Chapter 4

Climate Change, Smallholders farmers' Adaptation in Pangani Basin and Pemba

Implications for REDD+ initiatives

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Abstract

This chapter is based on a study conducted in Pangani river basin and on Pemba Island in Tanzania. The main objective of the study was to assess evidence of the climate, small farmers' adaptive strategies and associated implications for REDD+ initiatives in the country. Historical climate data over more than 30 years were collected from nine stations in Pangani river basin and on Pemba. Qualitative and quantitative data were collected from 11 villages purposively selected based on the location (upper and lower basin and altitude). A questionnaire survey and Focus Group discussions were used to collect data from 387 respondents and 40 key informants, respectively. The respondents for the survey were randomly selected from 11 study villages. The results show evidence of rising temperatures, changing rainfall patterns, an increase in extreme weather conditions such as droughts, floods and hurricanes and the shifting distribution of pests and

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diseases. Expert opinions also confirmed major changes in climate parameters in recent years. About 89 percent and 95 percent of small-scale farmers perceive that there is a change in temperature and rainfall, respectively, and linked the changes to crop types, cropping patterns, and outbreak of human, animal and crop diseases in their respective areas. Results from Multinomial Logit Model indicate that farmers' choices of climate change coping strategy depend on their access to extension services and credit, their education level, location as well as experience. Adaptive strategies range from change of crop types, farmers and livestock keepers moving to new areas near water sources and forests and increased farm activities. Unfortunately most of the smallholders' adaptive strategies are compromising REDD+ initiatives. The study concludes that successful REDD+ initiatives within the framework of smallholders adaptive strategies to impacts of the climate changes requires externally sourced support for sustainable adaptation to climate changes.

1.0 Introduction

Climate change is a global problem; however, the associated impacts and vulnerability vary across the countries, regions, districts and individuals. Studies indicate that Africa is one of the continents that have severely been affected by climate change. Over the past few decades the continent has experienced a decreasing number of extremely cold days coupled with an increasing numbers of warm days (New *et al.*, 2006). Spatial and temporal variability of precipitation, more intense and widespread of droughts and aggravated floods have been common during this period (Deressa, 2010). Climate change impact on natural and human systems alters the productivity, diversity and functions of many ecosystems and livelihoods around the world. The African continent is more vulnerable to climate change impacts because the majority of the population on the continent primarily depends on rain-fed agriculture (IPCC, 2007; Boko *et al.*, 2007). For poor people natural resource-dependent communities, climate change compounds the existing vulnerabilities. Heavy dependence on ecosystem services places their welfare at the mercy of environmental conditions. As the availability and quality of natural resources decline, so does the security of their livelihoods.

In Tanzania, temperature has generally increased and precipitation decreased in many areas of the country. The average annual temperature is projected to increase by 2.2°C and precipitation to decreased by 100mm by 2100 (Agrawal *et al.*, 2003). As a result, many of the country's nine river basins (Pangani, Wami and Ruvu, Rufiji, Ruvuma and the Southern Coast, Lake Nyasa, Lake Tanganyika and the Lake Victoria and internal drainage such as Lake Rukwa Basin) are drying out at an alarming rate. This is evidenced by reduced water flow from these basins (Kulindwa, 2005).

In developing countries such as Tanzania, water basins play a pivotal role in the livelihoods of poor communities. Their ability to supply water throughout the year provides poor communities with opportunities to grow crops and keep livestock throughout the year. However, in recent years communities in these areas have experienced a serious decline in the availability and quality of natural resources *in situ* water (MEA, 2005). As a result, agriculture, which is dominated by small-scale farmers in these areas, has been seriously affected (Sanga et al., 2013). In fact, many farmers have failed to recover from climate change effects (Sanga *et al.*, 2014).

The current literature proposes a number of mitigation measures designed to reduce GHG such as carbon in the atmosphere in a bid to reverse this worrisome trend (Gibbs *et al.*, 2007). Approaches such as REDD+, which emphasise on planting trees for carbon sink, are underscored and promoted in developing countries where land scarcity is not a problem. This approach is favoured because it has multiple advantages. To begin with, it allows for the absorption of carbon from the atmosphere, improves water retention capacity and reduces runoff hence curbing soil erosion. Although such mitigations are useful in reducing and reversing the impact of climate change and offering long-term solutions, they need to involve the entire world and take several decades. Therefore, short-term actions to cope with climate change effects are deemed necessary considering the current climate change effects. Conversely, projects that promote resilient crop species, diversified livelihood activities, and risk-reduction activities (such as seed banks, storage facilities, early warning systems) increase local adaptive capacity. Without having a clear understanding of the right intervention, at the right time and the right segment of the population (including men, women and indigenous people), all efforts aimed at introducing long-term mitigation measures such as REDD are less likely to succeed.

Nevertheless, in developing countries such as Tanzania agriculture is dominated by small-scale farmers who also have to contend with poverty and food insecurity. Thus, in these countries the farmers' primary objectives focuses on meeting basic food needs for their families and pay less attention to climate change adaptation and associated consequences (World Bank, 2006). This presents an important limitation to efforts on the ground to introduce long-term mitigations such as REDD. Apparently, long-term mitigation planners on the ground have insufficient understanding of the impacts of climate change, the vulnerability levels and small-scale farmers' adaptation choices (Hassan and Nemachena, 2008; Kurukulasuriya and Mendelsohn, 2006). Proposing that farmers should invest in long-term climate change mitigation measures in Pangani basin is one issue and understanding the impacts of climate change, especially the segment of the population who are vulnerable and how they respond to these impacts, is another entirely different issue. In fact, the latter issue if much more fundamental in the view of this paper as the former long-term mitigation measures depends on the success of the latter. In principle, it involves clarifying questions such as: What are impacts of climate change on Pangani basin? Which segment of the population of small-scale farmers who are vulnerable to climate change in the basin? What determines small-scale farmers' adaptation choices? Are the designed mitigation measures in line with the small-scale farmers' adaptation choices? This research was designed to provide a better understanding of these issues for the purpose of deepening our understanding before embarking on long-term mitigation measures related to REDD+ in Tanzania.

