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IMPACT OF CLIMATE CHANGE ON COTTON PRODUCTION UNDER RAINFED CONDITIONS: CASE OF GOKWE

Patrick Gwimbi[1]
Tanyaradzwa Mundoga[2]

[1] Ethiopian Civil Service College, Urban Management masters' Program
[2] Zimbabwe Open University, Department of Geography and Environmental Studies

ABSTRACT
Climate variability and change is a major threat to cotton production in Gokwe, which is largely dependent on rain fed. Cotton is the driving force for the district and changes in its levels, impact negatively farmers livelihood. This paper is a review of the farmers' vulnerability to climate change and the role adaptation in enhancing their livelihoods. Based on a time series trend analysis and correlation statistical analysis of the relationship between the climate variation scenarios and the cotton production level output over a 25 year period, and a random sample of 50 farmers; the results show that farmers are vulnerable to climate change. Cotton production levels declined as precipitation decreased and temperature increased across the district. Although other physical factors, such as soil fertility and farm management practices, among other factors, have an important influence on agriculture, climate remained the dominant influence on cotton production. Household revenues were also negatively affected by the decline in cotton production output. The integration of sustainable policies and adaptation against climate change into the national policies and development strategies is recommended as the way forward.

Keywords: Climate Change; Rainfall Variability; Cotton Production Output

BACKGROUND

Climate change is a significant constraint on agriculture throughout much of Sub-Saharan Africa (Burke et al., 2009). Recent evidence and predictions show increasing temperatures and drought frequency, as well as shifting rainfall patterns. The combination of increasing temperature and shifting rainfall amounts and patterns negatively impact on agriculture (IPCC, 2000; Muller, 2009).

Southern Africa in particular is highly vulnerable to extreme variability of precipitation given its high dependence on rain-fed agriculture and natural resources for livelihoods; limited knowledge on climate change and limited resources for adaptation (Manase, 2008). Consequently, there is an increasing concern regarding the impact of climate change on agriculture, especially in terms of the rainfall impact on crop production (Hulme, 1996). Scientific evidence on temperature and rainfall variability and its impact on crop yield is now stronger than ever. While globally the temperature has increased by over 0.5°C in the past 100 years, a similar rate of warming of about 0.05°C per decade has been observed in southern Africa (Hulme, 1996). The rainfall in the region has been erratic over the same period, with annual rainfall anomalies mostly below normal. Climate change scientists' view is that temperatures are likely to continue to rise and that increases in rainfall will be necessary in order to compensate for the loss of moisture from the land due to elevated evaporation rates (Hulme, 1996).

For Zimbabwe, a country of wide geographical diversity with a predominantly rural population that lacks some basic infrastructure, the impact of climate change on agriculture is very high (Manase, 2008). Most communal farmers in Zimbabwe rely on natural rainfall for their farming activities and are affected worse by climate change. Their difficulties are compounded by the erratic seasonal rainfall patterns, which have been experienced by the country in the last three decades. This dependence on natural rainfall has resulted in low agricultural productivity as communal farmers, who make up about 75% of the entire farming community, find difficulty in ensuring that their crops have adequate water supply until harvest. Significant rainfall deficits at critical stages of crop growth have frequently led to a serious shortfall in crop production.

Gokwe District is one such rural area in Zimbabwe affected by climate change. The district is a major cotton producing area in Zimbabwe and has been a destination for internal immigrants seeking the fortunes associated with cotton growing (Govereh, 1999). The area is relatively newly settled and farm sizes are larger than the national average. The soils have high agricultural potential and few farmers apply any supplementary nutrients.

Household incomes levels have improved and enabled them to acquire assets and sent their children to school, not otherwise possible by those not engaged into non cotton growing. To acquire assets like draft cattle Govereh's (1999) study in the district showed that 53% of the farmers used income from cotton, 20% used a combination of cotton and maize income and 18% used wage savings. Consequently, farmers not growing cotton had less than half the assets owned by those growing cotton. By 1990 cotton accounted for more than 30 per cent of the cropped area in the district, compared to only 5 per cent in other cotton-producing regions of the country. The average area under cotton increased from 0.5 ha per household in 1980 to almost 10 ha in 1985/86, while the average devoted to maize dropped substantially (Jayne, 1994; Govereh, 1999).

