COST BENEFIT ANALYSIS OF CLIMATE CHANGE ADAPTATION STRATEGIES ON CROP PRODUCTION SYSTEMS: A CASE OF MPOLONJENI AREA DEVELOPMENT PROGRAMME (ADP) IN SWAZILAND

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A Thesis Submitted in Partial Fulfilment of the Requirement for the Degree of

MASTERS OF SCIENCE

in

Agricultural and Applied Economics

of the

University of Swaziland

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June, 2013

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ABSTRACT

The study is a descriptive survey done at Mpolonjeni ADP which is a representative sample for the project as it is affected by climate change and variability. This is evident as there is high level of food insecurity, crop failure, poverty and hunger Mpolonjeni ADP. The increased involvement of food relief agencies nearly on an annual basis is a clear indication that agricultural production, the mainstay of the areas has drastically fallen, and households' livelihoods are at risk. The objectives of the study were to identify the impact of climate change on crop production, identify private adaptation strategies, conduct a cost benefit analysis for the adaptation strategies identified and identify socioeconomic factors influencing the choice of households when adapting to climate change. Sample was randomly selected and personal interviews were conducted. Data were analysed using descriptive statistics, Ricardian regression model, cost benefit analysis and multinomial logistic model. The results indicated that temperatures are increasing and rainfall is decreasing and this reduces maize yields. Adaptation strategies used are; drought resistant varieties, switching crops, irrigation, crop rotation, mulching, minimum tillage, early planting, late planting and intercropping. Switching crops has the highest NPV, where maize (E14.40) should be substituted with drought tolerant crops such as cotton (E1864.40), sorghum (E283.30) and dry beans (292.20). Factors influencing the choice of adaptation were; age of household head, occupation of household head, belonging to a social group , land category , access to credit, access to extension services training, high incidences of crop pest and disease, high input prices, high food prices, perceptions of households towards climate change. From the results, it is recommended that households should grow drought tolerant crops such as cotton, sorghum and dry beans instead of maize. The government should provide irrigation system, strengthen extension services and subsidise inputs. Further studies should analyse by CEA and MCA.

Key words: climate change, climate variability, cost benefit analysis, adaptation strategies, Ricardian model, multinomial logistic model

DEDICATION

To my parents, Mr P. M. and Mrs A. N Shongwe, entire family and friends for their unconditional love, encouragement, inspiration and support throughout the project period.

ACKNOWLEDGEMENT

The author extends special thanks, gratitude and appreciation to Professor. M. B. Masuku, my major supervisor and Professor A. M. Manyatsi, my co-supervisor for their constructive comments, suggestions, supervision, encouragement, patience, skills and time they have provided when the study was undertaken. Special appreciation and thanks go to FANRPAN for the financial support they have provided for the research project. It is an honour to be part of such a supportive and resourceful international organisation. Special thanks to my colleagues and immediate supervisors at work who encouraged and support me throughout the course of the study. The author will also like to thank World Vision Swaziland staff at Mpolonjeni, enumerators and the households who made data collection possible. Finally but not least, I thank God for all He has done for me.

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INTRODUCTION

Global climate change and its impacts on crop production

Climate change has serious environmental, economic, and social global impacts. Global climate is changing at rates that are unprecedented in recent human history and will continue to change (Gbetibouo, 2009; Pant, 2007). Even if greenhouse gas emissions would be stabilised, climate change and its effects will last for many years and therefore adaptation is necessary. Although climate change is global, its impact is geographically diverse and increasingly being felt and recorded across a range of regions, communities and ecosystems.

Climate change is the persistent change in the mean and variability of climate parameters due to unimpeded growth of anthropogenic greenhouse gas emissions (GHGs) observed and recorded over a long period (30 years or more) that a given region has experienced (Pant, 2011). Eighty percent of these gases results from human activities such as rising fossil fuel burning and land use changes which are emitting increasing quantities of GHGs into the atmosphere (Krysonova, 2006; Schipper, 2007). The main effect of the high levels of GHG is increasing global average temperatures, which cause a variety of secondary effects in the environment such as changes in precipitation patterns, rising sea levels, altered patterns in agriculture, increased extreme weather events, the expansion of the range of tropical diseases and opening of new trade routes (Aydinalp & Cresser, 2008 & Davidson, 2012).

Developing countries are more at risk and vulnerable to climate change and variability than developed countries because of their high dependence on climate sensitive agriculture for their economies, low adaptive capacity, few resources and options to combat damages of climate change and variability (Bruin, 2011; Gerald, 2009; Manyatsi, Mhazo & Masarirambi, 2010). Their vulnerability to climate change also emanates from the fact being predominately located in the tropics which are arid to semi-arid (Crosson, 1997), socioeconomic issues, demographic and policy trends that are limiting their adaptive capacity (Morton, 2007). This then results in millions of people in these countries faced with food insecurity because of crop failure, reduced cropping areas and natural disasters such as droughts and floods, water shortage and hunger.

Climate change and its impacts on crop production in Swaziland

Swaziland's sustainable development is threatened by climate change, through adverse effects in the environment, health, food security, economic activities and physical infrastructure. Climate change is characterised by changes in precipitation patterns, rainfall variability, and temperatures, which has increased the country's frequency of droughts, occasional floods, wildfires, windstorms and hailstorms (Manyatsi et al. 2010). According to Brown (2010), Gamedze (2006) and Manyatsi et al. (2010), droughts were the most prevalent climate-related shocks reported in the Lowveld. For the past four decades, the country has been hit by severe droughts in 1983, 1992, 2001, 2007 and 2008, cyclone Domonia in 1984 and floods in 2000.

According to Gamedze (2006), household livelihood vulnerability baseline surveys conducted in 1998, 2002 and 2006 showed that the impacts of droughts in the Lowveld was worse than the other regions. There has been a sharp decline in crop production levels and diversity in the country which then affected the economy as it is highly dependent on agriculture. Climate change and variability effects have resulted in deterioration of livelihood for most people living in the Lowveld. Households have since stopped farming and are solely dependent on social interventions and a dependency syndrome developed. In 2004/ 2005 cropping season, the Lowveld farmers ploughed only 10 percent of their arable land. Manyatsi et al. (2010) stated that, 40 percent of the arable land in the Lowveld has not been cultivated over the past 10 years, in the year 2010.

According to Nxumalo (2012), Lubombo region account for 30 percent of the total number of poor and vulnerable people in the country. During the 1991/1992 drought, the Lowveld was the most vulnerable to the effects of drought than the rest of the regions. According to Gamedze (2006), 91,000 herds of cattle died during this drought period. This makes the region to be more susceptible to the negative impacts of changing climatic conditions.

Manyatsi et al. (2010) stated that rural communities are aware of climate change and variability, but not aware of the scientific cause. For this reason, farmers do engage in livelihood strategies to cope with climate change and variability which are either agricultural or non-agricultural. These include selling livestock, migration to urban areas, mixed cropping, crop diversification, growing vegetables under irrigation, rain water harvesting. However, the current adaptation measures though useful at the moment are not sustainable and the communities have developed dependency syndrome on food aid (Gamedze, 2006; Nxumalo, 2011).

Climate change coping and adaptation strategies

Adaptation to climate change is not a new phenomenon, throughout human history, societies have adapted to natural climate variability but the human-induced climate change has led to a complex new dimension to this age-old challenge (Hachigonta, 2012). Adaptation refers to the adjustment to ecological, social and economic systems done by individuals, groups or institutions in response to actual or expected climate stimuli and their effects or impacts. This involves changes in processes, practices or structures to moderate, offset potential damages or to take advantage of opportunities associated with climate change and variability. This enhances resilience and reduces vulnerability of communities, regions or activities to climate change and variability as the people change their mix of productivity activities and modify their community rules and institutions in order to meet their livelihood needs.

In the agricultural sector, crop production, adaptation involves changes in management practices such as shifting planting dates, increasing fertilizer use, introduction of new plant varieties and installation of irrigation systems to offset the effects of reduced precipitation and higher temperatures on yields. These strategies can be short or long run, private or public (Bruin, 2011; Callaway, 2003; Sathaye & Christensen, 1998; Schipper, 2007).

A region's vulnerability to climate change depends on its adaptive capacity, sensitivity and exposure to climate change patterns. Adaptive capacity describes the ability of a system to adjust to actual or expected climate impacts or cope with consequences of climate change. Sensitivity is the degree to which a system is affected; whether positive or negative by extreme weather conditions and associated climate variability. Exposure refers to the degree to which a system is exposed to changing climate and the nature of the stimulus. Unfortunately, developing countries have low adaptive capacity, more sensitive and more exposed. Economic development is the best hope for adaptation to climate change as it enables the economy to be diversified and become less reliant on climate sensitive sectors such as agriculture which is a sector most vulnerable to climate change.

A key strategy for managing risk and vulnerability associated with climate change is developing and implementing evidence-based policies and programmes that respond to local realities and priorities. For adaptation to be successful, it should be taken within a comprehensive and interactive process of social institutions and organizational learning and changes. The post food-crisis era (2008-present) has seen an increase in funding for agriculture, with increased commitments from both international bodies (G8, US Global Hunger and Food Security Initiative) and regional bodies (Africa Union (AU), Common Market for Eastern and Southern Africa (COMESA), Southern African Development Countries (SADC) through Comprehensive Africa Agriculture Development Programme (CAADP)). Additional funding for agriculture emerged from the United Nations Framework Convention on Climate Change (UNFCCC), Conference of Parties (COP) 15 to support initiatives to adapt to climate change in developing countries. Therefore, existing and emerging investment programmes should be informed by climate science, risk analysis, and a deeper understanding of vulnerability and livelihoods at household level.

Manyatsi et al (2010) stated that agronomic and non-agronomic adaptation strategies have been practised in Swaziland but they are not sustainable and effective. Adaptation strategies that are successful in other southern African countries have not been effectively promoted and adopted in the country. These include rainwater harvesting to enhance water productivity of rainfed agriculture, minimum tillage and mulching. Water harvesting and recycling is promoted as an intervention by World Vision and is only for vegetable production.

Statement of the problem

Challenges of smallholder farmers cannot be overlooked as they provide 70 percent of the people in Swaziland living in rural areas manage vast areas of land but make up the largest share of undernourished. They are the most vulnerable and marginalised, often lack secure tenure and resource rights. Smallholder farmers in Swazi Nation Land are facing the challenge of low agricultural productivity due many factors including climate change. Manyatsi et al. (2010) stated that rural households are adapting to climate change, however the issue of poverty and hunger has not been fully addressed by such attempts as many people are still relying on food aid. The question might that are they using the economic strategies or are they using these the right way? Such questions cannot be fully addresses until these adaptation strategies are evaluated in term of their efficiency and effectiveness. To address this concern, the study uses a cost benefit analysis to evaluate adaptation strategies used by households in order to identity the most economic and practical strategies.

Research objectives

The main objective of the study was to examine the costs and benefits associated with climate change adaptation strategies in crop production, the specific objectives were to;

a) Identify the impacts of climate change on crop production.

b) Identify private (action by farmers) adaptation strategies implemented at Mpolonjeni.

c) Quantify the costs and benefits of private adaptation strategies to climate change at Mpolonjeni.

d) Identify socioeconomic factors influencing the choice of households when adapting to climate change in Mpolonjeni ADP.

Research hypothesis

H_0: climate change does not reduce crop yields

H_0: households are not adapting to climate change

H_0: all adaptation strategies are equally and economically efficient

H_0: socioeconomic factors do not influence the choice of households when adapting to climate change

Significance of the study

Cost benefit analysis allows the evaluation of intervention programmes by assessing their efficiencies and effectiveness. The fact that households were adapting to climate change does not guarantee food security and poverty alleviation. Researchers should provide with undisputed evidence about the costs and benefits of using one strategy or a group of strategies. The study as a cost benefit analysis therefore, provide such missing information as adaptation strategies would be compared against each other based on efficiency using net present value and internal rate of returns. The households would be able to choose the more efficient strategy in order to increase their resilience. The knowledge of the adaptation strategies and factors influencing the choice of adaptation methods would enhance policy towards tackling the challenges climate change is imposing to households in Mpolonjeni ADP. The study would also provide information to be used by policymakers when planning for climate change adaptation programmes in rural areas.

Chapter Summary

The chapter consist of the introduction of the study. It outlines the background information on global climate change and its impact on crop production. It presents predicted climate changes with its impacts on crop production at global level. Climate change in Swaziland is discussed, its impact on crop production, livelihood and food security. Several methods of adaptation strategies and mitigation are outlined. The chapter further discusses the statement of the problem, objectives and the significance of the study.

CHAPTER 2

LITERATURE REVIEW

Impacts of climate change on crop production

Climate is a primary factor for agriculture productivity such that any environmental change affects plant and animal production. Climate change has resulted in increased temperatures, which increase transpiration and evapotranspiration rate causing severe water stress as plants lose a lot of water and soil moisture is depleted (Aydinalp & Cresser, 2008). Although crops tend to grow faster in warmer conditions, but for some crops such as grains, faster growth reduces the amount of time for seeds to grow and mature hence reducing yields. More extreme temperature prevents crops from growing by damaging the plant as it interferes with plant biochemical reactions. The effect of increased temperature depends on the crop's optimal temperature requirements for growth and reproduction such that if warming exceeds a crop's optimum temperature, yields declines and in extreme cases results in total crop failure (Clair & Lynch, 2010).

Clair and Lynch (2010) suggested that the negative impacts of climate change on soil fertility and mineral nutrition of crops far exceeds the beneficial effect. This intensifies food insecurity in developing countries. During droughts, plant roots are underdeveloped and unable to absorb nutrients and mineral from the soil. Reduced soil moisture decreases the amount of dissolved nutrients, increase concentration of nutrients making them toxic, and increases salinization. Leaching of soil nutrients occur during floods and high intensity rainfall. This has a negative impact on plant growth as plants suffer from nutrients deficiency syndrome. In case of poor plant growth, crop residues are reduced and subsequently reduce organic matter and soil fertility. High rainfall intensity is one major cause of soil erosion. This removes the top nutritious soils and reduces nutrients available to plants and therefore reduces productivity.

Plant pests, weeds and diseases are a major constraint in crop production. Climate change alters the distribution, incidence, intensity of pests, diseases and invasion of alien species. High temperatures coupled with wet conditions create new niches and favours growth of pests and pathogenic organisms (FAO, 2008). The ranges of many insects tend to expand and new combinations of pests and diseases emerge as natural ecosystems respond to altered temperature and precipitation profiles. Any increase in the frequency or severity of extreme weather events, including droughts, heat waves, windstorms, or floods, disrupts the predator-prey relationships that normally keep pest populations in check (Chakraborty, Tiedemann & Teng 2000; Luck et al., 2010). This increases crop protection costs and if crops are not properly protected reduces crop yield.

Climate change is characterised by droughts and floods which destroy plants and depletes the soil. The frequent droughts that have been observed over the past decades reduce soil moisture and water resources for plants resulting in severe water stress. Reduced soil moisture decreases available water for irrigation and hinder plant growth in non-irrigated plants (Aydinalp & Cresser, 2008). As water level from water sources lowers, it becomes more difficult to meet plant water demand even by irrigation.

Droughts and floods kill animals that are used by small scale farmers for ploughing, therefore leaving them with no choice but to hire tractors. However, most rural households do not afford such services because of their poor financial background. Planted areas are therefore reduced and food insecurity increases forcing them to rely on food aid. Droughts reduce soil fertility by reducing the organic component of the soil as the amount of crop residues is reduced. This tends to increases the cost of farming as households need to apply commercial fertilizer and if this is not done reduces crop yields. Floods affect crop production through waterlogging and soil erosion where such conditions interferes soil fertility and therefore reduces crop yields.