2.0 Study Justification and Objectives

Essentially, agriculture is not just a victim of climate change; it is also a significant cause. It is directly responsible for 10–12 percent of human generated greenhouse gas emissions, and much more if the forest clearance to make way for crops and livestock is included. Enteric fermentation in livestock accounts for around a third of all the nitrogen oxide emissions produced by agriculture, and overgrazing by livestock leads to significant greenhouse gas emissions. This study was conducted in Pangani Basin and on Pemba Island with a view to drawing a deeper understanding of the impacts of climate change, the level of vulnerability across different segments of ecosystem users and its implication for the implementation REDD+ initiatives in Tanzania.

As already noted, water basins play a vital role in providing, supporting, regulating, and learning (cultural) aspects. However, many of the water basins in Africa have been affected by climate change extremes and variability, and this has affected a significant portion of the farming population in these areas (IUCN, 2009). In Pangani basin and on Pemba Island, climate change extremes have increased the number of largely subsistence farmers who are vulnerable. This has reduced their capacity to invest in the long-term mitigation measures such as REDD. Generally, efforts to reverse the situation which are suggested by the current literature are for the long-run. For example, Bolin *et al.*'s (2012) study "Can REDD+ reconciles local priorities and needs with global mitigation benefits? Lessons from Angai Forest, Tanzania" provides similar thoughts for research in Pangani river basin and Pemba. Thus, understanding the impacts of climate change prevailing in the basin, the level of vulnerability, farmers' respond to climate change and mitigation measures is necessary for designing appropriate policy measures aimed at enhancing adaptation capacities of vulnerable farming populations of the basin and Pemba within the REDD+ initiative framework. Nevertheless, the outcome of the study can guide us to make evidence-based decision recommendation to policy-makers and other practitioners on the best approach to intervening for sustainable REDD+ implementation.

Objectives

Specifically the study sought to:

i. Establish and characterise climate change scenarios in Pangani basin.
ii. Identify and assess the vulnerability of small-scale farmers to climate change impacts in the established scenarios.
iii. Investigate determinants of farmers' choice of climate change adaptation measures in the established scenarios.
iv. Assess the economic and environmental compatibility of farmers' adaptation measures in the established scenarios.
v. Establish smallholders' adaptive strategies and implication for REDD+ initiatives measures.

3.0 Methodology

3.1. Location of the Study

The study was conducted in Pangani river basin on Tanzania mainland and on Pemba Island in the Zanzibar archipelago. Pangani River basin is shared by Tanzania and Kenya extending as it does from northern highlands comprising mount Meru, Kilimanjaro and Taita hill to the north-eastern coast of the Indian Ocean. The basin lies between latitude 03° 05' 00 and 06° 05' 00 south and longitude 30° 45' 00 and 39° 00 east. The basin covers an area of 56,300 km^2 out of which five percent lies in Taita-Taveta district of Kenya (Figure 4.1). In Tanzania the basin is distributed among the Kilimanjaro, Manyara, Arusha and Tanga administrative regions. To improve our findings, Pemba Island has been included in the study.

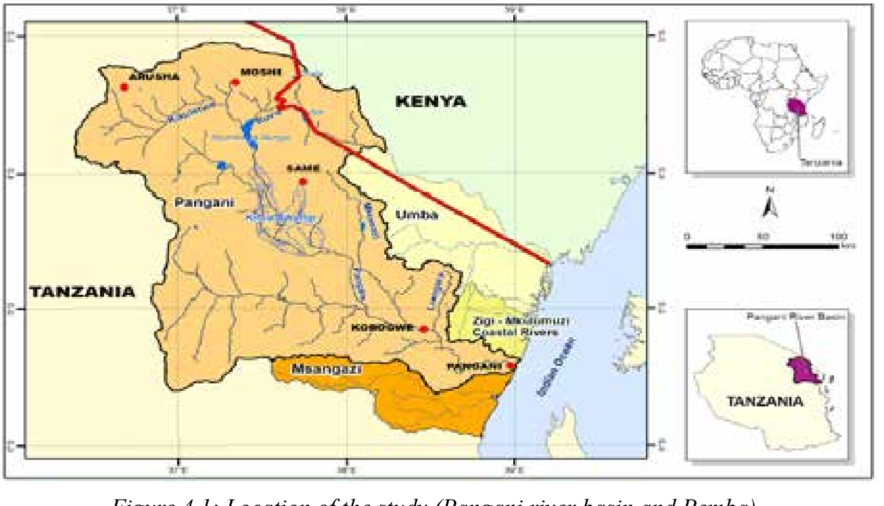


Figure 4.1: Location of the study (Pangani river basin and Pemba)

