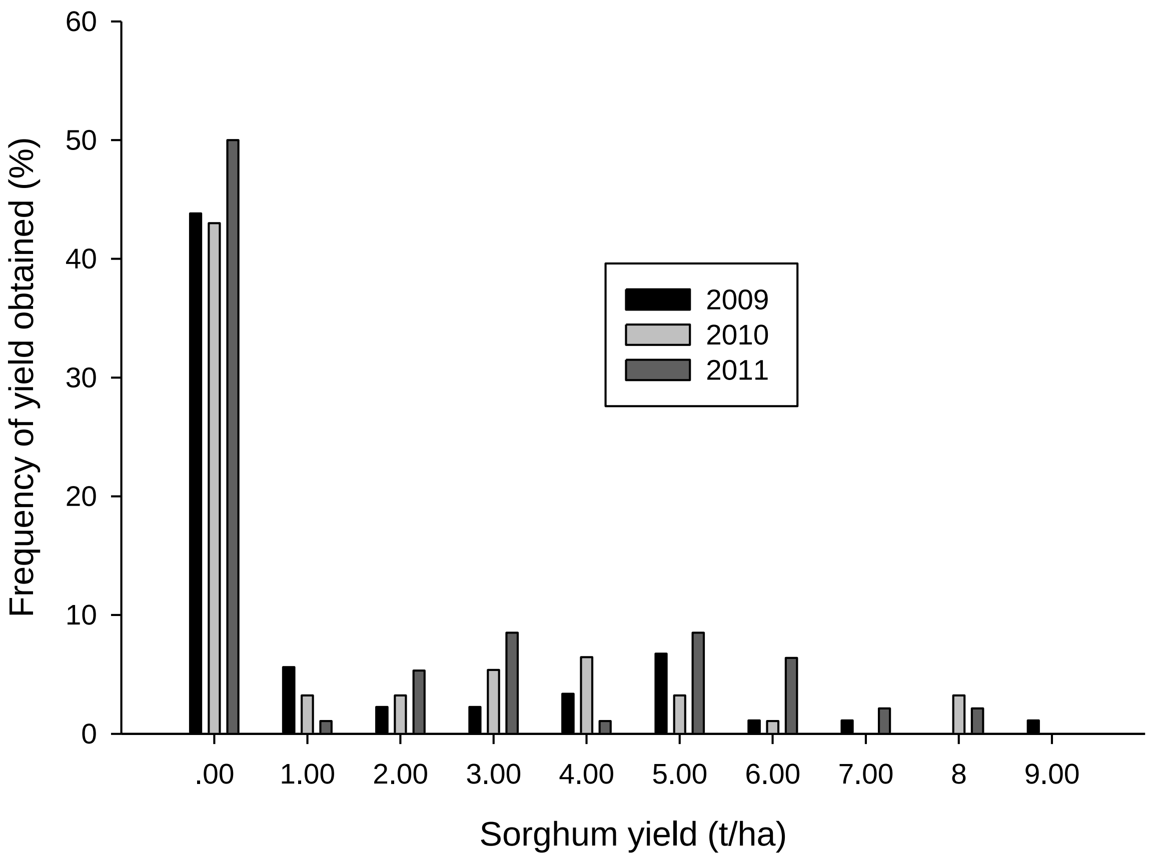

Figure 4. 7: Frequency of farmers obtaining different sorghum yields in Chiredzi district in 2009, 2010 and 2011 (Source: Survey data)

4.3.4 Farmer perceptions on other climate change indices

Farmers in Chiredzi perceive decreased bush encroachment (38.1%), reduced herbaceous cover (37.1%), disappearance of wetlands (8.3%) and 16.5% did not observe any changes. About 34% of the farmers perceive decreased crop heights while about 30% perceive shorter germination periods and variable maturation periods. About 62% of the farmers perceive an increase in crop pest abundance while about 2% and 6% perceive a changed seasonality of some crop pests and emergence of new crop pest species, respectively. About 46% of the farmers perceive increased crop disease prevalence while 5% perceive changed seasonality of crop diseases and emergence of new crop diseases. However, about 39% of the farmers perceived no change or a decrease in crop disease prevalence, severity and seasonality. Thirty one percent of farmers perceive increased weed abundance, 11% perceive new weed species and 3% perceive changed seasonality of weeds. About half of the farmers perceive increased livestock pest abundance while those farmers who perceive changed seasonality of livestock pests and emergence of new livestock species were 4% and 2%, respectively. About 43% of the farmers perceived an increase in livestock disease prevalence and severity while 3% perceive new livestock disease types. However, 47% of the farmers perceive no changes in livestock diseases or they are not sure if any changes in livestock disease prevalence, severity and seasonality, have taken place.

These results indicate that smallholder communal farmers are aware of impacts of climate change on crops, crops pests, livestock and the environment.

4.3.5 Smallholder farmers' adaptation strategies to climate change and variability

Table 4.2 shows the disaggregated data for adaptation options. Adaptation to climate change and variability through adjustment of agronomic practices (cropping adaptations) under dry land conditions was the main coping and adaptation mechanism in Chiredzi district (55.1% of smallholder farmers) (Table 4.2). A combination of agronomic and livestock practices was also a prevalent strategy (26.9%). Livestock adaptations only without crops were carried out by 15.4% of the smallholder farmers. Adaptation using socio-cultural beliefs and practices was shown to be the least common strategy used by smallholder farmers (2.6%) (Table 4.2). However, it is important to note the importance of social beliefs in climate adaptation, as they are the basis of indigenous adaptation strategies to climate change and variability.

Table 4.2: Adaptation measures used by smallholder farmers in Chiredzi

Adaptation measure	Percentage of adopters (%)
Different crop varieties	51.55
Crop diversification (Different crops)	63.92
New planting dates	68.04
Shortening the length of growing period	69.07
Mixing dry land and home gardens	83.51
Mixing farming and non-farming activities	83.72
Use of irrigation (home gardens)	80.41
Use of chemicals, fertilizers, manure and pesticides	77.32
Increasing water conservation on farms	60.82
Increasing soil conservation on farms	65.98
Shading and sheltering young plants	74.23
Mixing crops and livestock (diversification)	74.23
Livestock diversification (different animals)	82.47
Adjusting livestock management practices	82.47
Insurance	0
Use of prayer and socio-cultural adaptations	83.81

4.3.6 Factors influencing farmers' adaptation options

Table 4.3 shows a multinomial logit regression analysis of the factors influencing the choice of the farmers' adaptation strategy. Farmer socioeconomic attributes and farmer perception to climate change and variability significantly influenced the type of agricultural adaptation chosen by the farmer in response to the changing climate (Table 4.3). Male-headed households significantly improved chances of adopting agronomic practices and a combination of agronomic and livestock practices, but would not adapt to climate change through the adoption of livestock practices only (Table 4.3). Despite cattle being important in traditional ceremonies, the number of cattle owned had no significant effect on the adoption of agronomic and socio-cultural practices for climate change adaptation. However, the number of cattle owned had significant impact on the adoption of agronomic practices only, livestock practices only and a combination of agronomic and livestock practices.

Table 4.3: Socioeconomic and perception determinants of climate adaptation options by smallholder farmers in Chiredzi district

Variable	Agronomic practices only		Livestock practices only		Agronomic and livestock practices		Agronomic and socio-cultural beliefs/practices	
	Coeff.	P-level	Coeff.	P-level	Coeff.	P-level	Coeff.	P-level
Intercept	-2.008	0.017**	-2.649	0.093*	-5.004	0.015**	-4.233	0.993
Gender	0.541	0.050*	-2.905	0.094*	3.157	0.014**	-5.015	0.989
Age	0.660	0.061*	2.495	0.095*	0.052	0.018**	1.630	0.098*
Employment status	-1.896	0.084*	2.21	0.091*	0.030	0.097*	1.237	0.988
Farm size-dry land	-0.06	0.037**	-3.05	0.051*	0.122	0.070*	-2.072	0.986
Members fit for agriculture	0.155	0.003***	0.115	0.017**	0.223	0.000***	0.217	0.011**
Cattle owned	0.041	0.077**	7.433	0.072*	0.080	0.057*	-5.466	0.994
Maize yield	0.068	0.000***	5.272	0.916	0.032	0.076*	2.035	0.083*
Cotton yield	14.188	0.048**	3.661	0.854	13.797	0.000***	3.582	0.099*
Perception on climate	0.874	0.005***	1.032	0.604	0.173	0.040**	0.839	0.079*
Base category	**No adaptation**							
Likelihood Ratio Chi^2	61.966							
Pseudo R^2	0.615							
Log likelihood	-110.821							

Notes: ***, **, * = significant at 1%, 5%, and 10% probability level, respectively.

4.4 Discussion

In this study, the basis of farmers perceiving a changing climate is declining rainfall and increasing average temperatures over the years (Figure 4.1). This corroborates with measured annual rainfall and temperatures for Chiredzi district (Figures 4.2, 4.3 and 4.4). The mean annual rainfall for Chiredzi district was 466.49mm, fluctuating between 101.50mm and 932.30mm in the period between 1980 and 2011 (Figure 4.2). Trend analysis of the empirical rainfall data shows an average annual decrease in rainfall of 2.59 mm. The trend analysis for rainy days (Figure 4.3) shows that there is also a negative trend of 0.43 days per year from 1980 up to 2011. This means that the number of raining days per each season is decreasing. Majule et al. (2008) reported similar results of declining precipitation in Malawi and Tanzania by 0.85 mm per year over the last 30 years. An analysis for mean annual temperatures in Chiredzi showed an annual increase of 0.03ºC (Figure 4.4). These results are consistent with findings by Solh and Saxena (2011) and IPCC predictions for southern Africa (IPCC, 2007). Maddison (2006) obtained similar results which showed that a significant proportion of farmers in Africa are noticing increasing temperatures. Correct perceptions of a problem and the awareness of the potential benefits of redressing the problem is a critical determinant of adoption of agricultural adaptation initiatives (Nhemachena and Hassan, 2007, Bryan et al. 2009, Vermeulen et al. 2012). Maddison (2006) and (Vedwan & Rhoades, 2001) noted that farmers' perceptions on changes in temperature and rainfall are critical for farm-level adaptation decision-making. This is supported by Gould et al. (1989) who found a significantly positive relationship between farmer perceptions and awareness and the adoption of soil conservation measures. Results from the current study showed that those farmers who have perceptions that are in line with the actual trends in climatic changes will adopt measures to cope and adapt to climate change and variability (Table 4.3).

The results showed a continuous decline in maize yields (Figure 4.5). This could be a result of the average growing conditions over the years (Figures 4.2 and 4.4). The decline in maize yield is supported by other reports that have shown a decrease in maize yields as a critical impact of climate change and variability in southern Africa (Fuhrer and Gregory, 2014; (Bryan et al., 2013). From the multinomial logit analysis, the average yield of maize showed a very significant and positive effect on the probability of adopting agronomic practices only (Table 4.3). It also showed a significant positive effect on the chances of adopting combinations of agronomic and livestock practices as well as agronomic and socio-cultural beliefs/practices. Therefore, increasing maize yield results in framers adopting more robust adaptation strategies (Table 4.3).

Increasing maize yield is associated with improved household food security (Valdivia et al. 2010). This could be attributed to increased availability of labour for implementing agricultural adaptation options.

The gender of the household head has a positive and significant influence on agronomic and a combination of agronomic and livestock adaptation options (Table 4.3). This implies that gender of the household head plays a critical role in farm decision-making process. Several studies report that gender is a critical variable affecting decisions at farm level. In a study in southern Alberta, United States, Chiotti et al. (1997) showed that female farmers were more likely to adopt new natural resource management techniques than their male counterparts. In many rural African farming communities, married male farmers usually do not discuss farming decisions with their wives (Obayelu et al. 2014). They would rather discuss farming decisions with other male farmers (Obayelu et al. 2014). The marital status of the household head, however, may be critical in climate adaptation. This is because if married farmers can discuss farming decisions with their spouses they could make better adaptation decisions than single, widowed or divorced farmers (Obayelu et al. 2014; Apata, 2011).

The current study showed that the age of the farmer influences the farmer's choice of adaption options (Table 4.3). This agrees with most studies that indicate a significant positive relationship between the age of the farmer and the level of adoption of conservation measures on the farms (Bayard et al. 2007; Apata, 2011). In some studies, however, age was shown to have an insignificant effect on farmers' decision-making relating to adoption of technology. This negative relationship could be due to farmers being reluctant to undertake new innovations, as they grew older due to risk-aversion tendencies (Burton et al. 1999).

The relatively high proportion (32%) of farmers without any formal education might be due to the non-formal education among the predominantly Shangani community in Chiredzi district. It could also be due to children being introduced into farming at a very tender age, as common in many rural communities in Zimbabwe (Manjenwa et al. 2014). It is assumed that those who manage to proceed further with their education could be from wealthier families. A number of studies show that the level of education correlates to level of knowledge and the simplicity of making sound decisions (Dolisca et al. 2006; Anley et al. 2007). Higher levels of education coupled with more farming experience should improve farmer's perceptions on climate change. In contrast, however, Clay et al. (1998) discovered that education did not play an important role in determining whether a particular farmer adopted any technology or not. In some instances though, education has a negative effect on adoption of technology (Gould et al. 1989). Therefore, the choice of coping and adaptation options could be determined by the smallholder farmers' knowledge based on tradition, education level and experience.

Previous studies give conflicting effects of household size in explaining adoption of technology by farmers. Dolisca et al. (2006), notes that bigger household sizes allow farming households to adopt those adaptation strategies that require more labour per unit of land. Bigger families may also invest extra labour into other non-farming activities to earn extra income (Nhemachena and Hassan, 2007). The current study showed that households with more members who are fit and able to work in agriculture will adapt more than those households with fewer members who are fit enough to work (Table 4.3). Varadan and Kumar (2014) obtained similar results although in their findings the probability of adaptation only showed significance in the adoption of drought tolerant crop varieties. Such agronomic practices as implementing soil and water conservation techniques on farms, use of chemicals, organic manure and fertilizers, shading and sheltering young plants, diversifying crops and livestock require more labour. A larger family size will have a positive influence on the adoption of these adaptation strategies and techniques.

These results showed that as the number of cattle owned increases, smallholder farmers' likelihood of adopting agronomic practices only, livestock practices only or a combination of agronomic and livestock practices increases significantly (Table 4.3). This is probably because cattle provide draft power for crop production. Considering also that cattle are a sign of wealth in many rural communities, those farmers with more cattle are expected to have more resources and better access to adaptation information (Obayelu et al. 2014). However, the number of cattle owned has a negative impact on the probability of adopting a combination of agronomic and socio-cultural practices as an adaptation strategy (Table 4.3). This could be because in many rural communities have traditional cultural practices which use cattle for ritual purposes. Smallholder farmers are less likely to adopt such an adaptation strategy, which reduce their wealth.

Being a full-time farmer has a very significant but negative effect on the likelihood of adoption of agronomic practices only (Table 4.3). This indicates that full-time farmers may lack sources of non-farm income to help implement some adaptation strategies (Enete, 2011). Unlike part-time farmers who have access to external sources of income, full-time farmers may not be able to buy improved seeds or diversify cropping owing to the low yields obtained from cropping (for example, Figure 4.6 and 4.7). However, being a full-time farmer shows a significant positive effect on the probability of adopting livestock practices only and on the probability of adoption of a combination of agronomic and livestock practices. This may be because full-time farmers are able to allocate optimum time for both livestock and agronomic practices and then use the cattle for draft power.

Table 4.3 also showed that a unit increase in the dry land area owned by the farmer would reduce the chances of adopting agronomic practices only, livestock practices only and the combination of agronomic and socio-cultural practices. This could be because it is difficult to carry out meaningful agricultural adaptations like soil and water conservation techniques on larger dry land farm sizes due to the labour intensive nature of such operations (Turral et al. 2011). The size of the dry land area owned, however, has a significant positive effect on the adoption of a combination of agronomic and livestock practices. Farmers who own larger dry land farms therefore have a higher propensity to invest in agronomic and livestock practices as an adaptation strategy to the changing climate.

Farmer perceptions can reveal the farmer's access to information on climate change, the knowledge of the farmer, access to extension services and farmer-to-farmer extension as well as the farmer's social networks. Farmer perceptions are significant on adopting agronomic practices, followed by adoption of a combination of agronomic and livestock practices and finally the adoption of a combination of agronomic and socio-cultural beliefs/practices. Despite a positive influence of farmers' perceptions on the likelihood of adoption of livestock practices, this relationship is however not significant. Nhemachena and Hassan (2007) also revealed that, farmers who notice changes in climate had higher chances of taking up and implementing measures to respond to the changing climate. As noted by Madison (2006), farmer perception on climate change is a critical component of farmers' decision-making process regarding the farmer's decision on whether to or not to adopt any agricultural adaptation response. The various, suitable crop and livestock management practices which farmers could take should be based on correct climate forecasts for each location so as to have meaningful impact.

4.5 Conclusions

This study revealed that farmers have noticed decline in rainfall and increase in average temperatures over the years. These perceptions have influenced adoption of agronomic practices, livestock practices or socio-cultural practices to cope and adapt to climate change and variability.

While climate change and variability is an environmental problem, the scope of its impacts are strongly determined by underlying socioeconomic variables. The study concludes that, perceiving that the climate is changing increases the probability of uptake of certain adaptation strategies by indigenous smallholder farmers. Development of participatory approaches as tools to integrate knowledge systems by mapping perceptions of climate change and variability at the local level to document changes in crop and livestock production systems will increase adaptive capacity.

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CHAPTER 5

Contextual vulnerability of rainfed crop-based farming communities in semi-arid Zimbabwe: a case of Chiredzi District

Abstract

Smallholder farmers' vulnerability to climate change and variability was assessed based on the socioeconomic and biophysical characteristics of Chiredzi District; a region that is susceptible to the adverse effects of climate change and variability. Vulnerability was assessed using the Vulnerability to Resilience and the Climate Vulnerability and Capacity frameworks. The major indicators and drivers of vulnerability were identified as droughts, flash floods, poor soil fertility and out-migration leaving female and child-headed households. The results of this study indicate that the area and cropping systems are greatly exposed and are sensitive to climatic change stimuli as shown by decline in main cereal grain yield. From sensitivity analysis, it was shown that different areas within the district considered different biophysical and socioeconomic indicators to climate change and variability. They also considered different vulnerability indicators to influence the decisions for adaptation to climate change and variability. These results showed that there is need to define and map local area vulnerability as a basis to recommend coping and adaptation measures to counter climate change hazards.

