Climate Change Impacts and Adaptation Among Coastal and Mangrove Dependent Communities: A Case of Bagamoyo District

Mbwambo, J.S., Ndelolia, D., Madalla, N., Mnembuka, B., Lamtane, H.A., Mwandya, A.W., and Zahabu, E.
Sokoine University of Agriculture

Abstract

The study was done to determine perception, impacts and adaptation of coastal communities towards climate change. A total of three villages and 120 respondents were involved in the study. Both Focus Group Interviews and a structured questionnaire survey were employed for collection of both qualitative and quantitative data. Content and structural functional analysis was used for qualitative data while descriptive and logistic and regression analysis was employed for quantitative data. Results indicates that majority of the community are involved in both fishing and farming activities for both food and cash income. Results indicates further that majority of the respondents are aware of climate change and they perceive the same in relation to unusual rainfall (87.5%), drought (93.3%), floods (74.1%) and increased incidence of pest and diseases (55.8%). It was also found that farmers are coping with food insecurity as a result of declining food stocks and they have also developed adaptation strategies related to farming operations and livelihoods. However, adaptation varies depending on various farm and household factors and in this income, number of plots, extension services and farm size were highly significant and showed strong positive influence on adaptation to climate change. It is concluded that farmers are aware of climate change and have developed both coping and adaptation strategies against climate hazards. Promotion of extension and enhancement of off-farm activities are recommended for enhancing adaptive capacity of the population in the study area.

Key words: *Climate change, Adaptation and Mangrove Forests*

1.0 Introduction

1.1 Background information

Mangrove forest represent a vitally important coastal ecosystem as they offer coastal zone protection, and serve as an important carbon sink, effective sediment trap, and an important nursery and feeding ground for many marine species (Fig. 1). Studies conducted in Tanzania have showed that mangrove forests offer major socio-economic benefits to coastal communities and beyond (Semesi, 1998; Sesabo, 2006). Mangroves create unique ecological environments that are rich in species diversity (Kathiresan & Bingham, 2001; Lugendo, 2007) and supports the economically important fisheries sector in Tanzania. The fisheries sector directly employs about 70,000 people while an additional two million people indirectly depend on the industry through associated activities including processing, marketing, distribution and the supply industries (URT, 2008).

Climate change affects mangrove ecosystem and its associated fisheries directly and indirectly. It affects fisheries directly through changes in the distribution and composition of fish stocks, driven by subtle changes in recruitment patterns (Tolan and Fisher, 2009). Moreover, a number of critical stages in the life history of coastal fishes, especially larval recruitment, are sensitive to subtle change in temperature. Thus, the key impacts of climate change are associated with these factors together with other related parameters such as changes in the intensity, timing and spatial distribution of precipitation.

While mangroves are affected by the climate change, they can be used as carbon sinks just like other forest resources because of their high capacity for sequestering carbon. Being primary producer, mangroves utilize solar energy and carbon dioxide to produce organic carbon. Much of the carbon fixed by mangroves is retained as standing biomass (Alongi, 2002). Maximum retention of nutrients notably carbon is facilitated by ion immobilisation in soils, litter retention and incorporation into sediments and high nutrient use efficiency by mangroves (Alongi, 2002, Alongi *et al*. 2005). Given these characteristics, mangroves are recognized as being more effective ¨carbon sinks¨ than terrestrial forests (Alongi *et al*. 2005). As such, mangrove forests could effectively be used for implementing future Reduced Emissions from Deforestation and forest Degradation (REDD) scenarios. If not properly planned and managed, mangrove deforestation and degradation will not only lead to reduced carbon squestration, but will also result in the release of carbon stored in the trees and sediments to the atmosphere, further contributing to global warming.

It is anticipated that climate changes, especially global warming, will have harmful effects on coastal marine ecosystems such as mangroves. Given the importance of mangroves as nursery grounds, these anthropogenic and natural impacts will ultimately lead to a decline in fishery resources. Therefore, understanding the mechanisms through which climate change may affect mangrove ecosystem and fisheries resources, it is important to design and develop mitigation and adaptation strategies. However, this cannot be accomplished without a clear analysis and documentation of community related climate change impacts and adaptation. This is because local communities are not excluded from climate variability and change associated with longer droughts, erratic rainfall and floods that ultimately leads to climate change impacts in their life mostly in the field of agriculture, fisheries and the overall natural resources management. One thing which is important is, depending on their vulnerability and sensitivity, local communities are coping and adapting to climate change impacts using locally developed knowledge, skills and experiences. However, such communities' adaptive innovations, techniques, methods and processes are location and community specific. Documentation of perception and adaptive practices developed and practiced by farmers in Bagamoyo form the basis for this paper.