Topographically, the basin is not uniform. Its altitude ranges from 700-5825m above sea level; the ice cap of Mount Kilimanjaro forms the highest point not only of the basin but also of Africa. This altitude has a significant influence on the basin climatic conditions. The temperature ranges between 14°C and 25°Cin Kilimanjaro and 17 and 29°C in south-eastern part of the basin and Pemba Island. On the other hand, precipitation varies considerably. The basin is divided into three rainfall zone: the high rainfall zone which receives rains between 1200 and 2000mm per year. The high rainfall zone is distributed on the slopes of Mount Kilimanjaro, Meru, Pare and Usambara mountain ranges. Other zones have medium to low rainfall. In Pemba, two locations were chosen, low rainfall Micheweni and relatively high rainfall Makangale *Shehias*

The basin is characterised by bimodal rainfall pattern with two distinct rainy seasons: long rains from March to June and short rains from November to December. The highest rainfall is 1000-2000mm per annum and occurs in the south-eastern slopes of Kilimanjaro and Meru mountains (IUCN, 2003). The moderate rainfall zone, which receives rains of between 800 and 1200mm per year, is distributed on some parts of Babati and Simanjiro districts. Lastly is the low rainfall zone which receives rainfall ranging from 500-800 mm per year (Makurira *et al.*, 2007). The zone covers the low lands of the basin in all districts of Meru, Simanjiro, Same, Mwanga, Korogwe, Handeni, Muheza and Pangani. In this report, Pemba Island is also included in this zone. Also the basin is characterised by minimal seasonal variation of temperature (Senkondo *et al.*, 2004).

On the other end of the spectrum, Pemba Island is located a few nautical miles east of the point where Pangani River enters the Indian Ocean. The Island has a total of 984 square kilometres and is characterised by two major climatic conditions which also demarcates the Island into two sides: the wet and dry side. Similarly, the area is characterised by migration of people from the dry to the wet side, hence creating conflicts over land and other resources. Nevertheless, the Island faces an increasing salt water intrusion on farm land, making it unsuitable for crop production, an effect which is an indicator of rising seas levels which is eating away the Island gradually.

Figure 4.2: Pemba Island location in Tanzania

3.2. Justification for choosing Pangani Basin and Pemba Island

Pangani basin has been chosen because of its unique topography and ecology. The basin begins from the highest to the lowest point of Africa (the Kilimanjaro Mountain and Indian Ocean respectively). The basin is one of Tanzania's nine drainage basins. It plays three major roles of providing for, supporting, and regulating the communities within and downstream. Water in this basin is of great economic importance as it is used for irrigation to a large number of people living in the low lands of the basin. Water supports nearly 310 sq km of irrigated farmland owned by both small and large-scale farmers growing a variety of crops such as coffee, paddy, flowers and vegetables (Kulindwa, 2005; Mbonile, 2005). The basin also supports water demand for domestic and industrial use in the three major urban centres of Arusha, Moshi and Tanga and several small towns within the basin (Meena and Raphael, 2008). Furthermore, the basin is also used to generate hydropower (Nyumba ya Mungu and Hale). On the other hand, the basin provides habitat to a unique biodiversity and water to wild animals found in Kilimanjaro, Mkomazi, Arusha and Manyara national parks (URT, 1995).

However, in the last two decades years the basin has been unable to provide adequate ecosystem services to the communities in upper and downstream areas (Komakech *et al.*, 2004). Many of them have lost their economic power or have become more vulnerable to climate change. Almost similar situations have been reported on Pemba Island where various impacts of climate-related changes are critically changing the whole farming systems and livelihoods of the people to varying degrees. For example, women as the main household livelihood providers and water users for domestic purposes have been adversely affected (Mtabazi *et al.*, 2005). These reasons justified the choice of this basin as a study area.

Pemba Island was also chosen because of the challenges climate change poses to the area. As already noted, movement of people from the dry side to the wet side of the island foments conflict over limited resources available on the wet side. Moreover, the increasing encroachment of salt water on farm land increases challenges to the Island which are already overstretched by presence of drought on one side (Watkiss *et al.*, 2012). Equally important, the Island's population is growing and so is the need for arable land for food production to meet the need for food that is growing in the Island (URT, 2012). It was, therefore, considered important to find a better way to mitigate climate change impact in response to the migration and conflict over the little finite resources existing on the Island.

The sites were also selected to test another approach to the study of climate change. Most of the studies on climate change view the problem holistically without taking into account the most likely climate differences (scenarios) within the area which dictate the level of impact, vulnerability and adaptation choices in a given area (see, for example, Kurukulasuriya and Mendelsohn, 2006; Seo and Mendelsohn, 2006; Mano and Nhemachena, 2006). This study divides the Pangani basin into three area of the high rainfall low temperature, medium rainfall medium temperature and low rainfall high temperature and Pemba into two areas of the wet and dry scenarios. Each of these scenarios has unique characteristics in terms of land use, cropping patterns, livestock keeping methods and hence impact, vulnerability and adaptation. Categorising the areas under consideration into scenarios determines the likely effect of change of one scenario on another under the changing climatic conditions. Therefore, 10 districts in Pangani river basin and on Pemba were chosen for the study on which this chapter is based.

3.3. Type of data and collection

The study employed both secondary and primary data. Primary data used in this study were collected from eleven (11) villages found in 10 districts of Pangani river basin and Pemba Island using a cross-sectional survey of small-scale farmers. The villages were purposively selected to include different climatic variations in the Pangani river basin and Pemba Island. Initially, the basin was categorised into three scenarios:(i) upper, (ii) middle, and (iii) lower. On the other hand, Pemba Island into two scenarios: (i) wet and (ii) dry (see Table 4.1). These categories were established based on the assumption that the areas have different rainfall and temperature, hence offer different farmers' perception and adaptation strategies. From each of the eleven villages an average of 35 farmers was randomly selected based on the assumption that they all practice agriculture (including livestock keeping) and, therefore, are affected by climate change. To obtain data related to rainfall, temperature, change in crop/livestock types and cropping/grazing patterns, outbreak of both plant and animal diseases, the study also collected data from key informants aged between 40 years and above through focus group discussion.

