An In-Depth Appraisal of Smallholder Farmers' Adaptation Strategies to Rainfall Variability in Kirfi Lga Bauchi State

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Abstract* - Rainfall variability is a global phenomenon. Its impact on agricultural activities in the developing countries has been increasing. Higher temperature and decreasing precipitation depress crop yields. This is particularly true in low-income countries where adaptive capacities are perceived to be low. The vulnerability of poor countries could be due to weak institutional capacity, limited engagement in environmental and adaptation issues, and lack of validation of local knowledge. A better understanding of the local dimensions of vulnerability is therefore essential to develop appropriate adaptation measures that can mitigate these adverse consequences. The main aim of this study was to identify the determinants of smallholder farmers' choice of adaptation strategies and identify and analyse the adaptation strategies used by smallholder farmers in response to rainfall variability in Kirfi Local Government Area. Both primary and secondary data sources were used for this study. The results from the regression analysis showed that access to climate information, years of farming experience, respondents' perceptions on changing climate, level of education have significant and positive impact on rainfall variability adaptation strategies. The study was concluded with recommendation that policies aimed at promoting farm-level adaptation need to emphasize on the crucial role of providing information on better production techniques and enhancing farmers' awareness on rainfall variability to enable farmers adapt to impact of rainfall variability.

Indexed Terms: Smallholder Farmers, Adaptation Strategies, Rainfall Variability

I. INTRODUCTION

Agriculture is primarily and heavily dependent on climate. The climatic factors that have direct bearing on agriculture include rainfall, sunshine hours, temperature and relative humidity. Rainfall variability has a direct, often adverse, influence on the quantity and quality of agricultural production. The climate of an area highly correlates with the vegetation and by extension the type of crop that can be cultivated. The overall predictability of these climatic elements is imperative for the day-to-day and medium-term planning of farm operations.

Rainfall variability and their impact on human populations in sub-Saharan Africa are major global concern. The Sudano-Sahelian zone which is incidentally the food basket of the sub-region is the most affected by the unpredictable climatic patterns. Farming activities in the Sudano-Sahelian region of Nigeria is predominantly rural, over 80% of the farmers are practicing rain-fed subsistence agriculture (Ekpoh, 2010). These peasant farmers produce for subsistence in order to meet the daily nutritional needs of the family and the surplus are then sold for monetary income in the local markets.

The relationships between rainfall variability and agriculture involve climatic and environmental aspects, social and economic responses. These last can take either the form of autonomous reactions or of planned economic or technological policies. Indeed rainfall variability and agriculture interdependencies evolve dynamically over time, they often span over a large time and space scale and are still surrounded by large uncertainties.

Rainfall is one of the most important climatic variables because of its two-sided effects - as a deficient resource, such as droughts and as a catastrophic agent, such as floods. Several studies have been carried out on rainfall at different temporal scales - from daily to annual and in different areas. For example (Kurukulasuriya and Mendelsohn, 2008; Nhemachena et al., 2010) observed that in addition to soil and socio-economic characteristics, rainfall and temperature largely account for regional variations in rain-fed African agriculture. (Pass, 2003) indicated that differences in farming characteristics and yields have mainly been attributed to rainfall differences. At a broad scale, the negative impact of increasing temperatures and precipitation on crop yields is clear (Lobell and Field, 2007Funk and Brown, 2009; Gourdji et al., 2013; Lobell et al., 2011a, b). These negative impacts are likely to be stronger in warmer regions where increases in temperature will have a larger impact (Mendelsohn et al., 1994; Schlenker and Lobell, 2010). Most of these warmer regions also tend to include poorer countries; thus, the impacts of rainfall variability are likely to fall disproportionately on poorer nations and on poorer, agrarian households within those nations (Ericksen et al., 2011; Fu¨ ssel, 2010; IPCC, 2007a; Jarvis et al., 2011; Skoufias et al., 2011). It is expected to result in long-term water and other resource shortages, degrading soil condition, disease and pest outbreaks on crops and livestock and so on. It affects different crops differently. Therefore, changes in outputs and economic returns from different crops differ significantly which in turn also affects the corresponding crop growers differently. Farmers will be expecting losses, primarily, due to reductions in agricultural productivity, crop yields and loss of farm productivity.

The impact of rainfall on crop production can be related to its total seasonal amount or its intra-seasonal distribution. In the extreme situation of droughts, with very low total seasonal amounts, crop production suffers the most. But more subtle intra-seasonal variations in rainfall distribution during crop growing periods, without a change in total seasonal amount, can also cause substantial reductions in yields. This means that the number of rainy days during the growing period is as important, if not more, as that of the seasonal total.