1.2 Statement of research problem and justification

Tanzania, like other sub-saharan countries is highly vulnerable to effects of climate change mainly because of the lack of stable economic development and institutional capacity (IPCC, 2001). The negative impacts associated with climate change are also compounded by many factors including prevalent poverty, human diseases, and high population density, which increases the demand for food and water. Productivity of coastal fisheries relies heavily on the presence of healthy marine ecosystems including mangroves and coral reefs and seagrass beds. These biologically diverse marine ecosystems display a synergistic relationship based on their connectivity (Mumby *et al*., 2004), and together act as importance nursery areas for a variety of fish and crustacean species. Mangrove forest and fisheries resources are threatened by climate change due to variations in physico-chemical parameters of the ocean such as water temperature, salinity, wind speed, sea level and currents. It has been claimed that climate shifts e.g. 1°C increase in sea temperature, may produce major changes in dominant fish stocks as well as primary and secondary production (IPCC, 2001). Moreover, the biologically diverse mangrove forests, which are already being threatened by a variety of anthropogenic impacts, are now additionally being threatened by climate change and variability (Kathiresan & Bingham, 2001; IPCC, 2001). It has been established that mangrove degradation can lead to significant loss of carbon which otherwise would be sequestered

.

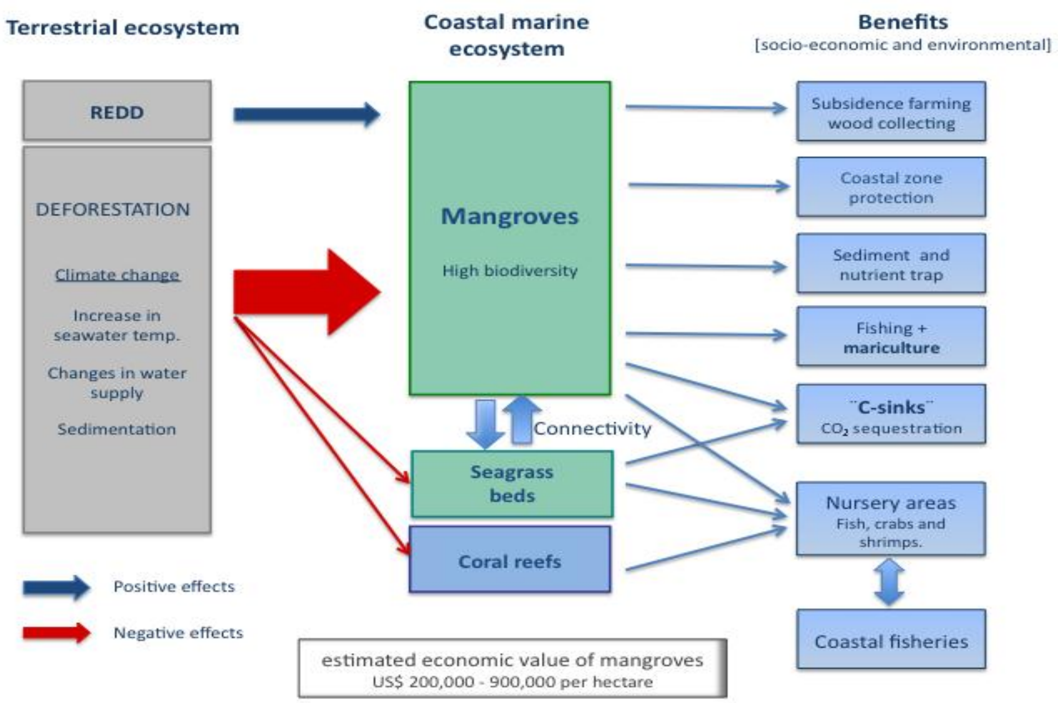

Figure 1. Inter-relationship between terrestrial and coastal marine ecosystems.