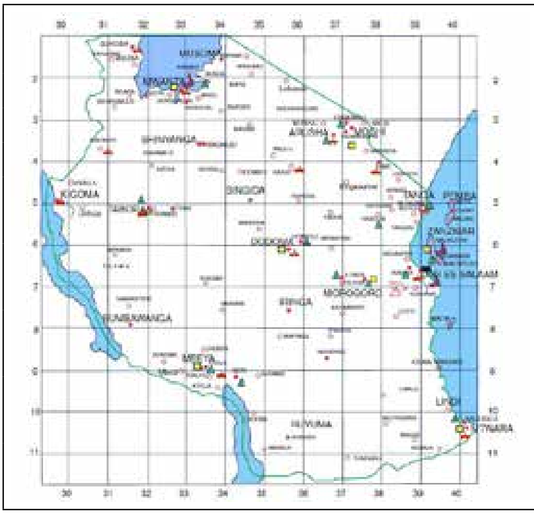
High rainfall & low temperature (I)		Climate scenarios (I, II, III) & study locations		
		Medium rainfall & medium temperature (II)	*Low rainfall & high temperature (III)*	
Basin position (L1, L2, & L3) & study locations	L_1 (Upper basin)	**Hai** ✓ Lyamungo Kilanya	**Moshi rural** ✓ Mahoma	**Meru** ✓ Lekitatu
	L_2 (Mid basin)	**Lushoto** ✓ Baga	**Same** ✓ Ngwasi	**Same** ✓ Mabilioni
	L_3 (Lower basin)	**Korogwe** ✓ Bungu	**Korogwe** ✓ Mafuleta	**Pangani** • Kigurusimba **Pemba** • Micheweni • Makangale

Table 4.1: Locations for defining climatic scenarios in studying climate change in Pangani basin

***NOTE**: For Pemba scenarios are based on rainfall pattern instead of elevation as in PRB*

In addition to the scenarios highlighted in Table 4.1, the study chose the location which is comprises eight main ethnic groups (the Meru, Maasai, Chaga, Pare, Sambaa, Bondei, Digo and Pemba) with differing socio-cultural practices, hence potentially with different outlook in understanding and adapting to different climate scenarios. These differences were deemed crucial in deepening our understandings of the dynamics necessary in achieving long-term climate change mitigation measures and establishing the implications for the REDD+ initiatives.

The secondary data on trends of rainfall and temperature were collected from the Tanzania Metrological Agency (TMA) for a span of 51 and 37 years. The period is long enough for detection of change and determining trend and correlation analysis. The monthly rainfall and temperature data from 16 rainfall stations and six synoptic stations, respectively, were collected, covering high to lower altitudes of Pangani river basin and wet and dry areas of Pemba Island (See Figure 4.3). Initially, there were 31 rainfall stations; others were rejected due to insufficient data. All the stations with missing monthly data equivalent to five or more years (that is around 15% of the data) were rejected (PWBO/ IUCN, 2008). Pangani basin and Pemba areas are characterised by bimodal rainfall patterns as two rainy seasons exist.



Location	Station's name
Meru	Arusha – Airport
Hai	Maua seminary
Moshi Rural	TPC Langasani
Mwanga	Mwanga agric.
Same	Same met. station
Lushoto	Lushoto agric. station
Korogwe	Korogwe agric. station
Pangani	Pangani agric station
Pemba	Karume - airport

Figure 4.3: Reference weather station used in the study and location in Tanzania (source TMA)

3.4 Data analysis

3.4.1 Smallholder farmers' awareness and perception of climate change effects

To collect requisite data, we employed both the descriptive and empirical analytical framework. Descriptive analysis was used to establish the farmers' awareness of climate change and its impacts; their ability to associate climate change with change in crop types, cropping pattern, livestock grazing, outbreak of human, animal and crop diseases in their respective areas; links with natural resources utilisation their efforts to cope with climate change; and what they perceive as the limitations to their efforts.

3.4.2 Trends of climatic parameters and correlation with climate change

Data on trends of rainfall and temperature were analysed using INSTAT statistical computer package (Kihupi *et al.*, 2007). Missing data were replaced by long-term mean values. Total annual rainfall, highest maximum temperature and lowest minimum temperatures were computed and linear trend analysis was carried out for each parameter. Results of computations were cross checked physically by viewing the raw data in spreadsheet format before making necessary adjustments.

3.4.3 Smallholder farmers' choices of adaptation strategies

Empirical framework was used to assess the factors influencing farmers' choices of adaption measures. The framework was selected based on the assumption that adaptation measures help farmers guard against crop failure due to increasing temperatures and decreasing rainfall, but the choices differ across them. In Pangani basin and Pemba smallholder famers have several adoption options such as migrating to water-rich areas such as river valleys and wetlands; increasing the application of fertilisers; planting drought-resistant crops; irrigating farm lots; early planting; using manure; growing fast-maturing crops; planting timber trees in their farm lots instead of crops; focusing on non-farming activities; and practicing mixed cropping. The Multinomial Logit (MNL) model was chosen as a farmer can adopt any or two to three of these options and our intension was designed to establish what conditions their choices against the base choice which in this case is migration to water-rich areas. The approach is appropriate for evaluating alternative combinations of adaptation strategies, including individual strategies (Green, 2000; Wu and Babcock, 1998; Long, 1997). In this study, we used Multinomial Logit (MNL) Model to analyse the determinants of farmers' decisions because it is widely used in adoption decision studies involving multiple choices and is easier to compute than its alternative multinomial Probit model.

