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Climate Change Impact and Adaptive Strategies in The Rufiji Delta, Tanzania

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Abstract

This article investigates the evidence of climate change and adaptive strategies in the Rufiji Delta in Tanzania. It describes local perceptions of climate and its associated changes, examines indicators of climate change, explores the effects of climate change on livelihood activities, and identifies the coping and adaptation strategies by local communities and other parties. Drawing on results generated from a combination of qualitative and quantitative techniques, the study finds that livelihood activities in the area, especially farming and fishing are already affected by climate change exhibited by, among other things, dwindling crop productivity and declining fish catch accompanied by disappearance of certain fish species. Subsequently, the study notes increasing scarcity of basic household necessities especially food and water, associated with the observed frequent dry spells and altered rainfall patterns. Moreover, the impact of sea water rise on settlements, underground aquifers and soils is noted.

Keywords: *climate change, livelihood, Rufiji Delta, Tanzania.*

1.0 Introduction

Climate[4] exerts a significant control on the day-to-day economic development of Africa at regional, local and household scales, and particularly in the agricultural and water resources sectors (IPCC, 2007b). The continent is highly vulnerable to the impact of climate change[5] because of widespread poverty, recurrent droughts, inequitable land distribution, and over-dependence on rain-fed agriculture (IPCC,

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[4] The IPCC (2001b) defines climate as the "average weather," or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands of years. The classical period is 3 decades, as defined by the World Meteorological Organisation (WMO). These quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system.

[5] Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. This usage differs from that in the *United Nations Framework Convention on Climate Change (UNFCCC)*, which defines "climate change" as a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (*ibid*).

2001b). The gradual, yet dramatic disappearance of glaciers on Mount Kilimanjaro, for instance, is a result of global warming (*ibid*). The ice cap on the mountain has been in a general state of retreat since the end of the little ice age around 1850. This retreat was driven by natural climatic shifts (particularly a decline in regional precipitation), but appears to have accelerated due to the warming observed in the second half of the 20th century. In 1976 the glaciers covered an area of 4.2 km^2 (Hasternrath & Greischar, 2001), compared with only 2.6 km^2 in 2000 (Thompson *et al.*, 2002). Based on measurements taken on the mountain between 2000 and 2001, it is indicated that its glaciers are not only retreating but also rapidly thinning (*ibid*).

The impact of climate change in Tanzania is not only evident on the slopes of Africa's highest mountain, but also in its maize fields. Estimates of the effects of climate change on maize yields in Tanzania are available from model runs of the Crop Environment Resource Synthesis Model (CERES-Maize) (Jones & Kings, 1986). In general, simulation results show that maize yields were lower between 1996 and 2002 compared to former years, a result of higher temperatures and, where applicable, decreased rainfall. The average yield decrease over the entire country during that time was 33%, but simulations produced decreases as high as 84% in the central regions of Dodoma and Tabora. Yields in the north-eastern highlands decreased by 22% and in the Lake Victoria region by 17%. The southern highland areas of Mbeya and Songea were estimated to have decreases of 10 to 15%. These results suggest that climate change may significantly influence future maize yields in Tanzania, reducing them in all zones that were studied, relative to baseline levels. These reductions are mainly due to increases in temperature that shorten the length of the growing season and to decreases in rainfall.

The majority of Tanzanians are agrarian and highly dependent on rain-fed agriculture for food production. Although agriculture is the principal economic activity undertaken, fishing, animal husbandry and other supplementing occupations such as trading are also important. Coastal communities are very vulnerable to climate change in Tanzania due to their low economic status, high population density and the ecological nature of coastal areas. Assessment of coastal vulnerability to sea-level rise along coastal Tanzania indicates that mangrove ecosystems, for instance, are the most vulnerable coastal resources. For example, vulnerability assessment of Tanga mangrove forests conducted by *Synthesis and Up-scaling of sea-level Rise Vulnerability Assessment Studies* (SURVAS) experts indicates that the total area vulnerable to sea-level rises of 0.5m and 1m are 35.2 km^2 and 70.45 km^2 respectively. Assessment of Dar es Salaam indicates that an area of about 12 km^2 will be lost with sea-level rise, threatening structures valued at about TZS 50 billion (US$ 62,500,000) and TZS 86 billion (US$107,500,000) for 0.5m and 1m of sea-level rise, respectively (Mwaipopo, 2000).