The continued degradation of coastal mangrove forests through increased anthropogenic activities together with indiscriminate deforestation may lead to a serious decline in fishery resources. While there is evidence of climate change in Tanzania (see for example, URT, 2007 and Majule, 2009) the impact of the same on communities depending on fisheries and mangrove forests resources is not well documented for Tanzania. Using data collected from Bagamoyo in the Coastal Region of Tanzania, this paper presents findings indicating climate change impacts, vulnerability and adaptation. Beginning with the conceptual framework the rest of the paper is organised into three sections. Following the conceptual framework is a section on the methodology followed by a section on the results and discussion. The paper ends with conclusion and recommendation under section four.

1.3 Conceptual framework

This study adopted and modified approaches used by Ayanwuyi *et al.*, (2010) and Dolan and Walker (2004). In their analysis of climate change impact and adaptation the authors uses a community based approach. It is argued that local communities perceive climate as having a strong spiritual, emotional, and physical dimension. It is therefore assumed that these communities have an inborn, adaptive knowledge from which to draw and survive in high-stress ecological and socio-economic conditions. Thus, the human responses are critical to understanding and estimating the effects of climate change on production and food supply for ease of adaptation. Accounting for these adaptations and adjustments is necessary in order to estimate climate change mitigations and responses (Apata *et al.*, 2009). However, adaptation and adjustments made by individuals of members of communities are associated with vulnerability. The Intergovernmental Panel on Climate Change defines vulnerability as the extent to which a natural or social system is susceptible to sustaining damage from climate change. In this study, vulnerability was taken as a function of sensitivity of individual or members of the community to climate change and their ability to adapt to changes i.e. adaptive capacity. As Figure 2 shows, vulnerability and later adaptation will very much depend on the exposure and the adaptive capacity depending on the socio-economic and demographic features of an individual or members of the community

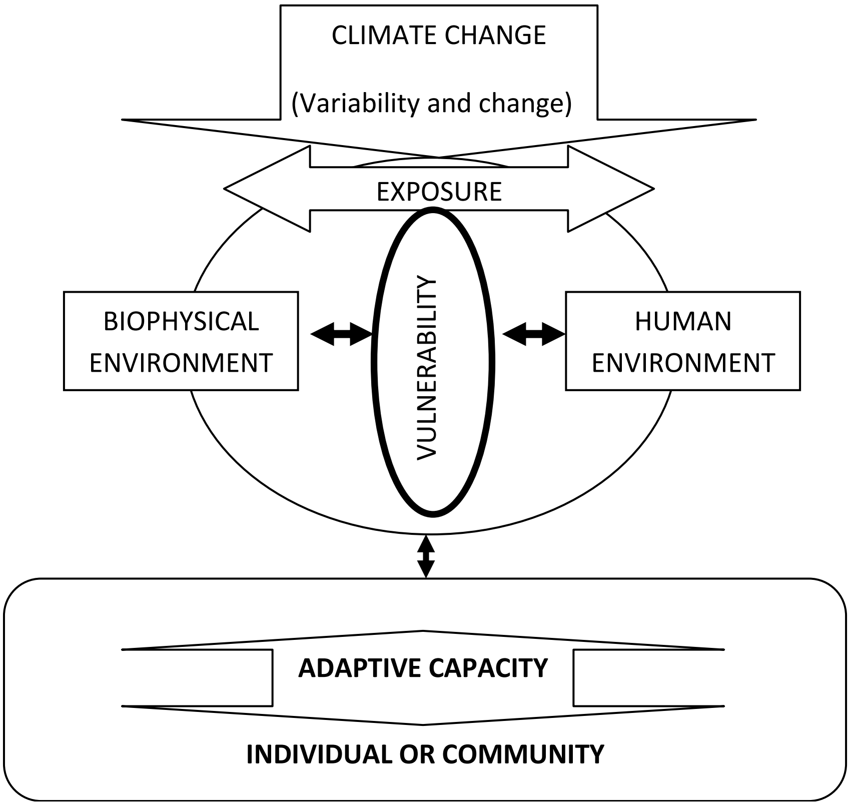

Figure 2: Conceptual framework adopted and modified from Ayanwui *et al.*, (2010) and Dolan and Walker, (2004)