Rainfall variability tends to be the dominant source of livelihood and production risk in the drier environments, greatly affecting rain-fed smallholder agriculture (Zimmerman and Carter, 2003). The annual rainfall variation, including the onset, intensity, duration and cessation of rainfall greatly impact on socio-economic and agricultural activities in Kirfi Local Government. The scenarios indicate that rainfall variability will lead to increased droughts and more uncertainty about the onset and cessation of rains. Under rain-fed agricultural systems, the seasonal rainfall variability means that farmers adopt a range of risk averse coping and livelihood strategies and this is evidenced by the highly variable production levels within different individual farmers' fields and among the farmers.

Predicted changes in climate pose a threat to agricultural production and local livelihoods worldwide. Averting this challenge requires that farmers adapt by making changes in farming and land management decisions that reduce the negative consequences associated with changing rainfall pattern (Jarvis et al., 2011). Climate- or weather-driven adaptation may be a direct response to changing temperature and precipitation patterns but may also come from an effort to reduce general weather risk even when change is not imminent. Farmers also respond to political and socio-economic factors and environmental factors other than weather and climates. At a broad scale, the negative impact of increasing temperatures on crop yields is clear (Funk and Brown, 2009; Gourdji et al., 2013; Lobell et al., 2011a, b; Lobell and Field, 2007).

Rainfall variability adaptation is viewed as a package of actions through which individuals or communities adjust themselves to the impacts or threats posed by rainfall variability (Nyong, et. al., 2007). It refers to adjustments at a system level, be it ecological, social or economic (Smit, et. al., 1999). Therefore, rainfall variability adaptation is a process through which individuals, communities, societies or systems adjust their common ways of doing things in response to rainfall variability stimuli, regardless of the purpose, timing, temporal and spatial scope, location, effects, form and performance (Smit, et. al., 1999).

Adaptation is the adjustment of practices, processes and structures to reduce the negative effects particularly, the unavoidable ones, and takes advantage of any opportunities associated with rainfall variability (FAO, 2008). Adaptation to rainfall variability refers to adjustment in ecological, social and economic systems in response to the effect of change in climate (Smit et al., 2000; Smit and Pilifosova, 2001). Until the last decade or so, adjustments to changing environments were generally viewed as positive, but we now know that adjustments are a series of trade-offs, that there are costs and benefits to choices that individuals and groups make. Adaptation is identified as one of the options to reduce the negative impact of rainfall variability (Kurukulasuriya and Mendelsohn, 2006).

II. MATERIALS AND METHODS

The study follows a multi-stage stratified random sampling procedure where combinations of purposive and random sampling procedures were used to select sample in the study area.

The sample size was determined using Yamane's formula of sample size with precision level of 7% and confidence level of 95%, the calculation from the estimated population of 11,000 farming household heads (previous population approximation) came up with 200 heads of farming households. Table 3.1 present sample sizes that would be necessary for given combinations of precision, confidence levels, and variability.

$$n = \frac{N}{1+N(e)^2}$$

Where n is the sample size, N is the population size, and e is the level of precision.

$$n = \frac{11,000}{1+11,000(0.07)^2} = 200$$

A. Procedure of Data Collection and Analysis

The primary data was collected from the smallholder farmers of the Kirfi Local Government Area using a questionnaire through interview method and focus group discussion. Data collection starts with a rapid rural appraisal to gain an overview of the significant social and physical features of the selected villages (Chambers, 1994). A mixture of participatory methods including key informant interviews, focus group discussions and household questionnaire surveys were used allowing local people the opportunity to participate by sharing their experiences and knowledge to outline possible solutions to rainfall variability challenges. A total of 200 structured household questionnaires were undertaken in the selected villages.

Purposive sampling was used to identify key informants. One focus group discussion was held in each farming village except in Bara, Kirfi and Badara where two focus group discussions were conducted in each of them involving between 5 and 10 farmers of different socio-cultural backgrounds, to ensure triangulation of the key issues emerging from the household questionnaire. A total of 9 key informants were selected for in-depth interview into the issues raised at focus group discussions.

Both descriptive and inferential statistics were used for the analysis of data. Information obtained from the administered questionnaire was analysed using charts, tables, percentage and regression analysis to understand the socio economic and demographic factors responsible for the choice of adaptation strategies by the smallholder farmers.