According to Aydinalp and Cresser (2008), erratic rainfall has been recorded and observed in many geographical regions in the world. Rainfall frequency, distribution and intensity have changed. Rainfall is poorly distributed throughout the growing season, such that there is no rain during the maturity stage of most crops. This results in total crop failure even if the crop has been performing well in the other stages of development. Rainfall intensity has changed in such a way that the total rainfall received does not balance the water demand for most crops. Long dry periods have been observed during the planting as a result of changed rainfall intensity. This affect plant growth and eventually crop yield.

Adaptation strategies and adaptation programmes to climate change

Types of adaptation to climate change

Adaptation strategies to climate change can be grouped as autonomous or private and planned or public sector adaptation. Private adaptation involves action taken by non-state agencies such as farmers, communities or organizations, firms in response to climate change perceived by them based on a set of available technology and management options. Private adaptations are implemented by farmers only when they considered them cost effective. These include switching crop, shifting crop calendar, management practices that suit the new climate, changing irrigation scheme and selecting different technologies. Public adaptation involves actions taken by local, regional and or national government to provide infrastructure and institutions that to reduce the negative impact of climate changes. Public adaptation includes modernization or development of new irrigation infrastructure, transport or storage infrastructure, land use arrangements and property rights, water shed management institutions (Bruin, 2011; World Bank, 2010).

According to Sathaye and Christensen (1998), Bruin (2011), adaptation strategies can be either proactive or anticipatory depending whether adaptation takes place before or after climate change. Reactive adaptation sort out problems linked to climate change after they have been observed. Proactive adaptations anticipate future problems and put solutions in place beforehand. In crop production**,** reactive adaptations include soil erosion control, dam construction for irrigation, soil fertility maintenance, development of new varieties, shifting planting and harvesting time. Anticipatory adaptations involve development of tolerant cultivars, research development, policy measures on taxation and incentives.

Adaptation to climate change in crop production systems

Developing countries have been cited as most the vulnerable to climate change than developed countries because of their low adaptive capacity. Enhancing adaptive capacity would reduce vulnerability to climate change and promotes sustainable development. Improving access to financial resources would allow farmers to buy farm inputs and equipment. This would increase production and reduce poverty. Improving education and information would help disseminate information on climate change adaptation and mitigation strategies. Providing good infrastructure such as building dams for irrigation and improving roads would make it easy for a farmer to access markets (IPCC, 2007).

The agriculture sector relies on availability of water for plants and livestock. Climate change has modified rainfall, evaporation, runoff and soil moisture. The occurrence of water stress during flowering, pollination and grain filling is harmful to crops. This has made farmers to use drought resistant and use early maturing seeds (IPCC, 2007) avoid the long dry spells during cropping seasons.

Climate change disturbs the distribution of rainfall posing a need to supplement rain water especially during the later stage of plant development. Rainwater harvesting and storage would provide water for irrigation during critical stages of development of plant growth such as flowering and seed maturity. Building physical infrastructures such as dams for irrigation and domestic use is another adaptation strategy (Admassie, Adenew & Tadege, 2008).

Nhemachena and Hassan (2007) recommended that institutions dealing with climate related issues such as meteorological agency need to be strengthened so as to provide households with necessary information to use when planning for crop production. Government need to support research and development in the agriculture sector, disseminates appropriate technology and ensure that cheap technologies are available for smallholder farmers.

Gbetibouo (2009) suggested that smallholder farmers can adapt to climate change changing planting dates and diversifying crops. This can be possible if government provides them with necessary support. Yesuf et al. (2008) added that smallholder farmer can also adapt to climate change by practicing soil and water conservation measures and planting trees.

Climate change and its mitigation

To address climate change, two approaches have been identified that deal with its causes and effects; mitigation and adaptation. Mitigation focuses on the reduction of greenhouse gas emission or enhancing their removal from the atmosphere while adaptation reduces the negative changes resulting from global warming and enhance beneficial impacts (Bruin, 2011; Verbruggan, 2007).

Mitigation through forestry and agriculture is the most important mitigation strategy for developing countries as they do not contribute much in GHG emission (Bryan, Akpula, Ringler & Yesuf, 2008). Mitigation policies therefore cannot be prioritized over adaptation. The developing countries have the potential for carbon sequestration through reduced emissions from deforestation and forest degradation (REDD) and land use practices such as agriculture, forest management and other land uses (AFOLU) (Chishakwe, 2012).

According to Manyatsi et al. (2010), mitigation strategies in Swaziland include; investing in renewable energy, intensifying energy policies, and enforcing switching off light and other electrical appliances in public institutions, enforcing legislation of cutting down trees, reducing veld burning, funding mitigation projects on methane capture, bringing services to people to reduce long distant transportation, installation of solar systems in all public buildings, installation of efficient appliances in all public places, improving wiring to and installation of smart devices to enable switching off lights when not in use, promoting energy efficiency in industries, licencing conditions to favour fuel switch in industry from coal to biomass, natural gas and methane.

Methodologies for analysing climate change adaptation and copping strategies.

Different assessment approaches and methodologies for evaluating adaptation strategies have been developed based on their efficiency, effectiveness, robustness, equity, flexibility, feasibility, legitimacy and synergy (UNFCCC, 2010). These include cost benefit analysis (CBA), cost effective analysis (CEA) and multi-criteria analysis (MCA). CEA is used to find the least costly adaptation option or options for meeting a selected physical target and does not evaluate whether the option is justified. This is more applicable where benefits are difficult to express in monetary terms. MCA allows different assessment adaptation options against a number of criteria giving each a weighing to select the option with the highest score. CBA focuses on the quantitative evaluation of climate change impacts and allows for estimation of the net benefits of different adaptation options and is used to assess adaptation options when efficiency is the only decision making criteria. This involves calculating and comparing all the costs and benefits which are expressed in monetary terms (Bruin, 2010). This approach identifies the most economic adaptation strategy and allows ranking all the proposed strategies based on economic efficiency.

Multi Criteria Analysis

MCA involves qualitative and quantitative assessment of adaptation strategies and ranking the options based on defined an overall score which is determined by stakeholders. Each criterion is given a weighting. Using these weighting an overall score for each adaptation is determined and the adaptation strategy with the highest score is selected (Bruin, 2010; Kingston, 2001).

Cost- Effectiveness Analysis

CEA is used to identify the least cost option or options in areas where adaptation benefits are difficult to express in monetary terms. The adaptation objective is defined in terms of reducing vulnerability, achieving a certain level of adaptive capacity or resilience. CEA can be used in projects that involve human health, freshwater systems, ecosystems and biodiversity systems. For instance in a water project, the aim of the assessment is not to find the adaptation option that might yield the higher adaptation benefit but one that ensures sustainable water quality and quantity for vulnerable communities. All costs are quantified, aggregated and discounted to their present values. The effectiveness depends on the objective of the project and the established baseline. The project with the least cost is selected (Bruin, 2010; Kingston, 2001).

Cost Benefit Analysis

Cost benefit analysis is an economic analysis to aid social decision-making and is used to evaluate the desirability of a given intervention or interventions. It is a formal discipline used to help appraisal or assess projects and informal approach to making decisions of any kind to establish weather a proposed public or private investment is worthwhile (Kingston, 2001). The method compares all cost and benefits that can be expressed in monetary terms. To indicate the most efficient method, net present values, cost benefit ratios or internal rates of returns for the adaptation strategies are compared.

Conceptual framework

Cost benefit analysis framework

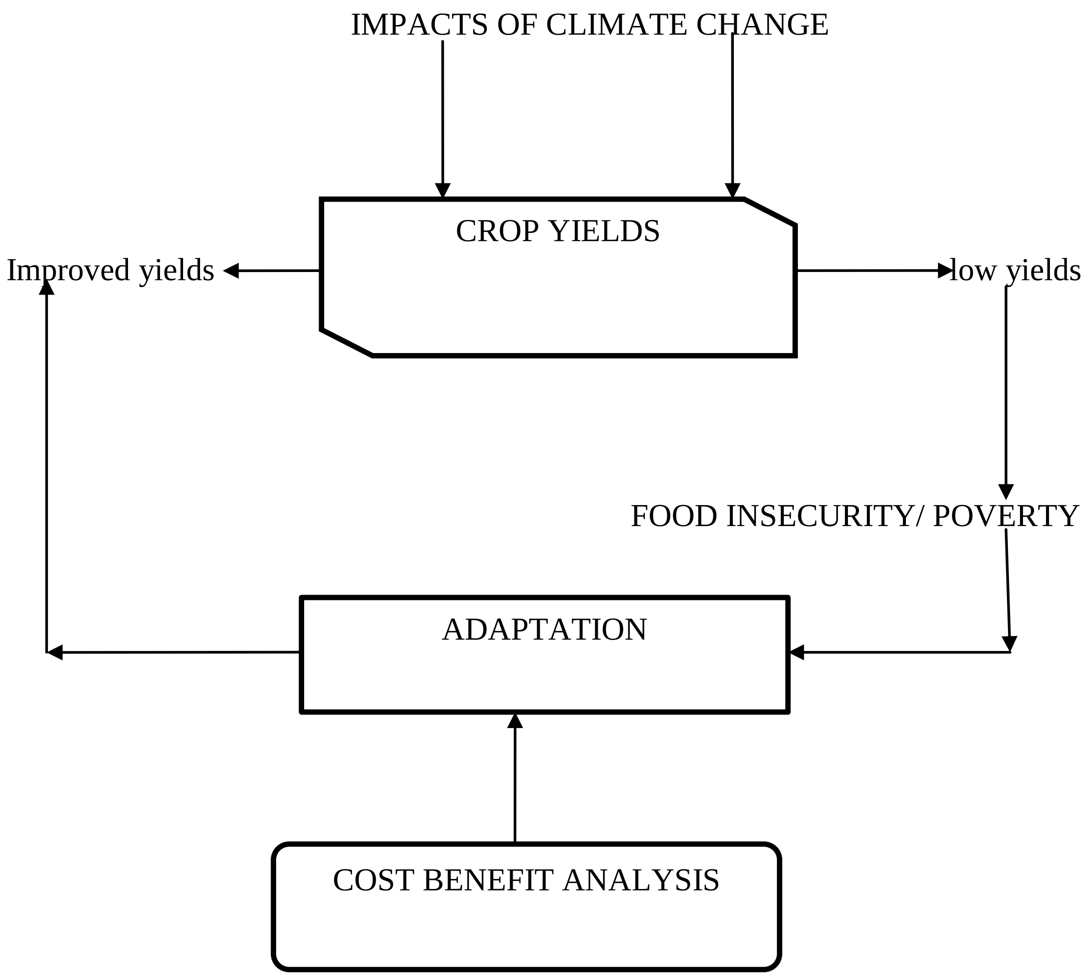

Figure 1 Conceptual framework of the study

The conceptual framework of the study was developed on the bases that climate change has an impact on agricultural sector. The effect can be negative or positive where positive impact results in improved crop yields while a reduction is observed with negative impact. The negative impact results in food insecurity, poverty and hunger.

To improve on this situation, households adapt to the changed climate with the aim of reducing the effects. However to achieve maximum yields, the adaptation strategies has to be assessed to identify the most economic and effective strategies. Cost benefit analysis is used to evaluate the strategies such that improved yields can be realised even if there are negative impacts of climate change.

Chapter Summary

The chapter describes the impact of climate change on crop production. Climate change has altered environmental conditions and this directly affects plant growth. This has resulted in; increase temperatures beyond optimal temperatures for most crops, increased crop pests, weeds and diseases, increases soil erosion, decreased soil nutrient and soil fertility. Adaptation programmes, coping strategies and types of adaptations strategies to climate change on crop production are reviewed. Climate change and its mitigation strategies are discussed as an alternative to adaptation.

The chapter further discusses the methodologies used when assessing the impacts of climate change in crop production when evaluating adaptation options. Conceptual framework for the study is discussed which describe how households can survive the impacts of climate change.

CHAPTER 3

METHODOLOGY

Study design

The study used a descriptive quantitative research design and describes the effects of climate change on cropping systems. It analyses adaptation strategies using a cost benefit analysis.

Study area

Mpolonjeni Area Development Programme of Swaziland (ADP) is located in the central east of Swaziland in the Lubombo administrative region and in the Lowveld ecological zone (Figure 2). It consists of two constituencies; Mpolonjeni constituency and Lugongolweni constituency. The ADP has five chiefdoms which are Mpolonjeni, kaLanga, kaNgcina, kaShoba and kaNdzangu and several communities under each chiefdom.

The area is mainly agrarian. Food crops that are grown include; maize, sorghum, cotton , dry beans, cowpeas, sugar beets, vegetables on relatively small scale. The crops are monocropped, mixed cropped or intercropped. The area receives 500-900 mm of rainfall per annum which occurred in summer and occasionally in winter. This is far less than the optimum water requirement for most crops. The area is arid to semi-arid. Households' livelihoods are on rainfed subsistence farming which is characterised by low yields and frequent crop failure due to climate change and climate variability.

The study area has an altitude of 303 m and is undulating plain to gently undulating plain. The soils range from red loam to red clay which is fertile soils (Vilakati, 1997) and are good for crop production. Average minimum temperatures are 15.4 ^{0}C and maximum temperature of 28.3 ^{0}C (Vilakati, 1997). Climate data shows that the area has hot summer and cold winter periods.

Figure 2 Map of Swaziland showing Mpolonjeni

The community has reported a high increase in temperatures for the past decades which has reduced crop production and livestock feed pastures. For the past years, households have reported maize yields of 0.2 tonnes per hectare or no harvest at all (Nxumalo, 2011). As a result of the high temperatures, erratic, less frequent, unreliable, changes in rainfall patterns, low intense rainfall in the area, farmers are more vulnerable to climate change and variability which reduces productivity and negatively affect their weather-dependent livelihood systems. This makes the area to be a representative sample of areas that are negatively affected climate change in the country.

Target population

The target population is 3 212 households at the Mpolonjeni ADP. The households are smallscale farmers practising subsistence rainfed and mixed farming in a communal land.

Sampling procedure and sample size

The primary data used for the study was obtained from a cross sectional survey of households at Mpolonjeni ADP. A sample size determination table was used to determine the desired sample size. For the 3 212 population, at 95 percent confidence level and 5 percent marginal error, the sample size is 341. This was the largest sample size for the population at 95 percent confident level. To accommodate non respondents, a sample of 350 households was used.

The population has strata based on chiefdoms, to determine a sufficient sample from the chiefdoms, stratified random sampling was used to obtain a representative sample from each group using a computer programme, sample randomiser. The sample was 9.02% of the population and from each stratum, the same proportion was obtained.

Table 1

Population and Sample size of Households from the Chiefdoms of Mpolonjeni ADP

Community	**Population size**	**Sample size**
Mpolonjeni	614	68
Langa	1645	183
Ngcina	157	17
Shoba	441	49
Ndzangu	300	33
Total	**3 157**	**350**

(Source: World Vision Swaziland Database 2008/2009)

The population and sample size for the chiefdoms are presented in Table 1. However, from this sample only 257 households were producing crops and analysis was based on these households.

Pilot testing of questionnaire

A panel of experts from the Department of Agricultural and Biosystems Engineering University of Swaziland (UNISWA), Agricultural Economics and Management (UNISWA), Climate Change Project Coordinator (FANRPAN) and a senior researcher from University of Geneva and London School of Economics were used to validate the questionnaire. The questionnaire was pretested in fifteen homesteads which were not amongst the sampled households. Appendix A shows the questionnaire used to collect the data.