Both short- and long-term adaptation[6] strategies in response to regional climate change are beginning to emerge in a region that is rife with challenges (Simms, 2005).

[6]Adjustment in natural or human systems in response to actual or expected climatic *stimuli* or their effects, which moderates harm or exploits beneficial opportunities. Various types of adaptation can be distinguished, including anticipatory and reactive adaptation, private and public adaptation, and autonomous and planned adaptation (IPCC, 2001b).

Given the impact of drought to pastoral and agro-pastoral communities in Tanzania for example, a number of multiple coping mechanisms have been developed. These include keeping diverse species of livestock, movements of species-specific and production-specific livestock herds over large areas, emigration out of the pastoral system until the perturbation passes, economic diversity, and even allocating seasonal and drought-induced nutritional stress among those community members better able to cope with it (Galvin, 1988, 1992; Galvin *et al.*, 1994). Rain-fed agriculturalists diversify with livestock and have close economic ties to pastoralists and markets. These strategies are opportunistic and flexible, and contingent upon existing conditions. Along the Tanzanian coast, leading conservation groups are working with natural resource managers and other stakeholders to integrate climate change adaptation strategies into their management philosophies and plans (Hansen *et al.*, 2003). Initial vulnerability assessment and adaptation planning strategies from Tanzania point to the need for mangrove protection, reforestation with 'climate-smart species', integrated land-use and marine planning, and activities to improve resource use technology. Coordinating the testing of adaptation methods in geographically diverse locations within a common habitat type, aims to increase the replicability so that the project results can be transferred to other conservation efforts around the globe (*ibid.*).

This article provides empirical evidence of the implication of climate change impact on the Rufiji Delta communities of Tanzania. The article primarily investigates the climate change impact and adaptive strategies in Mchungu and Mchinga-Mfisini villages. It has four main objectives. First it attempts to understand local perceptions of climate and its associated changes. Second, it investigates the indicators of climate change in the two villages. Third, it investigates the impact of climate change on livelihood activities. And finally, it explores the coping and adaptation strategies employed by local communities and other parties.

2.0 Mchungu and Mchinga-Mfisini villages

2.1 Climate and Livelihood

Mchungu and Mchinga-Mfisini villages in the Rufiji River Delta (the study site) are located at 7°42'51"S 39°16'49"E, and 7°45'06"S 39°20'27"E respectively, about 200km south of Dar es Salaam (Figure 1). The rainfall pattern in the area is characterised by two rainy periods between November and May, and a dry season from June to October. The heaviest rains are in March/April, and there is a relatively dry period in January and February. Rainfall normally occurs as conventional storms and is therefore uneven in its aerial distribution, particularly during the drier months. The average temperature varies between 24°C during the months of June and July and 28°C during the period from December to February. Values for humidity follow the rainfall pattern, with the highest figures (up to 100%) occurring during the rainy season, and the lowest, falling to a minimum of around 36%, during the dry season (Duvail & Hamerlynck, 2007).

The study area is drained by the Rufiji River which has developed a vast delta, partially covered by some 500km^2 of mangrove, the largest stand in East Africa (*ibid*). The

livelihood of the local community consists of two main components. The first component comprises livelihood related to primary and secondary productive activities such as agriculture, forestry, fishing and crafts; while the second component consists of transfers and tertiary incomes such as remittances. Fishing is the second major economic activity to farming in Rufiji District. Small-scale fisher folks using rudimentary fishing gear dominate the fishing activities. Fishing is carried out in the River Rufiji, the delta and some inland lakes formed by the flooding of the river. The main outlet for the fish catch is the local market.