Key words: vulnerability, smallholder farmers, exposure, sensitivity, adaptive capacity

5.1 Introduction

Understanding farmers' vulnerability to climate change and variability is complex as this depends on both biophysical and socioeconomic drivers of climate change impact (Berkes, 2007). The vulnerability of a society to climate disasters such as drought depends on several factors such as population, technology, policy, social behavior, land use patterns, water use, economic development, and diversity of economic base and cultural composition (Wilhite et al., 2014). Prevalence of drought and decline in food availability should not necessarily lead to famine and loss of livelihoods. Whether food availability decline would lead to disaster will depend on capability failure (value judgments relating to food production and access) which in turn depends on market access and people's social, economic and political entitlements (The

World Bank and GFDRR, 2013). In sub Saharan Africa, rainfed agriculture provides about 90% of the region's food and it is the principal source of livelihood for more than 70% of the population (Bauer & Scholz, 2010). Because of heavy dependence on rainfed agriculture, about 60% of sub-Saharan Africa is vulnerable to frequent and severe droughts (Viljoen, 2014).

The level of vulnerability of a society exposed to climate change impacts is contextual, and depends on many factors such as the nature of a drought or an extreme event. Therefore, vulnerability should be understood in the context of a system attributes of concern to a hazard in a temporal reference (Joshua et al., 2014). Vulnerability to climate impacts is defined in many ways and has different meanings when used in different disciplines and contexts (e.g., Brooks, 2003; Gbetibouo et al., 2010; Gitz & Meybeck, 2012).

According to the IPCC (2007) climate change 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. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity”. Smallholder farmers’ vulnerability to climate change and variability can, therefore, be described in relation to exposure to increased temperatures, drought, extreme weather events, the sensitivity of crop yields to the increased temperature and drought, and the ability of the farmers to adapt to the effects of this exposure and sensitivity. This adaptation could be by planting more drought tolerant crop varieties or diversification into new crops, for instance. The IPCC (2007) definition highlights three components of vulnerability: exposure, sensitivity and adaptive capacity. This means that a system exposed and sensitive to the impacts of climate change but with limited adaptive capacity is vulnerable. In contrast, a system is less vulnerable if it is less exposed, less sensitive or has a strong adaptive capacity (Smit et al., 2001; Smit & Wandel, 2006).

Adger (2006) points out that there are two climate change vulnerability concepts. These are outcome and contextual vulnerability, which differ depending on interpretation of vulnerability as being the end-point or the starting point of the analysis. The outcome vulnerability (“end-point” interpretation) concept considers vulnerability as the (potential) net impacts of climate change on a specific exposure unit (which can be biophysical or social) after feasible adaptations are taken into account (Fellmann, 2012; Seguin, 2010). Contextual vulnerability (“starting point” interpretation), on the other hand, considers vulnerability as the present inability of a system to cope with changing climate conditions, whereby vulnerability is seen to be influenced by changing biophysical conditions as well as dynamic social, economic, political, institutional and technological structures and processes (Fellmann, 2012). In the contextual approach, vulnerability is seen as a characteristic of ecological and social systems that is determined by multiple factors and processes (Adger and Kelly, 1999; Adger, 2006; Eriksen et al., 2011). Contextual vulnerability approaches focus more on the current socio-economic determinants or drivers of vulnerability, i.e. social, economic and institutional conditions. Specific factors that can affect vulnerability include, for example, marginalization, inequity, food and resource entitlements, presence and strength of institutions, economics and politics (Kelly & Adger, 2000; Reed et al., 2005). Thus, contextual vulnerability explicitly recognizes that vulnerability to climate change is not only a result of biophysical events, but is also influenced by the contextual socio-economic conditions in which climate change occurs. The contextual approach builds on the dual consideration of socio-economic and biophysical aspects that make a system vulnerable (Turner Ii, 2010). The contextual approach emphasizes that the social and ecological context in which climate change occurs is likely to be as important as the climatic shock itself (Eriksen, 2000; Eriksen et al., 2011; Turner Ii, 2010).

The contextual vulnerability approach has been ascertained by quantitative agricultural research, for example, quantitative work on the socio - economic factors that make grain harvests in China sensitive to rainfall anomalies (Li et al., 2013). Similarly, different crop yields during drought periods in Mexico could not be solely explained by different precipitation patterns but were strongly influenced by different land tenure and the historical biases of farmers' access to productive resources (Ericksen, Ingram, & Liverman, 2009). Likewise, Niggol et al (2008) finds that about 39% of the variations in average crop failure rates across the United States of America can be explained by variations in soils and climate, which basically implies that other factors such as management skills, socio-economic, institutional and political conditions, account for the remaining 61%. Therefore, from the contextual interpretation, vulnerability can be reduced by modifying the contextual conditions in which climate change occurs so that individuals and society are enabled to better adapt to changing climatic stimuli (Adger, 2006; Leary et al., 2006; Osman-Elasha et al., 2006). This study explores the vulnerability of smallholder farmers of Chiredzi District, Zimbabwe, to climate change variability. The biophysical and socio-economic vulnerability factors and the options that can be adopted to increase adaptive capacity and reduce vulnerability were also explored.

5.2 Methodology

Site description

The study was conducted in Chiredzi District, located in Masvingo Province, in the south east of Zimbabwe. The district is found in natural agroecological region 5 of Zimbabwe (Zimbabwe Meteorological Department, 2006). Zimbabwe is divided into five agroecological regions based on rainfall amount and distribution, where natural region five is characterized by aridity and uncertain rainfall patterns (Vincent &Thomas, 1960). Chiredzi receives mean annual rainfall of 450 - 600 mm with mean annual evaporation exceeding 1800 mm. Historical data shows that surface temperatures in the district have warmed by 0.6°C from 1966 to 2005, and is projected to rise to 1.5 – 3.5°C by about 2050 (Davis, 2011; Zimbabwe Meteorological Department, 2006). Despite the aridity of the district, the main source of livelihood for households in Chiredzi is rainfed agriculture.

Data collection for vulnerability assessment

This study used the Climate Vulnerability and Capacity Analysis framework (Care, 2009) and Vulnerability to Resilience Framework (Pasteur, 2011), to analyze local level vulnerability. The tools generally recognize that individuals and communities are vulnerable in different ways. A summary of the tool is represented in Figure 5.1. However, the governance component was beyond the scope to of this study.

The data collection tools used are: key informant interviews, household interviews, focus group discussions and secondary data. Four focus group discussions were held and 100 households were interviewed across four wards of the district (Mupinga (ward 4), Dzinzela (ward 6), Chibwedziva (ward 8) and Muteo (ward 25)). Farmer lists were produced for each village by the respective agricultural extension worker for each ward. Five villages were then randomly chosen from each ward so as to have a sample representing the whole ward. Within the randomly selected villages, five farmers were also randomly selected using the farmer lists in each village to give 25 respondents per ward. The respondents identified for this study were all dry land smallholder farmers. A total of 100 respondents were used for the study.

Key informant interviews were done with local government officials, agricultural extension officials, community leaders and the elderly members in the communities. Quantitative data collected was analysed using the Statistical Package for Social Sciences (SPSS) (SPSS, 2009)

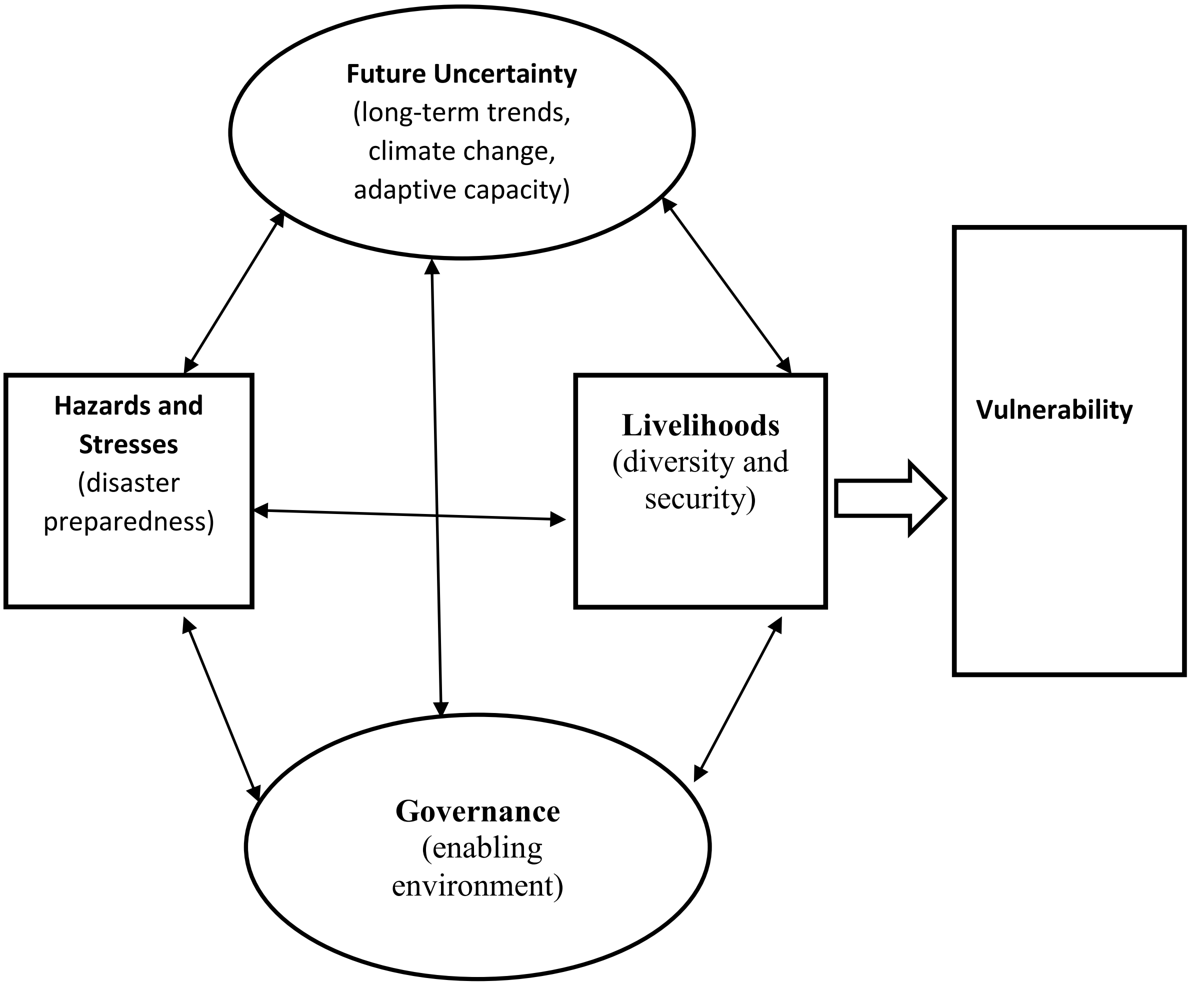

Figure 5. 1: Framework of vulnerability (adapted from Pasteur, 2011)

This assessment, based on the IPCC definition, attempted to quantify the three components by identifying appropriate indicators and combining them into indices for each. The components were then combined into an integrated index of vulnerability. The indicators used for the components included both biophysical (primarily for exposure and sensitivity) and socio-economic (mainly for adaptive capacity) sources (Adger et al., 2004; Wheeler, 2011). The arithmetic model for assessment of the two sub-indices of exposure and sensitivity, minus the adaptive capacity, obtained the final value of the vulnerability using equation 5.1:

$$\textbf{\textit{Vulnerability Index}} = \textbf{\textit{(exposure + sensitivity)}} - \textbf{\textit{adaptive capacity}} \quad \textbf{(5.1)}$$

Assessment of exposure to climate change

The exposure component of vulnerability evaluated characteristics of the local climate, described as changes and likely in key baseline climatic variables (temperature and rainfall). The assessment was based on the analysis of historical observations of temperature and precipitation in the 10-year baseline period (2000 - 2010). Because climatic threats are different for each season, there are no reasons to consider an exposure to their stressors in annual climatic variables.

Assessment of sensitivity

Sensitivity assessment was done on biophysical and socioeconomic parameters. These parameters were defined by a set of indicators (Table 5.1). Biophysical indicators were soil fertility, soil geomorphologic processes, droughts and flash floods. The socio-economic indicators were local area population and character of household (female-headed, child headed, migration).

Weighting of vulnerability

The components of vulnerability (exposure, sensitivity and adaptive capacity) were weighted on the basis of vulnerability index (calculated using equation 5.1 above).

5.3 Results

5.3.1 Defining local vulnerabilities

The farmers (in focus group discussions) and key informants indicated that vulnerability to climate change is broad. However, the common indicators include history of disasters (droughts and floods; Table 5.1). The increased frequency of droughts and other extreme events was noted as a major cause of increased vulnerability of individual households and the farmers. Increased food insecurity and poverty was identified as a key indicator to vulnerability to climate change and variability.

Table 5.1: Defining vulnerabilities by farmers in Chiredzi district

Indicator of vulnerability	Description
History of disasters	Perpetual droughts (1 good season in 10 years) Increase in flash floods
Other events or trends (temperature/rainfall)	More prolonged droughts More young people and men migrating to urban areas and other countries
Food insecurity	Perpetual food insecurity
Poverty	Women and child headed households considered poorest Households with many young children considered poor

5.3.2 Assessment of exposure to climate change

The assessment was mainly focused on the trends (and therefore impacts) of ambient temperature and precipitation. Chiredzi District is located in a semiarid and arid zones where rainfall is the main limiting factor for crops production, and any further aridization on its territory could substantially influence agricultural productivity. The observed temporal variability of temperature and rainfall indicated widespread exposure to climatic conditions of the district (Figure 5.2 and 5.3). Over the 32-year period of 1980 to 2012, there was a decline in annual rainfall of 2.5mm per year as shown in Figure 5.2. The temperature trend however shows an increase in annual mean temperature over the same period (by a factor of 0.04^{o}C per year, Figure 5.3).

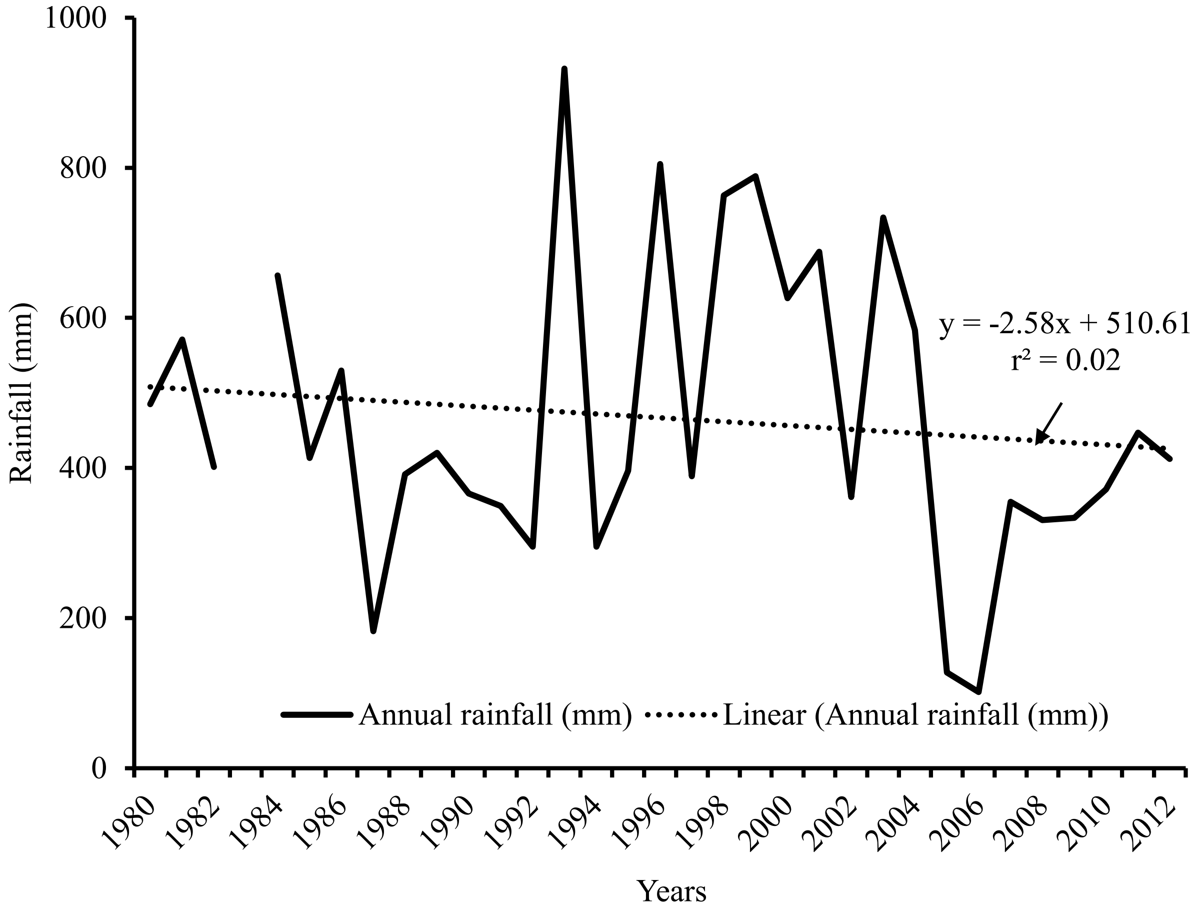

Figure 5. 2: Long term rainfall trends in Chiredzi District between 1980 and 2012 (Source: Chiredzi Research Station Temperature records, 2015)

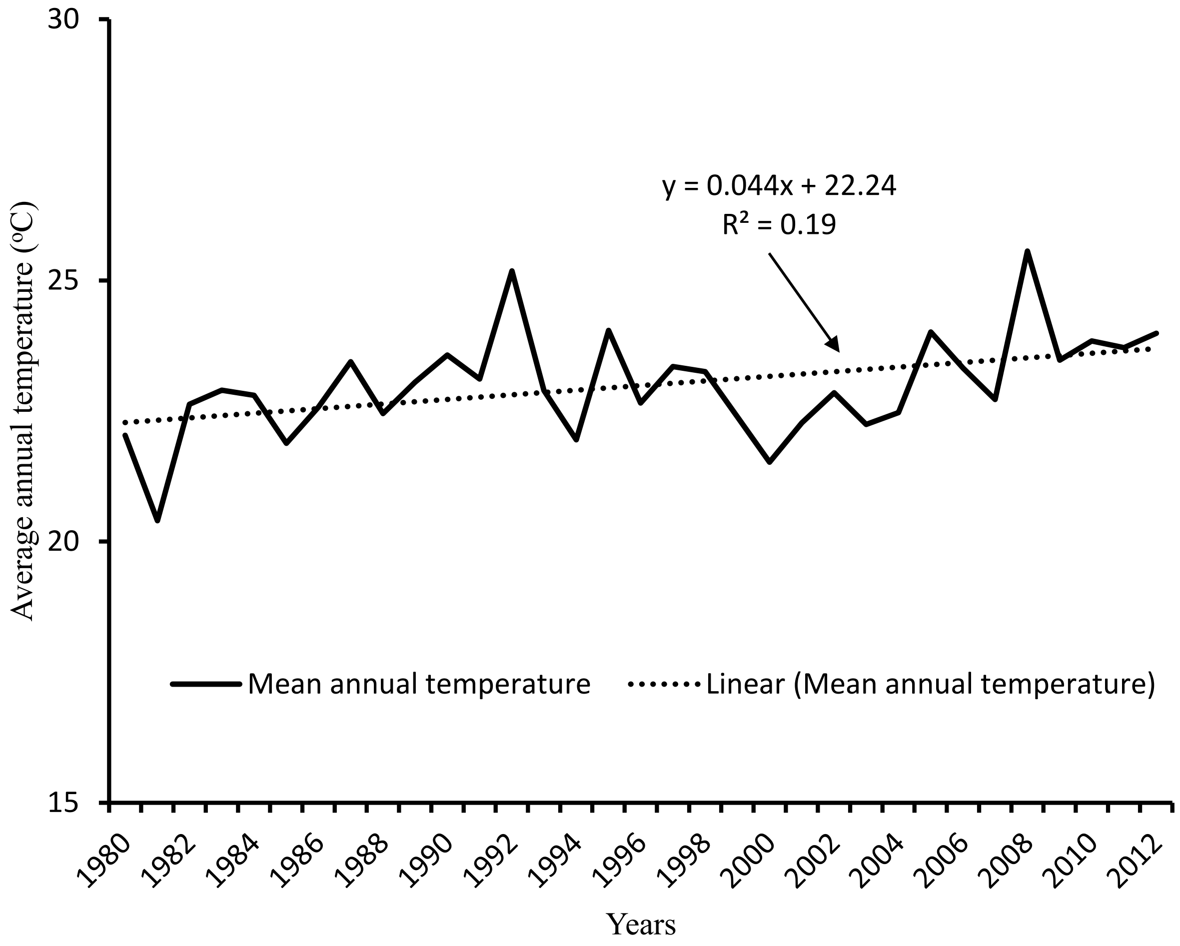

Figure 5. 3: Long term annual temperature trend for Chiredzi district (Source: Chiredzi Research Station Temperature records, 2015)

5.3.3 Assessment of sensitivity

The biophysical status of the agricultural land, defines environmental sensitivity, mainly an anthropogenic load on the land (Corobov et al., 2013). In these assessments, all indicators were treated as independent, and the ranking by a particular indicator implied equality of the rest. In addition to biophysical indicators, four socioeconomic indicators were ranked. The resulting sensitivity showed that female-headed households are considered to have more sensitivity to climatic threats (Table 5.2).