The success of farmers' cotton production however depends on the normal climate pattern, especially rainfall. Changes in climatic conditions worry farmers as this adversely affects farmers in a variety of ways.

While farmers' general vulnerability to climate change is now well known at a global scale, great uncertainty remains at specific locations. Limited knowledge on local livelihoods vulnerability to climate change exists and this poses challenges to policy makers when it comes to tackling adaptation to climate change. Against the above background, this study sought to assess the vulnerability of cotton farmers in Gokwe to climate change so as to provide the basis for mainstreaming climate change adaptation into their farming activities.

Vulnerability to climate change in this study is conceptualized with reference to climate change. The IPCC (2007) defines vulnerability as the degree to which a system is susceptible to, and unable to cope with adverse effects of climate change, including climate variability and extremes. Fussel (2007) argues that there are three dimensions of vulnerability to climate change, namely the physical, the socioeconomic and the external assistance.

The first dimension, the physical environment, focuses on the climate as the phenomenon that causes harm to those systems in its prone locations. This dimension puts emphasis on the climatic conditions in a region and to the biophysical impacts of climate change, such as changes in agricultural productivity or the distribution of disease vectors (Fussel, 2007). People in this context are treated as victims or vulnerable owing to their presence in locations where the hazard is experienced (Ford and Smit, 2004; Fussel, 2007). This approach has however been criticized for downplaying the role of the human system in modifying conditions within a region and the climate itself, hence contributing to the resultant climate change impacts (Ford and Smit 2004).

The second dimension, the socioeconomic, refers to the region's capacity to recover from extreme events and adapt to changes over the longer term (Fussel, 2007). This has also been referred to as social vulnerability by Brooks (2003). According to Brooks (2003), hazards and disasters are not a result of physical events alone, but are also influenced by the social, economic, and cultural aspects of the humans exposed to such hazards. This approach emphasizes the socioeconomic processes that constrain human ability to cope with climatic hazards. Central to this argument are factors such as the presence and strength of social protection measures such as food entitlements (Adger, 2000). The capacity of individuals or groups to cope with, resist, and recover from the impact of hazards determine their vulnerability (Fussel, 2007).

Furthering the debate of human vulnerability to climate change is the argument put forward by Sen(1981), that famine which is one output of vulnerability is not caused by lack of food, but by lack of access to food. From this perspective, vulnerability can be viewed as the lack of access to and entitlement of households or communities to available resources due to several factors such as prices and affordability by members of the community of the priced goods.

The third dimension to vulnerability is the external assistance, defined by Fussel (2007) as the degree to which a system may be externally assisted in its attempts to adapt to change. This conceptualization includes factors outside the vulnerable system, such as level of external assistance to address the impact.

Arguably, it is agreeable among researchers of different persuasions that vulnerability exists because of the presence of a hazard (Adger 2000; Brooks 2003; Ford and Smit 2004; Fussel 2007). It is also agreeable among authors that vulnerability to climate change is a function of exposure, sensitivity and adaptive capacity of the affected community members individually or collectively (Johnston et al. 2009, Devereux 2010). Exposure consists of factors such as temperature and precipitation that make up the climate system (Devereux 2010). Sensitivity is viewed as the degree to which the system of interest (e.g. agriculture) is affected by climatic stimuli.The combination of exposure and sensitivity is often referred as the impact of climate change (Devereux 2010).

This study, while incorporating the arguments presented above, views vulnerability as the likelihood of rural communities in Lesotho suffering from climate adverse impacts and their inability to respond to stresses resulting from such impacts.

Communities' inability to cope with negative impacts of climate change is at the center of the study. This inability is exacerbated by changes in the climate average conditions and the occurrence of extreme events and variability. This definition is also in agreement with the definition of IPCC (2007) given earlier in this argument.

The issues addressed in the study were first, evidence that climate change or variability vis-à-vis rainfall and temperature patterns existed in the district, and if it existed, what its impact on cotton production output was. Second, how the results of the study could be used by farmers and other stakeholders effectively to adapt to the changes.

The hypothesis of increasing temperature and decreasing precipitation trends associated with declining cotton production level was tested using annual temperature and precipitation data against cotton production output for the district.