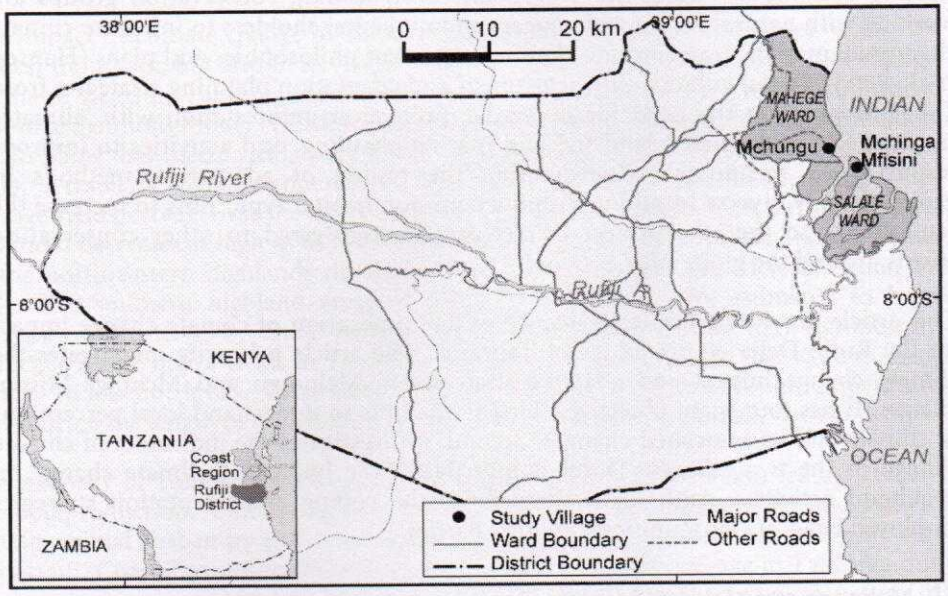

Figure 1: *Location of Mchungu and Mchinga-Mfisini villages in Rufiji Delta*
Source: Cartographic Unit, Geography Department, University of Dar es Salaam.

In addition to secondary sources, this article is based on fieldwork that was conducted in Mchungu and Mchinga-Mfisini villages within the northern part of the Rufiji Delta in January 2009. In-depth interviews using semi-structured questionnaires were carried out on 20% of the households in each village, thus 52 and 37 households were sampled in Mchungu and Mchinga-Mfisini respectively. These households were selected using a simple random sampling method. In addition, interviews were carried out with key informants, who were selected by a purposive sampling method. Five key informants were drawn from each village for interviews that were guided by an open ended questionnaire. The key informants in Mchungu village were selected according to the nature of the social and administrative set up in the village, in order to ensure collection of sufficient and representative information. The set up comprised of the village government chairperson, two hamlet chairpersons, a primary school teacher, and one elder

female who was also a member of the Village Environmental Committee (VEC). The composition in Mchinga-Mfisini was slightly different and included the village government chairperson, the hamlet chairperson, the VEC representative, and two elders, from both sexes. The aim of conducting key-informant interviews was to gather knowledge from prominent people in the area because such people tend to have access to resourceful information about the environment of their village. Also, such information was used to triangulate findings from the household surveys.

Furthermore, a total of three focus group discussions (FGD) were conducted – one in Mchungu and two in Mchinga-Mfisini. The FGD in Mchungu consisted of ten males, and the two conducted in Mchinga-Mfisini consisted of eight males and six females respectively. GIS and Remote Sensing were employed using the Thematic Mapper (TM) product from Landsat images dated 1991 and 2008. The two years were deliberately chosen in order to determine any shoreline changes between the two periods. This covered the area between 7°43'44.98"S to 39°19'00.37"E and 7°47'05.10"S to 39°21'22.98"E, which is Salale Ward in Rufiji Delta, Coastal Region. Image printouts were interpreted visually on transparent paper. Through the application of this method, the study determined the extent to which sea-wave erosion had impacted on the shoreline in the study area.

In this study, both quantitative and qualitative data were collected. The quantitative data were initially analysed by assigning numbers to the questionnaires in a chronological manner, followed by the editing of the raw data to check for any errors and inconsistencies. The data were then subjected to descriptive statistical analysis. Statistical outputs were set up to determine percentages, as well as the cross tabulation of variables for causal-effect analysis. Data cleaning to avoid errors in entries in the database was also undertaken. After that the data were summarised into tables, charts and graphs. Finally, they were organised into meaningful categories for interpretation. ArcGIS software was used to analyse the spatial data gathered from the Landsat Thematic Mapper (TM) satellite images of 1991 and 2008, in order to determine the land use/cover change along the shoreline. The satellite images of the study area were digitised, attributed, mapped and interpreted to enable analysis of the shoreline changes between 1991 and 2008. The data were analysed to determine local perceptions of climate and its associated changes; indicators of climate change in the two villages; the impacts of climate change on livelihood activities; and the coping and adaptation strategies employed by local communities and other parties.