Table 5.2: Ranking of assessed wards in Chiredzi District in order of sensitivity

Ward	Biophysical indicators					Socio-economic indicators					
	Indicators rank					Indicators rank					Final rank
	b1	b2	b3	b4	Biophysical indicators rank (b)	s1	s2	s3	s4	Socio-economic indicators rank (s)	
Dzinzela (Ward 6)	7	13	4	6	3	11	12	3	7	4	1
Chibweziva (Ward 8)	2	11	3	4	1	1	6	1	15	1	2
Mupinga (Ward 4)	1	14	10	7	4	2	19	5	1	2	3
Muteo (Ward 25)	4	12	8	6	2	4	18	4	2	3	4

Key: rank score – 1 least sensitive indicator and 20 the most sensitive indicator
b1=flash floods; b2=drought; b3=soil fertility; b4=geomorphologic processes
s1=population; s2=female headed household; s3=child headed household; s4=migration

5.3.4 Sensitivity of main crops to rainfall

Correlation of rainfall variability and cereal grain output in Chiredzi District (1990 – 2012) is shown in Figure 5.4 (maize) and Figure 5.5 (sorghum). The maize correlation shows a trend of continued decline of maize output with continued decline in rainfall amounts. While sorghum, which is more drought tolerant, the results also indicate a declining trend in sorghum output (Figure 5.5).

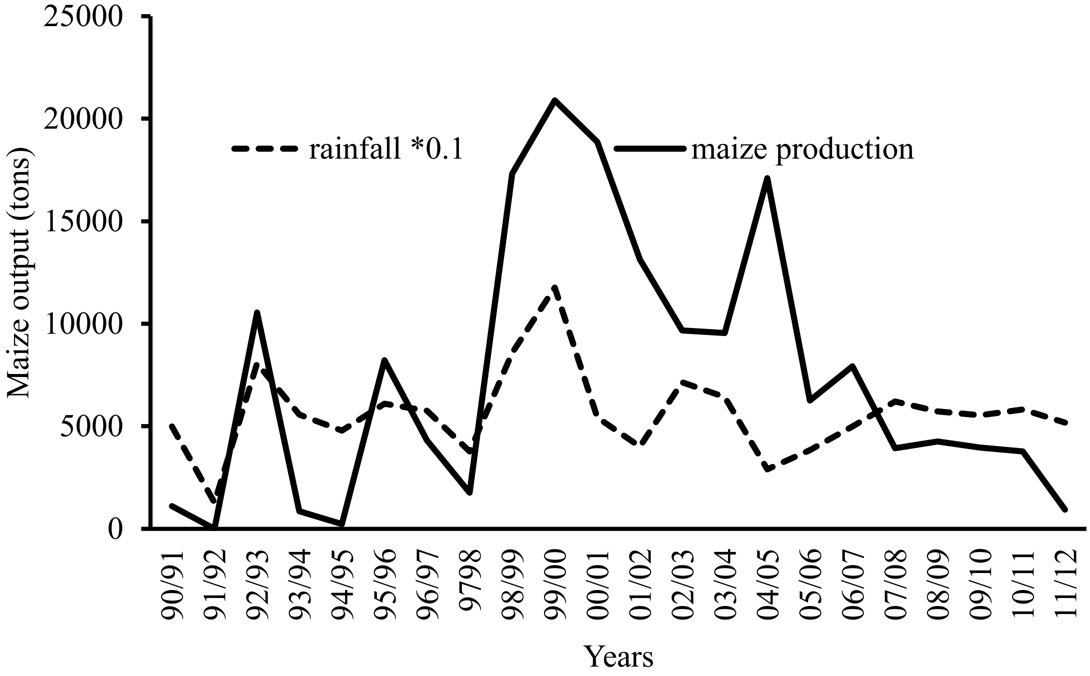

Figure 5. 4: Sensitivity of maize production to rainfall variability in Chiredzi district

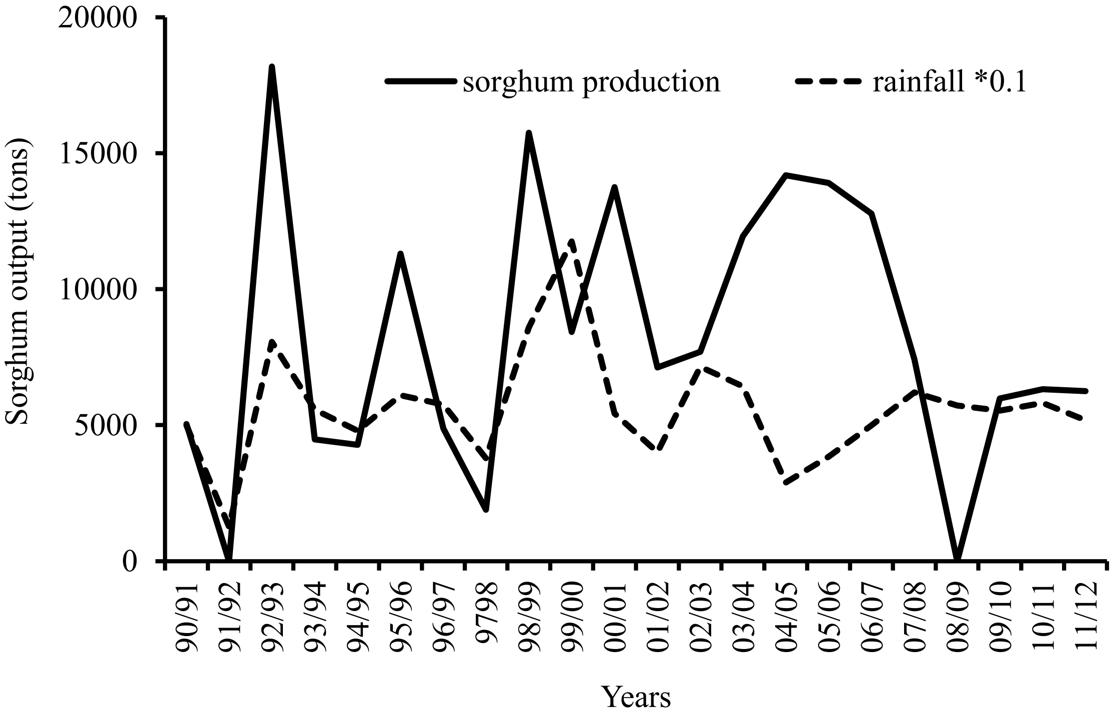

Figure 5. 5: Sensitivity of sorghum production to rainfall variability in Chiredzi district

5.3.5 Assessment of adaptive capacity

Adaptive capacity was evaluated as the function of a set of general economic and agricultural indicators (Table 5.3). The higher the levels of each of these indicators, the higher its adaptive capacity to climate change; the sum of indicators' ranks determines its adaptive capacity relative to other areas. Table 5.3 shows that Ward 25 had more adaptive capacity than Ward 6, for instance.

Table 5.3: Ranks of assessed wards in decreasing order of adaptive capacity

Ward	Adaptation indicators rank				
	a	**b**	**c**	**d**	**Rank**
Dzinzela (Ward 6)	9	9	1	1	1
Chibweziva (Ward 8)	12	5	2	3	2
Mupinga (Ward 4)	2	13	3	5	3
Muteo (Ward 25)	13	7	5	2	4

Key: rank score – 1 most used adaptation measure and 20 least used adaptation measure
a=crop diversification; b=livestock diversification; c=market gardening; d=off farm activities

5.3.6 Weighting of vulnerability

The field weighting of vulnerability had positive correlations with climate risk exposure (0.73) and sensitivity (0.71). The adaptive correlation was negative (-0.71) (Table 5.4). This implies that exposure and sensitivity are positively correlated with vulnerability, if either increase so does vulnerability (Table 5.4 and Figure 5.6). Increases in exposure and sensitivity tend to heighten vulnerability. For instance, extreme events, environmental issues or climate alone would be sufficient to increase household or community vulnerability. Adaptive capacity should reduce vulnerability and explain why the correlations of variables are negative.

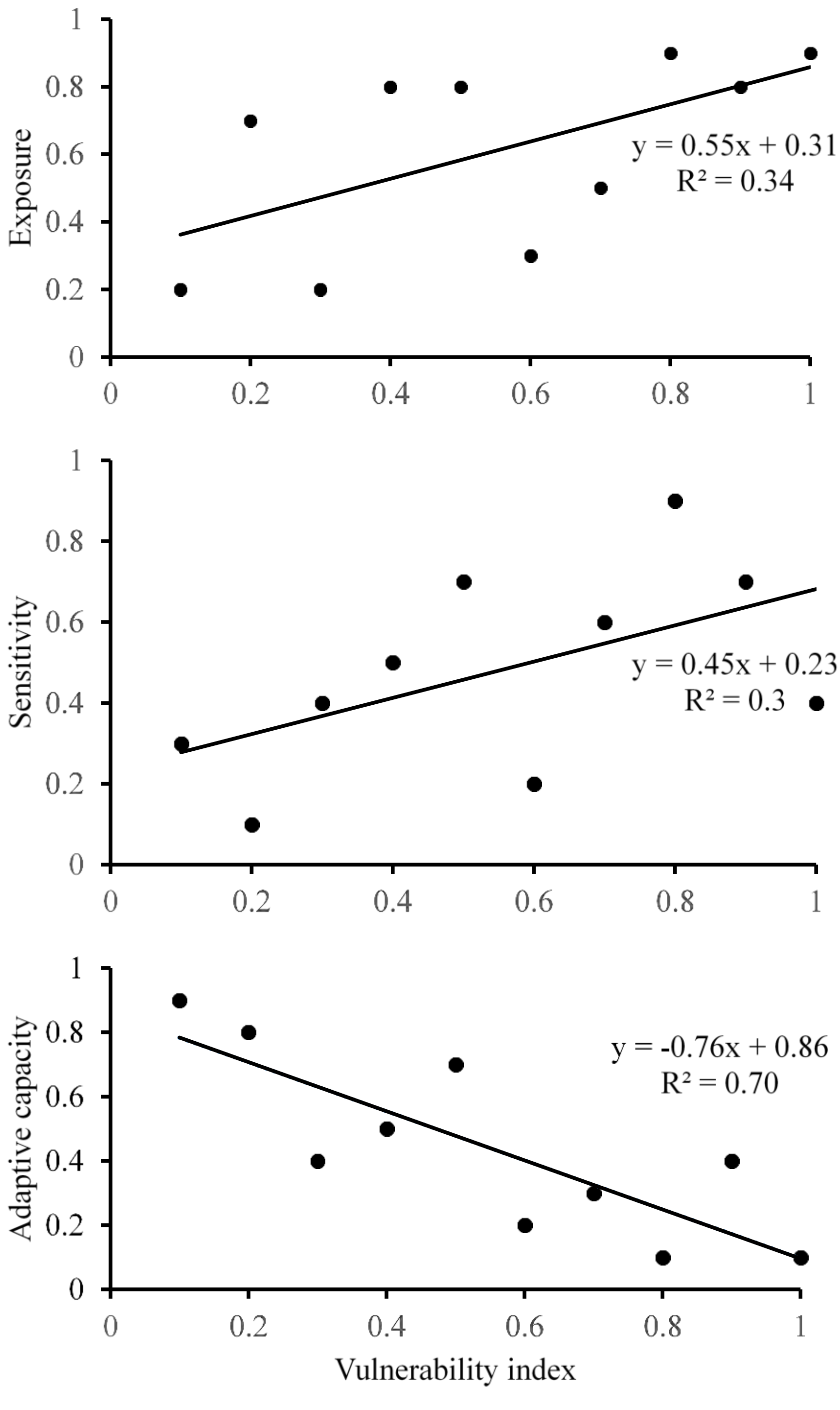

Figure 5. 6: Exposure, sensitivity and adaptive capacity contribution to vulnerability index

Among the exposure variables, the climatic variables best explained the variance, with a correlation of 0.68 (Table 5.4). Extreme events (0.61) and environmental problems (0.49) explained less of the variance. Sensitivity and adaptive capacity weightings are also shown in Table 5.4.

Table 5.4: Correlation with vulnerability index by indicators of exposure, sensitivity and adaptive capacity

Dimension	Indicator variables	Correlation with Vulnerability
Exposure	Extreme events	0.61
	Environmental problems	0.49
	Climate	0.68
	Index (exposure)	*0.73*
Sensitivity	Population	0.62
	Health issues	0.41
	Farming	0.72
	Index (sensitivity)	*0.71*
Adaptive Capacity	Labour	-0.63
	Social Capital	-0.22
	Access to credit	-0.53
	Index (adaptive capacity)	*-0.71*

5.4 Discussion

5.4.1 Exposure of rainfed farming to climate variability

Smallholder rainfed farming is highly exposed to climate change and vulnerability, particularly in the semi-arid and arid regions in southern Africa. These results show a decreasing trend in rainfall in Chiredzi District, which is found in Natural Region 5; i.e. the most arid natural region in the country (Figure 5.1). According to literature, this trend is expected to continue as southern Africa is predicted to become more affected by climate change and variability impacts (Shiferaw et al., 2014; Ziervogel et al., 2014). This agrees with simulations of temperature and precipitation under climate change scenarios which indicate temperature increases from 1 to 2 °C and rainfall reductions of 5 to 20 mm (10 %) in southern Africa (Davis, 2011). The combination of changes in temperature and precipitation (onset and patterns) can lead to a more exposed agricultural sector. This would lead to decline in crop yields and loss of livelihoods. In terms of vulnerability, smallholder farmers, dependent climate sensitive livelihoods, would need to adopt more drought tolerant crops and shift to hardier livestock (Chambwera & Stage, 2010). On the other hand, average annual temperatures are increasing in Chiredzi District (Jiri et al., 2015). Such warmer temperature would decrease the probability of cropping in the area (the opposite being true for increase in rainfall and decrease in temperature relative to the current conditions) (Lotsch, 2006). Thus increase in temperature and decrease in rainfall reduces crop and livestock choices and diversification for the smallholder farmers, increasing their vulnerability to climate change and variability. After integrating the exposure and sensitivity variables for a local area, it is possible to develop more detailed profiles that may enable governments to target their climate change adaptation policies.

5.4.2 Sensitivity of rainfed farming to climate variability

The results of this study further indicate the increased sensitivity, due to droughts and flash floods, of smallholder farmers who depend on rainfall for farming. Prevalence of droughts in Chiredzi district tend to mask the effects of poor soil fertility on crop production. While it is well established that inherently poor soils limit crop productivity in Africa (Rurinda et al., 2014; Shisanya, 2005; Whitbread, Jiri, & Maasdorp, 2004), smallholder farmers tended to attributed poor crop yields to drought. Soil degradation and geomorphologic processes (e.g. surface erosion) determine soil quality and ecological conditions (Shiferaw et al., 2014). Adaptation to climate change and variability, therefore, would not be cost effective if the farmers do not understand their exposure and sensitivity (Nelson et al., 2010).

Sensitivity increases with the increasing population (Table 5.4), particularly increasing share of female populations, which are among the most vulnerable categories (Lotsch, 2006). Growth of a demographic load, described as a ratio of incapacitated household members to the able-bodied household members, indirectly increases its vulnerability. The growth of female and child-headed households is a direct impact of climate change, as households seek alternatives to climate sensitive rainfed agriculture. Unfortunately, it is the able bodied men and young people who migrate to urban areas in search of better livelihoods leaving the women to face the drudgeries of farming (Ogalleh, Vogl, Eitzinger, & Hauser, 2012). The socio-economic impacts of such climate-induced migration need further exploration. However, the remaining female and child-headed households bear the brunt of climatic shocks and risks.