2.0 Methodology

2.1 Study areas description:

The Tanzania coastline extends over 800 Km stretching fronm latitude 4^o 47' at the border with Kenya in the North to the border with Mozambique in the south at latitude 10^o 28'. Mangroves along the Tanzania coast occur on gently sloping shores, and around river estuaries, creeks and bays. The mangroves of mainland Tanzania cover a total area of about 115,500 ha, the largest area being Rufiji delta. Fairly large areas are also found in Tanga, Kilwa and at the estuaries of Ruvu, Bagamoyo, Wami, Pangani and Ruvuma Rivers (Semesi, 1991)

Mangrove forests of Bagamoyo form a more or less continuous band along the 100 km coastline from Saadani to Kitine River. They cover an area of 5635 ha (Semesi, 1991). Four areas including Wami river 862 ha, Utondwe creek, 834 ha, Ruvu river, 2123 and South of Bagamoyo to Mpiji river, 809 ha form the main mangrove stands. The number of fishermen in Bagamoyo is estimated to be about 1100 and are scattered in several villages along the coastline. The major landing sites include Saadani, wami river, Manyema, Kitane, Buyuni, Bagamoyo Town, Mlingotini, Kaole, Mbegani and Ruvu River Camp.

2.2 Methods of data collection

This study used the participatory tools and methods in order to generate qualitative and quantitative information about climate change impacts and community based adaptation strategies to climate change. Primary information was acquired using focus group discussions (FGDs) with farmers. The groups consisted of 8-12 members of the same sex. Several questions of production systems, climate variability and change, vulnerability and adaptation were used to lead the discussion. Moreover, during FGD, participatory tools like matrix ranking (impact of risks and disasters vs. livelihood assets), timeline (for identifying major events and frequency of occurrence) and local knowledge documentation (documenting local knowledge, technology and practices related to coping and adaptation strategies) were applied. Gender, age, social position and income of respondents were considered during the process.

2.3 Household survey

A structured interview scheduled was used to collect data from 120 systematically and randomly selected respondents. Table 1 show the overall sample size from each village and the representation of male and female respondents included in the sample for this study .

Table 1: Proportion of sampled population by sex

SEX	NAME OF THE VILLAGE			TOTAL
	Mlingotini (n=55)	Pande (n=28)	Kondo (n=37)	
Male (%)	81.8	92.9	78.4	83.3
Female (%)	18.2	7.1	21.6	17.7
Total	100	100	100	100

Content analysis was used to analyse qualitative information from FGDs and quantitative data were subjected to descriptive statistics, such as frequency counts, tables and percentages.

A logit model was adopted to analyse the determinants of adaptation to climate change. The choice of the independent variables was based on the literature by Apata *et al*., (2009) and Ghazouani and Goaied, (2001). The logit model is specified as:

$Li(Di=1)= 1/1+e^{ii}$ -----------------------(1)

Where Li is a linear combination of explanatory variables of interest in this study (X_1-X_n), therefore,

$Li=ß_0+ßX_1+ßX_2+ßX_3+ßX_4+ß_5+....ß_n$ ----(2)

In this, the dependent variable is dichotomous i.e. one in which the respondent may develop and practice adaptation options or not. Some of the explanatory variables used in the analysis are farm size, household size, farming experience, education in years, age of the respondent, access to extension services, income and sex of the respondents.

3.0 Results and Discussion

3.1 Demographic and socio-economic characteristics of the respondents

Table 1 show that 25.2% of the respondents were above 56 years of age, 17.5% fell between the age range of 46-55 while 25.8% and 23.3% were between the age ranges of 36- 45, and 26-35 years, respectively. Data further shows that about 83.0% of the respondents were male and more that 85% were literate. Majority of the respondents are involved in both farming and fishing as indicated in Figure 3
.