STUDY AREA

Gokwe is the largest district in Zimbabwe and lies to the northwest of the country. It is in the country's agro-ecological region 3, which receives 600 to 650mm of rainfall, annually. Cotton production is the major agricultural income earner for farmers in the district. The most common land tenure system is communal, followed by a few resettlement schemes.

MATERIALS AND METHODS

Rainfall and temperature data for Gokwe was obtained from the Zimbabwe Meteorological Department. Records of cotton production levels output were obtained from the Cotton Company of Zimbabwe. A random sample survey, by means of a questionnaire, was carried out on 50 farmers. The survey included communal and resettled farmers from the district with records of regularly delivering cotton to the Cotton Company of Zimbabwe.

The question of climatic change as evidenced through changing rainfall and temperature patterns was explored using data from records, spanning more than 25 years, to assess evidence of change in the rainfall amounts and temperature figures over time. The result was a time series for the rainfall vis-à-vis cotton production output over 25 years in the district. This trend provided evidence of the relationship between rainfall variability and cotton production output over time. Next, the cotton production levels were plotted against temperature over the same period.

Climate pattern scenarios generated using rainfall and temperature data were statistically correlated to cotton production levels using Statistical Package for the Social Sciences (SPSS) software package. Statistical correlation coefficients between cotton output and climatic variables of rainfall and temperature were used to assess the nature, magnitude, and significance of the relationship between cotton production output and climate variables. To examine the contribution of each climatic variable in explaining cotton output the coefficient of determination (r^2) was used. The coefficient of determination described the amount of variability in cotton production, which could be explained by knowledge of climate variables.

A household survey of 50, randomly selected farmers was used to verify the statistical results and generate qualitative information on farmers' perceptions of the changes in temperature and rainfall in the district and adaptation strategies employed by farmers to mitigate potential adverse effects of climate change.

RESULTS AND DISCUSSION

Correlation between cotton production and rainfall variability

The relationship between the mean annual precipitation and cotton production is shown in Figure 1. The rainfall increase was associated with the increase in cotton production output and, similarly, a decrease in rainfall resulted in low output. These annual rainfall patterns plotted in Figure1 indicate that of the 25 years, from 1982 to 2007, at least ten had below normal rainfall. The drought conditions of 1981-1982, 1991-1992, and 2001-2002 were the major causal factors for the declining yields. In the 1991 to 1992 season, for example, a more than 80% decrease in precipitation resulted in a 38% decrease in cotton production in the district.