5.4.3 Farmers' adaptation to climate variability

The understanding of the farmers' own vulnerability helps to develop adaptive capacity. While subsistence farmers would continue to employ crop and livestock diversification to reduce exposure and sensitivity, there is an increasing trend to focus more on market gardening and off farm activities (Table 3; Coe & Sern, 2011; Li, Tang, Luo, Di, & Zhang, 2013). However, produce from market gardens, despite increasing nutritional security, may be difficult to market when there is surplus (Nelson et al., 2009). Off farm activities bring with them a lot of socio-economic challenges as described by Angus & Hassani-M (2009) and Twerefou, Adjei-Mantey, & Strzepek (2014). The may include situations where household members come back terminally ill, for example, when they had gone for seasonal employment off farm. These results show that the responsiveness of farmers to the impacts of climate change is determined by their current adaptive capacity (Shiferaw et al., 2014). Therefore, the results of this study may enable the shift of adaptation efforts to areas with greater exposure, increased sensitivity or lower adaptive capacity.

5.5 Conclusion

This study showed that Chiredzi district has high exposure and sensitivity to climate variability. However, the farmers have very low adaptive capacity. The increase in female headed households increases vulnerability and poverty. While it is difficult to evaluate, subsistence farmers' vulnerability in terms of climate change, this must be addressed in order to save livelihoods. It is the poorest members of smallholder farming areas or those that could be made poor by climate change that are most at risk. Without even considering specific climate scenarios, we can assert that poor, malnourished females and child-headed households, dependent on climate sensitive local production for food, are the most vulnerable in terms of hunger and malnutrition to climate change. Similarly, severe economic vulnerability is also most likely where a large share of the population depend on agriculture, leaving little alternative employment opportunities. Such vulnerability, from the contextual interpretation, can only be reduced by minimizing and modifying the contextual conditions of exposure and sensitivity to climate risk, and increasing indicators of adaptive capacity, so that individuals and communities are enabled to better adapt to changing climatic stimuli.

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CHAPTER 6

Building climate change resilience and adaptive capacity through adaptation in smallholder farming systems in semi-arid Zimbabwe: a case of Chiredzi district

Abstract

In order to increase adaptive capacity and resilience to the adverse effects of climate change, smallholder farmers in southern Africa have been devising strategies to cope and adapt to climate change and variability. However, not all farmers are able to cope with the adverse effects of climate change. The decision on which adaptation strategies to adopt is influenced by several factors such as resource endowment and social capital. In this study we used the Vulnerability to Resilience models and a binary logit model to analyse the factors influencing household decisions to adapt to climate change in Chiredzi district. The results showed that households with increased access to information on climate change and adaptation techniques through their access to extension services were likely to have better adaptation abilities. It was also shown that younger farmers were likely to adapt to climate change given their flexibility to adopt new techniques and their access and use of modern information and technology such as mobile phones. In addition, larger households were found to have higher probability of adapting to climate change due to the nature of most of the adaptation strategies which are labour intensive. Household's possession of livestock significantly enhanced their adaptation to climate change. Access to credit was also found to be a very significant factor in assisting household's adaptation to the adverse effects of climate change. However, those households with higher farm income have lesser incentives to adapt to newer ways of farming since their current farming practices might already be optimum. This means that if the available methods promise no better incentives, farmers are not willing to adopt them. These findings underscore the importance of enabling farmer access to resources such as information and better technologies which enable them to increase adaptive capacity and resilience to climate change. Given that most of the smallholder farmers are vulnerable, such as women-headed households and the elderly, who are labour constrained, there is need for research and development of labour saving technologies to increase resilience to climate change and vulnerability.

Key words: Climate change, Adaptation, binomial logit, smallholder farmers, resources, technology

6.1 Introduction

Scientific evidence suggests that global climatic conditions are changing mostly for the worst (CGIAR, 2012; Marin, 2010). Climate change has been regarded as a silent crisis, since the effects of climate change are not immediately visible (Maponya, 2010) However, climate change has changed weather patterns (onset of seasons and rainfall distribution) and increased the intensity and frequency of extreme weather events such as droughts and floods, which impact particularly on the poor in developing countries (Läderach et al., 2011).

The harsh seasonal variations in rainfall and temperature that have come as a result of climate change expose farmers to intense risks and affects agricultural production on which their livelihoods are dependent (Shiferaw et al., 2014). In Zimbabwe, 70% of the local population depend rain fed agriculture, which is also subsistence based, yet agriculture is the backbone of the economy. This means that rainfall and temperature variations have severe implications on production and food security. Using the 1961-1990 baselines, it is suggested that by 2050, average temperatures in Zimbabwe will be 2 – 4^{o}C higher and rainfall 10-20% less and this will consequently significantly reduce maize yields (Lobell et al., 2008). Climate models predict that Zimbabwe agriculture production levels might drop by around 30% due to climate change (Mano & Nhemachena, 2007).

The high rainfall variability, unreliability and uncertainty have prompted farming communities to engage in strategies to adapt to climate change and variability. Nhemachena and Hassan, (2010) underscored that adaptation measures are important in helping communities develop adaptive capacity and resilience to climate change (Klein et al., 2014; Smit & Wandel, 2006). Exogenous (scientific knowledge) and indigenous knowledge systems help smallholder farmers adapt to climate change and variability (Mapira & Mazambara, 2013). Such adaptation in agriculture is expected to help farmers achieve household food, income and livelihood security objectives in the face of changing climatic and socio-economic conditions including climatic variability, extreme weather events such as droughts and floods and volatile short term changes in local and large-scale markets (Dube & Sekhwela, 2007). Adaptation moderates vulnerability to climate change and helps farmers guard against losses due to increasing temperatures and decreasing precipitation (Hassan et al., 2008; Wilhite et al., 2014). Hence, understanding household adaptation to climate change is important so as to develop and implement effective adaptation measures which lead to improved adaptive capacity and resilience at the household level. On the other hand, the speed of current climate change is greatly feared to exceed the limits of adaptation in many parts of the world (Adger & Barnett, 2009), unless serious consideration is given to adaptation strategies that increase resilience in the short term. In smallholder farming communities, climate smart agricultural options such as conservation agriculture and use of drought tolerant crops are being encouraged (Pye-Smith, 2011).

Resilience is employed in various fields such as ecology and sociology, among others. Ecologists conceptualise resilience in analysis of population ecology of plants and animals, including in the study of ecosystem management. In sociology, resilience is mainly used in reference to socio-ecological systems (United Nations, 2011; Janssen et al., 2006; Holling, 1973). Generally, the initial conceptualisation of resilience was determined by empirical observations of ecosystem dynamics interpreted in mathematical models (Folke, 2006). However, since the late 1980s, there has been a shift from this conceptualisation and resilience has increasingly been used in the analysis of human-environment interactions, mainly to describe and understand how humans affect the resilience of ecosystems. These efforts are reflected in the large numbers of sciences involved in explorative studies and new discoveries of linked social-ecological systems (Folke, 2006). In some studies, resilience is regarded as the opposite of vulnerability (Folke et al., 2002), while in others this distinction is not so clear (Shiferaw et al., 2014). It is however important to note that resilience and vulnerability are not always two sides of the same coin: under different circumstances (time, context), a resilience factor can exacerbate vulnerability to climate change. For example, keeping livestock can be a resilience factor under non-drought and the early stages of drought, as livestock can be sold for income. However, under advanced drought conditions, holding onto livestock increases vulnerability to drought impacts (Speranza, 2006). This study evaluated adaptation options as a means to increasing resilience to climate change and variability, and thus increases adaptive capacity. This was done through analysis of socioeconomic factors influencing smallholder farmers' decisions to adopt adaptation strategies to climate change and variability.

6.2 Methodology

Site description

The study was conducted in Chiredzi District which is located south east of Zimbabwe. Chiredzi District lies in Masvingo province. Chiredzi town is located about 400 km from the capital of Zimbabwe, Harare. The district is found in natural agroecological region five of Zimbabwe (Zimbabwe Meteorological Department, 2006). In Zimbabwe, natural region five is characterized by aridity and uncertain rainfall patterns. Chiredzi receives mean annual rainfall of 450 - 600 mm with mean annual evaporation exceeding 1800 mm. Historical data shows that surface temperatures in the district have warmed by 0.6°C from 1966 to 2005, and is projected to rise to 1.5 – 3.5°C by about 2050 (Davis, 2011; Zimbabwe Meteorological Department, 2006). Despite the aridity of the district, the main source of livelihood for households in Chiredzi is agriculture.

Resilience analysis

Resilience analysis was done using the Vulnerability to Resilience Framework developed by Practical Action (Pasteur, 2011) and the Climate Vulnerability and Capacity Analysis framework developed by Care (Care, 2009). The tools generally recognize that individuals and communities are vulnerable in different ways. A summary of the tool is represented in Figure 6.1. However, the governance component was beyond the scope to of this study.

Data collection

Both qualitative and quantitative were used techniques to collect data. The tools used key informant interviews, household interviews, focus group discussions and secondary data. Four focus group discussions were held and 100 households were interviewed across 4 wards of the district (Mupinga (ward 4), Dzinzela (ward 6), Chibwedziva (ward 8) and Muteo (ward 25)). Farmer lists were produced by village by the respective AGRITEX officers for each ward. Five villages were the randomly chosen from each ward so as to have a sample representing the whole ward. Within the randomly selected villages, five farmers were also randomly selected using the farmer lists in each village to give 25 respondents per ward. The respondents identified for this study was all dry land smallholder farmers. A total of 100 respondents were used for the study.

Key informant interviews were done with local government officials, agricultural extension officials, community leaders and the elderly people in the communities. Quantitative data collected was analysed using the Statistical Package for Social Sciences (SPSS) (SPSS, 2009)

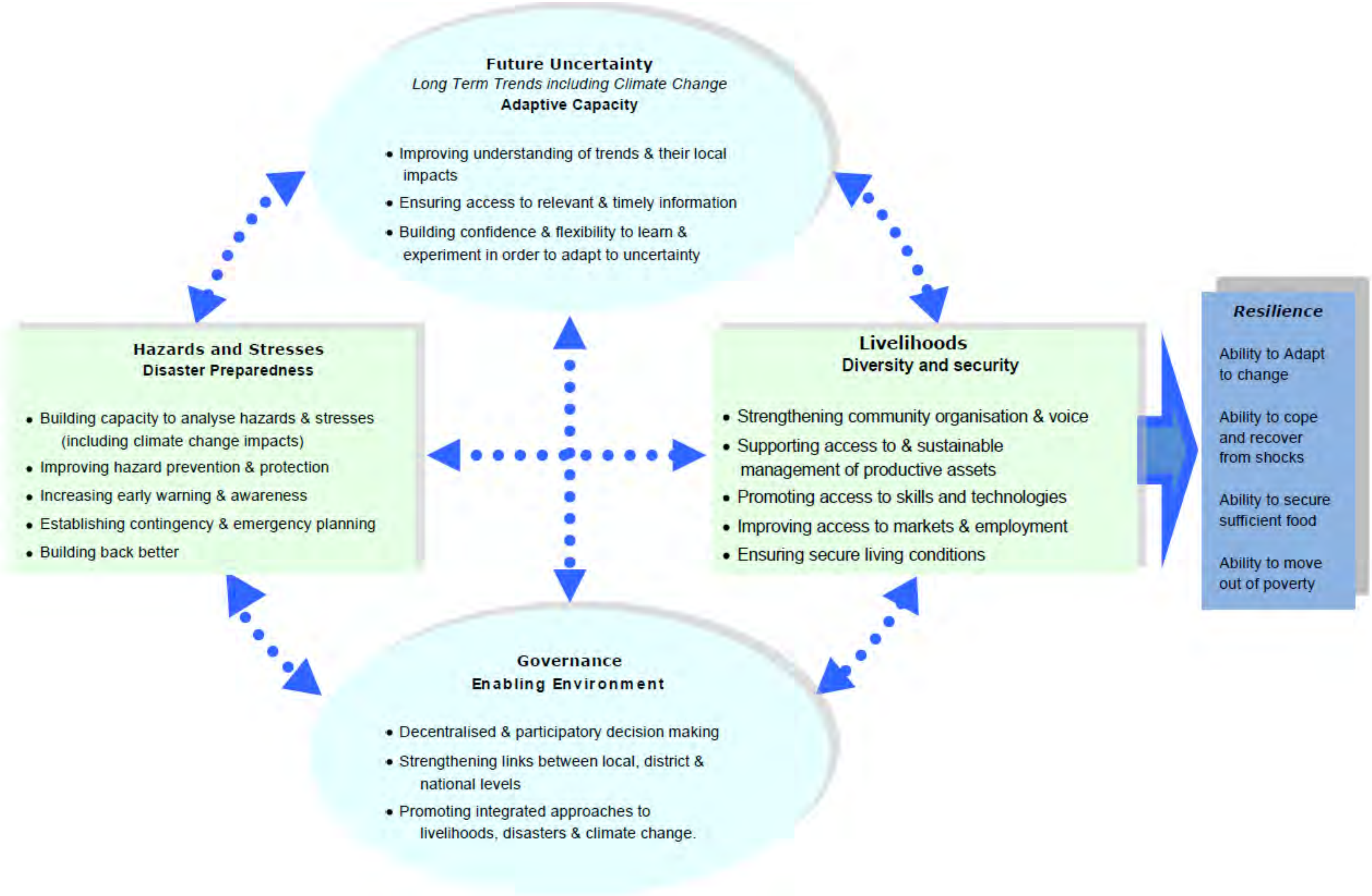

Figure 6. 1: Resilience framework (adapted from Pasteur, 2011)

Binary Logit Model

The study used a binomial logit model to analyse the socioeconomic factors affecting the households' decision to adapt to climate change or not to adapt. This method has been used by several authors to study household decision to adapt to climate change (Apata et al., 2009; Mandleni and Anim, 2011; Seo and Mendelsohn, 2006). The dependent variable is dichotomous i.e. households' decision to adapt or not adapt to climate change. The binary logit model in this case is appropriate because it considers the relationship between a binary dependent variable and a set of independent variables.

The model uses a logit curve to transform binary responses into probabilities within the 0 - 1 interval. In the logit model the parameter estimates are linear and assume a normally distributed error term (μ). The logit model is specified in equation 6.1 as:

$$\mathrm{Prob}(\mathrm{Y_i} = \mathrm{j}) = \frac{\exp(\beta_j' \mathrm{X_i})}{\sum_{\mathrm{k=o}}^{\mathrm{j}} \exp(\beta_k' \mathrm{X_i})} \qquad (1) \qquad (6.1)$$

Where β_{j} is a vector of coefficients on each of the independent variables $\mathrm{X_i}$. Equation (6.1) can be normalized to remove indeterminacy in the model by assuming that $\beta_0 = 0$ and the probabilities can be estimated as:

$$\mathrm{Pr}\,ob\,(Y_i = j|x_i') = \frac{\exp(\beta_j x_i)}{1 + \sum_{k=1}^{j} \exp(\beta_k x_i)}, j = 0,1,2 \cdots J, \beta_0 = 0 \qquad (2) \qquad (6.2)$$

The general form of the logit model is presented below:

$$Prob(Y_i = 1) = F(\beta' \, x) \qquad (6.3)$$

$$Prob(Y_i = 0) = 1 - F(\beta' \, x) \qquad (6.4)$$

The binary logit estimate is expressed in its implicit form as follows:

$$Y = f(X_1, X_2, X_3, X_4, X_5, X_6, X_7, X_8, X_9, X_{10}, X_{11}, X_{12}) \qquad (6.5)$$

Where Y is the adaptation status (1= farmers who adapted, 0= farmers who did not adapt; X_1 is age of household head; X_2 is access to extension (1=accessed extension; 0=no access to extension); X_3 is the number of individuals fit to work; X_4 is access to credit (1= access to credit; 0= no access to credit); X_5 is farm income; X_6 is livestock holding; X_7 is total dryland area; X_8 is employment status (1=full time; 0=otherwise), X_9 is literacy level ($1 =$ literate; 0 = otherwise). The a priori expected relationship between the dependent variable and explanatory variables is given in Table 6.1.

Table 6.1: Description of variables and expected signs

Variable	Relationship with dependent variable	Expected sign
Age of household head	Young farmers are quick to understand and accept new ideas and are more likely to be willing to adapt to climate change than older farmers *(better resilience)*	negative
Education level of the household head	Education increases the probability of adapting to climate change as it is associated with being open minded and the ability to embrace positive change *(better resilience)*	Positive
Number of people fit to work in the household	A larger household is expected to have a better labour endowment, enabling achievement of farm activities *(better resilience)* The consumption pressure as a result of a large household size may result in diversion to off-farm activities to generate more income, crippling ability to adapt *(less resilience)*	Negative or positive
Access to credit finance	Use of credit facilities enables farmer to fund farm operations therefore enhancing the probability of a farmer to adapt strategies *(better resilience)*	Positive
Employment status or time awarded to farming	A fulltime farmer primarily seeks to be productive in his farm activity and thus more likely to adapt *(better resilience)*	Positive
Household total dryland farm area	The larger the farm size, the greater the proportion of land allocated to other crop varieties (Gershon *et al*, 1985) *(better resilience, if climate smart technologies are adapted)*	Positive
Total farm income	High income enables farmer to be able to finance different activities *(better resilience)*	Positive
Total livestock owned by the household	Livestock ownership represent wealth, households with better livestock endowment adapt better.	positive
Access to extension advice (dummy variable 1=yes 0=no)	Access to extension advice is expected to increase one's choice to adapt. Extension increase access to useful knowledge meant to bring change and growth *(better resilience)*	positive
Access to information	Access to information via technology such as mobile phones and radio is expected to increase the awareness and choices to adapt *(better resilience)*	Positive

6.3 Results

6.3.1 Adaptation determinants for resilience

A comparative analysis of socioeconomic variables of households according to their adaptation status is given in Table 6.2. The results show that 71% of the farmers interviewed adapted to climate change and variability. From the sample 61.9% farmers who have adapted to climate change were male while 38.1% were female. On the other hand, 67.6% of non-adapters were male and 32.4% were female. However, the chi-square test showed no significant association between the gender concentration for adapters and non-adapters. Instead, there was a significant difference in the mean age of adapters (43 years) and non-adapters (57 years). Households adapting to climate change tended to be younger. Incomes of adapters were significantly higher and adapters had access to credit. A significant difference was also noted between the literacy status of farmers 74.6% of the farmers who adapted to climate change were literate and while 55.9% of the households that did not adapt were literate. The chi-square analysis showed the presence of systematic association between the literacy status of farmers and adaptation to climate change.

Table 6.2: Household characteristics

Characteristics		**Adapters to climate change** *N=100*	**Non adapters to climate change** *N=100*
Proportion		71	29
Age of household head (mean)		43	57
Gender	Male	61.9	67.6
	Female	38.1	32.4
Level of education of the household head	Literate	74.6	55.9
	Illiterate	25.4	44.1
Number of people fit to work (mean)		6	3
Credit finance	Access to credit	41.3	6
	Lack of access to credit	58.7	94
Extension advice	Accessed extension	63.5	
	No access to extension	36.5	
Farm income per household (mean)		USD 154	USD 27
Livestock holding per household (mean)		4	2.5

6.3.2 Development of resilience, farmer adaptation strategies

In order to cope with recurrent droughts, farmers used adaptation strategies that included dry planting, planting short season crop varieties, planting drought tolerant crops such as sorghum and millets , moisture preserving techniques such as conservation agriculture, holding prayers and religious festivals, and crop diversification (Table 6.3). Of these adaptation techniques the most common adaptation techniques was dry planting (26.8%) followed by conservation agriculture (17.5%) and planting short season varieties.