Data collection procedures

Primary data

The primary data for the study were obtained from a cross sectional survey of households in the ADP. The data were obtained from 2011 / 2012 cropping season. The data were collected using personal interviews with an aid of a semi-structured questionnaire. Six enumerators with Ordinary Level certificates were trained to administer the instrument. Three day training was conducted and enumerators were allowed to administer the instrument as part of the training programme.

Data collected on crops would include;

i) Demographic data for the households; demographic data for household head, household size, social institutions and groups,

ii) Field data; types of crops, costs and amount of inputs, soil characteristics (slope, fertility, type), crop yields and cropping systems, utilization of crops produced and household food security, marketing of produce and market systems, storage facilities and post-harvest management, household credit needs and income sources, extension service

iii) Perceptions and attitudes of households towards climate change and variability with reasons for attitudes and perceptions

iv) Adaptation strategies to climate change and variability, risks associated with climate change, socioeconomic constraints in crop production,

v) Livestock ownership and livestock sales

Secondary data

Secondary data from World Vision and FANRPAN database was used to obtain the sample frame. Data for temperatures (minimum and maximum), monthly and annual total rainfall from 1975 to 2011 were obtained from Big Bend weather substation and National Meteorological Weather Station. Yields of dry land crops produced in the Lowveld were obtained from the Ministry of Agriculture and Central Statistical Office which were from 1972/1973 to 1993/1914 cropping year and 1997/ 1998 to 2006/2007 cropping year. Yields on cotton were obtained from Swaziland National Cotton Board in Big Bend from 1980 to 2011. However yields for other dry land crops would were missing.

Data Analysis

Data were analysed using Microsoft excel 2010 statistical package and STATA 10 statistical package. Descriptive analysis using frequencies percentages was used to analysis the demographic data for the households. Pearson correlation was used to determine whether there is a relationship between the yield for maize and climatic variables and among the climatic variables themselves. Ricardian model was used to determine the effect of climatic variables to the yield of maize and cotton using STATA 10 statistical package. This is a function to use when both the dependent and the explanatory variables are linear. The dependent variable was maize and the independent variables were climate variables.

Adaptation strategies were summarised using STATA 10 statistical package. A Cost-benefit analysis for the adaptation strategies was computed and a net present value (NPV) for each strategy using Excel 2010 statistical package. The NPV was used to identify the most economic method and those with high NPV will be the most efficient. Results of MNL regression model, where factors influencing the choice of households when adapting to climate change using different adaptation strategies were computed using STATA 10 statistical packages.

Analytical framework

Bruin (2011), Callaway (2003), World Bank (2010), Watkins, Valley and Alley (2010) stated that analysis of adaptation options requires the assessment of climate change impacts and projecting climate change impacts on the area to be studied.

These adaptation options are then evaluated based on efficiency, effectiveness and feasibility. The cost benefit analysis used in the study would allow for quantitative evaluation and quantifying net benefits of different adaptation options practiced by households. It includes direct and indirect costs and benefits in order to assess the welfare effects on an adaptation option. The costs and benefits are expressed in monetary terms where possible and a discount rate is used to determine net present value for the adaptation options. A sensitivity analysis is done to check whether the adaptation methods would be efficient even when the discount rate changes.

Impact of climate change on crop production

Models specification: Pearson correlation

Pearson correlation was used to measure the degree of relationship between climatic variables and maize yields using STATA 10. This determines if there is a statistically significant relationship between maize yields against temperature and rainfall by calculating the Pearson product moment correlation coefficient, *r*. Pearson correlation is relevant for the study as it is used to measure the relationship between normal, scale or interval and the variables being correlated are all scales. A negative sign mean there is a negative relationship which means when one variable increases, the other one decreases while, for a positive sign the variables change the same way.

The expected relationship between maize yields and temperatures is negative and for rainfall is positive. Rainfall is expected to change the same direction as maize yields, while change in temperatures would be different with yields.

Ricardian regression model

The Ricardian model is an empirical approach to studying the sensitivity of agricultural production to climate change. It is used to explain the variation in crop net revenue over climatic zones (Hassan & Gbetibouo, 2004; Seo & Mendelson, 2008). The model account for the direct impact of climate on yields of different crops as well as the indirect substitution for inputs and introduction of activities and any other potential impact of climate change (Hassan & Gbetibouo, 2004). The model captures both linear and non-linear relationship for the climatic variables. For this reason therefore, the independent variables, which are seasonal rainfall and temperatures would be squared. A negative quadratic term reflects an inverted U- shaped relationship between the net revenue and climate variables while a positive quadratic term means a U-shaped relationship.

Ricardian regression model:

$$V= \beta_0+ \beta_1F_1+ \beta_2F_1^2+ \beta_3F_2 + \beta_4F^2{}_2 + \beta_5F_3 + \beta_6F^2{}_3 + \beta_7F_4 + \beta_8F^2{}_4 + \varepsilon$$

Where:

V = net revenue per hectare over climatic zones

F_1 = mean spring maximum temperature (^{0}C)

F_1^2 = mean spring maximum temperature squared (^{0}C)

F_2 = mean summer maximum temperature (^{0}C)

F_2^2 = mean summer maximum temperature squared (^{0}C)

F_3 = spring rainfall total (mm)

F_3^2 = spring rainfall total squared (mm)

F_4 = summer rainfall total (mm)

F_4^2 = summer rainfall total squared (mm)

β_0, β_1, β_2, β_3, β_4, β_5, β_6, β_7, β_8 are coefficients

ε = the error term

The expected signs of the model are presented on Table 2.

Table 2

Variables Used in Ricardian Model and their Expected Signs

Variable name	**Value**	**Expected sign**
mean spring maximum temperatures	^{0}C	+ /-
mean summer maximum temperatures	^{0}C	+ /-
spring rainfall total	$^0C^2$	+ /-
summer rainfall total	$^0C^2$	+ /-
mean spring maximum temperatures squared	mm	+ /-
mean summer maximum temperatures squared	mm	+ /-
spring rainfall total squared	mm^2	+ /-
summer rainfall total squared	mm^2	+ /-

Mean summer maximum temperatures: The expected sign is either negative or positive. High temperatures increases the rate of biological reaction but extreme high temperatures increases water stress due to increased evapotranspiration and soil moisture loss. High summer temperatures coincides with flowering and fruiting of most dry land crops, such that this can limit flower formation and destroys fruits resulting in low yields. However the effect depends on the maturity period for the crop.

Total spring rainfall: the expected sign is either positive or negative. Early spring rainfall allows farmers to plant early which minimises incidences of plant pests and diseases which reduces yields. This is also good for crops with long maturity dates as these can be planted earlier than being planted in summer. Spring rainfall decomposes crop residues and therefore, improves soil fertility and structure. A negative effect is expected with low spring rainfall because it limits water available to plants during the growing season for crops with long maturity periods.

Total summer rainfall: the expected sign is either positive or negative. High rainfall intensity provides water needed for plant growth. However in cases storms which normally occur in summer, these destroy crop and can reduce yields.

Mean spring maximum temperatures squared and mean summer maximum temperatures squared: the expected signs can be either negative or positive. A negative sign indicates an inverted U-relationship and a positive sign reflects a normal U-relationship. This shows a non-linear relationship between net revenue and climate variables.

Total spring rainfall squared and total summer rainfall squared: this shows a quadratic relationship between net revenue and climate variables. The expected sign can either be positive or negative. A negative sign indicates an inverted U-relationship and a positive sign reflects a normal U-relationship.

Cost benefit analysis (CBA)

CBA focuses on the quantitative evaluation of climate change impacts on crops and allows for estimation of the net benefits of different adaptation options and is used to assess adaptation options when efficiency is the only decision making criteria. This involves calculating and comparing all the costs and benefits which are expressed in monetary terms (Bruin, 2010). This approach identifies the most economic adaptation strategy and allows ranking all the proposed strategies based on economic efficiency. Net present Values are used to as this discounts the future benefits to present values. Internal rate of returns are used to evaluate the most economic impacts.

This involves;

i) Identification of the adaptation strategies employed in the households.

ii) For each adaptation strategy, the total costs incurred when using that strategy and benefits were computed to compute the net benefit for that particular adaptation strategy.

$$NB = \sum TB - \sum TC$$

Where;

NB represents the net benefits (E)

TB represents the total benefits (E)

TC represents the total costs (E)

For adaptations that do not have direct costs and benefits, shadow pricing and opportunity costs would be used and the quantities computed.

iii) NPV would be computed.

The Net present Value = NPV = $\sum (B_t - C_t) / (1 + r)^t$.

Where:

B_t = Total benefits in year t

C_t = Total costs in year t

r = Discount rate

$(1+r)^t$ = Discount factor for year t

The adaptation strategy with a positive and highest NPV is the most economic and efficient. A negative NPV indicates a none viable intervention strategy. Sensitivity test was carried out, where the net benefit was discounted at 5%, 10% and 15%.

Multinomial Logit model

Multinomial logistic model (MNL) was used to analyse the factors that determine adaptation techniques. According to Magombo, Kanthlini, Phiri, Kachula and Kabuli (2011), MNL model for adaptation choices specifies the relationship between the probability of choosing an adaptation option and the set of explanatory variables. MNL model was used to identify factors influencing households when adapting to climate change using various adaptation strategies compared to a reference point.

The adaptation strategies were grouped into six groups as households were using one or more adaptation strategies. The groups were; drought resistant and shifting planting time, conservational agriculture and shifting planting time, conservational agriculture, shifting planting time and drought resistant varieties, irrigation and any other strategies and using all strategies. Socioeconomic factors used were; sex of household head, age of household head, occupation of household head, name of social group, land category, access to credit, access to extension services and training on farming systems, high incidences of crop pest and disease, high input prices and high food prices, perceptions of households towards climate change. The dependent variable would be the adaptation strategy and explanatory variables were socioeconomic factors.

The logistic model for the households would be;

$$Y_i = \ln (P_{j/} P_1) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12} + e_i$$

Dependent variables

The adaptation strategy were grouped into; drought resistant and shifting planting time, conservational agriculture and shifting planting time, conservational agriculture, shifting planting time and drought resistant varieties, irrigation and any other strategies and using all strategies.

Where;

P_1 = probability that a household would adapt by planting drought resistant variety and shifting planting dates. This was the reference point.

P_2= probability that a household will not adapt to climate change

P_3= probability that a household will adapt drought resistant varieties and shifting planting time

P_4= probability that a household will adapt conservational agriculture and shifting planting time

P_5= probability that a household will adapt using all strategies

P_6= probability that a household will adapt irrigation and any other strategy

The explanatory variables were;

X_i, where i = 1, 2,…… 13.

Where;

X_1= sex of household head

X_2 = age of household head

X_3 = education level of household head

X_4 = occupation of household head

X_5 = name of social group where at least one member belong

X_6 = land category

X_7 = access to credit

X_8 = access to extension services and training

X_9 = high incidences of crop pest and disease

X_{10} = high input prices

X_{11}= high food prices

X_{12} = perceptions of households towards climate change

Table 3

Independent Variables Used in the MNL Regression Model

Variable	Coding	Category	Expected sign
sex of household head	1 = male, 0= female	Dummy	+ / -
age of household head	Years	Continuous	+ / -
education level of household head	Highest Certificate acquired	Continuous	+
occupation of household head	1= full time farming, 0= part time farming	Dummy	+ / -
name of social group	1= social group, 0= no social group	Dummy	+
land category	1= own land, 0= rented land	Dummy	+
access to credit	1 = access to credit, 0= no access to credit	Dummy	+
access to extension services and training	1 = access to extension services, 0= no extension services	Dummy	+
high incidences of crop pest and disease	1= high incidents of pests and diseases, 0= low incidences of pests and diseases	Dummy	+ /-
high input prices	1= high input prices, 0= low input prices	Dummy	-
high food prices	1= high food prices, 0= low food prices	Dummy	-
perceptions of households towards climate change	1= perceived climate change, 0= did not perceive climate change	Dummy	+

Definition of explanatory variables

Sex of household head (X_1): this is a dummy variable where 1= male, 0= female. The expected is either negative or positive. In rural communities women are the active group as man are in town and cities where they work. However, men are more financially stable than women.

Age of the households head (X_2): Maddison (2006) argued that household age represent experience in farming and the more the farmer is exposed to present and past farming conditions. However age can have a negative effect as the older the household head is the lesser she/he can be interested in learning new information. The expected sign will vary.

Education level of household head (X_3): the expected sign is positive as the education is related to early adopters and greater productivity of improved varieties. Households need to be taught about how to use some of these methods, so the higher the education level for the household head is, the easier to learn and adopt an adaptation strategies can be employed.

Occupation and wealth (X_4): this has mixed signs depending on the strategy adopted and the type of occupation involved. Full time farming enhances adoption, off –farm income provides financial resources for adopting strategies and yet it can limit the attention and amount of time spent in farming.

Social groups (X_5): these can provide information, credits and resources for adoption. The expected sign is positive.

Land category (X_6): when the household owns land, the sign would be positive as it is easier to protect and improve the land one owns but on rented land the expected sign would be negative.

Access to credit (X_7): the expected sign is positive as availability of credits enhances households to adopt strategies especially those involving costly inputs.

Training and access to extension services (X_8): this provides information on adaptation strategies and new cropping systems. The sign is therefore positive. Extension officers play a key role in monitoring and dissemination of information.

High incidences of crop pest and disease (X_9): this is expected to have a positive sign as it is one of the negative impacts of climate change but for no adaptation it is supposed to be negative.

High input prices (X_{10}): this has negative effect when adapting to climate change as it limits resources to be used by households. Rural households cannot afford high inputs prices. The expected sign is negative.

High food prices (X_{11}): this has a negative effect when adopting and it limits resources to be used by households in crop production. With high food prices, households are unable to buy inputs. The expected sign is positive and negative depending on the alternative category.

Perceptions of households towards climate change (X_{12}): households will not adopt strategies until they perceive a changed climate. The expected sign can be either negative or positive depending on the alternative adaptation strategy.

Chapter summary

The study is a descriptive survey research where cross sectional data was obtained from Mpolonjeni ADP. Data were collected using pretested well-structured questionnaire by trained enumerators using personal interviews. Stratified random sampling was used to obtain a representative sample. Personal interviews were conducted using structured questionnaires by trained research assistants. The results were analysed using Microsoft excel 2010 and STATA 10. Models used for analysis include; descriptive analysis, Ricardian model, cost benefit analysis and MNL model.

CHAPTER 4

FINDINGS AND DISCUSSION

This chapter presents and discusses the results of the study on impacts of climate change on crop production, private adaptation strategies employed by households, cost benefit analysis on adaptation strategies and socioeconomic determinates of adaptation strategies to climate change and variability. The results were analysed using descriptive statistics, Ricardian regression model, cost benefit analysis and MNL model.

Descriptive statistics for respondents

Table 4 presents the socioeconomic demographic characteristics of household heads. The percentage of male headed households is 68.5 % and this implies that females were 31.5 %. This indicates that in the households, the final decision makers are males and this has an implication on decision making regarding adaptation strategies to climate change and farming practices. Male household heads are less likely to adopt new technical and crop management changes than female household heads.

According to Nhemachena and Hassan (2007), female headed households are more likely to take up adaptation options as most of rural farming is done by women while men are based in towns and cities. Women therefore, have more farming experience and information on management practices and how to change them than man. However a report from International Fund for Agricultural Development (IFAD) (2007) stated that women are particularly vulnerable to poverty and have less access to education than men. Constitutionally in Swaziland, women control land and their finances but traditional social systems discriminate against them and bar them from owning and controlling land. This can have a negative impact when adopting climate change strategies. This is because wealth and education are important determinates of adaptation strategies where wealth and education have a positive implication to adoption (Gbetibouo, 2009).