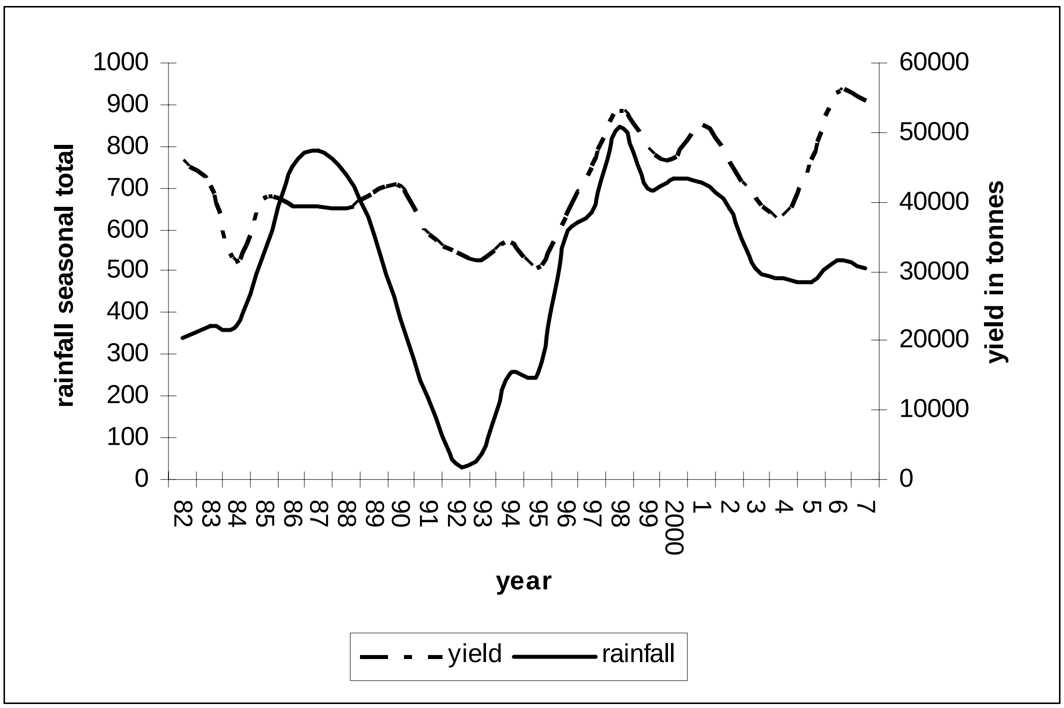

Figure 1: Annual rainfall variability and cotton yield output in the Gokwe District

When comparing cotton production output against the mean annual rainfall, the coefficient of determination (r^2) was 0.64. This analysis showed that 64% of the variation in cotton output could be explained by the rainfall trend pattern in the district. The correlation coefficient between the cotton output and the mean rainfall was positive and statistically significant ($r = 0.8$, $p<0.05$).

The temperature increases in the district was projected to be 0.4°C per annum. The average, annual temperature of in the district was 26^{0}C, which is conducive for cotton production. The results of this study showed that as temperature increased, cotton production output declined ($r = -0.4$, $p<0.05$).

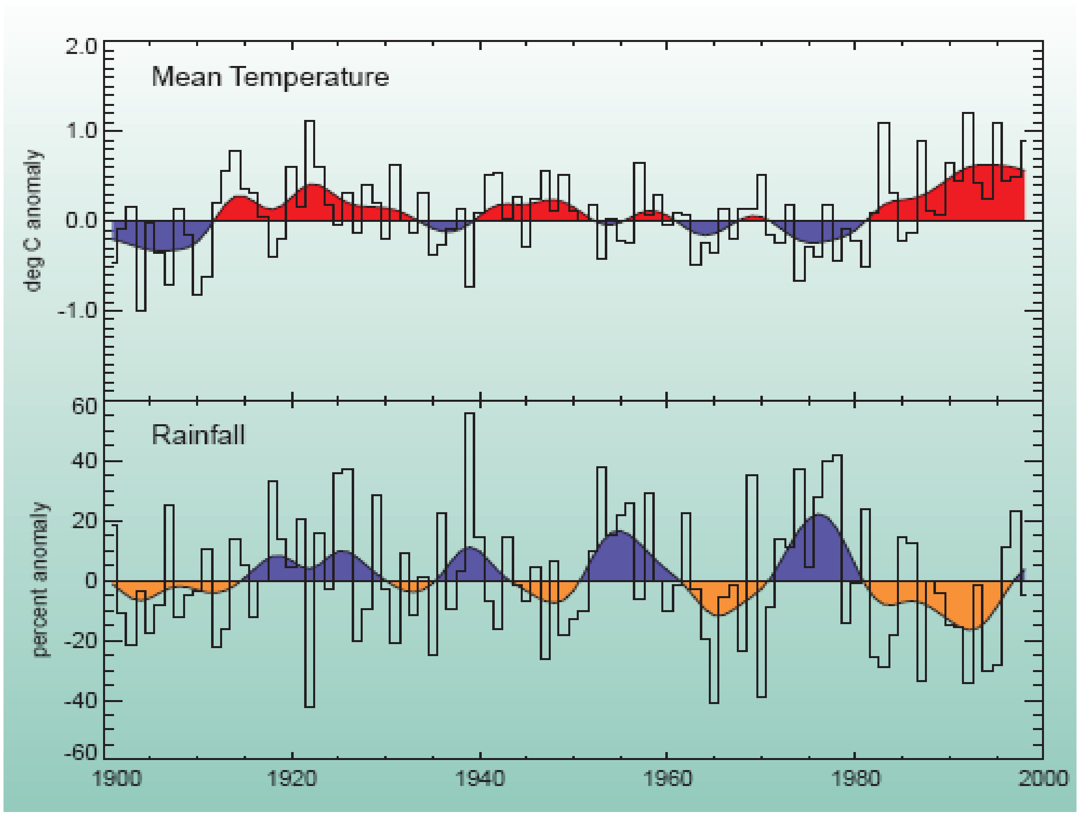

Figure2: Zimbabwe's national temperature and rainfall deviation patterns 1920 - 2000

Source: Zimbabwe Department of Meteorological Service

Figure 2 shows Zimbabwe's climate pattern from 1900 to 2000. The trend shown agrees with the results from the Gokwe district, especially with regard to the period 1980 to 2000. The annual-mean temperature has increased by about 0.4°C since 1900, and the 1990s decade has been the warmest this century. The early 1990s witnessed probably the driest period this century, as the drought, related to the prolonged El Niño conditions, affected southern Africa.