Table 6.3: Adaptation techniques

Adaptation technique	Percentage of farmers
Dry planting	26.8
Prayers and religious festivals	5.2
Planting short season varieties	12.4
Conservation agriculture	17.5
Crop diversification	3.1
No adaptation	35.1

6.3.3 The likelihood of farmers adapting, developing resilience and adaptive capacity

The results of the binary logit regression are shown in Table 6.4. The model had a 91.4 % correct prediction value denoting the accuracy of prediction of compared variables. The Likelihood Ratio Chi^2 value was 85.5 implying that the model is fit very well to the data, that is, the likelihood of the null hypothesis which states that the coefficients are equal to zero (i.e. farmers not adapting) being correct is extremely low. Most of the variables tested had the expected hypothesized signs (Table 6.1). From the logit regression results, draught power, access to credit, extension education and number of members fit to work positively and significantly influence farmers' decision to adapt to climate variability (Table 6.4). Thus the development of resilience to climate change is positively affected by these factors. At the same time, age of household head and farm income negatively and significantly influence farmers' decision to adapt. Thus these factors had a negative correlation to development of adaptive capacity and resilience.

Influence of age of household head on adaptation and resilience development

The estimated parameter for age of the household head is negative sign and is statistically significant at 1% showing that the age of the household head has a strong influence on farmers' decision to adapt to climate change. Thus, the older the household head is the lower the adaptation and resilience capacity of the household. The Exp (B) value shows that the odds of adapting to climate change decrease by a factor of 0.815 for a unit increase in age. Young farmers were more likely to take up adaptation to climate change and variability than older farmers. In general, as people grow older, they are reluctant to adopt new techniques and let go of the conventional way of doing things.

Influence of members fit to work in *the household on adaptation and resilience development*

The number of household members fit to work (those members who are not sick or too old to engage in manual agricultural work) positively and significantly influenced adaptation. For a unit increase in farm household size, the odds that farmers will adapt to climate change are expected to rise by a factor of 2.68. This implies that the bigger the family size the higher the probability of adapting to climate change.

Influence of access to credit on adaptation and resilience development

The results show that, access to credit increased the adaptation capacity of the farmer. The odds of a farmer adapting to climate change is expected to increase by a factor of 13 if a farmer gains access to credit.

Influence of total livestock holding of household on adaptation and resilience development

As per expectation, livestock holding had a positive relationship with adaptation to climate change. An increase in total livestock holding by one unit is likely to give an increase in the odds of adaptation to climate change by a factor of 1.74.

Influence of household access to extension services on adaptation and resilience development

This positively influenced a household's decision to adapt to climate change. It is expected that with increased information on climate change and adaptation techniques, farmers would choose to adapt.

Influence of total household farm income on adaptation and resilience development

Contrary to apriori expectation and empirical evidence the results show a negative relationship between farm income and the choice to adapt to climate change. This is an interesting finding. The most probable reason is that farmers who are still engaging in the conventional agricultural system and realising high farm incomes probably see no reason to take up new activities as they could be comfortable with what they are getting. The education level of the household head, farm size and employment status of the household had no significant influence of adaptation to climate change.

Table 6.4: Adaptation to climate change binomial logit regression model

Variable	β	S.E	P value	Exp (β)
Age of household head	-0.205	0.075	0.006***	0.815
Extension advice	5.347	1.963	0.006***	210.044
Members fit to work	0.986	0.385	0.010**	2.682
Access to credit	2.572	1.377	0.062*	13.098
Total farm income	-0.011	0.006	0.085*	0.989
Total livestock holding	0.553	0.287	0.054*	1.739
Total dryland area	0.240	0.308	0.437	1.271
Employment status	0.998	1.968	0.612	2.713
Literacy level	1.692	1.272	0.183	5.433
Constant	-0.686	2.936	0.815	0.504

Number of observations = 100
Pseudo R^2 = 0.835
Log likelihood = 32.828
LR chi^2 = 85.564
Prob > chi^2 =0.0000
Overall Percent correct 91.4%

***Significant at 1% level; **Significant at 5% level; * Significant at 10% level

6.3.4 Development of resilience

Table 6.5 summarises the key strategies that can be used by smallholder farmers to develop resilience and adaptive capacity to climate change and variability. Success and continued adaptation is defined by these factors. The key informant interviewees and focus group discussants also emphasised the nature, pathways and stakeholders for obtaining measurable outcomes on each strategy (Table 6.5).

Table 6.5: Suggestions on building smallholder farmer resilience at local level

Resilience building strategy	What can be measured as enabling information	Pathways and stakeholders for building resilience	Measurable outcomes
Access to localised information on local seasonal quality and	Downscaled climate modelling and up-to-date climate change scenarios and use of indigenous knowledge systems for disaster risk reduction	Scientific and academic community and stakeholders consolidate and downscale research; Integration of scientific knowledge with indigenous knowledge systems for adapters, organisations working in the local area and extension workers	Availability of relevant climate information, services and products
A compendium of adaptation options as a result of climate change and variability	Vulnerability and risk assessments Relevant downscaled climate modelling, weather and seasonal forecasts, and use of indigenous knowledge systems	Institutional capacity to support adaptation; Social capital and safety nets; Provision of services such as research, extension and credit; Emergency response services by government and local community	Improved long-term resilience against shocks and stressors; Early warning systems operational at local level using scientific and indigenous knowledge systems
Informed decision making by communities	Simple local and temporal maps by farmers and other stakeholders on hazards prevalence and vulnerability indices; Timely and relevant supply of climatic information	Engagement with climate information producers and knowledge brokers to discuss needs and availability of information and resilience building options	Useable and reliable climate change information available for use by policy makers and planners at the local and national level
Promotion of innovation and local research	Scenarios of future agro-climatic conditions Principles, practice and case studies of resilient options available for farmers	Research programmes specifically targeting climate resilient crops for expected climatic conditions	Climate resilient cropping options developed and being experimented with farmers
Extension workers with proper training in climate change and variability	Key skills required for climate resilient systems by farmers and extension workers	In-service training to fill skills gaps in current agricultural extension workers	Courses that support climate resilience building
Agronomic and socioeconomic conditions which build food security	Promotion of climate smart agricultural practices	Training in climate smart agricultural practices; Demonstration of climate smart options at farm level; Financial and other support available for climate smart agriculture	Number of farmers adopting climate smart agriculture; Institutionalisation of climate smart agriculture and its mainstreaming in agricultural policies

6.4 Discussion

6.4.1 Household characteristics

The influence of age on adaptation and development of farmer resilience has been mixed, with some studies showing no influence others showing positive or negative influence (Nhemachena, Hassan, & Chakwizira, 2014). The results in this study showed that the younger farmers would adapt better, developing resilience better than the older farmers. This is in contrast to results from a study by Bryan et al (2009) which showed a positive relationship between age of household head and adaptation to climate change, with more mature and experienced farmers adapting to climate. However, Mano & Nhemachena (2007) and Fosu-Mensah, Vlek, & MacCarthy, (2012) concluded that age did not significantly influence adaptation. The results of our study agree with a study by Seo et al (2005), who also found that the head of the household age negatively influenced adaptation. Nyong et al. (2007) also suggested the possibility that older farmers may be less amenable to change from their old practices.

The size of the household was found to have a significant influence of resilience development. Considering some of the adaptation strategies such as conservation agriculture and dry planting are labour intensive, households with large families are able to take up labour intensive adaptive measures than smaller households (Vincent & Cull, 2013). The results are consistent with findings of a study by (Gbetibouo, 2009; Nhemachena & Hassan, 2010). On the other hand Apata et al (2009) found that an increase in household size negatively influenced farmers' adaptation to climate change. In support, Mano and Nhemachena (2006) postulated that as household size increased, households are inclined to divert part of its labour force towards off farm activities.

6.4.2 Adaptation strategies

Adaptation strategies such as use of drought tolerant crop varieties has been one of the major strategies for managing water scarcity in agriculture (Rurinda et al., 2014), and long years of plant breeding activities have led to yield increase in drought affected environments for many crop plants (Mutekwa, 2009). Drought tolerance in crops such as maize, pearl millet, cowpea, groundnut and sorghum played important role in fighting the worst droughts in the last half of the 19th century in the Sahel (Berkes, 2009; Mertz, Mbow, Reenberg, & Diouf, 2009). By exploiting drought-tolerance genes, several national and international research institutions have scored important gains in improving the drought tolerance of major grain crops in Africa. Legume crops are vital sources of low-cost protein for smallholder farmers and generate farm income, serve as quality livestock feed and restore soil fertility. Groundnut followed by cowpea is the most widely grown grain legume in the dry areas of Africa, and several countries have released improved cowpea varieties with support from the International Institute of Tropical Agriculture (IITA) (CGIAR, 2012). Drought tolerant varieties of common bean, groundnut, Bambara nut and pigeon pea are also grown in highly variable rainfall areas of Africa (Verchot et al., 2007). The choice of these drought tolerant crops is against the background that most farmers in Africa rely on rainfall to grow maize; so dry conditions often have disastrous consequences, of leading to more vulnerability.

6.4.3 Determinants of adaptation choices

Several studies conducted on the determinants of adaptation show a positive relationship between adaptation and credit (Gbetibouo, 2009; Fosu-Mensah et al., 2012; Hassan et al., 2008). With access to credit farmers are able to purchase of appropriate crop seed varieties and fertilisers, plant early, and incorporate other farming practices such as crop diversification, in response to changes in climate. In addition with financial resources households can make use of the available information and the numerous adaptation options to respond to climate variability. Therefore, access to credit is a very important factor in determining whether a household adapt to the adverse effects of climate change and variability.

An increase in total livestock holding by one unit is likely to give an increase in the odds of adaptation to climate change by a factor of 1.74. Thornton et al (2007) and Deressa et al (2008), found livestock endowment to positively affect farmers choice to adapt to climate change or not. Possession of livestock in a rural setting in Zimbabwe signifies better endowed households or in other words wealthy households. This implies that households that are better off are likely to adapt to climate change since they have resources to enable them to adopt other means of livelihoods than those households without or with few resources at their disposal.

The positive influence of extension information to adaptation decision making is consistent with findings by Deressa & Hassan (2010) and Mano & Nhemachena (2007) who found that access to extension influenced farmer adaptation found access to extension to strongly and significantly affect adaptation to climate change. Gbetibouo (2009) noted that with access to extension households are aware of the climatic conditions and the various management practices to adapt to climate change. Soil nutrient depletion has become one of the major constraints to food security in sub-Saharan Africa because of low crop productivity that causes declining per-capita food production (Sanchez et al., 2004; Stocking, 2003). One of the reasons for under-investment in soil fertility inputs in rainfed production systems in Africa is the uncertainty and risks associated with climate variability (IAC, 2004), mainly because nutrients are not used efficiently when water availability is inadequate which results in considerable variability in profitability of fertilizer use and optimal application rates from year to year and season to season (Whitbread et al., 2004). One of the options for addressing this problem lies in seasonal climate forecasting which presents opportunity for increasing the efficiency of both water and nutrients through adaptive fertilizer management (Jiri et al., 2015a; Vanlauwe et al., 2013). Improved drought management and preparedness depends on access to climate information and early warning systems. The value of climate information lies in its ability to provide evidence of risk of a major climate shock in advance which help in anticipating the costs and the scale of measures that may be needed at the national and regional level (Jost et al., 2015). Climate information systems can contribute to strengthening institutional capacity and coordination to support generation, communication and application of early warning systems. As a component of disaster risk reduction, early warning systems in Africa have provided the information necessary to allow for early action that can reduce or mitigate potential disaster risks.

The negative influence of farm income to choice of adaptation is contrary to studies by Deressa, (2010) and Gbetibouo (2009) where income positively influenced household decision to adapt to climate change as availability of income would allow farmers to purchase enough inputs and better varieties. Farmers with more farm income indicate farmers who already have better income from farming. This means these farmers with higher farm incomes have no incentives of adapting than those farmers with falling or lower farm incomes. In other words, lower farm incomes is an incentive to adapt and need to develop resilience. Those households realizing already higher farm income have lesser incentives to adapt to newer ways of farming since their current farming practices might already be optimum. This means that if the available methods promise no better off incentives, farmers are not willing to adopt or adapt.

For communities to escape chronic poverty, they must increase their resilience to withstand shocks and hazards associated with climate change and variability (Table 6.5). By building resilience between and throughout hazard cycles, livelihoods would be improved, and the cost and scale of future adaptation reduced. Analysis of adaptation and the need to build resilience indicated that there is need for agriculture and structural changes in livelihood strategies in response to climate change and variability. The need for local climate information, informed by local indigenous knowledge and exogenous scientific data has been emphasised (Note, 2015). Locally researched climate smart cropping options are key to building resilience and enhancing food security at the local level (Food and Agriculture Organization, 2013).

6.5 Conclusion

The results from this study showed that action can be taken to build resilience to hazards and strengthen adaptive capacity to further climatic shocks. Farmers have traditionally adapted to climate risk by diversifying across crops and risk management options. Farmers generally diversify their production systems by employing activities that are less sensitive to drought and/or temperature stresses and activities that take full advantage of beneficial climate conditions. For example, farmers time their planting and inputs based on their best estimates of the cropping season; and they reduce risk exposure by diversifying their livelihoods. Farmers diversify their cropping practices using a mix of crop species both in space and time, growing different cultivars at different sowing dates and farm plots; combining less productive drought-resistant cultivars with high-yielding but water-sensitive crops. Nevertheless, managing droughts effectively in vulnerable areas requires diversifying livelihood strategies and income generating options within and outside agriculture especially into income generating options through non-farm enterprises and employment opportunities. This will require greater investments in infrastructure, road networks, electricity, communication and market development. Resilience can be strengthened through economic, sociological and technological interventions. The steps that need to be taken to build resilience include the anticipation of the hazard at the local level, the prevention, recovery and restoration from a hazard, balancing agricultural productivity against reducing the risk exposure.

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CHAPTER 7

Climate smart crops for food and nutritional security for semi-arid zones of Zimbabwe

Abstract

Southern Africa smallholder farmers continue to be the most affected by the challenges of climate change and variability. The variability of climate demands the use of a variety of agronomic strategies and crop choices. Traditional drought tolerant cereal crops such as sorghum and millets are often chosen when drought seasons are anticipated. However, there are certain crops, originating elsewhere, that could help the smallholder farmers increase diversity of crops that can be grown in changed climates. Trials were conducted to test a basket of known and introduced climate smart crops in the field. The crops tested were maize, sorghum, pearl and finger millet, and legumes: tepary bean (*Phaseolus acutifolias*), cowpea (*Vigna unguiculata*), Bambara nut (*Vigna subterranea*), ground nut (*Arachis hypogaea*) and pigeon pea (*Cajanus cajan*. A second experiment was done to determine the effects of inorganic fertilizer and rhizobium inoculation on the growth and grain yield of field grown tepary bean. Both experiments were laid out in a randomized complete block design with three replications. Due to drought conditions obtained during the season, cereal crops could not produce grain yield, as there was no grain filling even though grain was formed. Despite this, the cereals produced biomass, with maize producing the most biomass (5 tha^{-1}), followed by sorghum and millet. Legume crops managed to produce grain yield, with cowpea producing the 568.1 kgha-1, followed by tepary bean and common bean. This is important for food, nutrition and health security of the smallholder communities. Tepary bean inoculated with rhizobium and with fertiliser applied produced higher yield than when no fertiliser nor inoculant was applied ($P<0.05$). In conclusion, resource poor farmers, affected by drought effects of climate change, can adopt climate smart crops, both cereals and legumes, in order to create food and nutritional security. This is crucial for food and nutritional security of vulnerable households affected by climate change and variability.

Key words: tepary bean, climate smart crop, drought, smallholder farmers

7.1 Introduction

Cereals are the most important sources of food and cereal based foods are a major source of energy, protein, vitamin B complex and minerals for the world population (IRRI, 2009). Generally, cereals are cheap to produce, easily stored and transported, and do not deteriorate readily if kept dry. Over 50% of the world's cereal is produced in developing countries (Cordain, 1999). While cereal grains are rich in energy they lack other essential nutrients and minerals. However, small grains are more nutritious than maize, for instance pearl millet is rich in iron and zinc (Velu et al., 2007). Cereal grains are deficient in vitamin A nor its metabolic precursor, beta-carotene, except for yellow maize. Additionally, they are deficient in vitamin C, or vitamin B12. In most western countries these vitamin shortcomings are generally of little consequence, since the average diet is not excessively dependent upon grains and usually is varied and contains meat (a good source of vitamin B12), dairy products (a source of vitamins B12 and A), and fresh fruits and vegetables (a good source of vitamin C and beta-carotene) (McKevith, 1985). However, in some countries of Southern Asia, Central America, the Far East and Africa cereal product consumption can comprise as much as 80% of the total caloric intake, and in at least half of the countries of the world, bread provides more than 50% of the total caloric intake. In countries where cereal grains comprise the bulk of the dietary intake, vitamin, mineral and nutritional deficiencies are common (Topping, 2007).

Inclusion of legumes in the diet is important in control and prevention of various metabolic diseases such as colon cancer, diabetes mellitus and coronary heart disease. Legumes are sources of slow release dietary fibre (carbohydrates) and are rich in proteins (18 – 25%) (CGIAR, 2012). In Africa, legumes are the cheapest sources of supplementary proteins, besides being sources of minerals and vitamins. Legumes grain is an important food source used to provide dietary protein and energy requirements. They have high dietary fibre content and low lipid, with emerging evidence emphasizing the importance of legume grain as carriers of polyphenols, saponins, oxalates, lectins, phytosterols and enzyme inhibitors. Further evidence also suggest the importance of pulses in human health, particularly in prevention on coronary heart disease and diabetes (IAC, 2004).