Let A_i be a random variable representing the adaptation measure chosen by any farming household. We assume that each farmer faces a set of discrete, mutually exclusive choices of adaptation measures. These measures are assumed to depend on a number of climate attributes, socioeconomic characteristics and other factors X. The MNL model for adaptation choice specifies the following relationship between the probability of choosing option A_i and the set of explanatory variables X as:

$$\mathrm{Prob}(A_i = j) = \frac{e^{\beta_j' x_i}}{\sum_{k=0}^{j} e^{\beta_k' x_i}}, \; j = 0,1,........J \qquad (1)$$

Where b_j is a vector of coefficients on each of the independent variables X. Equation (1) can be normalized to remove indeterminacy in the model by assuming that $\hat{a}_0 = 0$ and the probabilities can be estimated as:

$$\mathrm{Prob}(A_i = J|x_i) = \frac{e^{\beta_j' x_i}}{1 + \sum_{k=1}^{j} e^{\beta_k' x_i}}, \; j = 0,2......J, \beta_0 = 0 \qquad (2)$$

Estimating equation (2) yields the J log-odds ratios

$$\ln \frac{P_{ij}}{P_{ik}} = x_i'(\beta_j \quad \beta_k) = x_i'\beta_j, \text{ if } k = 0 \tag{3}$$

The dependent variable is, therefore, the log one alternative relative to the base alternative. The MNL coefficients are difficult to interpret, and associating the b_j with the jth outcome is tempting and misleading as it simply show the effect of a change in x on y as if the y is continuous variable while is categorical. To interpret the effects of explanatory variables on the probabilities, marginal effects are usually derived as:

$$\delta_j = \frac{P_j}{x_i} = P_j \; \beta_j \quad \sum_{k=0}^{J} P_k \beta_k \; = P_j \; \beta_j \quad \bar{\beta} \tag{4}$$

Therefore, the full model is specified as follows:

$$y = \; _i x_i + \; _{ij} \tag{5}$$

Where: $b_{i's}$ are parameters to be estimated; y_i are adaptation options (or alternatives); x_i is a set of independent variables; and e_i are the error terms.

4.0 Results and key lessons from the study

4.1 Farmers awareness and perception of climate change

Results from a comprehensive household survey conducted in 11 villages of Pangani river basin and Pemba Island indicate that farmers perceive changes in the temperature and rainfall trends in their respective areas. Results in Table 4.2 indicate that 88.8 percent and 94.9 percent perceive that there have been significant changes on temperature and rainfall in their respective areas over the past 30 years. They testified that these changes have been characterised by change in the start and end of rainfall, its amount, intensity and frequency during the rainy season; 30.9 percent admitted that there have been erratic rain in their areas, 62.8 percent pointed out that there has been small amounts of rainfall which falls for a very short period.

Climate variables	Perception	% of farmers
Temperature	Increase	88.8
	Decrease	8.0
	No change	2.4
Rainfall amount	Decrease	94.9
	Increase	4.0
	No change	0.3
Rainfall intensity	Heavy rain and for short time	30.9
	Short rains and for long time	5.6
	Short rains and for very short time	62.8
	No change	0.3

Table 4.2: Farmers' perceptions of long-term change in climatic variables (temperature and rainfall)

Farmers were also asked to report on the changes they had witnessed in their respective areas and what they thought could be the reason behind such changes. Results in Table 4.3 show that 87.5 percent reported that they experienced crop failure due to drought in their areas, 63.7 percent experienced change in cropping pattern, 66.9 percent experienced disappearance of crops that used to be produced in their areas, 33.9 and 45.6 percent noted outbreak of crop diseases and human diseases such as malaria, respectively. Crops such as coffee and banana, which used to dominate mid and lower attitudes of the slopes of Mount Kilimanjaro, were being replaced with pasture vegetables. These farmers associated these problems with climate change. According to them the increase in temperature and reduced rainfall has favoured growth of some crop diseases such as head and fruit rots and pests such as aphids in plant and tick borne diseases in livestock. Most of these ailments were associated with changing trends of temperature, droughts and other attendant factors.

Climate change effect	**% of farmers** **n=375**
Crop failure	87.5
Change in cropping pattern	63.7
Disappearance of crops	66.9
Outbreak of crop diseases	33.9
Outbreak of other diseases like malaria	45.6

Table 4.3: Farmers linking of the climate change to the change experienced in agriculture cycle and health in their respective areas

4.2 Small farmers' climate risk perception and decisions

Information gathered from farmers through focus group discussions revealed that Pangani river basin and Pemba Island are increasingly experiencing droughts, with marked changes in the rain days and intensity (Table 4.4). In total, 90.7 percent of the respondents perceived that there had been significant changes in rainfall patterns in their respective areas over the past 15-30 years. About 30.5 percent of the farmers interviewed perceived long-term changes in temperature.