2.2 Local community's perception of climate

Having analysed the data collected, it was noted that the largest percentage of the total respondents in Mchungu village perceived climate in terms of temperature. Another variable significantly noted in the village was deforestation, an aspect locally associated with climate. Ocean currents and rainfall were also associated with climate in Mchinga-Mfisini and Mchungu villages respectively. Furthermore, Mchinga-Mfisini respondents informed that together with ocean currents, other aspects such as drought, and wind speed and direction were also associated with climate (Table 1).

Table 1: Community perception of climate

Perception	Villages	
	Mchungu (%)	Mchinga-Mfisini (%)
Temperature	24.6	9.6
Deforestation	20.8	0
Ocean currents	17	24.8
Rainfall	14.5	20
Drought	13.2	13.6
Wind speed and direction	3.8	12
Sea tides	1.3	0.8
Siltation	1.3	0
Fish availability	1.3	0
Floods	1.2	0.8
Plants	0.6	0.8
Sea-level rise	0	17.6

Source: Survey data, 2009

Respondents further admitted that their perception of climate was essentially influenced by the nature of their livelihood, most of which was climate dependent. Most farmers associated climate with rainfall and/or drought. Most respondents who were engaged in fishing for their livelihood perceived climate to be associated with forests, and linked deforestation to climate change. Another climate-related aspect noted by this group was temperature. Around a quarter of the respondents who were involved in trading, the third largest occupation in the region, had similar perception since they also identified forests (deforestation), drought and temperature as climate related aspects.

2.3 Climate change indicators

A significant percentage of the respondents (96%) said that the impact of climate change was affecting their daily livelihood. Further inquisition into this aspect revealed that a decrease in rainfall (amount and change of seasons), and associated drought (high temperatures), were the most significant indicators of climate change, as noted by respondents in both Mchungu and Mchinga-Mfisini villages.

Contrary to the impression by Mchinga-Mfisini villagers that the sea-level had risen, a significant percentage of Mchungu villagers said that the sea-level had actually been decreasing in the last 20 to 30 years. They cited alluvial deposition by the Rufiji River as a key reason for this state of affairs. Respondents associated this with poor soil/land use management in the upper course of the river. Table 2 lists some of the indicators of climate change as viewed by respondents from the two villages.

One informant in Mchinga-Mfisini village informed that sea wave erosion began in the 1960s but with quite insignificant impact. The informant further noted that the first decade of sea-level rise was not that critical as erosion and deposition along the shore were balanced; and that from 1990s to date the trend has actually worsened with continuous and advancing coastal erosion. Another respondent reiterated that since 1992, when he migrated to the village, he had (up to the time of the study) witnessed roughly about 300m of village land being inundated by the sea.

Table 2: Indicators of climate change according to respondents

Indicators	Villages	
	Mchungu (%)	Mchinga-Mfisini (%)
Temperature increase	14.9	10.1
Sea-level rise	2	32.1
Decrease in rainfall	29.7	28.4
Unpredictable sea tides pattern	2	0.9
Drought	25	11.9
Change in rain seasons	15.5	11.9
Siltation	6.1	0
Deforestation	0.7	0
Loss of soil fertility	0.7	0
Temperature decrease	0.7	0
Increase in animal/crop diseases	2.7	3.7
Increase in soil salinity	0	0.9

Source: Survey data, 2009

In relation to sea-level rise it was noted that most of the existing boreholes which had once been used as a source of fresh water had become saline, as a result of intrusion of saltwater into underground aquifers. This intrusion of saltwater has been associated with recent increase in soil salinity that is negatively affecting farming activities in the study area.