Lately grain legumes have come out of the shadows in research and extension because of their highly valued and multiple benefits for the farmer and the farming systems across the developing world (IRRI, 2009). For semi-arid regions in particular, inadequate and highly variable rainfall and short growing periods limit yield potential and create a risky primary production environment. Evidence from the Intergovernmental Panel on Climate Change (IPCC) is now overwhelmingly convincing that climate change poses as one of the greatest challenge to agriculture and food security especially in sub-Saharan Africa (SSA) (Kashyapi, P.Hage, & Kulkarni, n.d.). This is because the region is very widely recognized as one of the most vulnerable in the world due to adaptive capacity which is extremely low, which is linked to acute poverty levels and poor infrastructure, as reflected in a high dependence of rainfall agriculture (Brooks et al., 2011). Among the most significant impacts of climate change is the potential increase of food insecurity and malnutrition. Projections suggest that the number of people at risk of hunger will increase by 10 – 20% by 2050 due to climate change, with 65% of this population in sub-Saharan Africa (Lobell et al., 2008). The number of malnourished children could increase by up to 21% (24 million children), with the majority being in Africa (FAO, 2009). These negative impacts of climate change and variability are presenting new challenges to the majority of smallholder farmers in the absence of appropriate response measures, hence the need to address the challenges. Food and nutrition strategies that bring co-benefits in terms of enhanced production of and access to food should be explored and tested. Focusing exclusively on increasing agricultural production is too short sighted in the context of sustainable food and nutrition security under climate change because producing more food does not necessarily lead to a better access to food or to an improved nutritional status of those who need it most (Turral et al., 2011). Adaptation is increasingly seen as an inevitable answer to the challenges posed by climate change (Brassard et al., 2008). Diversification into new crop types and cultivars is one adaptation strategy that has been identified as a potential farm level response to climate change and variability (Newsham & Thomas, 2009). Integration of N_2-fixing legumes and other high value crops within smallholder farming systems has been identified as one of the climate change coping strategies to improve food and nutrition security. The potential for grain legumes as a food resource and for soil fertility replenishment has been widely researched (Rurinda et al., 2014; Vanlauwe et al., 2013). Drought tolerant crops and high protein leguminous crops that include tepary bean (*Phaseolus acutifolius*) have over the years been largely ignored and neglected by research, as minor crops could also be potential candidate to be included in the adaptation strategy by providing greater resilience in coping with climate change. Current global debates on climate change adaptation options for smallholders need also to consider benefits for human nutrition (Rurinda et al., 2014). Traditional crops such as small grains could be a strategy for reducing micronutrients deficiencies in humans (Kalanda-Joshua et al., 2011). Finger millet and sorghum contain high content of minerals and vitamins (Solh & Van Ginkel, 2014). Changes in climatic conditions have already affected the production of some staple crops. Maize (*Zea Mays.* L), the staple food of Zimbabwe, is the most widespread grain crop grown under rainfed conditions in the smallholder cropping systems. As such, food security in Zimbabwe is generally defined in terms of maize but average maize yields remain low (<0.5 tha^{-1}) and continue to decline thus threatening household food security (FAO, 2014), yet in terms of nutritional importance, maize make up 49.5% of the daily calorie intake in the country. However, cereal grain alone does not provide enough nutritional value. Grain legumes complement household dietary requirements since they have high protein levels (IAC, 2004). Physiologically, it is not only the quantity of food but also its quality and the combination into a varied, balanced diet which are crucial (Stocking, 2003; Vermeulen, Campbell, & Ingram, 2012).

The human race is faced with many issues related to need for nutritious and adequate amounts of food. According to McCaffrey (2012), there is no other food which has a more health-supportive nutrient profile than beans. This is because they contain nearly equal amounts of protein and fibre, which is a unique combination that is rarely found in other plant foods. This combination together with the antioxidant content of beans has proved to be a powerful weapon against today's common diseases. However, tepary bean has been noted to be better than all other bean crops. Because of the high fiber content, tepary beans have the lowest glycemic index (the rate at which a food raises blood sugar levels) of all beans (Weil, 2015). Studies in the United States and Mexico suggest the importance of lectin toxins and other compounds from tepary beans in chemotherapy, halting the growth of cancer (Hart, 2012). Furthermore, recent studies from the same region suggest that tepary beans are useful for treating cancer, and they could be ten times more effective than chemotherapy (McCaffrey, 2012). Tepary bean seeds were shown to contain at least two different groups of bioactive proteins with dissimilar effects on cancer cells. The lectins in tepary bean exhibited an anti-proliferative effect on non-transformed cells and on some cancer cells (Garcia-Gasca, 2012; Bogler, 2014).

There is the potential for the use of drought tolerant legumes, in combination with cereal crops in agriculture to provide adequate food and nutrition security. Such crop choices should be sustainable, resilient and of practical solutions to challenges facing smallholder farmers affected by drought due to climate change and variability. Consequently, in this study, we tested these climate smart crops for production in smallholder communities affected by climate changed variability. We also tested the agronomic performance of tepary bean, a new legume crop.

7.2 Materials and methods

The research was conducted at Makoholi Research Station in Masvingo Province, Zimbabwe (19.5˚S, 30.5˚E) in the 2014/15 agricultural season. Commonly grown legumes: cowpea, bambara nut, groundnut and well as introduced legumes, pigeon pea and tepary bean were tested. Cereal crops, maize, sorghum, pearl millet and finger millet, were also grown. All the crops were planted on 19 January 2015. The crops were fertilized at the known recommended rates for the area. Compound D was applied at a rate of 150 kg/ha before planting in the respective sub plots. Ammonium nitrate, at a rate of 100 kg/ha was applied as soon as flowering/tasseling started.

A separate experiment was done at Crop Science department, University of Zimbabwe, tepary bean was grown under the following treatments: Basal fertilizer only (compound D fertilizer – 7:14:7 – N: P: K); Top dressing (Ammonium Nitrate – 34.5% N) only; Rhizobium only; Rhizobium + top dressing; Basal fertilizer + top dressing; and a control with no fertilizer nor inoculant.

For both trials the experimental design used was a randomized complete block design.

Methodology

At both sites, the land was ploughed and disced using a disc plough. Planting was done by hand using a pre-marked wire cable in marking the planting stations at a spacing of 0.45 m between rows and 0.05 m within rows, with row length of 6 m, for legume crops. Inter-row spacing of 0.90m and in-row spacing of 0.30m was used for maize. Small grain cereal crops were planted at 0.90m inter-row and banded in-row. For the legumes, four seeds were hand planted per station then thinned to two plants per planting station after 2 weeks. For the rhizobium treatments, sugar was dissolved in 250ml of water and mixed with the inoculant and mixed with 20 grams of seed, and the seeds were sown immediately. Mechanical weed control methods were used throughout the season to keep the crops weed free. Agronomic and yield data was collected as the crop grew and at maturity, respectively.

Data analysis

Data was analyzed using the statistical package R and Genstat 14. Treatment significant differences were declared at $P \leq 0.05$ by comparison of means using the Least Significant Difference method.

7.3 Results

7.3.1 Season rainfall characteristics

At Makoholi Research Station, total precipitation for the 2014/2015 growing season, December through May, was below normal at the Makoholi Research station (Figure 7.1). Overall, this station had 115mm with was about 28.75% of the normal seasonal average (400mm). During the six-month period, all the months had below normal rainfall. The most damaging aspect of the rainfall pattern occurred during the month of January. Precipitation for January was erratic and was below half of normal (Figure 7.1).

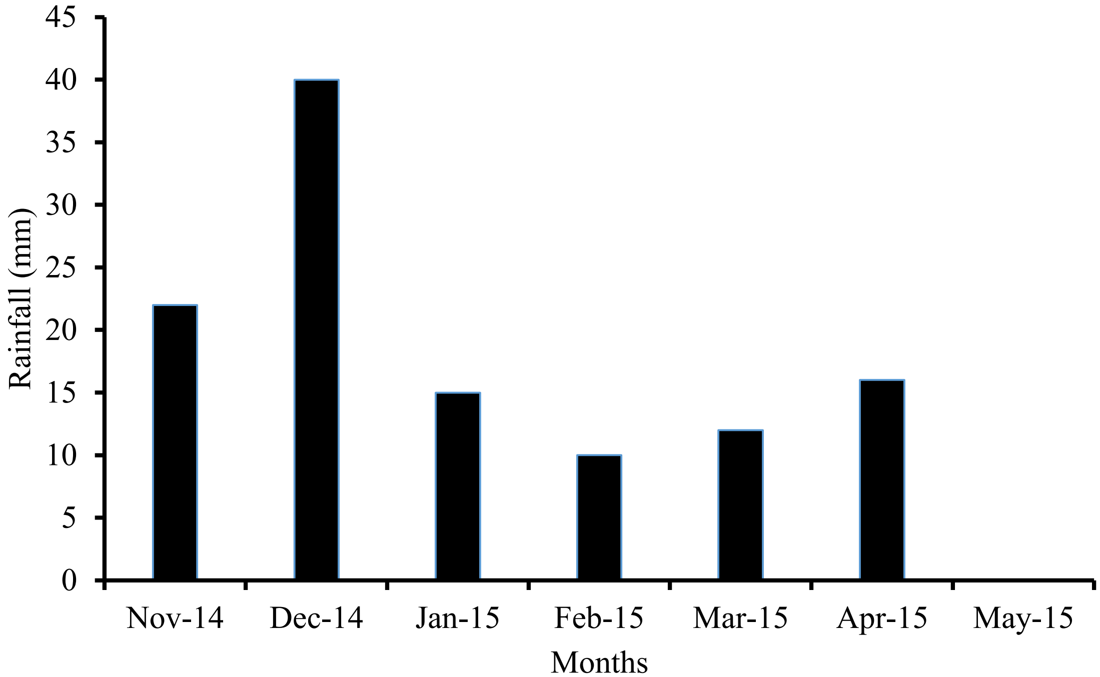

Figure 7. 1: Rainfall data at Makoholi (2014/15 season)

(Source: Makoholi Research Station rainfall records)

7.3.2 Cereal and legume growth and yield

Due to low rainfall (115mm seasonal total; Figure 7.1) and lack of moisture at tasseling and flowering cereal grain crops at Makoholi failed to produce grain despite producing biomass (Table 7.1). However, they all managed to produce biomass and also tasseled or flowered. Biomass production was in the order: maize > sorghum = pearl millet > finger millet. There was a significant difference in maize biomass yield compared with all other crops ($P < 0.05$), although there was no significant difference in biomass yield between pearl millet and finger millet (Table 7.1). Sorghum was eaten by birds, as it was an easy source of feed, because of its larger grain. The other cereal crops, pearl millet and finger millet, were also eaten by birds. However, no grain could be harvested owing to lack of grain filling due to drought conditions, and the little that could have been harvested was eaten by birds. The low rainfall in the months of January and February, when most grains flower, pollinate, and fill, affected grain filling. Moisture stress during this critical growth period was a major factor contributing to the lack of yields by the cereal crops.

The legume crops were able to grow and produce biomass and some legumes produced grain yield (Table 7.2). Cowpea yielded the highest yield (568.1 kgha^{-1}) followed by tepary bean and common bean. Tepary bean and groundnut were the earliest to flower. Bambara nut, pigeon pea and ground nut were not able to produce grain owing to lack of rainfall (Table 7.2; Figure 7.1).

Table 7.1: Cereal agronomic and yield performance in Masvingo Province, Zimbabwe

Crop	**Agronomic parameter**			
	Day to 50% emergence	**Days to 50% tasseling and flowering**	**Biomass (dry) (t/ha)**	**Grain yield (kg/ha)**
Maize	7a	59a	5.0a	0.0
Sorghum	6a	53a	1.3b	0.0
Pearl millet	5a	61a	1.2b	0.0
Finger millet	6a	65a	0.7c	0.0

Letters refer to significant differences at the P < 0.05 level.

Table 7.2: A field comparison of pulses agronomic and yield performance in Masvingo Province, Zimbabwe

Crop	Agronomic parameter				
	Day to 50% emergence	Days to 50% flowering	Pod yield (kg/ha)	Biomass (dry) (kg/ha)	Grain yield (kg/ha)
Tepary bean	5a	36a	151.1a	200.0a	245.9a
Cowpea	4a	51b	877.0b	502.2b	568.1b
Bambara nut	12b	46b	-	404.4b	0.0
Pigeon pea	11b	148c	-	493.3b	0.0
Common bean	12b	54b	14.8c	51.5c	227.0a
Groundnut	8b	38a	-	1,412.6d	0.0

Letters refer to significant differences at the $P < 0.05$ level.

7.3.3 Tepary bean yield

There were significant difference in the yield of tepary bean between inorganic fertilizer treatments and when nothing was applied to tepary bean ($P<0.05$). The highest final grain yield was recorded for the treatment with basal fertilizer + top dressing. However, this was not significantly different to the treatment which had rhizobium + top dressing and the one with top dressing only as well as rhizobium only (Figure 7.2). Tepary bean with no fertilizer nor inoculant applied yielded the least.

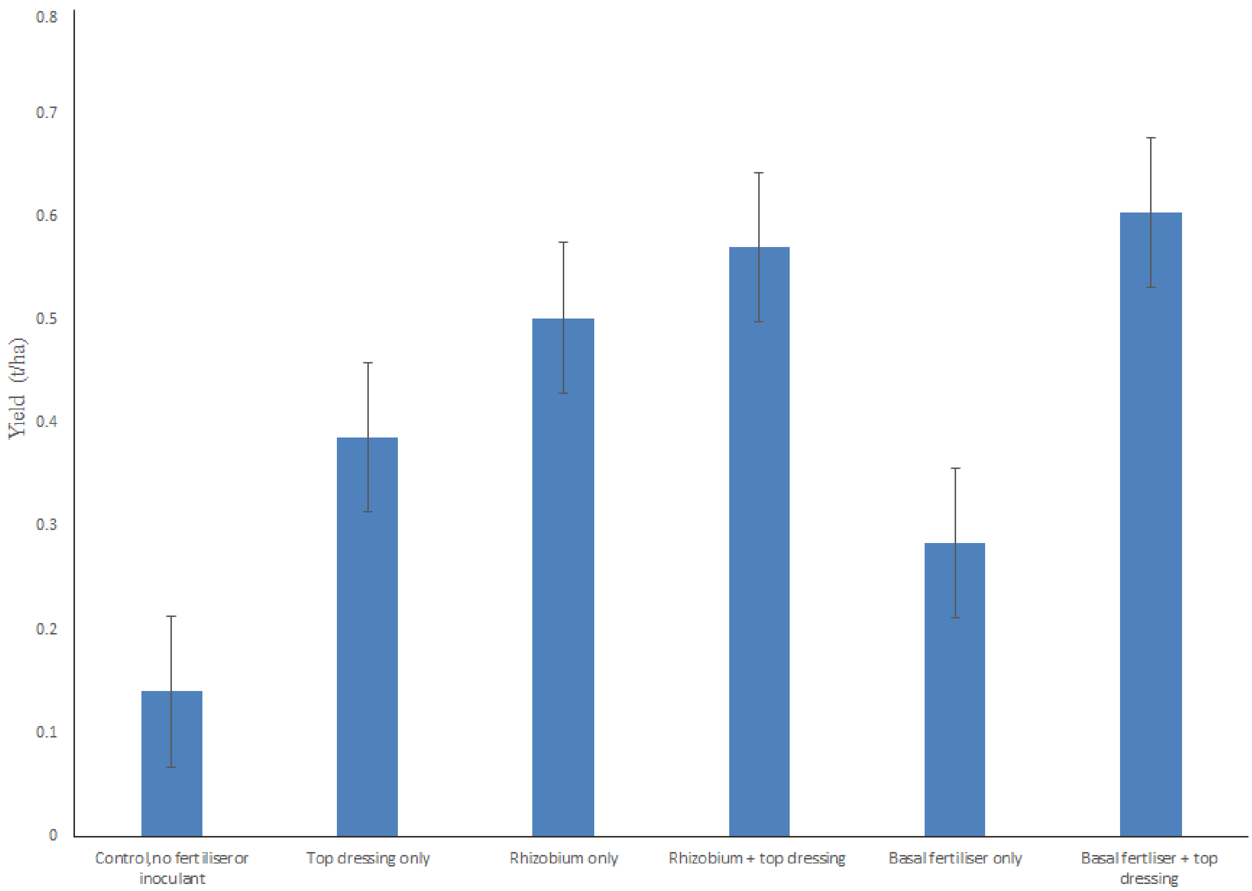

Figure 7. 2: Tepary bean grain yield under various treatments

7.4 Discussion

7.4.1 Cereal crop yields

The failure of cereal crops under the drought conditions at Makoholi (Figure 7.1) could be explained by adaptation failure. In the third assessment report, the IPCC defined such inappropriate outcomes as maladaptation. Specifically, the IPCC defined maladaptation as "any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli; an adaptation that does not succeed in reducing vulnerability but increases it instead" (McCarthy, 2001). As adaptation outcomes traverse spatial and temporal boundaries they may become less relevant, ineffective or even inappropriate (Adger & Barnett, 2009). Even more drought tolerant small grain cereals could not yield. This could mean that with increased drought conditions, cereals could become a less climate smart option for such areas.

However, it is important to note that birds preferred to eat sorghum grain compared to pearl millet and finger millet. This may mean that sorghum, if adopted as a climate smart crop, would be a challenging crop compared to pearl millet and finger millet, unless if it is widely grown in the area. Isaiah (2013) also made a similar observation in Kenya where sorghum was eaten by birds before it could be harvested.

7.4.2 Legume growth and yield

Despite the low rainfall at Makoholi, and the late planting of the crops, legume crops were able to grow and some produced good yields (Table 7.2). Thus with a short growing window period, and depending on residual moisture, it is possible to successfully grow most legume crops. This emphasizes the legumes as key climate smart crops that can fit into a small window of a very short growing season (Kandji et al., 2006; FAO, 2014). The climate change challenge and low soil fertility are major abiotic limitations for crop production, particularly for legume crops that are cultivated as escape crops and usually on marginal lands. Research has, however, placed legume crops to improve genetic adaptation to drought (Gary, 2010; McCaffrey, 2012). This could prove to be a major breakthrough in combating devastating effects of climate induced hunger and malnutrition, particularly in hard-hit areas of southern Africa (Chivenge et al., 2015).

The fact that groundnut, bambara nut and pigeon pea did not produce grain yield does not mean maladaptation of these crops. It is known that these crops are some of the most drought tolerant crops in Africa (CGIAR, 2012). There would need to evaluate response of short duration varieties of these known climate smart crops in drought prone areas. This is important as farmers diversify crops as a coping strategy to climate change and variability (Jost et al., 2015). CGIAR (2012) mentions important legumes for smallholder farmers as bambara nut (*Vigna subterranea (L.)* Verdc.), common bean (*Phaseolus vulgaris* L.), cowpea (*Vigna unguiculata* (L.) Walp.), pigeonpea (*Cajanus cajan* (L.) Millsp.), groundnut (*Arachis hypogaea* L.) and tepary bean (*Phaseolus acutifolius* (A. Gray)), among other few legumes. The majority of these pulses are already being grown worldwide.