Table 4

Descriptive Statistics for Respondents in Mpolonjeni ADP

Item	Frequency	Percentage
Sex		
Male	176	68.5
Female	81	31.5
Total	**257**	**100.0**
Age group		
19 - 30 years	7	2.7
31 - 40 years	34	13.2
41 - 50 years	57	22.2
Above 50 years	159	61.9
Total	**257**	**100.0**
Marital status		
Married	173	67.3
Single	16	6.2
Divorced	4	1.6
Widowed	57	22.2
Separated	7	2.7
Total	**257**	**100.0**
Education level of household		
Illiterate	143	55.6
Completed primary school	44	17.1
Junior secondary level	35	13.6
Senior secondary level	24	9.3
Professional college certificate	8	3.1
University education	1	0.4
Adult education	2	0.8
Total	**257**	**100.0**
Occupation		
Full time farming	99	38.5
Salaried employment	78	30.4
Non agribusiness	24	9.3
Casual farm work	20	7.8
Casual off farm work	1	0.4
Household chores	35	13.4
Total	**257**	**100.0**

Considering the age of the households, 61.9 % are about 50 years and there are no child headed households. The majority of the household heads are non-active age group which can have a negative bearing on adopting climate change adaptation strategies. This age group cannot provide much labour but have only experience. Deressa (2010) indicated that the household head age represents the experience in farming and more years correspond to more farming experience.

The percentage of married household heads was 67.3 % and this implies that a major of the household heads have land property rights. The results indicate that full time farming is the major occupation despite the fact that it is subsistence. Moreover, most farming is rainfed as the results show that 96.9 % of the households were not irrigating. The results shows that more than half of the households' heads are illiterate (55.6 %) and this make it difficult for most households' heads to understand new farming systems and technologies. Maddison (2006) urged that high education level diminishes the probability than no adaptation is taken such that highly educated household heads are more likely to adapt to climate change. The results of the analysis are presented in Table 5.

Table 5

Amount of Land Used for Different Adaptation Strategies for 2011/2012 Cropping Season

Item	Area (ha)
Crop	
Maize	1 361.0
Sorghum	12.0
Cotton	92.5
Dry beans	33.5
Groundnuts	4.5
Cowpeas	3.0
Total	**1 506.5**
Type of seed	
Hybrid seeds	300.0
Traditional seeds	1 061.0
Total	**1 361.0**
Type of watering system	
Irrigation	92.0
Rainfed	1 269.0
Total	**1 361.0**
Minimum tillage	
Minimum tillage	207.0
Convectional agriculture	1 154.0
Total	**1 361.0**
Crop rotation	
Groundnuts	4.5
Maize	1 361.0
Total	**1 365.5**

For results on crops, analysis was done to identify the amount of land used for the different adaptation strategies.

From the results, 1361 ha are used for maize despite the fact that the maize yields are low in the region. Hybrid seed varieties in maize only cover 300 ha while, traditional varieties cover 1061 ha as households indicated to be using yields from previous crops as seeds for the next season. Crop rotation where maize is rotated with groundnuts is not practiced by many households because the land used for groundnuts (4.5 ha) is far less than that used for maize (1361 ha). Minimum tillage is practiced on 207 ha while convectional cropping is on 1154 ha. From the cultivated land, 90.4 % is used for maize, 6.1 % for cotton, 2.2 % for beans, 0.7 % for sorghum and 0.3 % for groundnuts and 0.2 % is for cowpeas. This implies that the major crop is maize as it is the staple crop.

Soil and water conservation strategies

Respondents indicated that they are using strategies such as intercropping (32.7 %), mulching (9.4%), late planting (42.2 %) and early planting (66.9 %) to adapt to climate change. As much as these are adaptation to climate change, they are important management practices for soil and water conservation. Mulching also improves the soil structure and fertility as mulch decomposes to form organic matter. However a cost benefit analysis for these strategies cannot be possible because the costs and the benefits are not easily quantified and expressed in monetary values.

Perceptions and attitudes of farmers towards climate change and variability

Mudzonga (2011) indicated that farmers hold specific perceptions regarding the effect of an innovation and these subjective evaluations can be significant factors in the adoption decision. For this reason, the study investigates the perceptions and attitudes of households to climate change and variability as it has an effect on whether households adopt strategies or not. It is important for households to realize and appreciate that there is climate change or variability in the area before adjusting to the perceived changes.

Table 6 presents households' attitudes and perceptions regarding climate change and variability. Most households indicated that climate has changes (99.2 %) and 0.8 percent have not yet noticed any climate change nor variation. In addition, 95.3 % households stated that climate change and variation have negative impact on crop production. Households pointed out that temperature has increased while rainfall has decreased (22.2%), seasons have shifted (5.8 %) and there is crop failure and death of livestock (28.0%) which is all attributed to the changed climate.

Table 6

Attitudes and Perceptions of Households towards Climate Change and Variability

Item	Frequencies	Percentages
Perception		
Climate has changed	255	99.2
Climate has not changed	2	0.8
Total	**257**	**100.0**
Attitude		
Climate chance and variation is good	9	4.7
Climate change and variation is bad	245	95.3
Total	**257**	**100.0**
Reasons for the attitude and perception		
Good, lots of rainfall	68	26.5
Bad, high temperatures and low rainfall	57	22.2
Shifted seasons, unpredicted rainfall patterns	15	5.8
Crop failure and death of livestock	72	28.0
Poor harvest and low yields	16	6.2
Food insecurity and hunger	17	6.6
Destroy nature	12	4.7
Total	**257**	**100.0**

Precipitation changes

Figure 3 shows that total seasonal rainfall has been decreasing over the years, this is in line with households observations as the declared that there have receiving less rainfall with time. This has a negative impact to crop production in the area as the households are depending on rainfall. This can be the reason why some households are not planting even though they own land.

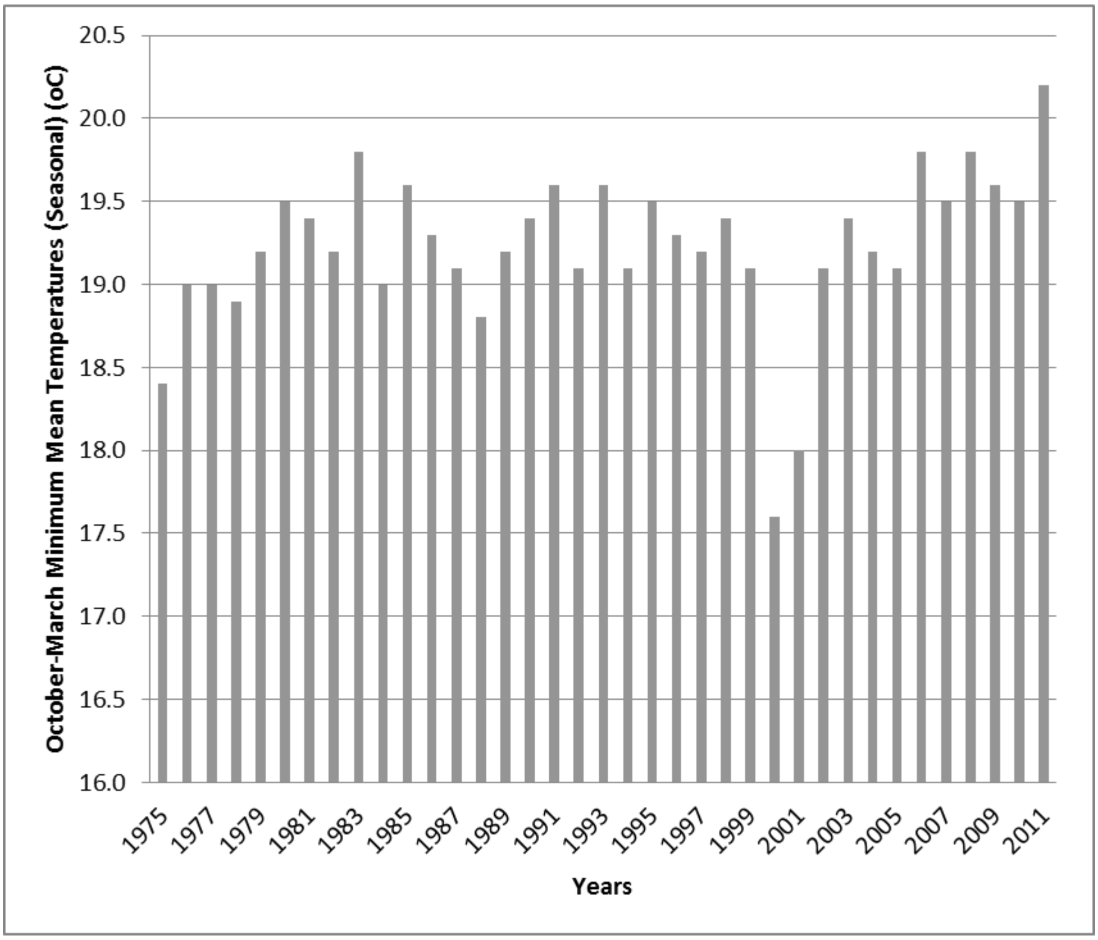

Figure 3 Mpolonjeni seasonal total rainfall trend (1975- 2011)

Temperature changes

Figure 4 shows that temperatures have been increasing for the past 37 years and this is in line with the perceptions of the farmers. They perceived that temperatures have increased and this has negative impacts on crops because sometimes results in total crop failure. Clair and Lynch (2010) stated that increased temperatures negatively impacts crop yields by altering phenology of plants and through heat stress at more extreme temperatures.

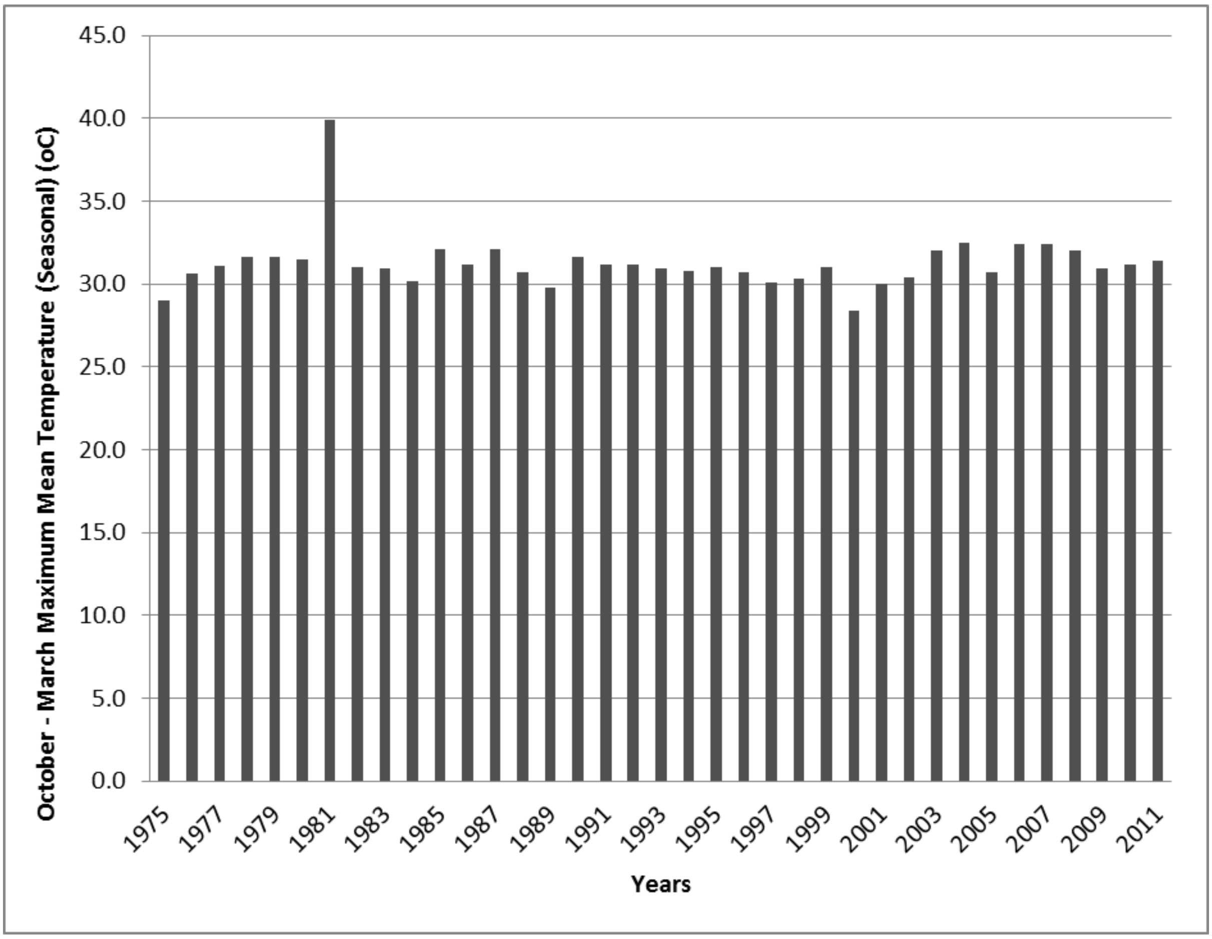

Figure 4 Average seasonal maximum temperatures trend for Mpolonjeni from 1975 - 2011

Maize yields trend

The results obtained from the Ministry of Agriculture and Swaziland Central Statistics on maize production and yields shows that maize yields in the Lowveld are declining. As maize production is heavily dependent rainfall, changes in rainfall patterns and amount would affect maize production. Oseni and Masarirambi (2011) discovered that climate change has reduced the yields of maize in Swaziland when they were comparing maize national maize yields with climatic variables.

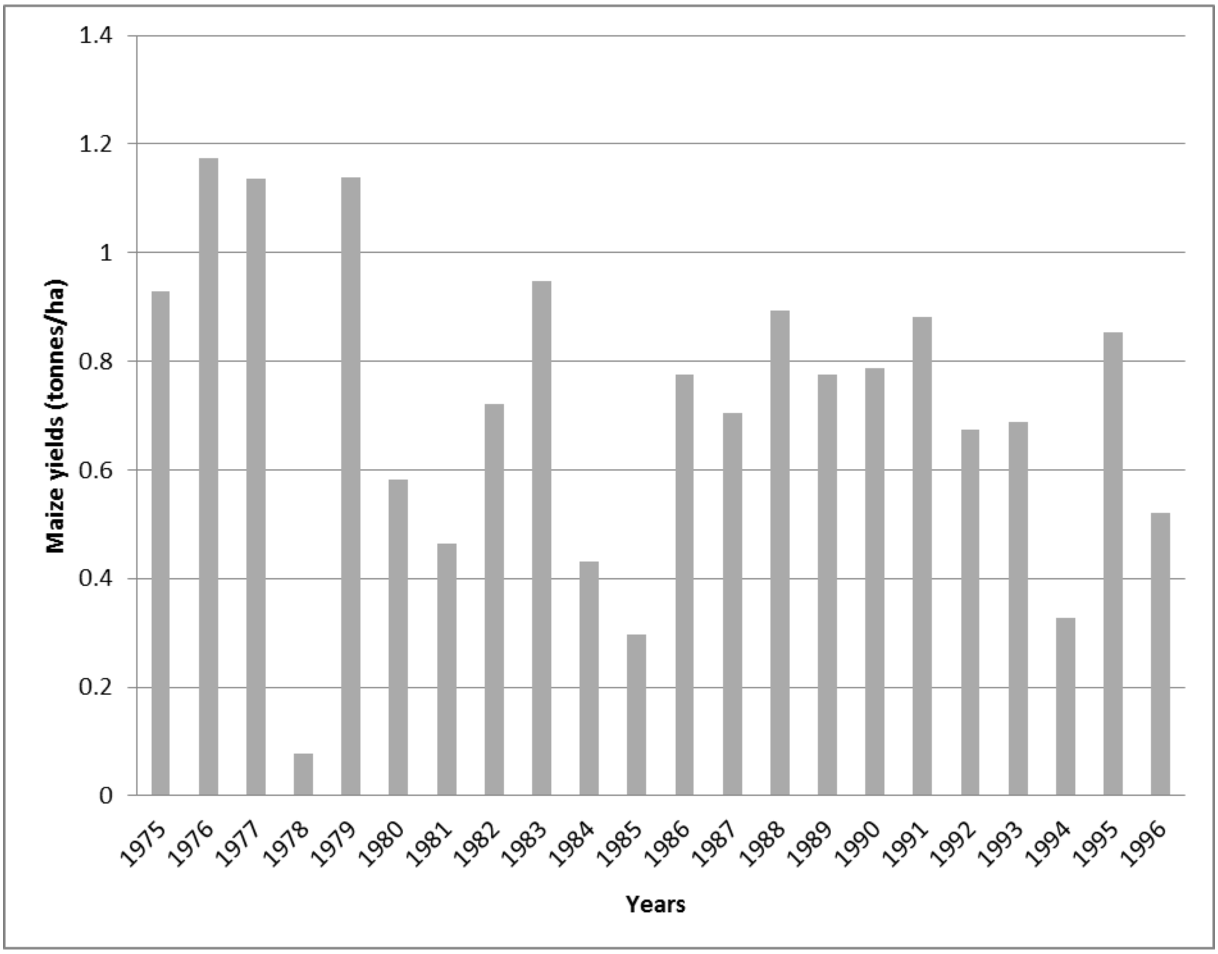

Figure 5 Maize yields trend in the Lowveld (1973 to 1996)

Objective a: Impact of climate change on crop production

Relationship between maize yields and climate variables

Results on correlation indicate a relationship between maize yields and rainfall and temperatures. The correlation was interpreted using Davis (1971) descriptive.