Perception	Heavy rainfall (N=105)	Moderate rainfall (N=175)	Low rainfall (N=140)	Total (N=420)	Sig diff
Rainfall Decrease	89.4	90.9	91.9	90.7	0.47
Increased in frequency of droughts and floods	34.1	25.6	26.6	28.6	2.91
Temperature Increased	18.2	31.1	42.7	30.5	18.25***

Table 4.4: Perceptions of rainfall trend

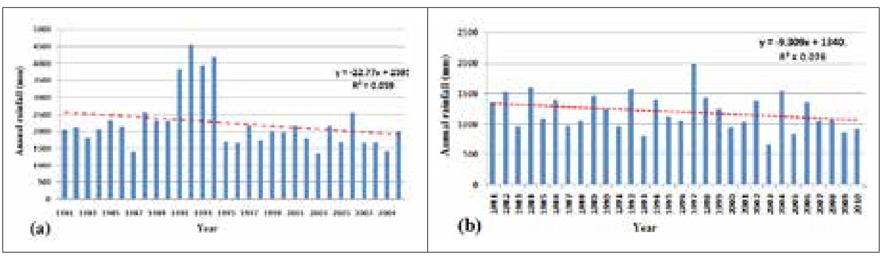
Furthermore, the results shows that, the subjective rainfall satisfaction index obtained from asking farmers a series of questions related to rainfall adequacy in the previous growing season, of 0.22 was obtained, which indicates that during the growing season of February to July the rainfall situation was undesirable (Table 4.5). Farmers' generally reported late onset of rain, poor distribution within the season, and sometimes early cessation. Also farmers highlighted specific problems of variability in the duration, timing and intensity of the rains, including winds and heavy rains at the start of the seasons. In the moderate and lower rainfall areas of the basin respondents highlighted drought as an increasing problem, and more frequent flash floods as a result of increased rainfall intensity. In the highland areas, increased rainfall intensity leading to increased runoff was reported.

Variables	Heavy rainfall (N=105)		Moderate rainfall (N=175)		Low rainfall (N=140)		Overall (N=420)		sig diff
	Mean	St.d	Mean	St.d	Mean	St.d	Mean	St.d	
Annual Rainfall trend Decreasing	0.11	0.31	0.09	0.29	0.08	0.27	0.09	0.29	0.23
During growing season Rainfall come on time	0.21	0.41	0.27	0.44	0.36	0.48	0.28	0.45	3.51*
During growing season Rainfall stopped on time	0.3	-0.46	0.26	0.44	0.3	0.46	0.29	0.45	0.37
Enough rain at the beginning of the growing season	0.18	0.38	0.18	0.39	0.16	0.37	0.25	0.43	0.13
Enough rain during the growing season	0.26	0.44	0.23	0.42	0.25	0.43	0.17	0.38	0.16
Frequency of heavy rainfall increase	0.24	0.43	0.2	0.4	0.25	0.43	0.23	0.42	0.57
Number of Rainfall days decrease	0.14	0.35	0.14	0.35	0.16	0.37	0.15	0.35	0.16
frequency of dry spells/ droughts increased	0.18	0.38	0.32	0.46	0.43	0.49	0.3	0.46	9.26**
Average rainfall satisfaction index	0.20	0.28	0.21	0.40	0.25	0.41	0.22	0.40	1.29

Table 4.5: Farmers' rainfall satisfaction index

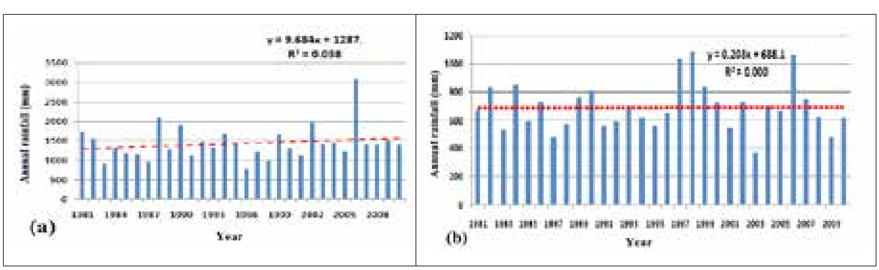
4.2.1. Meteorological results on climate change (rainfall and temperature)

The results in Figures 4.4a and 4.4b show that there is a general decrease of rainfall in the area over the period under review (i.e. more than 30 years). Moreover, there is a high variation of rainfall in the area, with five stations registering a significant decrease of rainfall. Higher rainfall decreases are evident in Maua seminary and Kilema Chini (Lower) in Moshi rural which are found in the upper altitude of the basin. The trend also evident on Pemba Island, in Pangani and Korogwe districts, which are found in the lower altitudes of the basin. A slight decreasing trend in rainfall is observable in Arusha, Lyamungo, Moshi and Same. These factual data confirm the perception of the farmers (see Table 4.4)



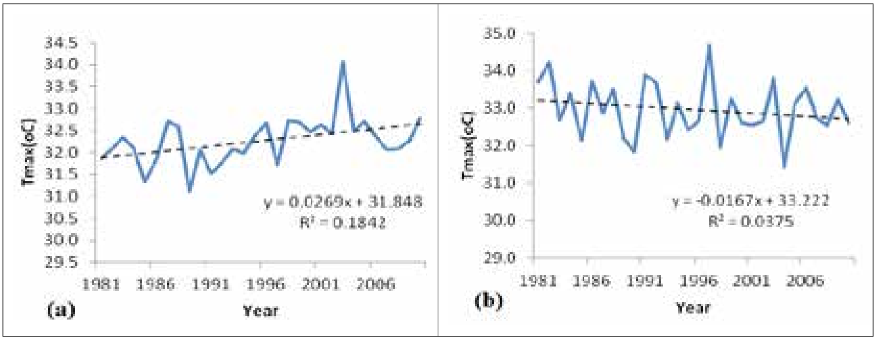
Figures 4.4: Rainfall trends at (a) Maua seminary station (upper altitude) and (b) Pangani district station (lower altitude of Pangani Basin)

On the other hand, a slight increase in rainfall (see Figure 4.5a) is observable in Lushoto, Shingatini (Mwanga) and Kibong'oto (Hai), which are found in high altitudes of the basins. The highest value recorded during the period is 4551mm at Maua Seminary and lowest value is 265mm over Same, which are higher and lower altitude areas, respectively, implying that the higher the altitudes the more the rainfall. Constant rainfall trend is observed in Mazinde, Figure 4.5b, which is found in highest altitude of the basin.