7.4.3 Complementarity of cereal and legume grain for human nutrition

Weil (2015) emphasises the importnace of legumes as a cost-effective option for bettering diets of low-income consumers who cannot easily afford other sources of protein. This generates substantial benefits to the well-being of smallholder farm families. With many of the poorest countries deriving 10-20% or more of their total dietary protein from grain legumes, the importance of low resource legumes cannot be overemphasized (CGIAR, 2012). Cereal diets, such as maize-based diets in eastern and southern Africa, are low in lysine content relative to human amino acid balance. Legumes are superior sources of lysine, and increase the biological value of the combined protein. The current WHO-endorsed index for protein quality is the protein digestibility-corrected amino acid score (PDCAAS) which estimates the true value of dietary protein. Experts recommend that foodstuffs of at least 70% PDCAAS should be consumed (CGIAR, 2012). Cereals have a low PDCAAS value of about 35%, indicating their low protein quality when consumed in isolation, while a cereal legume combination in the proportions of 70/30 (weight/weight) can usually reach or exceed this PDCAAS threshold (CGIAR, 2012; Lal, 2013). Thus, even in countries where a cereal is the dominant source of protein, every gram of legume protein potentiates another gram of cereal protein. Legume proteins are rich in globulins and albumins and generally have isoelectric points of 4.2 to 4.4 (IAC, 2004). These protein fractions are rich in lysine and other essential amino acids but generally low in sulfur containing amino acids; therefore, they complement protein quality of cereal-based foods (González-Quijada et al., 2003).

Other health benefits of legumes include enhanced iron concentration in beans (Bargout & Raizada, 2013). Grain legumes exhibit low glycemic index thus reducing the risk of obesity and diabetes (CGIAR, 2012). A bean diet, with exercise, was shown to decrease typical changes in weight gain, glycemia and lipid profile (Bargout & Raizada, 2013). The low oil content in beans means that their consumption would have positive effects on colon and breast cancer (Tinsley, 1985; Vermeulen et al., 2012) and cardiovascular disease. Preliminary tests with HIV/AIDS victims fed grain legumes shows an increase in cell counts of CD4 cells, a primary element of the immune system (CGIAR, 2012). This may imply further importance of beans in diets.

7.4.4 Growth, yield and importance of tepary bean, a climate smart crop option

The high tepary bean yield obtained with fertilizer application contradicts with results from Kenya where nitrogenous fertilizer did not have a significance on the yield of tepary bean (Shisanya, 1998). This might mean that the effects of the rhizobium and basal fertilizer are the same if combined with ammonium nitrate. Basal fertilizer provides the plant with starter nutrients that are needed for early growth. However, according to (Gary, 2010) phosphorus does not increase grain yield. The nutrient may have played an indirect role of promoting a good root network which enabled the crop to absorb nutrients efficiently. Biological fixation of nitrogen by rhizobium contribute large amounts of plant usable nitrogen to the soil nitrogen pool (Ministry of Science And Technology Development, 2014). This plant usable nitrogen might have an effect in the early growth of the crop which is equally as good as that provided by the basal fertilizer

Basal dressing fertilizer is known to be effective in the soil for the first four weeks after application. The low tepary bean yield for this treatment may be attributed to this. By the time the crop was harvested basal fertilizer might have been exhausted and the crop was already thriving under nutrient deficiency conditions. Ahmad (2007) states that balanced use of inputs like fertilizers and moisture is essential for improving harvest index of grain crops. Yields obtained in this study consummate with those obtained elsewhere, estimated to reach 200 to 900 kg per hectare; variations come as a result of differences in sowing density and rainfall (Greenfingers, 2014).

These results show that tepary beans are a resilient food resource, able to survive in drought climates. This agrees with Albala (2007) and Debouck (1913) who reported that the plant is highly drought and disease resistant, and provide a quick harvest that is high in nutritional value. It is, therefore, expected to have significant potential for introduction into semi-arid areas (Debouck, 1991). Patel (2009) reported that, with climate change, droughts would become more frequent and more severe in southern Africa and drought affected areas are projected to increase in extent.

Although cowpea yielded the most, tepary bean compared well with common bean at Makoholi (Table 7.2). This is attributed to tepary bean being one of the most drought resistant legume species in the whole world according to Weil (2015). Gary (2010) also highlighted that tepary bean is recognized for its resistance to heat, drought and many diseases. It is capable of giving a notable yield with annual precipitation of less than 400 mm (Constantino, 2009; Andrews, 2014). Compared to common bean, it is shown to be superior in combining desirable traits that make it well adapted to drought stress (Stephens, 2013). Tepary bean particularly provides hope to smallholder bean farmers affected by climate change in southern Africa as it has naturally evolved with resistances to drought and high temperature conditions (Andrews, 2014).

7.5 Conclusion

This study shows the potential importance of climate smart crops in the food security, nutrition and human heath nexus. It is possible that the key to future food and nutrition security may very well lie in the untapped potential of climate smart crops. Therefore, it is imperative that we study locally adaptable climate smart crops and evaluate them for drought tolerance using agronomic techniques as well as modern techniques such as crop modelling, which allow for rapid evaluation of production scenarios. The combination of water scarcity, climate change and variability and increasing population that southern Africa is facing paints a gloomy picture of future food security for a region that already has scarce water resources. In addition to their adaptation to diverse ecological niches, small grain cereal crops and drought tolerant legumes are said to be highly nutritious and in some cases to have medicinal properties. There is, however, limited quantitative information proving some of these claims. However, increased drought conditions due to climate change and variability can lead to maladaptation. Extremely drought tolerant grain legumes such as tepary bean can be grown in the smallholder drought prone farming areas. Most of these legumes are capable of giving a notable yield with annual precipitation of less than 400 mm. From this study, smallholder farmers can be recommended to grow cowpea, tepary bean and common bean. There is need for more research to promote the production and utilisation of tepary bean by smallholder farmers in Zimbabwe as it is a new climate smart crop.

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CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The results from this study highlight the limitations of scientific forecasts to make an intended impact on smallholder farmers due to the inaccessibility and inequitable distribution of this information to smallholder farmers as the primary users of the information. The dominance of scientific forms of forecasting against indigenous indicators is still prevalent in smallholder areas. While indigenous forecasting is not without its challenges, a lot more can be learnt and used to implement adaptation strategies that are long lasting by integrating scientific forecasts and indigenous knowledge. This will likely lend legitimacy of these forecasts in the eyes of smallholder farmers. Certain inconsistencies in indigenous indicators, including shifts in phenological patterns and changes in indigenous indicators due to changes in rainfall patterns, all point to negative implications for traditional forecasting as a reliable method of forecasting. However, indigenous forecasting remains a sound entry point given its social nature and acceptability by smallholder farmers. Moreover, indigenous knowledge has a strong practical emphasis that is oriented towards planning, and exhibits dynamism that allows for incorporation of new elements; where scientific forecasts can then come in to complement and add credence to indigenous knowledge.

This research has also proved that mostly the traditional leaders and the elderly fully understand the use of indigenous knowledge in forecasting season quality. However, even these have noticed the erosion of local knowledge. Despite this, the farmers still use indigenous knowledge to make certain coping and adaptation decisions. Climate change may bring about a new set of weather patterns and extreme events that are well beyond what the local communities are capable of dealing with. External help is necessary to enhance the social and ecological resilience among rural communities. Indigenous coping mechanisms, albeit not enough on their own to respond to climate change, can serve as a useful entry point for interventions by governments, relief organizations and development agencies.

This study also revealed that farmers have noticed decline in rainfall and increase in average temperatures over the years. These perceptions have influenced adoption of agronomic practices, livestock practices or socio-cultural practices to cope and adapt to climate change and variability. While climate change and variability is an environmental problem, the scope of its impacts are strongly determined by underlying socioeconomic variables.

While perhaps most difficult to evaluate, subsistence farmers' vulnerability in terms of climate change must be addressed in order to save livelihoods. It is the poorest members of these areas or those that could be made poor by climate change that are most at risk. Without even considering specific climate scenarios, it can be asserted that those who are currently poor, malnourished and dependent on climate sensitive agricultural production are the most vulnerable in terms of hunger and malnutrition. Such vulnerability, from the contextual interpretation, can only be reduced by minimizing and modifying the contextual conditions of exposure and sensitivity to climate risk, and increasing indicators of adaptive capacity, so that individuals and communities are enabled to better adapt to changing climatic stimuli.

However, action can be taken to build resilience to hazards and strengthen adaptive capacity to further climatic shocks. Farmers have traditionally adapted to climate risk by diversifying across crops and risk management options. Farmers generally diversify their production systems by employing activities that are less sensitive to drought and temperature stresses and activities that take full advantage of beneficial climate conditions. Farmers diversify their cropping practices using a mix of crop species both in space and time, growing different cultivars at different sowing dates and farm plots, combining less productive drought-resistant cultivars with high-yielding but water-sensitive crops.

Consequently, to reduce vulnerability and increase resilience to climate change and variability, climate smart crops can be adopted by smallholder resource poor farmers to achieve triple wins of food nutrition and health security. In this regard, cowpea, common bean and tepary bean, a new crop, were shown to be some of the most drought resistant legume species that can be grown in the smallholder drought prone farming areas.

The study concludes that, perceiving that the climate is changing increases the probability of uptake of certain adaptation strategies by indigenous smallholder farmers. Development of participatory approaches as tools to integrate knowledge systems by mapping perceptions of climate change and variability at the local level to document changes and improvement of crop production choices and systems will increase adaptive capacity.

8.2 Recommendations

1. Despite the inclusion of indigenous knowledge in the design and implementation of sustainable development projects, little has been done to document and incorporate this into formal climate change adaptation strategies. Further research is needed to better understand the usefulness of these traditional indicators and to see how they can be used as an entry point to operationalize science-based climate forecasting at local community level. This will enhance resilience to climate stresses and buttress copping and adaptation strategies.

2. Managing droughts effectively in vulnerable areas requires diversifying livelihood strategies and income generating options within and outside agriculture especially into income generating options through non-farm enterprises and employment opportunities. This will require greater investments in infrastructure, road networks, electricity, communication and market development.

3. There is need to characterize the protein and mineral composition of tepary bean seeds and to compare the composition of mature raw tepary bean seed to some of legumes commonly grown by smallholder farmer in Southern Africa. Further research on rhizobium strain efficacy is recommended to determine the strain that has more effectiveness in terms of giving a higher Tepary bean yield. There will be need for further testing of other agronomic practices particularly planting dates and densities to determine the optimum yield.

8.3 Future research

1. Multicriteria adaptation planning needs to be done in order to develop robust adaptation strategies to influence adaptive capacity and resilience to climate change and variability at the local level.
2. There is also need to test and develop a basket of climate smart cropping options to increase resilience for farmers dependent on climate sensitive agriculture.

APPENDICES

APPENDIX 1: Indigenous Knowledge Systems Questionnaire

Introduction:
The University of KwaZulu-Natal has undertaken to study how communities have interpreted climate and weather patterns as they affect various aspects of their livelihoods. Whilst seasonal forecasts have been provided by the Meteorological services, these have been more widespread only recently ago but as communities you have had your ways of measuring how seasons are going to unfold. These are the indicators which as communities have helped you predict the season and thus make choices on the types of crops to grow. It is therefore the thrust of this survey to get information on indicators used by communities to forecast seasons.

Name of interviewer………………………………………………………………………..

Name of Respondent……………………………………………………………………….

District………………………………………………Ward …………………………………

1. Age
   (Ndingazivawo kuti mune makore mangani ekuberekwa)

2. How long have you stayed in this area?
   (Mave nemakore mangani muchigara munharaunda ino?)

3. What crops do you intend to grow this season?
   (Imbeu dzipi dzamuri kutarisira kurima mwaka uno)

4. What are your reasons for choosing these crops?
   (Nemhaka yei makasarudza kurima mbeu idzi?)

5. What sort of indicators did you rely on to forecast performance of rainfall season?
   (Takatarisana nekunaya kwemvura, chii chamunoshandisa semunongedzo wekuziva kuti mwaka wekunaya kwemvura unenge wakamira sei?)

6. Which tress in particular do/did you use in forecasting the season?
   (Miti ipi –revai mazita ayo yamaishandisa pakuziva mamiriro emwaka

7. If the season was good, what are the phenological properties/characteristics observed on these trees
   (Kana mwaka wakananaka (mvura yakawanda) chii chamaiona pamiti yamareva pamubvunzo wapfuura)

8. If the season was bad what phenological characteristics did you observe on the trees
   (Kana mvura iri shoma zvii zvaionekwa pamiti iyi yamareva zvaitaridza kuipa kwemwaka)

9. Talking about animals, which animals/creatures did you use to forecast the season
   (Takatarisana nemhuka ndedzipi mhuka kana zvipukanana zvamaishandisa kuziva mamirire emwaka)

10. What was the behaviour of these animals when a good season was expected?
    (Pamhuka/zvipukanana zvamareva chii chamaiona chichitika chaikuzivisai kuti mwaka wakanaka?)

11. In the event of a bad season, how did the animals behave?
    (Mhuka/zvipuka zvaitaridzawo sei kuti mwaka wainge usina mvura yakakwana)

12. Once the season started there are times when a dry spell would occur, what indicators helped you know a dry period was coming through?
    (Mwaka uchinge watanga pane zvainekwa here kutaridza kuti mvura yave kumboenda kwemazuva)

13. At the end of the dry spell what would indicate the coming back of rains?
    (Ko kana mvura yodzoka mushure mekunge kwambooma, chii chamaiona chaitaridza kudzoka kwemvura?)

14. (Have you checked on the indicators you use whether they are really good at forecasting the season?)
    (Makambozviongorora here kuti muone kuti minongedzo iyi yainyatsoshanda zvakadii?)

    Hongu kwete

15. If yes which indicators really gave good results
    (Kana mati hongu, minongedzo yainyatsokubuda nemazvo (kana sezvazviri) ndeipi pane yamareva?)

16. Are the indicators you used in past years still as good today?

Ko parizvino muchiri kuona minongedzo iyoyo ichinyatsokushanda sekare here?

Hongu kwete

17. If you said no, can you explain what has changed on the indicators
(Kana mati kwete, chii chashanduka paminongedzo iyi?)

18. How did you get to know about these indicators?
(Makaziva sei pamusoro peminongedzo iyoyi yose?)

19. Do you think the youth still use these indicators for seasonal forecasting? Give reasons
(Munofunga kuti vechidiki vachiri kushandisawo minongedzo iyi here? Ipai zvikonzero)

20. Do you use seasonal forecasts issued by the Meteorological Services Department?
(Ko munoshandisa here ruzivo runoburitswa nevemamiriro ekunze uye munozvinzwisia here?)

Hongu kwete

If yes;

Do you get the seasonal forecast in time and during the season do you get updates?

Nhau dzememariro ekunze munodziwana mwaka uchitanga here, uye mukufamba kwemwaka munowana nhau idzi zvakadini?

Hongu Kwete

HOW DO THEY HEAR OR GET TO KNOW OF THESE FORECASTS (radio, newspapers, AEW, cellphone, hearsay etc)

21. Do you understand the seasonal forecasts issued by the MSD?
(Munonzwisisa here mamiriro emwaka amunopiwa nevemariro ekunze?)

Hongu kwete

22. (Have you ever analysed to see if there is agreement between the forecasts given by MSD and your own forecasts using indigenous indicators?)
Pane pamunoona panopindirana zvinobva kunana mazvikokota vemamiriro ekunze nezvamunoonawo imi muchishandisa minongedzo yenyu here?
Hongu Kwete

23. Name the areas of agreement if you said yes
(Revai pamunoona pachipindirana kana mati hongu)

24. Considering forecasts that are generated by the MSD, do you think you want to continue using your own ways of forecasting seasons or you want to shift to climate science?
Muchienzanisa nezvinobva kune vemamiriro ekunze, mungada here kuramba muchishandisa nzira dzenyu idzi dzekuziva mwaka kana kuti motora zvinobva kune vemamiriro ekunze?

25. Nhau dzememariro ekunze munodziwana mwaka uchitanga here, uye mukufamba kwemwaka munowana nhau idzi zvakadini? (Do you get the seasonal forecast in time and during the season do you get updates?)
There is suggested change.

26. Can you tell me what crops you would grow when a bad season was forecast
(Mungandiudzawo here mbeu dzamairima mushure mekuziva kuti mwaka unenge uine mvura shoma?)

27. After growing these crops did you get good yields to help you survive the bad season? (Kana marima mbesa dzmataura pamusoro maikwanisa kurarama zvakanaka here kusvika mwaka uchipera?)

28. What agricultural measures would help you get some food during droughts?
Takatarisana nekurima zvii zvingaitwa kukubastirai kuti muwane chikafu kunyange mvura iri shoma munguva dzenzara.

TATENDA. THANK YOU. SIYABONGA

APPENDIX 2: Farmers perceptions and adaptation questionnaire

UKZN: QUESTIONAIRE FOR SMALLHOLDER FARMERS:

Management of Risks & Uncertainty in smallholder agriculture: CHIREDZI DISTRICT

Interview No.............. Interviewer's Name .... Date..........................

Ward................................... Village....................................

1. **HOUSEHOLD INFORMATION**

A. **DETAILS ABOUT HEAD OF HOUSEHOLD (HoH)**

a. **Gender :** 1: Male 2: Female

b. **Marital Status:** 1: Single 2: Married 3: Divorced 4: Widowed 5: N/A (< 16yrs)

c. **Age of HoH (yrs) ....**

d. Level of Education 1: Primary 2: Secondary 3: Tertiary 4: None 5: Other (Spec)

e. **Employment Status:**
1: Employed 2: Not Employed 3: Self Employed 4: Full time farmer

5: Farm Labourer 6: Student 7: Other (Specify

B. Household size: Males.......... Females ....

C. **How many members are fit to work in Agric related operations (for crop/livestock management)?**

Males.......... Females ....

D. **How many are too young to work in agricultural operations?: Males.......... Females ....**

E. How many members are stay of farm? ***(away but rely on this household eg school children in boarding schools*):**

Males.......... Females..........

F. How many are in the household and not working? (18years-35yrs)

Males.......... Females..........

G. **How many members are chronically sick?** ***(eg diabetic, BP, HIV Athritis etc)***

Males.......... Females..........

[NB: Household member is considered to be anyone who stays with the family for 3 consecutive months and eats from the same pot with other family members]

H. HOUSEHOLD INCOME

a. **Indicate household sources of income**

1. Selling Livestock: $....... 2.Crops:$....................3. Meat $: ....4.Wool/Mohair: $.............

5.Eggs: $.................. 6.Milk: $...................... 7.Family remittances $................

8.Government Grants: $.................. 9.Cooperatives: $..................10.Personal Savings $............

11.Family business $....................... 12. Part time work $................13. Craft/Carpentry $................