Where;

0.70 or higher = highly correlation

0.50 – 0.69 = substantial correlation

0.30 – 0.49 = moderately correlation

0.10 – 0.29 = low correlation

0.01 – 0.09 = negligible

The results are shown in Table 7 below.

Table 7

Pearson Coefficients for Maize Yields and Climatic Variables (r)

	Y	X_1	X_2	X_3	X_4	X_5	X_6
Y	1.00						
X_1	-.13	1.00					
X_2	-.26	.22	1.00				
X_3	-.23	.45	.04	1.00			
X_4	-.15	.27	.50	.49	1.00		
X_5	-.05	-.71	-.18	-.47	-.25	1.00	
X_6	-.09	-.77	-.26	-.45	-.44	.85	1.00

Where;

Y= yield of maize (tonnes /ha)

X_1= annual maximum mean temperatures (^{0}C)

X_2= annual minimum mean temperatures (^{0}C)

X_3= seasonal maximum mean temperatures (^{0}C)

X_4= seasonal minimum mean temperatures (^{0}C)

X_5= annual total rainfall (mm)

X_6= seasonal total rainfall (mm)

The correlation results show that there is low negative correlation between maize yields and maximum annual mean temperatures (*r* = -0.13), seasonal mean temperatures (*r* = -0.26), annual mean minimum temperatures (*r* = -0.23), seasonal mean minimum temperatures (*r* = -0.15). However, the correlation between maize yields and annual total rainfall (-0.05), seasonal total rainfall (*r* = -0.09) is negative and negligible.

Ricardian regression model results

The Ricardian model is an empirical approach to studying the sensitivity of agricultural production to climate change. It is used to explain the variation in crop net revenue caused by climatic variables (Hassan & Gbetibouo, 2004; Seo & Mendelson, 2008). Table 8 presents the results of the impact of climate change variables on maize yields in the Lowveld.

Table 8

Ricardian Regression Results on Maize Revenue

Variable	Coefficients	Std. error	t-statistics	p-value
Constant	197470.2	264495.8	0.75	0.469
Mean spring maximum temperate (^{0}C)	23207.1*	58.86121	-0.122	0.040
Mean summer maximum temperate (^{0}C)	-23583.29*	10155.86	2.29	0.039
Spring rainfall total (mm)	-10.38761	10268.46	-2.30	0.436
Summer rainfall total (mm)	4.84516	12.91584	-0.80	0.786
Mean spring maximum temperate squared (^{0}C)	-421.7859*	17.51849	0.28	0.033
Mean summer maximum temperate squared (^{0}C)	375.9537*	177.2575	-2.38	0.040
Spring rainfall total squared (mm)	0.245935	164.7318	2.28	0.435
Summer rainfall total squared (mm)	-0.016699	0.305057	0.81	0.469

Note: * = significant at 0.05 level
Number of observations= 23
R- Squared = 0.4619
Adjusted R-squared= 0.1544
Prob. > F = 0.0001
Root MSE =1263.5; Confidence interval = 95 %

The model accounts for 15.4 % of the variability in net revenue. It is important to note that a relatively high proportion of the variation in net revenue is not accounted for by the explanatory variables in the model. The major sources of the error accounting for this unmeasured error variation include misreporting of revenue and limited number of observations. Mean spring temperature and summer mean temperature ($p < 0.05$) significant influenced the change in maize net revenue. However, the signs of the coefficients of summer mean temperatures (-23583.29) and spring mean temperatures (23207.1) are different. This implies that 1^0 C changes in summer rainfall decreases the net yield revenue of maize by E23 583.29, while 1^0C changes in spring temperatures increase the net yield revenue by E23207.10. Expected signs for both variables were ether positive or negative. Households have been encouraged to practice early planting to make good use of early rainfall and avoid late summer heat waves. The results imply that early plating increases maize yields while late planting decreases the yields. The Ricardian regression model also shows the quadratic relationships between net revenue and climate variables where a negative sign describes an inverted U- relationship and otherwise. Spring summer squared temperatures have an inverted U-relationship. This is in line the expected sign as net revenue is expected to have hill-shaped relationship with temperature (Gbetibouo & Hassan, 2004). While summer squared temperatures have an ordinary U-relationship which was contrary to the expected signs.

Socioeconomic and climatic risks affecting households as ranked by respondents

Respondents were asked to indicate whether they have been affected by droughts, crop pests and diseases, high input and food prices. The results are presented in Table 9 below.

Table 9

Observations and Percentages of Households when Ranking the Most Occurring Socioeconomic Risks

Socioeconomic risk	**Frequency**	**Percentage**
Drought	234	91.9
Crop pest and disease	96	37.4
High input prices	167	65.0
High food prices	238	92.6

Drought is the most occurring climatic risk as most households reported to be affected by drought. When households ranked how drought, crop pests and diseases, high input prices, high food prices were affecting cropping systems, 91.1 % ranked drought as the most occurring climate risk. According to Brown (2010), Gamedze (2006) and

Manyatsi et al. (2010), droughts were the most prevalent climate-related shocks reported in the Lowveld. For the past four decades, the country has been hit by severe droughts in 1983, 1992, 2001, 2007 and 2008, cyclone Domonia in 1984 and floods in 2000. Climate change affects crops by limiting the amount of water available to plants (Manyatsi et al., 2010).

Objective b: Adaptation strategies employed by households

Sofoluwe, Tijani and Baruwa (2011) indicated that agriculture is negatively affected by climate change and adaptation is one of the methods to be used to reduce the impact of climate change. To respond to the perceived changes in climate, households are employing adaptation strategies in order to reduce the negative impacts on crops. Adaptation strategies employed by households are indicated on Table 10. Although the majority of the households interviewed claimed to be using more than one type of adaptation option, 4.7 % were not taking adaptive measures.

The results indicate that the majority (68.9 %), of the households are adapting by using hybrid seeds, early planting (66.9%) and late planting was used by 42.0 %. Failure to use hybrid seeds suggests lack of access to improved varieties due to financial constraints or unavailability of the seeds in the area. Sixty six percent of the households are taking advantage of the early rains as indicated by the results compared to late planting. Depending on the crop maturity days, early planting, can ensure that critical plant growth stages do not coincide with very harsh climatic conditions that normal occur towards the end of the season. This period normally occurs in end of December and early January. However shortage of farm machinery might be major cause of those who did not adopt this option.

Adaptation strategies that received the least responses were mulching, irrigation, crop rotation and minimum tillage. Irrigation involves high capital investment which can be a challenge to most rural households because of poor financial background. The strategy also needs a good, reliable water source. However, there are no major rivers near the area and water harvesting by earth dams has not been fully exploited.

Table 10

Adaptation Strategies Employed by Households in Response to Climate Change and Variability

Adaptation strategy used	**Frequency (Did use)**	**Percentage (Did use)**	**Frequency (Did not use)**	**Percentage (Did not use)**
Drought tolerant varieties	177	68.9	80	31.1
Early planting	172	66.9	85	33.1
Late planting	108	42.0	149	58.0
Minimum tillage	32	12.5	225	87.5
Crop rotation	47	18.3	210	81.7
Mulching	22	8.6	235	91.4
Irrigation	8	3.1	249	96.9
Switching crops	17	6.6	240	93.4
Intercropping	84	32.7	173	67.3
No adaptation	12	0	0	4.7

Objective c: Cost Benefit analysis of climate change adaptation strategies

Cost benefit analysis for adapting by shifting crops from maize to drought tolerant crops

Households (6.6 %) have reported that they have adapted to climate change by shifting to drought tolerant crops. These are sorghum, cotton and beans. However, they still do not grow these crops at larger scales and so maize still dominates.

The NPV was computed based on per hectare average returns. The crop that has the highest NPV is cotton and this shows that when planting cotton, the benefits would more than the costs by E1864.40 for each household while maize will give E14.40 on average. Compare with maize all the other crops had higher net present values. This shows that households should consider switching maize for drought tolerant crops based on the value of the NPV calculated. However the results have to be compare with the NPV for the other adaptation strategies. The sensitivity analysis shows that even if the discounts rate can change to 5 % or 15 % the NPV for the different crops still be positive. The IRR shows that if the discount rate at which the cost will be equal to returns.

Table 11

Net Present Value and Internal Rate of Returns for Switching Crops from Maize to Drought Tolerant Crops

Crop	**TC E'000**	**TR E'000**	**NB E'000**	**IRR**	**NPV (10%) (E)**	**NPV (5%) (E)**	**NPV (15%) (E)**
Maize	542. 0	563. 5	0.1	8.3	14.4	15.1	13.7
Sorghum	5.6	9.3	3.7	6.1	283.3	296.8	271.0
Cotton	148. 3	338.0	189.7	43.9	1 864.4	1 953.2	1 783.3
Dry beans	3. 3	14.1	11.4	23.7	292.2	306.1	279.5
Groundnuts	3 .5	4.9	1.4	72.4	284.6	298.5	272.2
Cowpeas	0.2	1.1	0.9	19.0	252.3	264.3	241.3

Cost benefit analysis for using hybrid varieties over traditional varieties

The NPV for hybrid varieties is calculated based on the average revenue for those using hybrid varieties and those producing their own traditional seeds. The NPV for those producing their own seeds was lower than those using hybrid varieties (Table 12).

Table 12

Net Present Values and Internal Rate of Returns for Using Hybrid Seeds

Adaptation system	**TC E'000**	**TR E'000**	**NB E'000**	**IRR**	**NPV (10%) (E)**	**NPV (5%) (E)**	**NPV (15%) (E)**
Hybrid seeds	299 .4	306.5	7.1	97.6	21.7	22.7	20.8
Traditional seeds	246.0	257.0	11.0	96.0	12.3	12.9	11.8

Most rural households are financially challenged and cannot afford most inputs. The households use the previous harvest as seeds for the next season. The results show a higher NPV for hybrid varieties than traditional seeds. The sensitivity analysis also shows that hybrid varieties have higher NPV than traditional seeds.

Cost benefit analysis for irrigation and rainfed

Table 13 shows the NPV for irrigated and non-irrigated maize. The NPV for irrigation was more than rainfed maize, indicating that those who were irrigating had more revenue than those not irrigating. The households use fuel engines to pump water in earth dams or seasonal streams in order supplement rainfall during planting season. Few households are irrigating and the reason might be that irrigation requires high initial cost which is not afforded by rural subsistence farmers.

To set up an irrigation system, households should get loans and credits from financial institutions in order to buy and construct an irrigation system. Such services are not easily provided to dry land farming because they have no collateral. The area does not have a main river nearby, such that sourcing irrigation water from far dams and rivers would become expensive. The few that are irrigating rely on earth dams and seasonal streams. Acquiring a good and sustainable irrigation system would need the involvement of the government and non-governmental organisations.

Table 13

Net Present Value and Internal Rate of Returns for Irrigation

Adaptation system	**TC E'000**	**TR E'000**	**NB E'000**	**IRR**	**NPV (10%) (E)**	**NPV (5%) (E)**	**NPV (15%) (E)**
Irrigation	127. 2	171.8	44.6	74.0	440.3	451.3	403.6
Rainfed	391.7	434.8	43.1	90.0	30.8	32.3	28.3

The IRR shows that for the cost to equal the returns, the discount rates should be changed to over 90%. This shows these strategies cannot be easily affected by shifts in discount rates.

Cost benefit analysis for crop rotation

Households (18.3 %) indicated that there are using crop rotations as an adaptation strategy. The households were rotating groundnuts and maize. Groundnuts being legumes, fix nitrogen in the soil, therefore increasing the soil fertility. Table 13 presents the results for crop rotation. Shadow pricing was used to estimate the amount of fertility change brought by legumes fixing nitrogen. This is calculated as a proportion of the fertilizer applied by the households per hectare. Average amount of fertilizer applied by the households is 75 kg/ ha and assuming that the legume will reduce the amount applied by 30%. The net benefit would be E157.50/ha. The net revenue is increased by E708.75.

Table 14

Net Present Value and Internal Rate of Returns for Crop rotation, Rotating Maize and Groundnuts

Adaptation strategy	**TC E'000**	**TR E'000**	**NB E'000**	**IRR**	**NPV (10%) (E)**	**NPV (5%) (E)**	**NPV (15%) (E)**
Maize	542. 0	563. 5	21.5	96.2	14.4	15.1	13.2
Groundnuts	3. 5	4.9	1.4	72.0	284.6	298.5	260.9

Cost benefit analysis for minimum tillage

Minimum tillage reduces the cost of ploughing and conserves moisture. These improved the water holding capacity for the soil, reduce evaporation and make more water available for the plants. However, most households are not using the right implement for minimum tillage such that the benefits are not maximised. Households are using hand hoes for digging and this makes the plant roots not to be deep enough, such that during very hot days, the plants easily wilt.

Table 15

Net Present Value and Internal Rate of Returns for Minimum Tillage in Maize Field

Adaptation strategy	**TC E'000**	**TB E'000**	**NB E'000**	**IRR**	**NPV (10%) (E)**	**NPV (5%) (E)**	**NPV (15%) (E)**
Minimum tillage	90.5	100.6	10.1	90.0	44.0	46.5	42.1
Convectional tillage	451.5	463.0	11.5	81.0	9.11	9.5	8.7

To compare all the strategies, a summary of the NPV are presented in Table 16 below. The results indicate that planting drought tolerant crops was the strategy with the highest NPV, where maize was switched with cotton.

Table 16

Net Present Value and Internal Rate of Returns for all Adaptation Strategies

Adaptation strategy	**IRR**	**NPV (E) (10%)**
Switching crops (cotton)	6.1	1864.4
Switching crops (sorghum)	43.9	283.3
Switching crops (dry beans)	23.4	292.2
Switching crop (groundnuts)	72.4	284.6
Switching crops (cowpeas)	97.6	252.3
Irrigation	74.0	440.3
Crop rotation (maize and groundnuts)	97.9	284.6
Minimum tillage	90.0	44.0
Drought resistance varieties	72.0	21.7

Note: maize is the reference point, NPV = E14.40 at 10% discount rate.