Impact of drought on farmers' livelihoods

The climate scenario shown on figs. 1 and 2 did not just impact on cotton output alone, but also on social and human capital. All the farmers in the survey depended on farming for their livelihood, and 60 per cent of their income came from cotton farming. The impact of drought on farmers is therefore severe and long lasting when it comes. The majority of households (73.4%) indicated food insecurity as the most severe impact they endured. Cattle loss came second at 57% while 30% indicated hunger related diseases and water scarcity as significant problems they also suffered when drought occurred. About

28% reported inability to send children to school as major problem whilst 15% reported failure to repay loans, a key concern, especially for the cotton growers.

The loan scheme system was introduced in the early 1990s as a new marketing system where cotton is grown under contractual agreement between buyers, consisting mainly of large firms and smallholder farmers. As part of the contract, the contracting firm provides loans to the farmer in the form of essential inputs. In return, the farmer is under obligation to sell his produce to and only to the contracting firm and repay the loans as well. Incidences where farmers had assets reposed by the buyers when farmers failed to delivered the cotton to the buyers markets were reported by 30% of the respondents.

Overall, about 70% of the households identified erratic rainfall as their principal vulnerability factor. Another important vulnerability factor was capacity to respond in the event of drought, identified by 61% of sampled households. Other factors identified included lack of extension advice (21%) and lack of climate forecasts (23%).

Farmers' climate change coping strategies

Farmers were asked to rank their climate change coping strategies. The majority ranked seeking off farm jobs and selling livestock as some of their options. About 10% indicated engaging in barter trade while 15% selected food for work programmes as their strategy.

What also emerged from discussions with farmers was that climate change issues are not well known to farmers and therefore not a priority in terms of finding solutions to the resultant problems. A significant percentage of the farmers were of the view that both rainfall and temperatures were alternating between above and below normal while 25% reported that there was no change.

The significant proportion of farmers noticing a decrease in precipitation could be attributed to the substantial decline in cotton output realized from farming over years. There was a general agreement among all the respondents that the rainfall was no longer as what it used to be in the past. The worst drought experiences in the district in the 1991-92 and 2001-2 seasons were frequently mentioned by 80% of the farmers who lost most of their produce to the drought.

The preferred adaptation measures identified by farmers are shown in figure 3. More than 65% of the farmers were of the view that their solution to climate change laid in use of irrigation (31%), introducing drought resistant cotton varieties (10%), diversifying into other crops (11%) or timing the planting period to coincide with the onset of the rains (14%). Majority of the respondents (71%) preferred short-season hybrid varieties because the growing season was getting shorter. Farmers noted that rainfall patterns had hindered the growing of long-season cotton varieties. A significantly though small number of farmers (15%) however maintained that nothing could be done. It was however noted that this group had little or no information about climate change.