Statistical computation was done using the Statistical Package for Social Sciences (SPSS) and Microsoft Excel (Version 2010). Descriptive analysis such as frequencies and cross tabulations was used to determine simple number of occurrences of a variable or relationship among variables.

B. Discussion

A diversity of adaptation options was employed by the farming community to counteract the impacts of temperature and rainfall pattern changes. The strategies used by the different farming communities to minimize the impacts of the perceived changes of climate were more or less similar, but the extent of implementation varied.

III. ADAPTATION STRATEGIES ADOPTED BY THE SMALLHOLDER FARMER

Adaptation Strategy	Farming Villages																			
	Badara		Bara		Beni		Dewu		Guyaba		Kafin Iya		Kirfi		Shongo		Tubule		Wanka	
	Response (%)																			
	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Change Crop Variety	85.0	10.0	55.0	45.0	25.0	75.0	85.0	15.0	55.0	45.0	65.0	45.0	70.0	30.0	50.0	50.0	70.0	30.0	50.0	50.0
Mixed Farming	90.0	10.0	65.0	35.0	30.0	70.0	80.0	20.0	55.0	45.0	65.0	35.0	75.0	25.0	45.0	55.0	70.0	30.0	60.0	40.0
Planting Early Maturing Crop	75.0	25.0	60.0	40.0	25.0	75.0	80.0	20.0	50.0	50.0	50.0	50.0	65.0	35.0	50.0	50.0	65.0	35.0	50.0	50.0
Soil and Water Management	75.0	25.0	65.0	35.0	20.0	80.0	70.0	30.0	40.0	60.0	50.0	50.0	75.0	25.0	35.0	65.0	65.0	35.0	50.0	50.0
Irrigation	25.0	75.0	25.0	75.0	35.0	65.0	45.0	55.0	15.0	85.0	30.0	70.0	30.0	70.0	15.0	85.0	20.0	80.0	40.0	60.0
Changing Planting date	90.0	10.0	65.0	35.0	35.0	65.0	80.0	20.0	55.0	45.0	75.0	25.0	70.0	30.0	50.0	50.0	70.0	30.0	55.0	45.0
Seek off farm Employment	55.0	45.0	35.0	65.0	15.0	85.0	35.0	65.0	50.0	50.0	35.0	65.0	45.0	65.0	25.0	75.0	50.0	50.0	10.0	90.0

Change in precipitation pattern caused far more serious problems in crop production than temperature change in the study area. This could be evidenced by two of the dominant climate hazards in the study area, namely, flood and erratic rainfall, are resulted from change in precipitation, not in temperature. Even the remaining high level impact climate hazard in the study area, drought, is partly resulted from the change in precipitation. Among those who made adjustment to perceived precipitation change, not less than 40.0% of the respondents in each of the farming villages except in Beni and Shongo implemented soil conservation practices, not less than 45.0% in each farming village except Beni which recorded 30% practiced mixed farming, more than half of the respondents (50.0% and above) at the village level except Beni (with 35.0%) changed planting dates, 85.0% in Badara and Dewu,70.0% in Kirfi and Tubule, 65.0% in Kafin Iya 55.0% in Bara and Guyaba, 50% in Shongo and Wanka, 25.0% in Beni switched to other crop verities, about 50.0% or more of the respondents in each of the farming villages except Beni plant early maturing crops, 45% of the respondents in Dewu and 40.0% from Wanka, 55.0% of the respondents in Badara, 50.0% in Guyaba and Tubule, and 45.0% in Kirfi engaged in off-farm activities. Majority of the respondents believed that under the current constrained environment the adaptation measures employed were best and suitable for the current and future changes of precipitation.

This indicates that the farming community will continue to use the existing adaptation strategies despite increasing effects of rainfall variability in the future unless local specific adaptation interventions are done.

As it was indicated by the farmers there is a problem of rainfall variability in the study area. These problems call for the farmers to take adjustment to tackle the issue. In general, majority of the farmers in the study area adopt one or the other adaptation major, different crop variety and improved crops are the common adaptation strategies used as compare to other adaptation strategies to tackle the adverse impact of rainfall variability.

However, despite the smallholder farmers' willingness to adapt to changing climate pattern in the study area there are some factors that hinders their adaptive capacity.

IV. BARRIERS TO ADAPTATION STRATEGIES

The study explicitly indicated that the farming community had tried to counteract the impact of rainfall variability by employing local adaptation strategies. However, farmers' perceived adaptation measures were not the same with the adaptation measures they actually employed, for lack of access to information, knowledge, productive resources, institutional arrangements, infrastructure, and other factors which are described below

Results on barriers to taking up adaptation options indicated that lack of information (78.8%), lack of capital (90.9), lack of knowledge (90.9%), shortage of farming land (50.0%), not observing climate related problems (81.8), and giving less emphasis to climate related problems (78.8%) to be major constraints of adaptation for most farmers.