Table 17 presents the net present values and internal rate of returns for the alternative adaptation strategies. These have lower NPV than those discussed in Table 16.

Table 17

Net Present Value and Internal Rate of Returns for alternative strategies

Alternative adaptation strategy	IRR	NPV (E) 10%
Maize	8.3	14.40
Rainfed	90	30.84
Convectional agriculture	81	9.05
Traditional seeds	96	11.76

The hypothesis for the study is that adapting to climate change by irrigation, shifting crops, crop rotation, using drought resistance varieties and minimum tillage does not increase yields. The results indicate a higher NPV for all these strategies compared to their alternatives which are presented in Table 17. Base on the results, the null hypothesis is rejected.

Objective d: Socioeconomic factors influencing the choice of households when adapting to climate change

Table 18 present descriptive statistics on socioeconomic factors that affect households when adapting to climate change. These results indicate that most households do not have access to credit and loan (91.6 %), have no access to extension services (76.3 %), do not have access to cooperatives and union groups (70.4 %). Most households indicated to be affect by high food prices (92.6%) and 65.0% are affected by input prices.

Table 18

Socioeconomic factors hindering households from using adaptation strategies

Factors	**Frequency**	**Percentage**
Access to loans		
Yes	22	8.6
No	235	91.4
Total	**257**	**100.0**
Access to extension services		
Yes	61	23.7
No	196	76.3
Total	**257**	**100.0**
High input prices		
Most	167	65.0
Moderate	18	7.0
Least	14	5.4
None	48	22.9
Total	**257**	**100.0**
High food prices		
Most	238	92.6
Moderate	10	3.9
Least	2	2.3
None	1	0.4
Total	**257**	**100.0**
Access to unions and cooperatives		
Input supply/farmer coops/union	4	1.6
Crop/seed producer and marketing group/coops	2	0.8
Farmers' Association	3	1.2
Women's Association	10	3.9
Saving and credit group	53	20.6
Funeral association	4	1.6
No social group	181	70.4
Total	**257**	**100.0**

MNL logistics results on climate change adaptation strategies employed by households in Mpolonjeni

Factors influencing the choice of climate change adaptation strategies by households

MNL regression model was used to identify factors affecting households' choice of adaptation strategies to climate change. The dependent variable was the adaptation strategies and predictor variables were socioeconomic factors. From the results, households indicated to be either adapting to climate change by employing one or more adaptation strategies or no adaptation at all. For this reason therefore, the adaptation options were grouped into six categories and the reference category was planting drought resistant varieties and shifting planting time.

The adaptation group categories were: no adaptation; drought resistant varieties, conservation agriculture and shifting planting time; conservation agriculture and shifting planting time; all strategies; irrigation and any other strategies. Explanatory variables were: sex of household head (sex); age of household head (age); education level of household (edu); occupation of household head (occp); name of social group (soc); land category (land cat); access to credit (cred); access to extension services training (ext); high incidences of crop pest and disease (pstdz); high input prices (inp) and high food prices (food); perceptions of households towards climate change and variability (percp).

The results of the multinomial logistic regression for the different adaptation strategies categories are presented in Table 18. Perceptions of households towards climate change (percp), high food prices (food), access to credit (cred) and land category (land cat) significantly ($p < 0.01$) influence the choice of not adapting to climate change compared to adapting using drought resistant varieties and shifting planting time. The results suggest that when households perceive a change in climate, the probability for not adapting becomes reduced compared to that of adapting by using drought resistant varieties and shifting planting time. High food prices reduce the probability for not adapting to climate change compared to adapting by using drought resistant varieties and shifting planting time. This is because households will adapt to increase crop production so that they will be able to produce their own food to avoid high food prices.

Owning land increases the probability that the household will not adapt to climate change by 313% compared to that of adapting by using resistant varieties and shifting planting dates. This shows that renting land increases the likelihood of adapting because rural households do not have enough money to by hybrids seeds so they would rather not adapt than using drought resistant varieties. When households have access to credit, the probability that they will not adapt to climate change is increased by 1 031 394 % compared to adapting using drought resistant varieties and shifting planting dates. However, the results are in contradiction to *a priori* expectation where access to credit was expected to reduce the likelihood that households will not adapt to climate change. High food prices and perceptions of households towards climate change reduce the probability of not adapting to climate change by 100%. This implies that faced with high food prices, households with rather adapt buy than buy expensive foods. When households perceive that climate has changes the probability of not adapting is reduced by 100%. When households perceive that climate has changed, they adapt to the perceived changes.

Age of household head (age) significantly ($p< 0.05$) influence the choice of not adapting to climate change compared to adapting using drought resistant varieties and shifting planting times. This implies that for every additional year in age of the household head, the probability of not adapting to climate change is 283% compared to adapting by using drought resistant varieties and shifting planting time. This shows that as the household head gets older, he or she is reluctant to use new technology, but rather opt for not adapting to climate change.

Occupation of the household head (occp) and perceptions of households towards climate change (percp) significantly ($p <0.01$) influence the choice of adapting to climate change using conservation agriculture, drought resistant varieties and shifting planting time compared to using drought resistant varieties and shifting planting times. This implies that when the household head is a farmer the probability of adapting to climate change using conservational agriculture, drought resistant varieties and shifting planting time is 43.3 % higher than adapting using drought resistant varieties and shifting planting time. This is because when fully engaged in farming, households will have enough time to explore more adaptation options and focus all their resources to farming as it is their livelihood than those with other sources of income. Perceiving that climate has changed reduces the probability of adapting using conservational agriculture, drought resistant varieties and shifting planting time compared to adapting using drought resistant varieties and shifting planting time by 100%.

Access to credit (cred) and high incidence of crop pest and diseases (pstdz), significantly ($p < 0.05$) influence the choice of adapting to climate change using conservation agriculture, drought resistant varieties and shifting planting time as adaptation strategies compared to using drought resistant varieties and shifting planting time. The results suggest that access to credit reduces farmers' probability of adapting using conservational agriculture, drought resistant varieties and shifting planting time by 76.6% compared to adapting using drought resistant varieties and shifting planting time. High incidence of crop pests and diseases reduces the chances of adapting using conservation agriculture, drought resistant varieties and shifting planting time by 34.3% compared to adapting using drought resistant varieties and shifting planting time. However, conservational agricultural methods such as crop rotation reduces crop pests and diseases such that when households have observed that there has been an increase in crop pests, they are expected to include conservation agriculture as they adapt to climate change. These results are contrary to *a priori* expectations where these variables were expected to increase the probability of adapting of adapting using conservation agriculture and shifting planting time.

Being a member of a social group (soc) and access to extension services (ext) significantly ($p < 0.1$) influence the choice of adapting to climate change using conservation agriculture, drought resistant varieties and shifting planting time as adaptation strategies compared to using drought resistant varieties and shifting planting time. This implies that being a member of a social group increases the probability of adapting using conservation agriculture, drought resistant varieties and shifting planting time by 18.5% over and above that of adapting using drought resistant varieties and shifting planting time. This is because social groups such as farmers' cooperatives provide information on farming, credits and resources that can be used when adapting to climate change. Access to extension services reduces the probability of adapting using conservation agriculture, drought resistant varieties and shifting planting time by 64.7% compared to adapting using drought resistant varieties and shifting planting time.

Access to extension services (ext) and perceptions of households towards climate change (percp) significantly ($p < 0.01$) influence the choice of adapting to climate change using conservation agriculture and shifting planting time as adaptation strategies compared to using drought resistant varieties and shifting planting time. Access to extension services reduces the probability of adapting using conservation agriculture and shifting planting time by 76.5 % compared to adapting using drought resistant varieties and shifting planting time. Perceiving that climate has changed reduces the probability of adapting using conservational agriculture and shifting planting time over and above that of adapting using drought resistant varieties and shifting planting time by 100 %.

High incidence of crop pests and diseases (pstdz), high input prices (inp) and being a member of a social group (soc) significantly ($p< 0.1$) influence the choice of adapting using conservation agriculture and shifting planting time as adaptation strategies compared to using drought resistant varieties and shifting planting time. The results suggest that high incidences of pests/diseases reduces the probability of adapting using conservation agriculture and shifting planting time by 27.7% compared to adapting using drought resistant varieties and shifting planting time. However, high incidence of crop pests and diseases was expected to increase the likelihood of adapting using conservational agriculture and shifting planting date over using drought resistant varieties and shifting planting dates. The reason might be that households are not aware of the importance of conservation agriculture in reducing the occurrence of crop pests and diseases. High input prices increase the probability of adapting using conservation agriculture and shifting planting time by 46.2% compared to that of adapting using drought resistant varieties and shifting planting time. Being a member of a social group increases the likelihood of adapting to climate change using conservational agriculture and shifting planting date by 16.2% compared to using drought resistant varieties and shifting planting dates.

High input prices (inp), high incidences of crop pest and diseases (pstdz) and perceptions of households towards climate change (percp) significantly ($p<0.01$) influence the choice of adapting to climate change using all adaptation strategies compared to adapting using drought resistant varieties and shifting planting time. This implies that high input prices increase the likelihood of using all adaptation strategies by 65.6 % over and above that of adapting using drought resistant varieties and shifting planting time. High incidence of pests and diseases reduces the probability of adapting using all adaptation strategies by 43.4% compared to adapting using drought resistant varieties and shifting planting time. Perceiving that climate has change reduces the probability of adapting using all adaptation strategies over and above that of adapting using drought resistant varieties and shifting planting time by 100%.

Occupation of household head (occp) significantly ($p< 0.05$) influence the choice of adapting to climate change using all adaptation strategies compare to adapting using drought resistant varieties and shifting planting time. This implies that the probability of adapting to climate change using all adaptation strategies is 30.0% higher and above that of adapting using drought resistant varieties and shifting planting time. The reason is that households whose livelihood is on farming will have more time to engage and try many adaptation strategies than those who are part time farmers. Adapting using all strategies would also increase the chances for crops to survive even in harsh climatic conditions.

Being a member of a social group (soc) significantly ($p< 0.1$) influence the choice of adapting to climate change using all adaptation strategies compare to adapting using drought resistant varieties and shifting planting time. This implies that the probability that the household will adapt using all adaptation strategies is increased by 13.9% above that of adapting using drought resistant varieties and shifting planting time. This is because social groups provide information such as farming management systems, credits for inputs and adaptation resources that can be important when adapting to climate change.

High input prices (inp), access to extension (ext) and high incidences of crop pests/diseases (pstdz), and perceptions of households towards climate change (percp) significantly ($p< 0.01$) influence the choice of adapting using irrigation and any other strategies compared to adapting using drought resistant varieties and shifting planting time. This implies that high input prices increase the probability of adapting using irrigation and any other strategies by 90.0 % compared to using drought resistant varieties and shifting planting time. Access to extension services reduces the probability of adapting using irrigation and any other strategies by 88.1% compared to that of using drought resistant varieties and shifting planting time. High incidence of pests/diseases reduces the probability of adapting using irrigation and any other strategies by 50.8% over and above that of using drought resistant varieties and shifting planting time. Perceiving that climate has change reduces the probability of adapting using all adaptation strategies by 100% compared to adapting using drought resistant varieties and shifting planting time.

Occupation of the household head (occp) significantly ($p < 0.05$) influence the choice of adapting using irrigation and any other strategies compared to adapting using drought resistant varieties and shifting planting time. This implies that being a full time farmer increases the probability of adapting using irrigation and any other strategies by 25.7 % compared to using drought resistant varieties and shifting planting time. Age of the household head significantly ($p<0.1$) influence the choice of adapting using irrigation and any other strategies compared to adapting using drought resistant varieties and shifting planting time. This implies that for every additional year in age of the household head, the probability of adapting using irrigation and any other strategies increases by 73.3 % compared to using drought resistant varieties and shifting planting time.

Perceptions of household head towards climate change influenced the choice of households when adapting using the alternative strategies compared to using the reference category. Sex of household head and age of household head did not significantly influence the choice of households when adapting to climate change.

De Jonge (2010), Hassan & Nhemachena (2007) and Maddison (2006) studied the perceptions and adaptation strategies of farmers using multivariate probit model, MNL model, logit model and Heckman probit model. The findings of these studies revealed the following socioeconomic factors as important when farmers adapt to climate change; sex, age, access to credit and extension services, awareness of climate change, increasing annual mean temperatures, increasing mean annul precipitation, access to electricity, tractor and heavy machinery, wealth, cropping systems, technology, farm assets, livestock ownership, non-farm income, education level as some of the determining factors.

Table 19 ***Multinomial logistic regression estimates for the choice adaptation strategies***

	no adaptation			**drought resistant varieties, conservation agriculture and shifting planting time**			**conservation agriculture and shifting planting time**			**using all strategies**			**irrigation and any other strategies**		
	Coef. (β)	**Exp.(β)**	**p-value**	**Coef. (β)**	**Exp.(β)**	**p-value**	**Coef. (β)**	**Exp.(β)**	**p-value**	**Coef. (β)**	**Exp.(β)**	**p-value**	**Coef. (β)**	**Exp.(β)**	**p-value**
β_0	-14.60	0.000000456	0.005	11.76	128027.42	0.001	13.31	602202	0.000	11.50	99176.7	0.000	12.59	294612.4	0.000
	(5.23)			(3.70)			(2.75)			(2.51)			(3.36)		
Sex	0.53	1.700	0.398	0.11	1.116	0.837	0.04	1.040	0.931	-0.43	0.651	0.280	-0.77	0.4630	0.268
	(0.63)			(0.55)			(0.51)			(0.40)			(0.70)		
Age	1.34**	3.829	0.031	0.72	2.054	0.118	0.24	1.271	0.406	0.32	1.377	0.146	0.55*	1.73325	0.080
	(0.62)			(0.46)			(0.29)			(0.22)			(0.32)		
Edu.	0.71	1.074	0.795	-0.05	0.951	0.828	-0.13	0.879	0.527	0.15	1.162	0.248	0.17	1.1853	0.303
	(0.27)			(0.24)			(0.21)			(0.13)			(0.16)		
Occp.	0.42	1.043	0.741	0.36***	1.433	0.000	0.13	1.139	0.179	0.19**	1.209	0.020	0.23**	1.2586	0.039
	(0.13)			(0.10)			(0.10)			(0.81)			(0.11)		
Soc.	0.13	1.141	0.428	0.17*	1.185	0.089	0.15*	1.162	0.075	0.13*	1.138	0.056	0.16	1.1735	0.195
	(0.17)			(0.10)			(0.86)			(0.70)			(0.12)		
Land cat.	1.42***	4.125	0.001	.037	1..443	0.494	0.38	1.462	0.413	0.11	1.116	0.817	0.33	1.3909	0.599

	(0.42)			(0.54)			(0.46)			(0.46)			(0.64)		
Cred.	13.84***	1031395.77	0.000	-1.45**	0.234	0.037	(0.23	1.259	0.799	1.06	2.886	0.166	0.73	2.0750	0.463
	(0.81)			(0.70)			(0.90)			(0.46)			(0.99)		
Ext.	0.17	1.185	10.847	-1.04*	0.353	0.092	-1.45***	0.235	0.010	-0.77	0.463	0.106	-2.12***	0.11938	0.001
	(0.87)			(0.62)			(0.56)			(0.74)			(0.62)		
Pstdz.	0.38	0.687	0.240	-0.420**	0.657	0.029	-0.3244*	0.723	0.081	-0.57***	0.566	0.003	-0.71***	0.492	0.001
	(0.32)			(0.19)			(0.18)			(0.19)			(0.22)		
Inp.	0.30	1.350	0.442	-0.03	0.970	0.931	0.38*	1.462	0.060	0.50***	1.656	0.003	0.64***	1.900	0.008
	(0.39)			(0.36)			(0.21)			(0.17)			(0.24)		
food	-11.8***	0.0000	0.000	-0.24	0.787	0.787	0.49	1.050	0.908	-0.50	0.854	0.612	0.11	1.122	0.799
	(0.97)			(0.89)			(0.42)			(0.31)			(0.45)		
Percp.	-13.8***	0.0000	0.000	-14.37***	0.0000	0.0000 0574	-15.81***	0.00000	0.00	-15.56***	0.00000	0.00	-16.50***	0.00000	0.000
	(1.58)			(1.13)			(0.83)		136	(0.87)		0174	(0.87)		68

*** = values statistically significant at 0.01 probability level, ** = values statistically significant at 0.05 probability level, * = values statistically significant at 0.10 probability level
Base reference category: drought resistant and shifting planting time
Number of observations: 257

Chapter summary

The chapter presents and discusses the results of the study. Temperatures are increasing, rainfall is decreasing and maize yields are decreasing. The Ricardian regression indicates that spring and summer temperatures significantly affect maize revenue. The net present value for drought tolerant crops are higher than maize and this implies that drought tolerant crops perform better than maize at Mpolonjeni. Households are adapting to climate change and variability. Private adaptation strategies for the households are as follows; planting drought resistant varieties, early planting, late planting, minimum, crop rotation, mulching and irrigation. Households' barrier to adopting climate change strategies are; age of household head, occupation of household head, name of social group, land category, major cropping system, access to credit, access to extension services and training on farming systems, high incidences of crop pest and disease, high input prices and high food prices.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Summary of research findings

Mpolonjeni households are affected by climate change and variations. Summer mean temperature has been increasing, while seasonal total rainfall and maize yields have been decreasing for the past four decades. The results show that spring and summer mean temperatures affect maize yields. This has resulted in food insecurity and hunger as maize being the staple crop has a low yields.