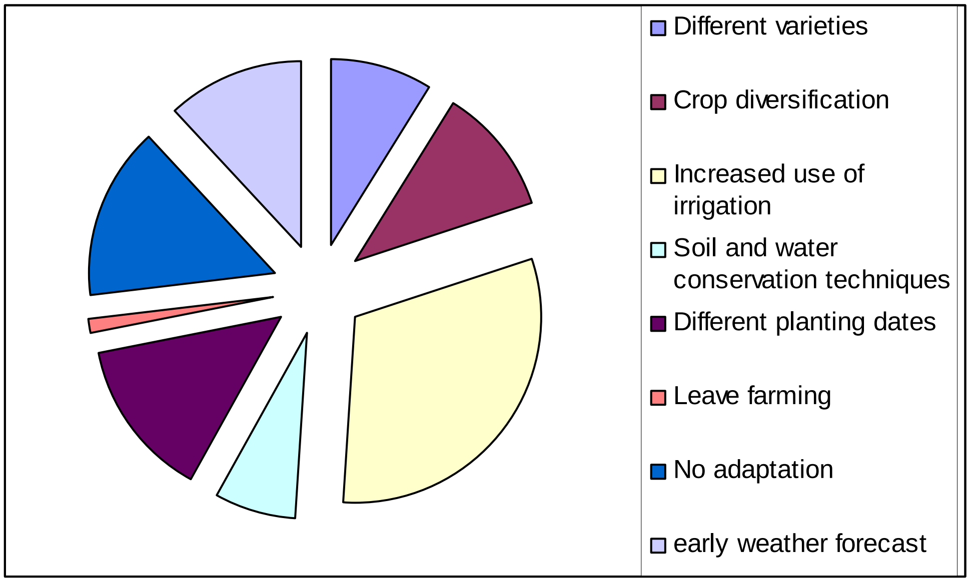

Fig.3. Farmers' preferred adaptation to climate change

Improvements to drought early warning systems could offer solutions to some of the farmers concerns regarding adaptation. The government of Zimbabwe in collaboration with other Southern African Development Community (SADC) countries has already institutions in place that deal with early warning systems so as to deal with the issue of drought at both the national and regional level. A few such institutions include the National Early Warning unit (NEWU), Regional Early Warning unit (REWU), Regional Early Warning Systems (REWS) and Drought Monitoring Centre (DMC) under the National Meteorology Department (Phillip, Makaudze and Unganai, 2001). But the major draw back with these systems is that most of the activities are concentrated towards preparing for drought emergency and logistics. Yet the availability of climate information, especially seasonal forecasts to rural farmers remain a challenge.

These forecasts are likely to be of immense value to the farmer if such information is delivered to local communities on time with expert agricultural advice of when they should plant. The involvement of agricultural extension workers as a channel of communicating and interpreting such seasonal forecasts could fuel the effectiveness of the forecasts and increase farmers' resilience to droughts.

This study has showed that there are clear linkages between climate change and variability and cotton production output.

The link between climate change and sustainable development stems from the fact that climate change is a constraint to development, and sustainable development is a key to capacities for adaptation. In Gokwe farmers' vulnerability to climate change is exacerbated by low levels of low adaptive capacity. For farmers' farming processes to be sustainable, it must be made more resilient to climate change. Although drought cannot be eliminated, its impact can be reduced through implementation of sustainable management policy programs.

CONCLUSION AND RECOMMENDATIONS

The impacts and adaptation of climate change raised above need to be analyzed within the context of sustainable development. This is because, efforts to cope with the impacts of climate change and attempts to promote sustainable development share common goals. Burke, Lobell and Guarino(2009) argue that sustainable development measures and climate-change policies, including adaptation can reinforce each other. Climate change adaptation policies can reduce vulnerabilities and risks by enhancing the adaptive capacity of communities.

The ability of rural farmers to adapt to climate change is intertwined with sustainable development and poverty reduction. Enhancing farmers' adaptive capacity would entail a variety of actions that are sustainable such as improved access to resources and improved infrastructure that add to their resilience in future. Farmers should be supported in planning their own adaptation processes, for example with community based water conservation strategies.

Adaptation to climate change is vital for increasing the resilience of cotton farmers in order to sustain their livelihoods. This paper showed that farmers are highly vulnerable to climate change. Current adaptation strategies adopted by farmers to address the negative impacts of climate change are mostly reactive, selective and protective, and not sustainable in the long term. Informally, some rural households have responded to climate change shocks using strategies such as selling their assets like livestock mostly at depressed prices. Some households have bartered their livestock for food, a practice that effectively reduced the value of the cattle, goats, or other animals to a fraction of the normal or expected price.

The farming communities need to respond to climate change challenges by adopting strategies that can withstand climate change risks raised above. The adaptation measures need to take into consideration the national policy on agriculture and response strategies that should be multi-sectoral in nature. Analyses from studies elsewhere have shown that large reductions in adverse impacts from climate change are possible when adaptation is fully implemented (Mendelsohn & Dinar, 1999).

Climate change adaptation initiatives would greatly support the resilience of farmers to climate change impact in the long term if they were successfully implemented. The main challenges to their implementation however remain, bordering on lack of capacity, financial constraints and absence of policy among other factors.