Rainfall and temperature data collected over thirty years, between 1978 and 2008, indicate that the amount of rainfall has slightly fallen along the coastal areas of the country. Likewise, the mean annual temperature trend for those 30 years affirms that the average coastal temperature has significantly increased by 1°C (Figures 2 and 3).

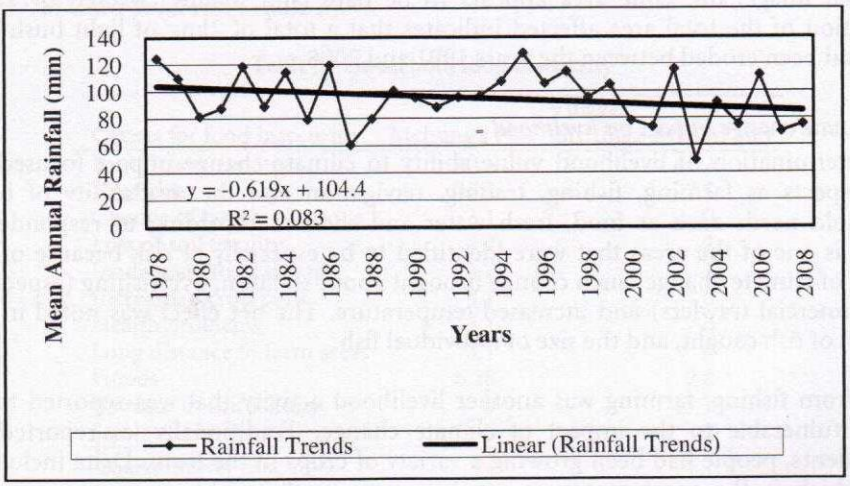

Figure 2: *Mean annual rainfall record 1978-2008*
Source: Tanzania Meteorological Agency, 2009

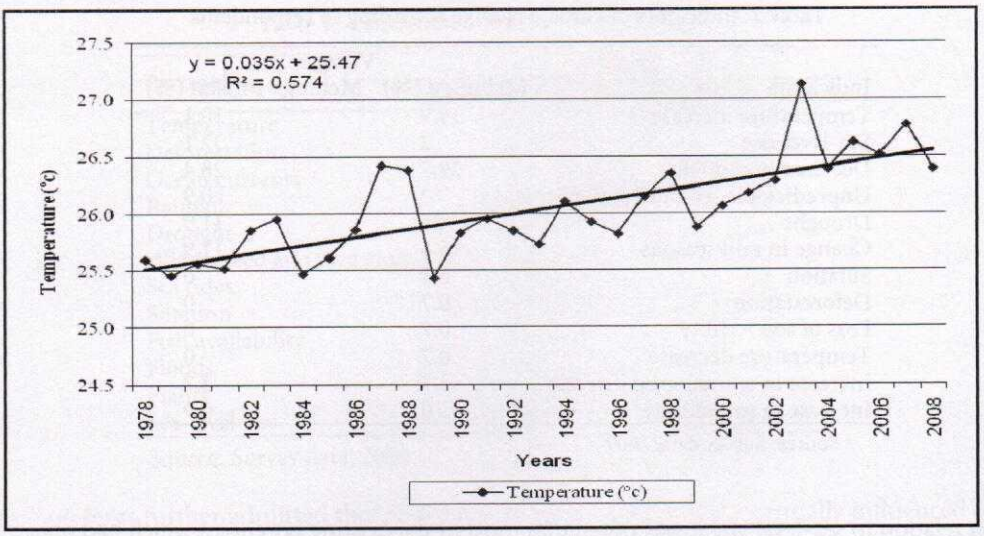

Figure 3: *Mean annual temperature record 1978-2008*
Source: Tanzania Metereological Agency, 2009

In addition to rainfall and temperature data, the interpretation of the Landsat Thematic Mapper (TM) images of 1991 and 2008 covering Mchinga-Mfisini village affirm that the erosion observed along the shore was due to sea wash on the shoreline, coupled with high and low tides. The 1991 image depicts that most of the low-lying areas, where the high tide waves could reach, were covered by light bush and grass. In the 2008 image, the same area appears to be bare land mainly covered by sand. Estimation of the total area affected indicates that a total of 2km^2 of light bush and grass had been eroded between the years 1991 and 2008.