Barriers to Adaptation Strategies

Barrier to adaptation strategy	Response			
	Yes		No	
	Frequency	Percentage (%)	Frequency	Percentage (%)
Lack of information	52	78.8	14	21.2
Lack of capital	60	90.9	6	9.9
Lack of knowledge	51	77.3	15	22.7
Shortage of farming land	33	50.0	33	50.0
Not observing climate related problems	54	81.8	12	18.2
Giving less emphasis to climate related problems	52	78.8	14	21.2

The problem of Lack of capital is also among main barrier to adaptation; hence, 90.9% of the reason why the farmer did not take any adaptation measure in the study area was this factor. This is for the reason that capital includes human capital, physical capital as well as financial capital. Therefore, having this capital, for instance, will strengthen the farmers' adaptive capacity. Hence, adaptation to rainfall variability needs money to purchase improved crop and adoption of new technology. Similarly, lack of sufficient land is also among the main barriers to adaptation. Hence, about 50.0% of the reason for not taking any adaptation measures relies on this barrier. In farming activities land is among the main inputs necessarily required. It also has direct impact on farmers' income and their adaptive capacity. For instance, the farmer who has large farm size can have a chance to produce multiple cropping which in turn has a crucial role for risk diversification against climate related problem. Similarly, lack of information, lack of support from government and not giving emphasis by the farmers themselves are also among the barriers to rainfall variability adaptation in the study area.

Regression analysis was estimated to determine the factors influencing a households' choice of adaptation strategies to reduce adverse effect of rainfall variability.

V. ACCESS TO CLIMATE INFORMATION VERSUS CHANGING PLANTING DATE

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.117	.181		6.167	.000
	Access to climate information	.460	.129	.245	3.563	.000

Dependent Variable: Changing planting date

Even though service on climate information delivery is not formal, access to information from different sources has significant impact on the adaptation combination of changing planting date. Indeed, it is an important precondition for farmers to take up adaptation measures (Madison 2006). Getting information about seasonal forecasts and rainfall variability increase the probability of using a combination of changing planting date. Because the availability of better climate and information helps farmers make comparative decisions among alternative adaptation practices and hence choose the ones that enable them to cope better with changes in climate (Baethgen et al., 2003; Jones, 2003).

VI. YEAR OF FARMING EXPERIENCE VERSUS SOIL AND WATER MANAGEMENT

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.497	.166		9.002	.000
	Year of farming experience	.118	.055	.152	2.168	.031

Dependent Variable: Soil and water management

Year of farming experience of the household head, which represents experience, affected adaptation to rainfall variability positively and significantly. Because as the year of farming experience of the household head increases, the person is expected to acquire more experience in weather forecasting and that helps increase in likelihood of practicing different adaptation strategies to rainfall variability. This result is in line with the findings of Deressa et al. (2008); Ajibefun and Fatuase (2011); Nhemachena and Hassan (2007); Maddison (2006) and Ishaya and Abaje (2008)

VII. RESPONDENTS' PERCEPTION VERSUS PLANTING EARLY MATURING CROPS

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	.553	.548		1.010	.314
	Respondents' perceptions on changing climate	1.223	.536	.160	2.282	.024

Dependent Variable: Planting early maturing crop

The results show that perceptions of households towards rainfall variability, significantly (p=0.024) influence the choice planting early maturing crops. The results suggest that when households perceive a change in climate, the probability for not adapting becomes reduced

Perception in the context of adaptation is considered an important aspect for the stressed to awake and take initiatives as well as measures to adapt (Maddison, 2006). Understanding smallholder farmers' perception on their local climate is significant because it raises individual cognition (Grothmann and Patt, 2005) to what he/she should do to adapt and hence, having a bearing on adaptive capacity. For smallholder farmers, for example, perception on changes in the local climate may help them to make decisions at the right time to either change their practices to accommodate themselves to the changes or do otherwise to adapt. It is in this line of argument that perception was necessary to be identified as a first step before getting into other details. Maddison (2006) suggests that perception is an important aspect and a first step in the adaptation process as he wrote.