Among the climate change adaptation strategies recommended by this study include those outlined below.

There is need for the government to incorporate climate change adaptations in its long-term policies and developmental programmes, including budgetary allocations to adaptation programmes that promote climate change adaptation strategies.

Capacity building in climate change knowledge and skills across all the sectors of development and farmers would positively contribute to reduced impacts. This could transcend to farmer learning institutions so that agriculture extension workers who work with these farmers are fully knowledgeable to impart this knowledge on farmers.

Strengthening climate change monitoring and early warning systems information capacity.Raising awareness of climate change impacts and adaptation options should be given priority and adequate funding. Unless the general public has deep understanding and appreciation of climate change issues and the adaptation options available to them, it remains difficult to implement new policies and measures, even if they are potentially beneficial to all the parties concerned.

There is also a need to ensure good forecasts on climate to ensure early responses to climate problems and promote adaptations by farmers. Farmers need to adapt to climate by changing land-use and management practices.

REFERENCES

Adger, W.N. (2000). Institutional adaptation to environmental risk under the transition in Vietnam. *Annals of the Association of American Geographers,* 90(4), 738– 758.

Brooks, N. (2003). *Vulnerability, risk and adaptation: a conceptual framework.* Working Paper 38, Tyndall Centre for Climate Change Research, Norwich, UK.

Burke, M. B., Lobell, D. B., & Guarino, L. (2009). Shifts in African crop climates by 2050, and the implications for crop improvement and genetic resources conservation. *Global Environment Change.*

Devereux, S. (2010). *Building Social Protection Systems in Southern Africa.* Background paper for the European Report on Development

Hulme, M. (Ed.). (1996). Climate Change in Southern Africa: An Exploration of Some Potential Impacts and Implications in the SADC Region. Climatic Research Unit, University of East Anglia.

Ford, J. D. & Smit B. (2004). A Framework for Assessing the Vulnerability of Communities in the Canadian Arctic to Risks Associated with Climate Change. *ARCTIC, 57*(4), 389– 400.

Fussel, H.M. (2007). Vulnerability: a generally applicable conceptual framework for climate change research. *Global Environmental Change*, *17*, 155–167.

Govereh, J. (1999). Impacts of Tsetse Control on Immigration and Household Accumulation of Capital: Zambezi Valley, Zimbabwe. Ph.D. dissertation, Michigan State University.

IPCC. (2000). Emission scenarios, summary for policy makers. Online at http://www.grida.no/climate/ipcc/spmpdf/sres -e.pdf.

IPCC. **(**2007). *Climate Change 2007 the physical science basis.* Contribution of Working Group I to the Fourth Assessment Report of IPCC. Cambridge. UK.: Cambridge University Press.

Jayne, T. (1994). Do High Food marketing Costs Constrain Cash Crop Production? Evidence From Zimbabwe. *Economic Development and Cultural Change*, 42, 387-402.

Kurukulasuriya, P. & Rosenthal, S. (2003). Climate Change and Agriculture: A Review of Impacts and Adaptations. The World Bank Environment Department.

Manase, G. (2008). Documentation of Research on Climate change and water in Southern Africa, 2nd Draft, The Danish Water Forum.

Mendelsohn, R. & Dinar, A. **(**1999). Climate Change, Agriculture, and Developing Countries: Does Adaptation Matter? *World Bank Research Observer*, (14), 27293.

Müller, C. (2009). Climate change impact on Sub-Saharan Africa: an overview and analysis of scenarios and models. Discussion Paper.

Phillips J.G., Makaudze, E., & Unganai, L. (2001). Current and Potential Use of Climate Forecasts for Resource-Poor Farmers in Zimbabwe. *Impacts of El-nino and Climate Variability on Agriculture*, 63, 1-20.

Reilly, J.M. & Schimmelpfenning, D. (1999). Agricultural impact assessment, vulnerability, and the scope for adaptation. *Climatic Change,* 43, 745–788

Sen, A. (1981). Poverty and Famines: An Essay on Entitlement and Deprivation. Oxford: Oxford University Press.

ABOUT THE AUTHORS:

Patrick Gwimbi: Lecturer: Ethiopian Civil Service College, Urban Management masters' Program

Tanyaradzwa Mundoga: Researcher, Zimbabwe Open University, Department of Geography and Environmental Studies