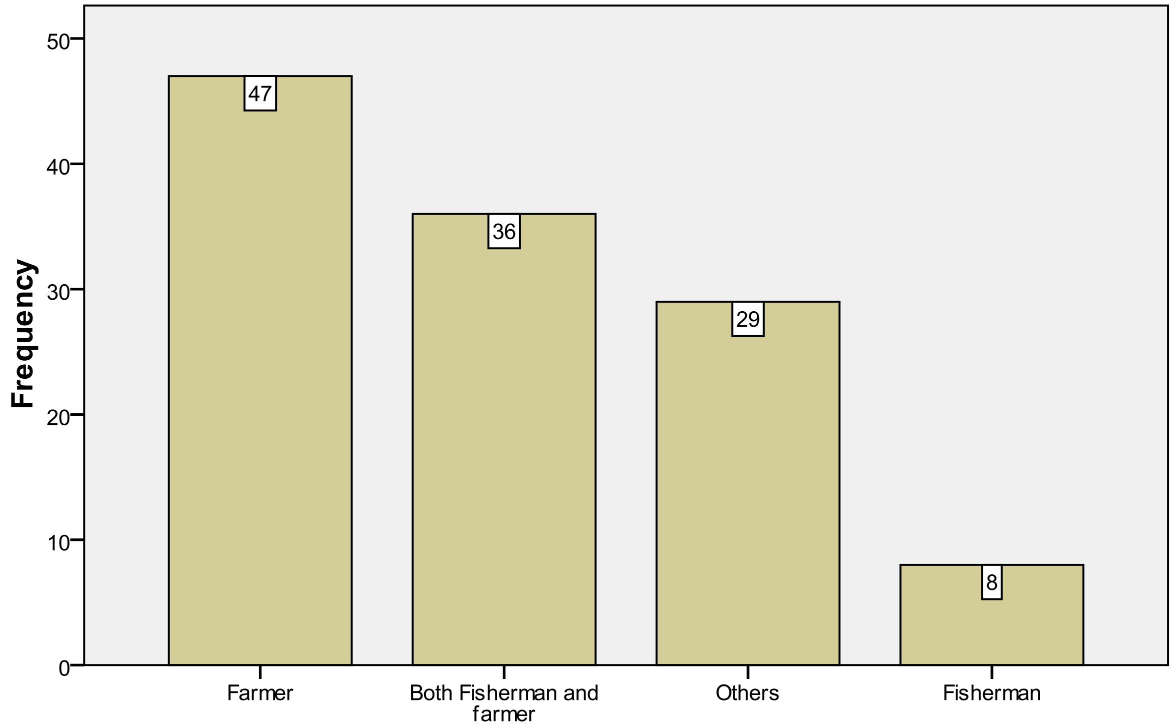

Figure 3: Main Occupation of the respondents

Figure 4: Reasons fishing in the study area

It is important to note from Figure 3 that a significant number of the respondents and hence the population is engaged in both farming as fishing. This as indicated in Figure 4 is done for both food and household income. This implies that any changes that may lead to the decline in fishing and or farming would have severe impacts on nutrition and the overall welbeing of the people in the study area.

3.2 Farmers perception on climate change

Data in Table 2 indicates that respondents perceived climate change in relation to weather and climate variables. As Table 2 shows, more than 87 percent of the respondents perceived climate change in relation to unusual timing and the amount of rainfall.

Table 2. Community perception of climate change

Events	Frequency*	Percent
Unusual/untimely rainfall	105	87.5
Prolonged drought	112	93.3
Floods	89	74.1
Pest and disease	67	55.8

***Multiple responses**

However, while respondents perceived climate change as indicated under Table 3, it is important to note from Focus Group Discussion that such changes could be traced back in history as presented in the next section.

3.3 Climate risks and hazards: A historical review

Past and current climatic stresses and frequencies of such stresses were analyzed using timeline over the 30 years. These subjective perceptions of farmers revealed that how the communities are affected by climate stresses over the years. According to respondents, climate risks and hazards are increasing in terms of magnitude; frequency and severity of impacts are high as compared to past events. While discussing and drawing timeline, almost 90% of the respondents perceived that risks and uncertainty of the climate has increased. The timeline showed that occurrence of climatic stresses like drought increased in recent years as compared 25 - 30 years back. Based on timeline; floods, drought, erosion and increased crop pests and disease were seen as most prominent climatic stresses in the studied villages.

3.4 Climate change impacts

This study attempted to analyse the impact of climate change as perceived by farmers in the study area. Using a scale of low to high impact, data indicates that Infrustructure and Agricultural sectors are most hit by climate change as indicated in Table 3. Others includes Mangroves forest and water sources.