VIII. LEVEL OF EDUCATION LEVEL VERSUS CHANGING CROP VARIETY

Model		Unstandardized Coefficients		Standardized Coefficients	T	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.384	.179		7.747	.000
	Level of education	.127	.057	.157	2.236	.026

Dependent Variable: Change crop variety

Level of education is one the statistically significant explanatory variable at 5% level of significance as shown by a p-value of 0.026 as shown in the table 4.5. It had a positive and strong relationship with the dependent variable showing that education increases the probability of adapting to climate change. The beta is positive implying that education has a positive influence in decision of changing crop varieties as well as taking other adaptation measure to rainfall variability. This could possibly, literate farmers who are more likely to respond to rainfall variability by making best adaptation option based on his preference and influences individual decision making as it tends to reduce farmers' risk aversion. This finding is in line with the investigation of Maddison (2006). It is also in support of the findings of Deressa et al (2009) who found a positive relationship between education and adaptation to rainfall variability in Ethiopia.

IX. CONCLUSIONS

The study revealed that the smallholder farmers adopt many agronomic practices, or socio-cultural practices to cope and adapt to rainfall variability. While rainfall variability is an environmental problem, the scope of its impacts is strongly determined by underlying socioeconomic variables. The study concludes that, perceiving that the climate is changing increases the probability of uptake of certain adaptation strategies by the smallholder farmers.

Farm level decision making occurs over a very short period of time, usually influenced by seasonal climatic variations, local agricultural cycle and other socio-economic factors. Adaptation is important for smallholder farmers to achieve their farming objectives such as food and livelihood security, high income and significantly reduce the potential negative impacts that are associated with rainfall variability and other socioeconomic conditions.

This study explored the determinants of households use of about four adaptation strategies (changing crop variety, planting early maturing crops, soil and water management techniques, and changing planting date (given the high perception that timing of rain is changing)). These adaptation options if adopted on a larger scale will enhance management of the impacts of rainfall variability in the study area and assist in rainfall variability mitigation.

It is therefore recommended that Policies aimed at promoting farm-level adaptation need to emphasize on the crucial role of providing information on better production techniques and enhancing farmers' awareness on rainfall variability to enable farmers adapt to rainfall variability. The role of appropriate climate forecast is very crucial for pre-informing the farmers about the future weather condition.

REFERENCES

[1] Ajibefun A. and Fatuase A. (2011), Analysis Of Perception And Adaptation To Climate Change Among Arable Crop Farmers In Ikogosi Warm Spring Communities Of Ekiti State, Nigeria.

[2] Baethgen W.E., H. Meinke, and A. Gimene. (2003). Adaptation of agricultural production systems to climate variability and climate change: lessons learned and proposed research approach. Paper presented at Climate Adaptation.net conference "Insights and Tools for Adaptation: Learning from Climate

Variability," 18-20 November, 2003, Washington, DC.

[3] Chambers, R., (1994). The origins and practice of participatory rural appraisal. World Development, 22(7), 953-969. Doi: org/10.1016/0305-750X(94)90141-4.

[4] Deressa, T.T., Hassan, R.M., Ringler, C., Alemu, T., and Yesuf, M. (2009), Determinants of Farmers' choice of adaptation methods to Climate change in the Nile Basin of Ethiopia.Global Environmental Change 19, 248-255.

[5] Ekpoh IJ (2010). Adaptation to the Impact of Climatic Variations on Agriculture by Rural Farmers in North-Western Nigeria. J. Sustain. Develop. 3(4): 194-202.

[6] Eriksen, S., Aldunce, P., Bahinipati, C. S., Martins, R. D., Molefe, J. I., Nhemachena, C., O'Brien, K., Olorunfemi, F., Park, J., Sygna, L. and Ulsrud, K. (2011). When not every response to climate change is a good one: Identifying principles for sustainable adaptation. Climate and Development, 3: 7–20.

[7] FAO, (2008). Climate Change and Food Security: A Framework Document. FAO: Rome.

[8] Funk, C.C., Brown, M.E., (2009). Declining global per capita agricultural production and warming oceans threaten food security. Food Security. 1, 271–289.

[9] Fu¨ ssel, H.-M., (2010). How inequitable is the global distribution of responsibility, capability, and vulnerability to climate change: a comprehensive indicator-based assessment. Global Environ. Change 20, 597–611.

[10] Gourdji, S.M., Mathews, K.L., Reynolds, M., Crossa, J., Lobell, D.B., (2013). An assessment of wheat yield sensitivity and breeding gains in hot environments. Philos. Trans. R. Soc. B 280, 20122190.