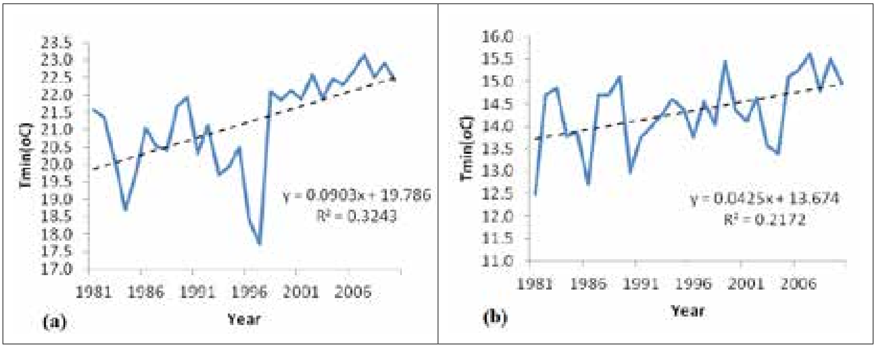


Figures 4.5: Rainfall trend (a) increasing at Shigatini station and (b) remaining constant at Mazinde station (both in middle altitude of Pangani basin)

The results on temperature trends indicate that the annual highest maximum and lowest minimum temperature has been increasing over the 30-year period in the entire area of the basin and Pemba Island. A slight increase of maximum temperature has been observed Kilimanjaro airport, Moshi and Tanga, and Pemba, which shows the highest increasing trend (Figure 4.6a). On the other hand, decreasing trends of maximum temperature has been observed in some areas of Arusha and Same (Figure 4.4b). The highest maximum value of temperature recorded during the period is 35.9^0C at Kilimanjaro airport and the lowest maximum value is 28.2^0C recorded over Arusha. Similarly, the results indicate that the lowest minimum temperature has been increasing at a higher rate over 30 years in the basin and on Pemba Island. The highest minimum value of temperature recorded during the period is 23.2^0C at Pemba (Figure 4.7a) and lowest minimum value is 11.4^0C in Arusha (Figure 4.7b).



Figures 4.6: Temperature trends (a) increasing in Pemba and (b) decreasing in Same (middle of Pangani Basin)



Figures 4.7: Temperature trends in (a) in Pemba and (b) in Arusha (upper altitude of Pangani Basin)

The variation in rainfall and temperature observed indicate that climate is changing over time and by so doing it influences the type of crops, cropping patterns and crop diseases. It also influences adaptive strategies with the likely implication for the REDD+ initiatives. This is confirmed by data gathered from small-scale farmers, elders, opinion leaders, and local government leaders from high altitudes of the basin who admitted that over the period there had been a change in type of crops produced in the area: for example, 30 years ago in the high altitudes of Kilimanjaro, particularly Moshi rural (Mahoma and

Kilanya villages), yams, sweet potatoes, mangoes, avocados, and maize were being produced, but these crops have since disappeared. Now farmers in this area depend on banana, coffee, and beans for food and cash. Witnesses also attest to the fact that, although banana is currently the main source of food and income in the area, the crop is highly affected by diseases, which many of these plants' stems rotting before they withered and died.

A similar observation is shared by smallholder farmers in the other upper altitudes (Lekitatu) of the basin which are dominated by irrigation agricultural practices. The witnesses in these areas admit that 30 years ago they were producing a number of crops (i.e. maize, coffee, banana, beans, finger millet, sweet potatoes, paddy, sugar cane, Irish potatoes, yams and tree fruits such as oranges, avocado, and pawpaw), but very few of these still exist and even then marked by low productivity due to unfavourable climate. One of the witnesses pointed out that to-date you hardly find orange and lemon fruit trees, yams, banana, Irish potatoes, and coffee in their area. He further mentioned that even the remaining crops were severely attacked by diseases, hence leading to higher production costs than was the case 30 years ago. The witnesses also admitted that, water was aplenty 30 years back and the area was mainly rain-fed agriculture, with very few irrigating their fields. This was attributed to the fact that rain was enough to ensure good harvests.

On the other hand, witnesses from the middle altitude (Mgwashi, Mabilioni and Baga villages) also admit to experiencing changes in climatic parameters, which have induced shifting in economic activities in the area over the past 30 years. Crops such as banana, yams, beans and coffee have disappeared from the area over this period. Persistent drought and the emergence of diseases were reported as the main cause of the disappearance of these crops from this area. Changes in climatic parameters have also induced changes in cropping pattern, with the witnesses admitting that 30 years ago they were tilling small pieces of land, but now they were cultivating large pieces of land and diversifying crops for the purpose of spreading out the risks of crop failure due to drought and diseases.