Table 3: Climate change impact on selected vulnerability sectors

Threat/Sector	Agriculture	Infrustructure	Mangrove forest	Water sources	Total	Rank
Delayed rainfall	4	3	3	4	14	1st
Floods	4	3	2	1	10	2nd
Droughts	4	3	3	4	14	1st
Beach erosion	3	4	4	3	12	3rd
Pest and disease	4	2	1	1	9	4th
Total	19	15	13	13		
Rank	1st	2nd	3rd	3rd		

1 = low/no impact; 2 = Medium impact; 3 = High impact; 4 = Severe impact

Climate change impacts on agriculture was associated with low yield of crops (83%); stunted growth (11%) and higher incidences of pests and diseases (9%). This as indicated in Figure 5 contributes to the decline in food stocks and hence food insecurity

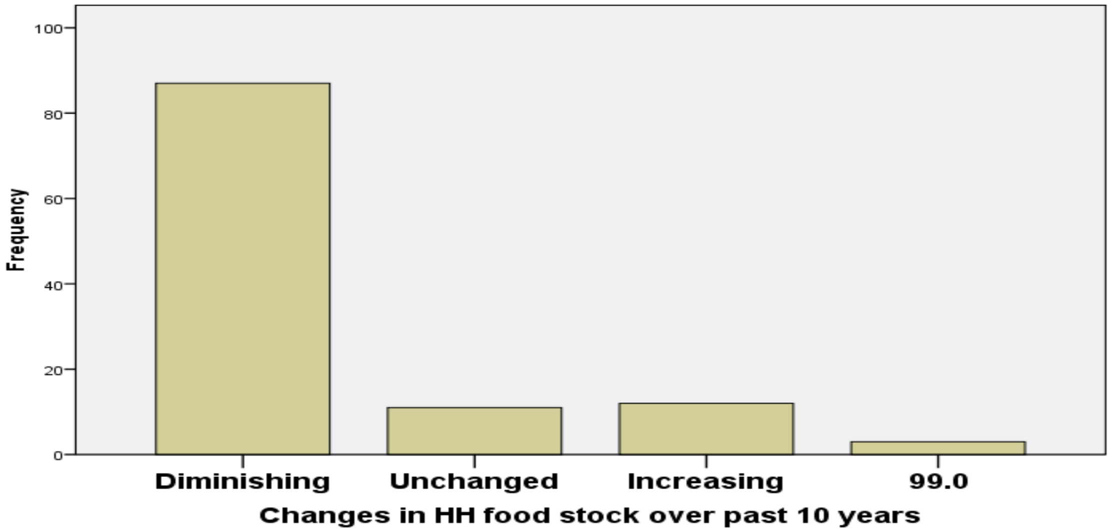

Figure 5: Changes in food stocks over the past 10 years

However, this varies depending on the types of crops and location where farming is practiced. For instance, farming in lowlands tends to benefit from prolonged drought campared to farming in raised areas and vice versa.

It is important to note that respondents could not associate climate change with declining fish catch and composition. Instead, they pointed out a number of factors indicated in Figure 6. However, the fact that mangroves forests were also ranked among sectors affected by climate change implies that the decline in fish catch and composition is associated with climate change impacts on mangroves forests because, as seen in the introduction, mangroves forests are known as vital breeding sites for fish and associated organism

.