2.4 Climate change impact on livelihood

The determination of livelihood vulnerability to climate change impact focused on such aspects as farming, fishing, trading, navigation and the availability of basic household needs such as food, fresh water and shelter. According to respondents, fishing is one of the areas that were identified to be especially at risk because of the impact of climate change. Such change brought about siltation, overfishing (especially by commercial trawlers) and increased temperature. The net effect was noted in the amount of fish caught, and the size of individual fish.

Apart from fishing, farming was another livelihood activity that was reported to be highly vulnerable to the impact of climate change. Traditionally, as reported by respondents, people had been growing a variety of crops in the Rufiji Delta including rice (which is the most common crop), cassava, cashew nuts, sugarcane, maize, vegetables, fruits, sorghum, sesame, and coconuts. However, most of these crops have been abandoned, with the exception of rice paddy and coconuts; and this has been caused by infiltration of seawater into the farmland. In connection to that, saltwater

intrusion into farmland (i.e., salinity increase) has been another factor noted by almost a quarter of the total households surveyed. In the same village, one informant gave the following comment:

> *In previous years, all these crops were grown in the valley which used to exist in the middle of our village. The valley covered almost twenty hectares; thus villagers could distribute some portions of land amongst themselves for farming, but now the valley has been lost into the sea and very little land is now available for us to grow crops.*

Further, about 10% of the respondents in Mchinga-Mfisini village reported that unpredictable rainfall was another factor behind the abandonment of some crops. In Mchungu village this observation was not as significant since only 5% of the 40 households that had abandoned most crops were of the opinion that drought was one of the main factors. Another 5% cited insufficient income to finance farming activities, as another problem which had led to the abandonment of some crops. Regarding coconut plantations, one informant in Mchinga-Mfisini village alleged that the largest portion of coconut fields had been inundated by seawater since the 1990s, leaving behind only a few sands which are also vulnerable to ongoing seawater inundation. Respondents also reported that coconut fruits were being attacked by a certain pest that caused the fruits to shrink and dry up before they matured. They believed that the pest was associated with increased temperature in the area.

Given the changes in climate that were noted during the study, their impact on household livelihood was inevitable in many aspects. One significant aspect was household food insecurity. About 85% of the respondents asserted that their households had experienced food shortage; and this food insecurity had been brought about specifically by low household income levels, drought, change in the pattern of the rainy seasons, floods, increased crop pests, loss of soil fertility, increased soil salinity, and sea-level rise (Table 3).

Table 3: Household food insecurity

Causes for food insecurity	Village	
	Mchungu (%)	Mchinga-Mfisini (%)
Insufficient income	40.6	41.2
Drought	31.2	27.5
Change of farming seasons	3.1	0
Loss of soil fertility	4.7	2
Inadequate food storage	4.7	2
Increase in crop pests	3.1	0
Health problems	3.1	0
Long distance to farm areas	3.1	0
Floods	6.25	9.8
Increase in soil salinity	0	15.7
Sea-level rise	0	2

Source: Survey data, 2009.

In addition to food insecurity, the study also looked at how seriously climate change had affected the availability of fresh water. Significantly, 96% of the respondents

reported that they were not getting the same quality and quantity of water from the existing sources as they used to do two to three decades earlier. As already noted, the causes for this problem in both villages were drought, saltwater intrusion into underground aquifers, and inundation of boreholes by sea water.

2.5 Coping and adaptation strategies

As already explained in preceding sections, farming and fishing are the most vulnerable livelihood activities to climate change, in the study area. As one of the coping strategies, a significant number of respondents in the study area who had been engaged in fishing decided to venture further into distant waters in order to try and increase their catch. Another significant initiative identified by respondents was in regard to the use of alternative fishing equipment that would help to enhance fish catch.