Households perceive that climate has changed and it is has negative impacts the crops. Climate changes effects that were reported by the households include; shifted seasons, poor rainfall distribution, low rainfall amount and intensity, increased temperature. Climate change effects have increased the level of poverty, hunger and food insecurity.

Households are adapting to climate change and variation by using the following adaptation strategies; drought resistant varieties, early and late planting, minimum tillage, crop rotation, mulching and irrigation. Most households are using drought resistant varieties and the least used strategies are the soil and water conservation management strategies.

Cost benefit analysis for the adaptation strategies shows that switching crop, where maize is replaced with drought tolerant crops has the highest NPV so is the most economical and efficient strategy. Irrigation has the second highest NPV but this strategy needs government intervention as households cannot afford constructing dams with their own resources. However, combining the strategies would be the best practice and will give a synergy effect. Households' barrier to adopting climate change strategies are; age of household head, occupation of household head, name of social group, land category, access to credit, access to extension services and training on farming systems, high incidences of crop pest and disease, high input prices and high food prices and perceptions towards climate change and variability.

Conclusions

Based on the research findings, climate change affects crop yields as from the Ricardian regression summer and spring mean temperatures significantly affected maize yields. The null hypothesis was therefore rejected because climate change affects crop yields. Households are adapting to climate change using; drought resistant varieties, early and late planting, minimum tillage, crop rotation, mulching, irrigation, intercropping. The null hypothesis was that households were not adapting to climate change.

Results on cost benefit analysis indicated that switching maize with drought tolerant crops has the highest NPV followed by irrigation. This implies that adaptation strategies employed by households are not equally economical and efficient. The null hypothesis was therefore rejected as it stated that all adaptation strategies are equally efficient.

Socioeconomic factors that influence the choice of households when adapting to climate change were; age of household head, occupation of household head, name of social group, land category, major cropping system, access to credit, access to extension services and training on farming systems, high incidences of crop pest and disease, high input prices and high food prices. The null hypothesis was therefore rejected. It is concluded that socioeconomic factors does affect the choice of households when adapting to climate change.

Implication of the study to existing literature

The study is a cost benefit analysis of climate change adaptation strategies. It has been discovered that the communities at Mpolonjeni ADP should adapt by switching from maize to drought tolerant crops such as cotton, sorghum and dry beans. However, combining many strategies can be a good practice as it will ensure synergetic effect.

Recommendations

Recommendations to households

It has been projected that temperatures are still going to increase and rainfall intensity, frequency and distribution would be unpredictable and unreliable. For rural households, whose livelihood is dependent on rainfed agriculture, adaptation would increase their resilience to climate impacts and improve their livelihoods and food security.

Not all adaptation strategies are economical, so households should consider those that have higher benefits and practical in their situations. It is recommended that households should consider planting drought tolerant crops such as cotton, sorghum, dry beans. These crops are more marketable and they sell to buy maize as it is the staple crop. Irrigation can also be exploited as household should build earth dams to harvest water during heavy rainfall days to supplement rainwater during dry critical growth stages of their crops. Households should exploit all these adaptation strategies to full capacity in order to realise their benefits. As households have financial constraints, they should focus more on those that have lower costs such as switching crops, crop rotation, minimum tillage and drought resistant varieties.

To enhance adoption of adaptation strategies, households should overcome the negative factors that hinder them from adapting to climate change. They should seek information on climate change to avoid maladaptation, form unions and cooperatives, change cropping systems to mixed farming or intercropping. These adjustments can be possible even without external intervention from government.

Recommendations to policymakers

Factors influencing households' decisions to adopt climate change strategies point the need for government to support households and to ensure sustainability of agricultural activities and enhance food security. Agriculture extension services should be strengthened by increasing the interaction between households and extension officers by providing enough transport to ensure field visits. Agriculture Finance Institutions need to be strengthened and accommodate farmers on communal land. Rural micro finance institutions need to be developed in order to provide micro loans to households. Policies must aim at enhancing household level adaptation through the support of Department of Meteorological Service by reporting and alerting households about weather changes in an understandable form so that they can be able to plan for the future when farming.

Irrigation shows a high NPV but with the high initial cost that is associated with irrigation, policymakers should consider providing irrigation system for the community. This would allow the household to supplement rain water during long dry period within the planting season which mostly occurs towards crop maturity.

Households should be provided with input subsidies to reduce the financial constrain associated with the high input prices.

Recommendation for further studies

As there are many methods of evaluating the effect of climate change, a study analysing the adaptation strategies using the other methodologies can be of help and interesting. A majority of the adaptation strategies have non-quantifiable costs and benefits, so costs effectiveness analysis and multi criteria analysis can allow the assessment and evaluation of these methods.

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APPENDICES

Appendix A: Research questionnaire

QUESTIONNAIRE NUMBER ____ HOUSEHOLD IDENTIFICATION NUMBER____ Interviewer's code___________________________

Cost-Benefit Analysis of Climate Change Adaptation Strategies in Crop Production Systems: A case of Mpolonjeni in Swaziland

RESPONDEND CONSENT

- Hello, I am___________________________________. I am working with a research team from the University of Swaziland as an enumerator interviewing farmers on cropping systems and socioeconomic issues.
- The objective of the survey is to identify farmer's crop management systems with respect to climate change adaptation strategies. I would like to ask questions related to your farming systems.
- The information you provide would be used to find the current crop management systems and would be used to plan for adaptation strategies in the area with respect to climate change.
- You have been selected to participate in the study randomly, participation is voluntarily and you would not be affected in any way if you choose not to participate. However, the information collected to this effect would be used for planning and guiding future interventions.

  All the information you give will remain confidential. It is important that the answers to the questions are correct since the results of the study depend on the correctness of the responses.
- If you agree to participate the interview will take 45 minutes. We thank you in advance for your patience and co-operation. May we proceed?
- Yes ( ) [continue with the interview] No ( ) [terminate the interview and submit] [Tick]

PART 0: INTERVIEW (FARMER'S) BACKGROUND

Name of Respondent: ……………………………………..	Date.…/……./……...	Start time………..…	Stop time……….………..	Homestead number………………………………………….………..……
HH name………………………………………....…………	HH age [1] ………………..…	HH Education level[2]………………..…...	HH Marital Status[3]: ……………	HH sex: [4]……………………….
Number of years the homestead has been in the village[5]…………………………………….	Constituency …………...……………	Chiefdom …………...…………	Community……………..………	

PART I: CURRENT HOUSEHOLD COMPOSITION AND CHARACTERISTICS

Family Codes	Name of household member (start with respondent)	Sex **Codes A**	Marital status **Codes B**	Age [1]	Education (yrs) **Codes C**	Relation to HH **Codes D**	Occupation **Codes F**		Contribution on farm labour **Codes G**
							Main	Secondary	
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
01 (HH)									
02(Respondent)									
03									
04									
05									
06									
07									
08									
09									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20	Record household members that have relocated in the last three months								
21									
22									
23									

PART II: SOCIAL CAPITAL AND NETWORKING: SECTION A: SOCIAL CAPITAL

Have the household head or family members been member of formal and informal institutions in the last 3 years? 1= Yes; 0=No. If yes, list at most three and complete the following table and if no, go to next section.

Family Codes	Type of group; **Codes A**	Three most important group functions: **Codes B**			Year joined (YYYY)	Role in the group **Codes C**	Still a member now? **Codes D**	If No in column 8, reason/s for leaving the group (**Codes E**), Rank 3		
		1st	2nd	3rd				1st	2nd	3rd
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**

SECTION B: SOCIAL NETWORK

1. Do you have any people that you can rely on for support in times of need within this village? Please tick; Relatives ◯ Non-Relatives ◯ 2. Do you have any people you can rely on for support in times of need outside this village? Relatives ◯ Nonrelatives ◯ 3.Do you have any government support on; ◯ subsidies for farm inputs, ◯ food aid if your crop fails. 4. Do you have any NGO's support on; ◯ subsidies for farm inputs, ◯ food aid if your crop fails. 5. Give any other support system……………………………………………………………………………………………………..

PART III: HOUSEHOLD ASSETS: SECTION A: CROP PRODUCTION EQUIPMENT

Asset	Does your HH own these items1=yes 0=no (→9)	How many items do you have?	How much did you pay for it? **(E)**	When did you acquire them?(yr)	When acquired, were they new?1= yes, 0= no	If you were to sell,what will be the price? (E)
1	**2**	**3**	**4**	**5**	**6**	**7**
Pick-up/ truck						
Tractor, trailer, Tractor plough						
Ox / Donkey cart, plough						
Tractor planter / ox planter						
Wheelbarrow						
Hoe/ Spade/						
Hand sprayer						
Engine pump						
Fence						

Crip						
Water tank						
Grain tank						

SECTION A: PRODUCTION EQUIPMENT

Asset	Did you lose or sell any item last year?1= yes 0= no	Did you own any in the last five years?1= yes;0= no (→**13)**	If yes what happened?	When did this happen?(yr)	If sold why?	Do you plan to buy any of these this in five years time? 1=yes; 0=no
	8	**9**	**10**	**11**	**12**	**13**
Pick-up/ Trucks						
Tractor /Trailer / plough						
Ox/ Donkey cart/ plough						
Tractor planter / ox planter						
Wheelbarrow						
Hoe/ Spade						
Hand sprayer						
Engine pump						
Fence						
Crip						
Water tank						
Grain tank						
			1= lose; 2= sell; 3=stolen; 4=broken; 5=other,		1=buy food; 2= school fees; 3= medication; 4= other	

PART IV: CROP PRODUCTION: SECTION A: LAND HOLDING DURING THE YEAR 2011/2012 CROPING YEAR

Land category	Land size	wet season		dry season	
		Cultivated[4]	Uncultivated[5]	Cultivated[4]	Uncultivated[5]
1	2	3	4	5	6
1= Own land used (A)					
2= Rented/ borrowed in land (B)					
3= Rented/ borrowed out land (C)					
4= Total owned land (A+B)					
5= Total operated land (cultivated in both seasons)					

SECTION B: PLOT CHARACTERISTICS, INVESTMENT AND INPUT: Section B1. Plot characteristics, investment

If more than one crop is grown on a plot, repeat the plot code in next row. Consider only 3 main intercrops if more than 3 on a (sub) plot.

Plot **code** (start with one next to residence)	Estimated plot size	Season **Codes A)**	Crop(s) grown **(Annex 1 codes)**	Crops variety	Intercrop 1=Yes; 0=No	Percent of area under each intercrop	Plot distance from residence (walking minutes)	Soil fertility **Codes D**	Soil slope **Codes E**	Soil type **Codes F**	Soil/water conservation method **Codes G**	No. of mature trees in the (sub)plot	Crop residue left, 1=Yes; 0=No	Irrigation **Codes H**	Zero or minimum tillage on the plot? (1= yes, 0= no	
															Ever practiced	Practiced'11/'12

i) What is the major cropping system? Please tick.

ii) Monocropping ( ) Mixed cropping ( ) Intercropping.

iii) What are the reasons for choosing the system mentioned above…………………………………….…………………………………………………………..

iv) What are the reasons to choose intercropping or mixed cropping…………………..……………………………………………..……………………………..……………..

v) For the farming system chosen above, what are the crop combination……………………………………....…………………..………………………………………………………

vi) Have you ever practiced crop rotation? ( ) Yes ( ) No

vii) If yes, what are the reasons……..

Soil erosion and control measure

i) Are there any signs of soil erosion on your cropping land? Please tick. ( ) Yes ( ) No

ii) If yes,, what extend were the signs and extend of soil erosion……………………………………………………………………...?

iii) What are the soil conservation measures applied?..

iv) What costs are associated with applying these soil conservation measures technique?...

Section B2: Inputs use: plot code and crop(s) grown in this Section should be in exactly the same order as in Section A.

				Fertilizer (not used =0)					Seeds used, separate by comma if intercropped					Manure			Pesticides	
												Bought		Own	Bought			
Plot **code** (start with one next to residence	Season **(Code A in section A)**	Crop(s) grown **(Annex 1 Codes)**	Previous season main crop **(Annex 1 Codes)**	Amount of basal fertilizer (Kg)	Total cost **(E)**	Amount of topdressing fertilizer (Kg)	Total costs **(E)**	Main seed source **(Code A)**	Total Cost	Own saved/ gift (Kg)	Number of seasons own saved or gift recycled	Amount in Kg	Total cost (E)	Amount in Kg	Amount in Kg	Total cost (E)	Amount of pesticides	Total costs (E)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**

Section C: Input use, planting, crop management and harvested: plot code, and crop(s) grown in this Section should be the same order as in Section A.

Plot code	Season **Code A in section A)**	Crop(s) grown **(Annex 1 codes)**	Land preparation						Crop management cost		Harvesting Costs		Labour costs									
			Man power		Oxen/ donkeys		tractor						Ploughing and planting		Crop management		Harvesting		Post-harvest management (shelling to storage)		Total harvested[6]	
			Days	Total cost (E)	Hours	Costs	Hours	Cost in (E)	Animals	Tractor	animals	Tractor	No: of labour	Total cost	No: of labour	Total costs	No: of labour	Total cost	No: of labour	Total costs	Fresh	Dry
1	**2**	**3**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**

[6] Total harvested per plot. Intercrops: separate by comma.