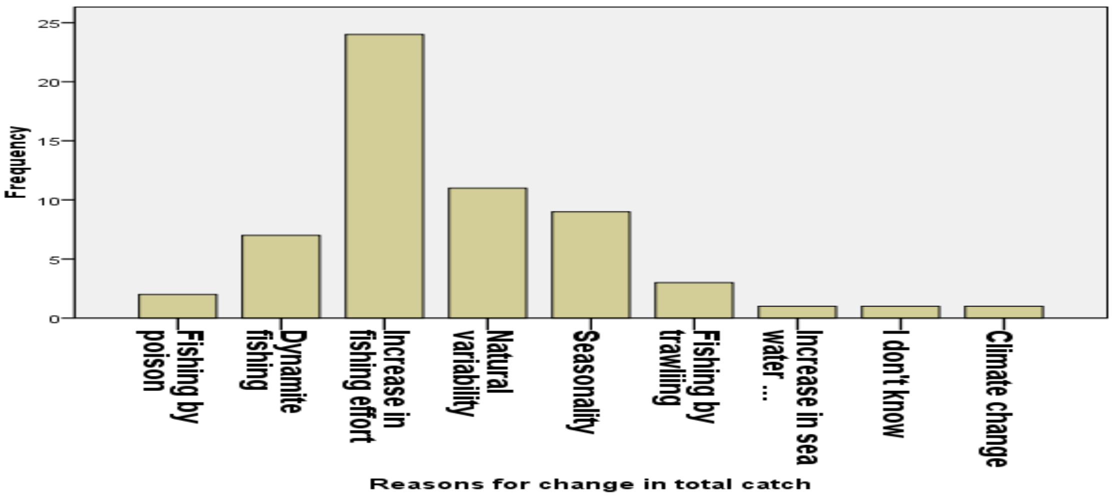

Figure 6: Factors responsible for declining fish catch and composition

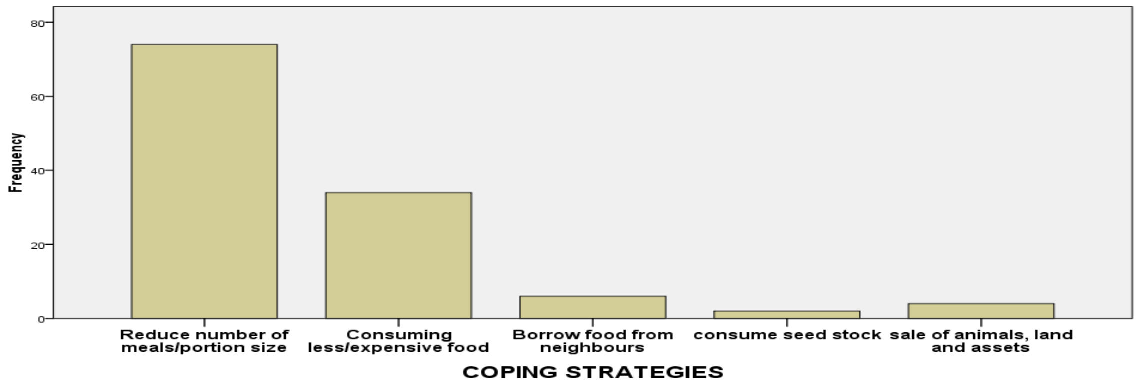

Figure 7: Coping starategies

3.5 Perceived coping and adaptation strategies

Results in Figure 7 indicates that most of the respondents developed coping strategies in relation to food security. Majority of them reduced number of meals serve per day as a result of reduced food stock explained earlier.

However, while reduction of food stocks resulted into the development of temporary measures to sustain households over periods of food shortages, a number of permanent and sustainable adaptation strategies were also documented. Such adaptation strategies are related to farming operations and household livelihoods as presented under Table 4.

Table 4: Adaptation strategies to climate change

Adaptation Practice	Frequency*	Percent
Farming operations		
Use of fertilizers	50	41.7
Change of planting dates	112	93.3
Plots diversification	117	97.5
Mixed cropping	89	74.2
Mixed farming	92	76.7
Household livelihood		
Undertake non-farm activities	113	94.2
Sale of household labour	87	72.5
Reduce expenditure	120	100.0
Migration	54	45.0
Borrowing	88	73.3

*Multiple responses

3.6 Determinants of adaptation to climate change

Results in Table 5 shows a significant model with most of the explanatory variables considered being significant as either 10% or 5%. The results shows that age and sex of the respondents had no effect on adaptation. All explanatory variables related to farm and livelihood factors were significant implying that farmers are likely to develop adaptation practices when farming and livelihoods is compromised by climate change. In this, household income, number of plots owned, farm size, education and access to extension services have strong positive influence on adaptation while household size have negative influence on adaptation.