Such initiatives aimed at curbing the impact of climate change have not been carried out only by the local people; the government has also chipped in some assistance. More than half of the surveyed households in Mchungu village informed that support from the government had been in the form of materials, although they were also of the opinion that unless these interventions come in the form of capacity building programmes, particularly training, improving community livelihood would not be sustainable. In the village, a Government of Tanzania/World Bank initiative has been implemented; this is the Marine and Coastal Environment Management Project (MACEMP). Broadly, the project aims to promote the sustainable use of coastal resources. Again, District Agricultural Development Projects (DADPs) have been introduced in the area whereby farming and livestock-keeper groups, with 25 members each, have been formulated to facilitate farmers' exposure to modern and sustainable cultivation and livestock keeping methods.

The initiatives notwithstanding, overall assessment of the interventions indicate that 90% of the respondents (with 85% majority from Mchungu village) were still not happy about the degree of progress that their communities had made towards improving their livelihood. Besides, many people seemed ignorant about the initiatives that were being undertaken, as the following personal account from one participant testifies:

> *This is the second year since fishing groups were established, but most group members have not earned even one thousand shillings. In order for fishing to be run efficiently, facilities like boat engines, fish nets, and storage equipment are needed. All groups that have been sponsored by MACEMP in the coastal area have been given boat engines except those of Mchungu. If the government has failed it should look for other donors to support us. Boats with no engines are not very useful as we are forced to stay out longer at sea when the sea gets rough. We are then forced to salt the fish so that it lasts longer, resulting to poor fish quality, which subsequently attracts lower prices. For instance, a medium-sized fresh fish called Ngulu is sold at TZS 8,500, so if one catches forty of them it is a lot of money but inefficient and unreliable fishing boats force us to salt the fish hence ending selling one such fish at between TZS 2,000 and TZS 3,000.*

3.0 Lessons from the study

This study found out that people perceived and defined climate according to their local environment, based on common climatic variables. The dominant livelihood activities of the majority of the people in the Rufiji Delta region include fishing and farming, which are highly influenced by such climatic variables as ocean currents and rainfall. Therefore, the knowledge of farmers and fisher folks about climate was expected. Furthermore, comparing people's perception on climate between the two villages that were studied, it was found that terrestrial-based aspects of climate were most often referred to by people in Mchungu village, whereas people in Mchinga-Mfisini related their livelihood more closely to marine aspects of climate. This observation further proved that people's perception of climate is predominantly based on their local environment and this would tend to differ from place to place.

Further findings have shown that the amount of rainfall has decreased in the last two decades, and this decrease has been accompanied by unpredictable rainfall pattern and seasons. Changes in the rainy season were normally associated with short rains which used to commence in September, contrary to the current situation where such rains may begin as late as January, or sometimes never come at all. Such incidences of prolonged dry spells have resulted into droughts in the study area, a situation that has adversely affected the livelihood of the local community. However, statistical analysis of rainfall data over the past thirty years does not suggest a significant fall in the amount of rainfall; rather changes in seasons and/or rainfall distribution has been mainly the concern of the community. Likewise, temperature increase in the study area is said to have intensified within the last decade. As mentioned earlier, this has been locally associated with an increase in crop pests that results to coconut fruits drying up. In some delta island villages in Rufiji, coconut production has drastically declined due to diseases attributed to coconut lethal yellow (Mbiha & Sonkondo, 2001). It was reported that the pest had increased.

Changes in sea water temperature are expected to affect fisheries along the coast, thus compromising socio-economic sectors (Alusa & Ogallo, 1992). In the study area, this is associated with the fact that the sea has become shallow along the coastline, mainly as a result of alluvial deposition from the Rufiji River catchment. Therefore, higher temperatures and alluvial deposits have resulted in less fish in the shore area. There are other studies that have affirmed similar observations in the southern Tanzanian coast, Mtwara in particular, of variations and changes in temperature and rainfall.

Despite this direct impact on fisheries which in turn adversely affects livelihood, the study also noted that climate change had impact on coastal vegetation, particularly mangroves. Mangrove wetlands are crucial for fisheries as they provide favourable breeding sites for a number of fish species, especially shrimps. Therefore, deterioration of these mangrove wetlands has led to loss of such breeding sites, and subsequently decline in the amount of fish caught. As said earlier, fishermen have taken up several coping and adaptive measures in order to secure sufficient catch; they are now under pressure to fish farther out at sea where the water is deeper and cooler, a condition preferred by fish when there an increase in temperature. They have also found it necessary to use alternative fishing equipment and nets that

enable them catch more fish. Fishing nets with small-sized mesh have increasingly been adopted, although such nets have been declared illegal by the government (URT, 2004). The local hooked fishing bow has been another method of fishing that has been introduced.