Section D: Utilization of crop produced and household food security:

Crop (From section C)	Season (From section C)	Stock before 2010/11 harvest (kg)	Production of 20011/2012 last columns of Section C) (kg) or bags	Total available stock after 2009/10 harvest (kg) or bags	From total available stock '10/11: Quantity sold after '10/11 harvest (kg)	In-kind payments (labour, land & others) paid , '11/12 (kg)	Seed used during '11/12 cropping year (kg)	Gift, tithe, donations given out , '11/12 (kg)	Consumption during '11/12 cropping year (kg	Ending stock (Stock before '10/11 harvest) (kg)	If total available stock of '10/11 was not sufficient for consumption until harvest: Amount bought (kg)	Food aid/gifts received (kg)
1	**2**	**3**	**4**	**5=3+4**	**6**	**7**	**8**	**9**	**10**	**11=5-10**	**12**	**13**

Section E: Marketing of crops: one row per sale (different months, different buyers), per crop and per season

Crop (**crops codes**)	Season (Column 2, Section D)	Form : 1= fresh; 2= dry	Market type **Codes A**	Month sold **Codes B**	Quantity sold (kg)	Price (E) /kg)	Buyer **Codes C**	Relation to buyer **Codes D**	Quality **Codes E**	Mode of transport **Codes F**	Actual transport cost (E)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**

Section F: Utilization crop residues for the cropping year 2011/2012

Please tick the applicable and specify the crop.

1) Used for soil fertility……

2) Left in the field to be used as animal feed……...

3) Cut and burnt after harvesting………..

4) Other uses, specify……...

Section G: Grain storage practices of 2011/12 season

Crop	Main storage structure **Codes A**	Form stored **Codes B**	Reasons for preferring the storage structure **Codes C** ; Rank 3	Amount stored at beginning; **(Kg)**	Amount used during harvesting (Kg)	Did quality deteriorate during storage **Codes D**	If **Yes** in column **6**, % of stored grain affected	Storage loss control measures **Codes E**	Cause of storage loss **Codes F**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
maize									
sorghum									
beans									
groundnuts									
Pigeon peas									
Jugo beans									
Cowpeas									

PART V: LIVESTOCK PRODUCTION AND MARKETING: Section A: Livestock ownership and livestock sales in the past 2 years

Type of livestock	How many do you have now?	What is the estimated price if you were to sell today?		How many were sold?	When were they sold?		At what price were they sold?	Why were they sold? **Codes A**	How many were slaughtered and consumed in HH?	How many have been received?	How many bought?	How many were stolen?	How many have died?
		Young	Adult		Year	Month							

PART VI: TRANSFER AND OTHER SOURCES OF INCOME DURING 2011/12CROPPING YEAR: Section A; Resources

Sources	Cash (E)	Total income
Rented out oxen for ploughing		
Farm labour wages		
Non-farm labour wages		
Non agribusiness lncome		
Pension income		
Drought/flood relief		
Safety net or food for work		
Remittances (sent from non-resident family and relatives living elsewhere)		

Section B: Social capital and welfare perceptions

1. All things considered, how satisfied are you with your life over the past 12 months? [Circle] *1= unsatisfied; 2=neither unsatisfied or satisfied; 3=satisfied;*
2. Compared with other households in the village (or community), how well-off is your household? *1=worse-off 2=about average 3=better-off*
3. How well-off is your household today compared with the situation 5 years ago? *1=less well-off now; 2=about the same; 3=better off now*
4. Do you consider your village (community) to be a good place to live? *1=no; 2=yes; 3=partly; why?*......................................

PART VII: ACCESS TO FINANCIAL CAPITAL, INFORMATION AND INSTITUTIONS: Section A: Household credit need and sources during 2010/11 cropping year

Reason for need of loan	Needed credit? **Codes A**	If **Yes** in column 2, then did you get it? **1= yes 0= no**	If **NO in column 3**, then why not? **Rank 3 (codes C)** 1st	2nd	3rd	If **Yes** in column 3... Source of Credit, **Codes B**	How much did you get	Did you get the amount you requested	Annual interest rate charged	Debt outstanding including interest rate at end of season
No need for finance										
Buying seeds, fertilizer, herbicide , pesticides										
Ploughing, management and harvesting, transportation										
Buy farm equipment and machinery										
Invest in irrigation system										
Buy livestock										
Non-farm business										
Buy food										
Others, specify										

Section B: Access to extension services

Extension services	Did you receive training or information on [......] before 2009/10? (**Codes A**)	Received training or information on [.....] during 2009/10? (**Codes A**)	Main information source for 2011/12, Rank 3 (**Codes B**)			Number of contacts during 2011/12 (days/year)		
			1st	2nd	3rd	Govt extension	Non-profit NGOs	Private Companies
New crop varieties								
Soil, crop and water management								
climate change								
Irrigation								
Produce markets								
Livestock production								
Crop rotation								

Section C: Constraints in accessing key inputs in crop production: C1: Socioeconomic, Please tick all applicable.

Timely availability of improved seed, of fertilizer ( )	Soil fertility ( )
Prices of inputs ( )	Drought ( )
Pests and diseases ( )	Floods ( )
Access to markets and information ( )	

C2: Biophysical. Rainfall assessment in the last 3 years, Please tick all applicable.

Did the rainfall season come on time?	( )Yes	( ) No	Did the rains stop on time?	( )Yes	( ) No
Was there enough rain during the growing season?	( )Yes	( )No	Did it rain near the harvest time?	( )Yes	( )No

PART VIII: RISK, LIVELIHOOD SHOCKS AND COPING STRATEGIES

Risk factor	Rank importance of […] in affecting household livelihood (1=most important) **scale: 1= most, 2= moderate, 3= least, 4= none**	copping strategies before […], **Codes A; Rank 3**			Important copping strategy after […] occurrence **Code B;** Rank 3			How did […] affect production of main food crop of the household **(% reduction**	As a result of […] did you lose (part of) your income **(% reduction**	Do you think […] will become more frequent in future due to climate change	If **Yes**, how often do you think […] will occur in future?	Which crops were most susceptible – rank 3 **Codes in Annex 1** - attached sheet
		1st	2nd	3rd	1st	2nd	3rd					
Drought												
Floods												
Hail storm												
Crop pests/diseases												
Livestock diseases												
Large decrease in agricultural output prices												
Large increase in agricultural input prices												
Large increase in food prices												
Theft of assets or crops												
End of regular assistance, aid, or remittances from outside HH												
Conflict/violence												

Have you ever considered growing sorghum?

State reasons………

…….

PART IX Perceptions and attitudes

Section A: perceptions:

i) Do you think climate has change? Tick ( ) yes.................. ( ) no..............................
ii) Give reasons……
………
………
iii) Do you think that there is climate variation in your area? Tick ( ) yes......... ( ) no..............
iv) Give reasons……
………
………

PART II: attitudes

i) Do you think climate change is bad or good
………
………
………
………
ii) Give reasons
………
………
………
………
iii) What can farmers do in response to climate change
………
………
………
………

PART X: CLIMATE CHANGE COPPING STRATEGIES:

Have you ever used the following climate change copping strategies? Please tick the applicable response?

Agronomic strategies

1) Planting drought resistant varieties; yes no
2) Early planting yes ( ) no ( )
3) Late planting yes ( ) no ( )
4) Minimum tillage yes ( ) no ( )
5) Crop rotation yes ( ) no ( )
6) Intercropping yes ( ) no ( )
7) Mulching yes ( ) no ( )
8) Irrigation yes ( ) no ( )
9) Any other method, specify …….

Non- agronomic strategies

1) Non agribusiness enterprises yes ( ) no ( )
2) Selling livestock yes ( ) no ( )
3) Selling firewood yes ( ) no ( )
4) Look for employment in town and cities yes ( ) no ( )
5) Any other method, specify ……

Annexes

ANNEX 1 : CROPS CODES

CEREALS	LEGUMES	CASH CROPS
1 = Maize	5= beans	9= Cotton
2= sorghum	6= cowpeas	10= sugarcane
3= wheat	7= groundnuts	11= Tobacco
4= others	8= others	12= others

ANNEX 2: PART 0: INTERVIEW (FARMER'S) BACKGROUND

[1] 0 = <1; 1= 1 -18; 2= 19 – 30; 3= 31 -40; 4= 41 -50; 5= > 50

[2]1=Illiterate; 2= Completed primary school; 3= junior secondary level; 4=senior secondary school; 5= Professional college certificate; 6= University education; 7= Adult education; 8= others

[3] 1= Married; 2= Single; 3= Divorced; 4= Widowed; 5= Separated; 6= Consensual

[4]sex 1= male; 2= female

[5] years: 1= < 10 years; 2= 11- 20 years; 3= >20

PART I: CURRENT HOUSEHOLD COMPOSITION AND CHARACTERISTICS

Code A	Code B	Code C	Code D	Code F	Code G
1= Female	1.=Married living with spouse	0=Illiterate;	1= Household head	1=Farming	1= 100
2= Male	2= Married but spouse away	1= Lower primary	2= Spouse	2= Salaried employee	2=75
	3=Divorced/separated	2= Completed primary	3=Son/daughter	3= non agribusiness	3= 50
	4= Widow/widower	3= Junior secondary	4=Parent	4= Casual on-farm	4= 25
	5= single	4= Senior secondary	5= Son/daughter in-law	5=Casual off-farm	5=0
	6=Other, specify………	5= Professional college	6=Grand child	6= School/college child	
		6= University education	7=Other relative	7= Non-school child	
		7= Adult education	8= Hired worker	8= Herding	
		8= Other, specify…	9=Other, specify……………	9= Household chores	
				10= Other, specify…….	

PART II: SOCIAL CAPITAL AND NETWORKING

Codes A		Codes B		Codes C	Code D	Code E
1= Input supply/farmer coops/union 2= Crop/seed producer and marketing group/coops 3= Local administration 4= Farmers' Association 5= Women's Association 6= Youth Association 7= Church	8=Saving and credit group 9= Funeral association 10= Government team 11= Water User's Association 12=Other, specify…………….	1= Produce marketing 2= Input access/marketing 3= Seed production 4= Farmer research group 5= Savings and credit 6= Funeral group 7= Tree planting and nurseries 8= Soil & water conservation	9= Church group 10= Input credit 11= Other, specify………	1= Official 2= Ex-official 3= Ordinary member	1= Yes 0 = No	1= Left because organization was not useful/profitable 2= Left because of poor management 3= Unable to pay annual subscription fee 4= Group ceased to exist 5= Other, specify ……………

PART IV: CROP PRODUCTION: PLOT CHARACTERISTICS, INVESTMENT AND INPUT

Section A. Plot characteristics, investment and input use

Code A	Code B		Code C	Code D	Code E	Code F		Code G			Code H
1= summer ; 2= winter;	1= Owned; 2= Rented/ borrowed in;	3= Borrowed/ rented out; 4= Other, specify….	1= Women; 1= Men; 2= Both ;equally	1= Good; 2= Medium 3= Poor	1= Gently slope (flat); 2= Medium slope 3 =Steep slope	1= clay ; 2= sand; 3= silt; 4= loam;	5= silt loam	1= None; 2= Terraces; 3= Mulching	4= Grass strips; 5= Trees on boundaries; 5= no tillage 6= minimum till	7= Soil bunds 8= Stone bunds	2= Irrigated 1= Rainfed

Section B2: Input use

Codes A

1= Own saved	5=Extension demo plots	9=Agro-dealers	13= Other (specify)……………
2= Gift from family/neighbor	6= Farmer groups/Coops	10= Bought from seed company	
3= Farmer to farmer seed exchange	7= Local seed producers	11= Provided free by NGOs/govt	
4= On-farm trials	8= Local trader	12=Govt subsidy program	

Section E: Marketing of crops

Code A	Codes B		Codes C		Code D	Codes E	Codes F
1= Farm gate 2= Village market 3= Main/district market	1= January 2= February 3= March 4= April 5= May 6= June	7= July 8= August 9= September 10= October 11= November 12= December	1= Farmer group 2= Farmer Union or Coop 3= Consumer or other farmer 4= Rural assembler 5=Broker/middlemen 6=Rural grain trader	7= Rural wholesaler 8= Urban wholesaler 9=Urban grain trader 10=Exporter, 11=Other, specify…….	1= No relation but not a long time buyer 2= No relation but a long term buyer 3=Relative 4=Friend 5=Money lender 6=Other, specify……	1=Below average 2= Fair and Average 3=Above average	1= Bicycle 2= Hired truck 3=Public transport 4=Donkey 5= Oxen/horse cart 6=Back/head load 7=Other, specify….

Section F. Marketing. (For each crop that was sold, please ask)

Codes A	Codes D	Codes C	Codes D	Codes E	Codes F	Codes G
1= Head load 2 = Ox cart 3 = Bicycle 4 = Vehicle 5 = Wheelbarrow 6 = others	1= Immediately after harvest 2= They stored and sold at later date 3=Sold some after harvest but stocked some for sale at later period 4= Other	1=Household needed an immediate source of income 2=To take advantage of prevailing high prices at the time 3=Lacked storage place/ mechanism 4= Wanted to wait for better prices after harvest season 5=Others (specify	1=Granary 2= Bags, sacks, baskets 3=Late harvest 4=pit storage 5=Others (specify	1= pesticides 2= traditional	1=No 2=Theft 3= Destruction by pests 4= Other (specify)	1= No 2= Yes

Section G: Grain storage practices used

Codes A	Codes B	Codes C	Codes D	Codes E	Codes F	Codes F
1= Traditional crib 2= Improved granary 3= Wooden store 4= Metal silo 5= Polythene bags 6=Other, specify…….	1= Shelled 2= Unshelled 3=Other, specify……..	1= It is cheap 2= It dries well 3= Keeps off rodents 4= Keeps off other pests 5=Other, specify………	1= No 2= Yes	1= pesticides 2= traditional	1= None 2= Actellic Super 3= Spin dust 4= Scanner dust 5= Ash 6= Smoking 7=Other, specify…….	1= Pest damage 2= Moisture loss 3= Rotting 4= Moulds 5= Theft 6=Other, specify…

PART V: LIVESTOCK PRODUCTION & MARKETING: Section A: Livestock ownership and livestock sales in the past 2 years

Codes A

1= to buy food: 2= medical reasons; 3= other, specify……………………………..….

PART VII: ACCESS TO FINANCIAL CAPITAL, INFORMATION AND INSTITUTIONS

Section A: Household credit need and sources during 2009/10 cropping year

Codes A	Codes B			Codes C		
1= No 2= Yes	1=Money lender 2= Farmer group/coop 3= Merry go round	4=Microfinance 5= Bank 6=farmer's coops	7= Relative 8= Other, specify	1= Borrowing is risky 2= Interest rate is high 3= Too much paper work/ procedures	4= Expected to be rejected, so did not try it 5= I have no asset for collateral 6= No money lenders in this area for this purpose	7= Lenders don't provide the amount needed 8= No credit association available 9= Other, specify………

Section B: Access to extension services

Codes A	Codes B				
1= No 2= Yes	1= Government extension service 2= Farmer Coop or groups 3= Neighbour farmers	4= Seed traders 5= Relative farmers 6= NGOs	7= Other private trader 8= Private Company 9= Research centre	10= School 11= Radio/TV 12= Newspaper	13= Mobile phone 14= Other, specify……

PART VII: RISK, LIVELIHOOD SHOCKS AND COPING STRATEGIES

Codes A				Codes B			Codes C
1= Planting drought tolerant crops 2= Plant drought tolerant varieties 3=Early planting	4= Plant disease/pest tolerant varieties 5= Crop diversification	6= Increase seed rate 7= More non-farm work 8=Saving	9= Soil and water conservation 10= None 11= Other, specify…………	1= Replanting 2= Selling livestock 3= Selling land	4= Selling other assets 5= Eat less (reduce meals) 6= Out-migration	7= Borrowing 8= Seek treatment 9= Stop sending children to school 10= None 11= Other, specify……………	1= No 2= Yes