Table 5: Results from Logistic regression

		Likelihood function= -112.45 Significant level = p<00001 Constant = 0.65
Variable	**Estimate**	**t-value**
Age	0.2433	0.4121
Sex	-0.6122	-0.7421
Household Income	0.9120	4.342***
Number of farms owned	0.5798	2.900***
Household size	-0.126E+10	-4.4362***
Years of farming	0.5187	2.589*
Farm size	0.84266	2.1253**
Education in years	0.1126	5.01***
Access to extension	0.371	2.745**

* Significant at p<0.01; ** Significant at p<0.005, *** Significant at p<0.001

4.0 Conclusion and recommendation

It is etablished from this study that famers were aware of climate change and its impacts on food security and the overall livelihoods. Furthermore farmers are able to develop both copping and adatation strategies related to crop production and household livelihood in a way that allowed them to constantly cope with an erratic impacts of climate change on food and livelihoods. Reduction of number of meals as a results of deminishing food stocks, crop and farm diversification are some of copping and adaptation strategies developed and practiced by famers. In case of livelihoods, the study showed that famers decided to engage into off-farm activities as a way of adapting to climate change. Results from logistic regression analysis showed that household income, number of plots owned, farm size, education and access to extension services have strong positive influence on adaptation while household size have negative influence on adaptation.

It is therefore recommended that promotion of off-farm and climate risk reduction activities would enhance farmers adative capacity. Thus, interventions such as farmers groups for non-farm activities, small and medium enterprises would be helpful in enhancing both copping and adaptive capacity of the farmers in the study area. Moreover, educational intervention and placement of extension staff may have significant impact on enhancing farmers ability too develop and use climate change adaptation strategies.

References

Apata T.G., Samwel K.D. and Adeola, A.O (2009).Analysis of climate change percetion and adaptation among arable food crops farmers in South Western Nigeria. Paper presented at the International Association of Agricultural Economists, Beijin, China, August 16-22 2009. www. Globaljournal.org.

IPPC (2007). Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of the Working Group II to the Third Assessment Report of IPCC. Cambridge University Press, Cambridge, UK. Pp 1000.

Ghazouan, S.i and Goaied, M. (2001). The determinants of urban and rural poverty in Tunisia. Laboratoire d'Eonometric Appliquee (LEA) facultedes Sciences Economiques et de Tunis.

Ayanwuyi, E.K., Ogunlade, F.A. and Oyetoro, J.O. (2010). Farmers perception of impact of climate changes on food crops in Ogbomosho Agricultural Cone of Oyo State, Nigeria. Global Journal of Human Social Science. Vol. 10 (7), pp 33-39.

Dolan, A.H. and Walker, I.J. (2004). Understanding of vulnerability of coastal communities to climate change related risks. Journal of Coastal Research, 39.

Alongi, D.M. 2002. Present state and future of the world´s mangrove forests. *Environmental Conservation*, **29**: 331-349.

Alongi, D.M., Pfitzner, J., Trott, L.A., Tirendi, F., Dixon, P., Klumpp, D.W. 2005. Rapid sediment accumulation and microbial mineralization in forests of the mangrove *Kandelia candel* in the Jiulongjiang

Estuary, China. *Estuarine, Coastal and Shelf Science*, **63**: 605-618.

IPCC, 2001. Intergovernmental Panel on Climate Change. Summary for policymakers. A Report of Working Group 1 of the Intergovernmental Panel on Climate Change, pp. 1-20. R.T.Watson, ed. Cambridge: Cambridge University Press.

Kathiresan, K. and Bigham, B.L. 2001. Biology of mangroves and mangrove ecosystems. *Advances in Marine Biology*, **40**: 81-251.

Lugendo, B.R. 2007. Utilisation by fishes of shallow-water habitats including mangroves and seagrass beds along the Tanzanian coast. PhD Thesis, Faculty of Science, Radboud University Nijmegen, The Netherlands, 168pp.

Mumby ,T. 2004. Mangroves enhance the biomass of coral reef fish communities in the Caribbean. *Nature*, **427**: 533-536.

Semesi, A.K., Mgaya, Y.D., Muruke, M.H.S., Francis, J., Mtolera, M. and Msumi, G. 1998. Coastal resources utilization and conservation issues in Bagamoyo, Tanzania. *Ambio*, **27**: 635-644.

Sesabo, J. 2006. Marine resource conservation and poverty reduction strategies in Tanzania. Hamburg studies on maritime affairs 8: 131pp.

Tolan, J.M., Fisher, M. 2009. Biological response to changes in climate patterns: population increases of gray snapper (*Lutjanus griseus*) in Texas bays and estuaries, *Fishery Bulletin*. **107**: 36–44