As substitute activities, people have been engaged in the trading of fish, charcoal and mangrove poles. However, this venture is risky and non-promising since fishing, as noted above, is dwindling while charcoal burning and mangrove felling in forest reserves (in this case mangroves) are prohibited by law (URT, 2002).

Rise in sea water level has resulted into increase in salinity. There has also been beach erosion by sea waves. These two factors – increase in salinity and beach erosion – have been linked to sea-level rise. Some stands of *Avicennia Marina* mangrove species (white or grey mangrove) in Mchinga-Mfisini village, as observed during the study, were withering away. This certainly proved that the level of salinity had increased dramatically. The grey mangrove shows stunted growth in water conditions that are too saline, but thrive to their full height in waters where both salt and fresh water is present (Ripey & Rowland, 2004).

Similar other studies have shown that several areas along coastal Tanzania including Mtwara, Mikindani, Kilwa, Dar es Salaam, Tanga and Zanzibar have been severely affected by coastal erosion attributed to sea-level rise (Shaghude *et al.*, 2009). It is further documented that there has been land loss as a result of inundation and erosion due to sea-level rise in four African countries of Côte d'Ivoire, Egypt, Gambia and Tanzania. As a result of such rise in sea water levels, socio-economic and natural systems along coastal areas have been greatly affected (Dixon *et al.*, 2003). This observed rate of sea-level rise during the 20th century is (within present uncertainties) consistent with model simulations, and it is very likely that 20th century warming contributed significantly to the observed sea-level rise through thermal expansion of sea water and widespread loss of land ice (Gitay *et al.*, 2002).

In connection to climate change and its impact on farming, the study went further to appraise the extent to which farming has been affected. It was established that several crops that had previously been grown in the area e.g. sugarcane, maize, vegetables, fruits, sorghum and sesame had been abandoned. This means that climate change has adversely affected farming in the study area thus jeopardising household food security and income generation opportunities, given the fact that farming is a sector which employs the majority of the population in the study area. As a result of this change in climate, farmers switch between and among a variety of crops – those that are resistant to drought such as cassava and sorghum and those that require abundant rainfall such as rice and bananas – depending on the direction of climatic change (Pavoola, 2009). The most reliable crop in the study area was found to be rice paddy which is highly dependent on irrigation from the Rufiji River. However, rice paddy cultivation is not sustainable as some farmers have to clear government-protected mangrove forests to allow for rice paddy cultivation, and as said earlier, this is an act that is against the law. In addition, rice paddy cultivation is vulnerable to intrusion of salt water as a result of sea-level rise.

4.0 Conclusion

The study has noted that local communities possess broad-based local knowledge about their environment, which has always guided them in determining changes occurring in their surroundings. In the Rufiji Delta area, the study specifically observed how the local communities' perception of climate is associated with physical environmental parameters such as rainfall patterns, marine systems, hydrology and soils. Therefore, changes associated with such features are being interpreted by the community as constituting climate change. This study, which was based on the Rufiji Delta, supports this assertion as several climate change-related effects were observed.

In addition, this study noted that basic livelihood systems in developing countries are still nature-dependent such that any slight environmental variation could lead to adverse impact on livelihood. Subsistence rain-fed farming and small-scale fishing are good examples of activities that are affected by such variation. Due to the ongoing changes in climate, such economies have been significantly impacted, leading to decline in the production of food which causes household food insecurity, water scarcity and even a trend of settlement destruction in fragile and vulnerable environments such as the coast.

Local communities in the study area were found to have developed means to cope with environmental changes. The study observed how communities in Rufiji Delta strive to cope with climate changes. While farmers have largely resorted to irrigated farming, fisher folks have devised new fishing equipment as well as identified new areas that could promise better catch. However it should be noted that most of the coping strategies that have been deployed are quite unsustainable given their incompatibility with the existing legal and policy frameworks as well as the poor economic status of most people, to finance such initiatives.

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