[11] Grothmann T. and Patt, A. (2005). Adaptive capacity and human cognition: The process of individual adaptation to climate change. Global Environmental Change, 15:199–213.

[12] Intergovernmental Panel on Climate Change (IPCC). (2007a). Climate Change, 2007: Impacts, Adaptation and Vulnerability. Exit Epa Disclaimer Contribution of working group II for the fourth assessment report of the intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom.

[13] Ishaya, S. and Abaje, I.B., (2008). Indigenous people's perception of climate change and adaptation strategies in Jema's local government area of Kaduna State, Nigeria. Journal of Geography and Regi. Planning, 1 (18):138-143.

[14] Jarvis, A., Lau, C., Cook, S., Wollenberg, E., Hansen, J., Bonilla, O., Challinor, A., (2011). An integrated adaptation and mitigation framework for developing agricultural research: synergies and trade-offs. Exp. Agric. 47, 185–203.

[15] Jones, J.W. (2003). Agricultural responses to climate variability and climate change. Paper presented at Climate Adaptation.net conference "Insights and Tools for Adaptation: Learning from Climate Variability," November 18-20, 2003. Washington, DC.

[16] Kurukulasuriya, P. and Mendelsohn, R. (2006). A Ricardian Analysis of the Impact of Climate change on African Cropland. CEEPA Discussion Paper No. 8. Centre for Environmental Economics and Policy in Africa, University of Pretoria.

[17] Kurukulasuriya, P and R. Mendelsohn, (2008). Crop switching as a strategy for adapting to climate change. Afr. J. Agric. Resour. Econ., 2: 105-125.

[18] Lobell, D.B. and Field, C.B., (2007). Global scale climate–crop yield relationships and the impacts of recent warming. Environ. Res. Lett. 2, 014002.

[19] Lobell, D.B., Banziger, M., Magorokosho, C., Vivek, B., (2011a). Nonlinear heat effects on African maize as evidenced by historical yield trials. Nat. Clim. Change 1, 42– 45.

[20] Lobell, D.B., Schlenker, W., Costa-Roberts, J., (2011b). Climate trends and global crop production since 1980. Science 333, 616–620.

[21] Maddison, D. (2006). The perception of and adaptation to climate change in Africa. CEEPA Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa, University of Pretoria, South Africa. 47pp.

[22] Mendelsohn, R., Nordhaus, W.D., Shaw, D., (1994). The impact of global warming on agriculture—a Ricardian analysis. Am. Econ. Rev. 84, 753–771.

[23] Nhemachena, C., and R. Hassan. (2007). Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper No. 00714. International Food Policy Research Institute, Washington, D.C.

[24] Nhemachena, C., R. Hassan and P. Kurukulasuriya, (2010). Measuring the economic impact of climate change on African agricultural production systems. Climate Chang. Econ., 1: 33-55.

[25] Nyong, A., Adesina, F., and Elasha, B., (2007). The value of indigenous knowledge in climate change Mitigation and adaptation strategies in the African Sahel. Mitigation and Adaptation Strategies for Global Change, 12: 787–797.

[26] Pass, (2003). Retrieved from: ochaonline.un.org/Ocha LinkClick.aspx?link=ochaanddocid=34913.

[27] Schlenker, W., Lobell, D.B., (2010). Robust negative impacts of climate change on African agriculture. Environ. Res. Lett. 5, 014010.

[28] Skoufias, E., Rabassa, M., Olivieri, S., (2011). The poverty impacts of climate change: a review of the evidence. World Bank Policy Research Working Paper No. 5622 The World Bank, Washington, DC.

[29] Smit, B., Burton, I., Klein, R. and Street, R. (1999). The science of adaptation: a framework for assessment. Mitigation and Adaptation Strategies for Global Change, 4, 199–213.

[30] Smit, B., Burton, I., Klien, R. J. T. &Wandel, J. (2000). An Anatomy of Adaptation to Climate change and Variability.Climate Change45:223-251

[31] Smit, B. and Pilifosova, O. (2001). Adaptation to Climate Change in the contexts of Sustainable Development and Equity. In: Climate Change 2001: Impacts, Adaptation and Vulnerability. J. J. McCarthy, O. F. Canziami, N. A. Leary, D. J. Dokken, and K. S. White (editors). Intergovernmental Panel on Climate Change, Cambridge University Press, New York. Pp. 876-912.

[32] Zimmerman, F.J. and Carter, M.R. (2003). Asset smoothing, consumption and the reproduction of inequality under risk and subsistence constraints. Journal of Development Economics 71 (2): 233-260.