14. Brick Making $............................ 15. Other (Specify).....................................

b. **What was your gross monthly income, last year (USD)?**

1: No income 2: 1 – 50 3: 51 – 100 4:101 – 150 5: 151 – 200

6: 201 – 250 7: 251 – 300 8: 301 – 350 9: >351

c. What was your household expenditure pattern per month?

1: Groceries: $................ 2: Transport: $............. 3: School fees: $............

4: Input purchase: $............ 5: Clothes: $................ 6. Maintenance costs, $............

7. Entertainment, $............. 9. Church contributions $........... 10. Burial levies, $............

11. Other (Specify) ....

d. Do you use credit to finance household activities? 1.Yes 2.No

e. If you used credit what are the sources of the credit?

1. Bank 2.Cash Crusaders 3.Co-operative 4. N/A

5.Other(specify)

f. If you use credit what interest are you charged per month? *(specify as a percentage)*

g. Indicate your frequency of borrowing.

1 . Fortnightly **2.** Monthly **3.** Once in 2 months **4.** Every 6 months

5. Yearly **6.** Other (Specify)

I. LAND HOLDINGS

a. **Agricultural Land-use system**	b. **Do you have any of the listed land-use systems** ***[1.Yes 2.No]***	c. **Type of land ownership:** 1: Leasehold 2: Freehold 3: Private 4: Communal 5. Traditional allocation by chief 6. Other (specify)...............................	d. **Total Area (Ha)**	e. **Indicate position of land holding on landscape** 1: top land 2: mid slope 3 :lowland or vlei 4:Other (Specify).............	f. **Area currently being used:** [1=0%, 2=25%, 3=50%, 4=75%, 5=100%]	g. **Reasons for Under/Full Utilisation of land.**	h. **State the condition of the field/ garden** [1.Fenced 2.Not fenced 3.Partly fenced]
1: Homestead garden							
2: Dryland farming							
3: Irrigation							
4:Grazing							
5. Other *(specify)*			**Total (ha)**				

(How big an area do you have access to for your farming activities (cropping and livestock): within the farm, homestead, dry-land and irrigation scheme and grazing area? Indicate the total area for each of the land-use systems in your operations)

4. RAIN FED CROP FARMING

AA. Which factor(s) greatly affects crop production in your area?

1. Rainfall 2.Temperature 3.Grazing 4.Pests & Diseases 5. Fertility 6. Labour 7. Lack of knowledge 8. Don't know

Variables →	AB. What season was crop grown 1.Summer 2.Winter 3.Both			AC. Area of production (ha)			AD. How much did you harvest?(write quantity eg 20x50kg bags)			AE. How much was sold? (write quantity eg 20x50kg bags)			AF. Selling Price (R)			AG. Reasons for gain /loss in yield
Crop Year → ↓	2000	2005	2010	2000	2005	2010	2000	2005	2010	2000	2005	2010	2000	2005	2010	
1: Maize,																
2: Millet,																
3:Cotton																
4:Butternut																
5:Wheat																
6:Cabbage,																
7:Onions																
8:Lettuce																
9:Tomatoes																
10:Carrots																
11:Cauliflower																
12:Spinach																
13:Potatoes																
14:Beans																

AH. Explain your challenges in agriculture for the past 10-20 years.
....
....

AI. Explain how you conserve or capture water/moisture if any on your fields/garden?
....
....

AJ. **What is your major reason/goal for crop farming?(Tick)** 1: Marketing 2: Consumption 3:Cultural purposes (could be all: need to specify how to capture this)	**AK.** **Do you aspire to increase your scale of production?(Tick)** **1: Yes 2.No**	**AL.** **If you market, what is your preferred market/buyer** 1. Hawkers 2. Neighbours 3. Local shops 4. Fresh produce market 5. Agro- processors 6. Don't sell
Explain whether you meet your goals ………………………………	Explain reason …………………………………………………..	Explain why?

AM. What implements do you use for your farming operations? 1. Tractor drawn 2. Animal drawn 3. Hand implements

Operational Cost Aspects	Tractor [ha...........]	Animal [ha...............]	Hand [ha.............]
1. Do you own the means of power? 1. Yes 2. No			
2. How much do you pay per hectare- Ploughing?	$	$	$
3. How much do you pay for planting/ha?	$	$	$
4.Weeding Cost	$	$	$
5.Harvesting Cost	$	$	$
6.Fertilisers	$	$	$
6.Herbicides	$	$	$
7.Water cost	$	$	$
Total Cost			

5. LIVESTOCK PRODUCTION

AN1. Does the household keep any livestock? **1**. Yes **2**.No

AN2. Livestock Type	**AO. Total Number Owned**	**AP. Source of Livestock** 1:Purchased 2:Donated 3:Inherited 4:Lobola 5.Other…….	**AQ. What is your water source for each and every livestock?** 1: Dam 2 : River 3 : Tap water 4: Borehole 5: None	**AR. Do you have adequate water for all livestock categories that you keep?** 1: Yes 2 : No	**AS. What challenges greatly affect livestock production in your area?** 1.Rainfall 2.Temperature 3.Grazing/ feeding 4.Pests&Diseases 5. Lack of knowledge 6.Don't know	**AT. Explain your challenges for each livestock enterprise.**
1: Cattle						
2:Sheep						
3 :Goats						
4 :Chickens						
5:Turkeys						
6:Donkeys						
7 Pig						
8.Hanga						
9.Ducks						
10.Geese						

AU. Changes in household livestock numbers

Livestock	2000	2005	2010	AV. Reasons for Loss in numbers	AW. Reasons for gain in numbers
				1.Disease related death 2.Drought related death 3. Sold/slaughtered 4.Theft 5. Paid lobola 6.Other (specify)	1.Purchased(Buying in) 2.Natural increase (calving) 3.Donations 4.Recieved from lobola 5.Other(specify)
Cattle					
Sheep					
Goats					
Pigs					
Donkeys					
Hanga					

What is your assessment of the condition of the rangelands?

AX. Browse	AY. Grazing pastures
1.Very good condition; improving 2. Good; plenty of shrubs 3. Fair; fair amount of shrubs 4. Good; plenty shrubs 5. Poor; some big trees; bush encroachment 6. Very poor; little grass and no shrubs. 7. I cannot say; do not know.	1.Very good condition; improving 2. Good; plenty grass 3. Fair; fair amount of grass 4. Good; plenty grass 5. Poor; some grass; bush encroachment 6. Very poor; little grass 7. I cannot say; do not know
Answer:	Answer:
Explain:	**Explain:**

Farmer perceptions on long term Climatic and Environmental changes

1.Have you noticed any long-term changes in the mean temperature over the last 20 years? (please explain) Please mark with x if used.
[If too difficult: Has the temperature/hot days : 1. Increased 2.Decreased 3.range altered 4. No change 5. Don't know 6. Other
over the last10- 20 years? (please explain)
2.What adjustments in your farming have you made to these long-term changes in temperature? Please list below.

3.Have you noticed any long-term changes in the mean rainfall over the last 20 years? (please explain)
If too difficult: Has the rainfall amounts/ rainfall days 1. Increased 2.Decreased 3.range altered 4. No change 5. Don't know 6. Other
over the last10- 20 years? (please explain)
4.What adjustments in your farming have you made to these long-term changes in rainfall? Please list below.

5.Have you noticed any long-term changes in frost/snow occurrences over the last 20 years? (please explain)
If too difficult: Has the frost/snow occurrences */ frosty days 1. Increased 2.Decreased 3.range altered 4. No change 5. Don't know 6. Other*
over the last10- 20 years? (please explain)
6.What adjustments in your farming have you made to these long-term changes in frost/snow occurrences l? Please list below.

7.Have you noticed any long-term changes in uncontrolled veld fire occurrences over the last 20 years? (please explain)
If too difficult: Has the veld fire occurrences *1. Increased 2.Decreased 3.range altered 4. No change 5. Don't know 6. Other*
over the last10- 20 years? (please explain)
8.What adjustments in your farming have you made to these long-term changes in uncontrolled veld fire occurrences? Please list below.

9.Have you seen changes in the vegetation cover and landscape changes over the last 10-20 years? (please explain)
If too difficult: Have you noticed 1. Increased bush encroachment 2.Decreased bush encroachment 3.reduced herbaceous cover 4. Increased herbaceous cover 5. Emergence of wetlands 6. Disappearance of wetlands 7.No change 8. Don't know 9. Other

XX.Have you noticed any change(s) in crop phenological/growth patterns over the last 10-20 years? (please explain incl. type) ?

If too difficult: Have you noticed 1. shorter germination period 2.l onger germination periods 3. Increased crop heights 4. Decreased crop heights 5. Shorter maturation periods 6. Longer maturation periods 7. No change 8. Don't know 9. Other

XXX.What adjustments in your farming have you made to these long-term changes in crop phenological/growth patterns ? Please list below.

10. Have you noticed any change in pest abundance and seasonality over the last 10-20 years? (please explain incl. type) ?

If too difficult: Have you noticed 1. Increased pest abundance 2.Decreased pest abundance 3.changed seasonality of pests 4. Changed pest species 5. No change 6. Don't know 7. Other

11.What adjustments in your farming have you made to these long-term changes in crop pest abundance and seasonality ? Please list below.

12. Have you noticed any change in crop disease prevalence, severity and seasonality over the last 10-20 years? (please explain incl. type) ?

If too difficult: Have you noticed 1. Increased disease prevalence/severity 2.Decreased disease prevalence/severity 3. Changed seasonality of diseases 4. Changed disease types/species 5. No change 6. Don't know 7. Other

13.What adjustments in your farming have you made to these long-term changes in crop disease prevalence, severity and seasonality? Please list below.

14. Have you noticed any change in weed abundance/density and seasonality over the last 10-20 years? (please explain incl. type) ?

If too difficult: Have you noticed If too difficult: Have you noticed 1. Increased weed abundance 2.Decreased weed abundance 3.changed weed species 4. Changed weed seasonality 5. No change 6. Don't know 7. Other

15.What adjustments in your farming have you made to these long-term changes in weed abundance/density and seasonality and seasonality? Please list below.

16. What do you think could be the reason for the change(s) you have mentioned above for crops? (Can guide by temp., rainfall, frost days, weeds, pests, and diseases)

XXX Have you noticed any climatic/weather patterns following periods of peak abundance of these weeds, crop pests or severity of crop diseases?

Perceived farm-level adaptation strategies among smallholder farmers in Chiredzi District
Based on responses given 2, 4, 6, 8, 11, 13 and 15 ask for the options listed below in a quizzing way!!

(BF1. In your own view, has the climatic conditions influenced the way you do your agriculture in current years (tick)? 1. Yes 2. No) to go off

Why did you not use/adopt	**Explain your strategies *(see footnote)***
Different crop varieties	
Crop diversification (Different crops)	
Livestock diversification (different animals)	
Different planting dates	
Shortening length of growing period	
Moving to different site	
Changing amount of land	
Changed from crops to livestock	
Changed from livestock to crops	
Left dryland Farming for home garden only	
Adjust livestock management practices	
Farming to non-farming	
Increased irrigation	
Changing use of chemicals, fertilizers, manure and pesticides	
Increasing water conservation	
Increased soil conservation	
Shading and shelter	
Use insurance	
Prayer/Cultural adaptations	
Other adaptations	

[1: lack of money, 2: lack of information, 3: shortage of labor, 5: Others) ……….]

XX. What were the main constraints/difficulties in changing your farming ways? (Could be repetition of table above??)…can use key under table above….could be linked to 8.1 of the original or 7BU?

a. **Have you noticed any change in animal pest abundance and seasonality over the last 10-20 years? (please explain incl. type) ?**

If too difficult: Have you noticed 1. Increased pest abundance 2.Decreased pest abundance 3. Changed seasonality of pests 4. Changed pest species 5. No change 6. Don't know 7. Other

b.What adjustments in your farming have you made to these long-term changes in animal pest abundance and seasonality ? Please list below.

c. Have you noticed any change in animal disease prevalence, severity and seasonality over the last 10-20 years? (please explain incl. type) ?

If too difficult: Have you noticed 1. Increased disease prevalence/severity 2.Decreased disease prevalence/severity 3. Changed seasonality of diseases 4. Changed disease types/species 5. No change 6. Don't know 7. Other

d.What adjustments in your farming have you made to these long-term changes in animal disease prevalence, severity and seasonality? Please list below.

e. What do you think could be the reason for the change(s) you have mentioned above for animals? (can guide by temp., rainfall, pests and diseases)

f. Have you noticed any climatic/weather patterns following periods of peak abundance of these animal pests or severity of diseases?

g. Have you noticed any change in human pests and diseases over the last 10-20 years? (please explain incl. type) ?

If too difficult: Have you noticed 1. Increased malaria cases 2.Decreased malaria cases 3. Changed seasonality of pests/diseases 4. Changed pest species and diseases 5. No change 6. Don't know 7. Other [CAN BROADEN DISEASE/PEST EXAMPLES]

h. What do you think could be the reason for the change(s) you have mentioned above for animals? (Can guide by temp., rainfall, pests and diseases)

6. WATER SOURCES AND AVAILABILITY. (5-20yrs??)

BG. What is your source of water for domestic uses? 1.Rivers 2. Dams 3.Boreholes 4.Wells 5.Tap water 6. Rain water tanks 7.Other(specify)	BH. Do you consider available water sources like dams and rivers secure to provide enough water for livestock and domestic uses? 1. Yes 2. No	BI. Have there been any changes in dam water holding capacities recently? 1. Yes 2. No	BJ. In the past, 5-10 yrs ago, which month did you expect dams to run out of water. 1. Jan 2. Feb 3. Mar 4. April 5. May 6. Jun 7. Jul 8. Aug 9. Sep 10. Oct 11. Nov 12. Dec	BK. Which month do you expect dams to run out of water in current years? 1. Jan 2. Feb 3. Mar 4. April 5. May 6. Jun 7. Jul 8. Aug 9. Sep 10. Oct 11. Nov 12. Dec	BL. Which month do you expect dams to fill water in current years? 1. Jan 2. Feb 3. Mar 4. April 5. May 6. Jun 7. Jul 8. Aug 9. Sep 10. Oct 11. Nov 12. Dec	BM. Which month did you expect dams to fill water in the last 5-10years? 1. Jan 2. Feb 3. Mar 4. April 5. May 6. Jun 7. Jul 8. Aug 9. Sep 10. Oct 11. Nov 12. Dec	BN. What is the frequency of floods in your area? 1.Monthly 2.Twice a year 3.Yearly 4.Once in two years 5.Once in 5years 6.No floods 7.Other (specify)	BO. Has the frequency of floods increased or decreased? 1.Increased 2.Decreased
Explain	**Explain**	**Explain**	**Explain**	**Explain**	**Explain**	**Explain**	**Explain**	**Explain**

BP. What measures have you put in place to improve water storage or availability in the area?
....
....
....

BQ. What can be done to improve water availability in storage facilities?
....
....
....

BR. What factors negatively affect water usage in the area? ....

BS. 01What can be done to improve access to both agriculture and domestic water in the community?

....

.... ……………………………

BT. What support (government/private) are you currently getting to improve water availability and usage, for both agriculture and domestic uses?
....
....

7. PRODUCTION

BU. Which factors greatly affect you as a farmer in your production? ....
....
....

BW. What can be done to improve farm productivity?
Explain... ....
....
....

BV. Have you ever thought of stopping farming due to unfavourable weather/climatic conditions? Yes=1, No=2

....

....

....

BX. Given an option would you still like to engage in agriculture? 1. Yes 2. No

Explain. ....

BW. Are the youth (18-35yrs) actively involved in crop and livestock activities in the household?   1. Yes   2. No

BY. What is the participation of the youth in agriculture? If they are not participating, why are they not participating?
....
....
....

BZ. What can the youth do to reduce the impact of climate change and variability on household agricultural activities?
....
....

APPENDIX 3: Vulnerability and resilience questionnaire

Country:______________________ **District:** ______________________

Institution: ______________________

1. Prevalent hazards, risks and risk drivers in Chiredzi District

In your opinion…

1.1) What would be your 3 priority hazards? Why?

Hazard 1:

Category	**Comment**
Hazard	
Who is most vulnerable?	
Why are they vulnerable?	
Where is highest vulnerability?	

Hazard 2:

Category	**Comment**
Hazard	
Who is most vulnerable?	
Why are they vulnerable?	
Where is highest vulnerability?	

Hazard 3:

Category	Comment
Hazard	
Who is most vulnerable?	
Why are they vulnerable?	
Where is highest vulnerability?	

1.2) Are there sectors/services with internal shortcomings that increase the likelihood of a localised or more widespread disaster … if so, which ones?

1.3) Are there risk and vulnerability mapping exercises?

If so, who does them?

When was the last exercise done?

1.4)

DO SAME FOR RISKS

2. Information on capacities of government agencies, essential services and management practices

2.1) To address these threats what are your organisation's strengths?

2.2) What major risk assessments, related to your area of work, have been undertaken in the 5 years?

2.3) Are they readily accessible/May I have access to them? *Maybe not necessary*

2.4) How do you monitor rural/urban water shortage risk?

2.5) Tell me about the adequacy of your district water storage

2.6) What capacity do you have to respond to rural/urban water shortages?

3. Opinions of the 3 most significant disaster events since 2000

3.1) Do you have a disasters' database or list of disasters? Where can I find this database?

3.2) What are the 3 disasters since 2000 that stand out the most to you? Why do these disasters stand out? (economic, livelihood/infrastructural loss… etc)

Disaster Name	Type	Year	Spatial Extent	No. affected	Reason why significant

4. Top ranked disaster since 2000

4.1) What happened? How many people were affected? Etc.

4.2) What factors escalated the impacts of the disaster?

4.3) What management practices were effective?

4.4) What factors stabilized/deescalated the impacts of the disaster?

4.5) Speak about the effectiveness of the early warning systems

4.6) Were there any warning signals that were missed?

4.7) Were there any escalating risk factors that were ignored?

4.8) If an event of this magnitude were to occur again, what would happen?

5. Other institutional Qs

5.1) How effective do you feel regional collaboration on disaster risk is?

- What are the strengths of these?
- What are the weaknesses?
- Give an example

5.2) At what point is an emergency situation declared as a national disaster?

5.3) At what point do you appeal for international assistance?

5.4) What is the protocol for mobilising international assistance?

5.5) How effective do you feel the co-ordination of government, NGO's and humanitarian aid is?
- How can this be strengthened?
- What are the shortcomings?

6. Interviewee's opinions on projected future changes

6.1) In your opinion, what is likely to change in the future? Where, for whom, why, when?

6.2) How do you expect the risk profile to change?

6.3) What factors influence this change?

6.4) What do you feel the response of the population will be to these changes? Government's response …constraining/enabling factors

6.5) Do you feel your institution will be able to cope with/benefit from these changes?