Finally, witnesses from lower altitude of the basin (Bungu, Mafuleta, Kigurusimba and Pemba – Makangale and Micheweni) also admitted experiencing changes in climatic parameters. This has induced a shift from rain-fed agriculture to irrigation, which has resulted into conflict due to water shortage. Demand for water has increased abruptly as more and more small-scale farmers shift to irrigation to cope with climate change effects. Similarly, these areas have experienced a disappearance of many crops that used to be grown 30 years ago; crops such as maize, beans, and coffee are slowly replaced by new crops like paddy and vegetable. Paddy and vegetable are mainly grown in irrigated areas. In some areas, farmers have turned to livestock keeping that allow for mobility when drought sets in.

4.3 Small farmers' adaptive strategies

To cope with the climate change effect at least in a short-term some farmers in the area reported that they have increased the use of inorganic fertilisers (see Table 4.6). Farmers living in areas where water is relatively available pointed out that they use irrigation to cope with climate change stresses (35.7%) (see Table 4.6). A significant proportion of the farmers in the area admitted to resorting to soil and water conservation mechanisms (10.7%), change crop from perennial to annual which matures faster (14.3%).

Copping strategy	% respondents
Irrigating farm plots	35.7
Grow crops that mature faster	14.3
Practice intercropping	16.8
Planting trees around the farm plots for shading and wind break	13.3
Applying soil and water conservation mechanisms	10.7
Planting drought resistant crops	8.4
Involved non-farm activities such as charcoal business	6.9
Change planting dates (i.e. planting at first rain)	6.5
Increase use of inorganic fertilizers	0.01
Migrating from dry to wet, river banks, wetlands and deforestation	0.01
Total	**100.0**

Table 4.6: Adaptation strategies farmers employ

Other farmers, especially those found dry areas in Pangani river basin and Pemba indicated that they plant at the onset of first rains, plant fast-maturing crops, plant drought-resistant crops and mix crops on the same plot to accommodate climatic changes. About 8.3, 18.1, 10.1, and 16.8 percent admitted to employing these mechanisms, respectively. Some farmers mentioned that they have abandoned agriculture and embraced non-farming activities. About 8.8 percent of the farmers pointed out that they have turned to non-farm activities due to increased risk of crop failure and disease in their areas (see Table 4.6).

On the other hand, a significant proportion of the farmers believe that the long-term solution to climate change challenges is increasing efforts to plant trees, which will help in absorbing greenhouse gases that are major causes of climate change. They also admitted that planting trees improved shading, shelter and produced foliage which is important for mulching and making farmyard manure. Survey results presented in Table 4.6 show that 13.3 percent of farmers plant trees in and around their farm plots and river banks for the aforementioned purposes.

The study also asked farmers' about barriers to using various farm level climate change adaptation strategies presented in Table 6. Results in Table 4.7 show that, 9.6 percent pointed out that the shortage of farm land is the main barrier to adopting coping mechanisms. Others pointed out that the shortage of water for irrigation limits adaptation to climate change in the area. About 47.7 percent cited this as a climate change adaptation barrier. In a situation where rainfall reliability is low, the use of irrigation remains the most sustainable means for assured crop and livestock production. Also, lack knowledge or information about proper adaptation mechanisms was pointed out as the one of the limiting factors in the area; about 14.7 percent mentioned it as the main limiting factor. Lack of timely weather forecast information on the expected climate change (variability) was pointed out as one of the limiting factor; about 8.8 percent declared that this is one of the main limiting factors.

Constraints	% of respondents (n=375)
Shortage of water for irrigation	47.7
Lack of necessary farm inputs	20.0
Lack of information about proper adaptation mechanisms	14.7
Shortage of farm land	9.6
Lack of timely climate forecasting information on the expected climate changes	8.8
Lack of capital	8.0
Shortage of labour force to implement some of the copping strategies	2.4

Table 4.7: Farmers' constraints to adaptation methods

Other factors pointed out by the farmers include lack of necessary farm inputs such crop varieties tailor made for coping with extreme climatic conditions as the main constraint to applying the mechanism. About 20 percent pointed out this as the limiting factor. Finally, lack of capital to invest in adaptation mechanisms such as irrigation, rain water harvesting and soil water conserving mechanisms were cited as major limiting factors according to eight percent of the respondents.

4.4. Factors conditioning farmers' choice of adaptive strategy

To adapt to climate change effects, farmers employ strategies analysed here in combination with other strategies. The various combinations of measures and practices may be grouped into the following categories: Increase in the use of inorganic fertilisers (INCUSEINOFERT); Planting drought resistant crops (DROURESCROPS); Irrigating farm lots (IRRIGATEFARMPLOTS); Early planting (EARLYPLANTING); Use of mulching (USEMA); Grow crops that mature faster (GROWCROPMATFAST); Plant trees (PLANTTREES);focus more on or turn to non-farming activities (FOCUSNONFARMACT); and Practice mixed cropping (MIXEDCROPPING).

To capture the effect of various factors on the probability of adopting various climate change adaptation alternatives at the farmers' disposal, we used *migration to river banks, wet or wetlands that are available in the basin and Pemba Island* as the base category for no adaptation and evaluate other choices as alternatives to this option. The first column of Table 4.9 compares the probability of increased adoption of the use of inorganic fertilisers (INCUSEINOFERT) as opposed to no adaptation. The marginal effects and their signs reflect the expected change in probability of preferring to increase the use of inorganic fertilisers to migrating to river banks or wetlands available in the basin and Pemba Island (the base) per unit change in an explanatory variable. The same applies to the remaining alternatives in the table.

Variable	Mean	Minimum	Maximum	Std
HH head age	46.97	25	85	13.92
HH head education level (measured as number of years in schooling)	7.01	0	20	2.69
Upper	989.65	787.98	1356.42	178.97
Middle	756.54	698.76	936.46	169.33
Lower	213.43	0	456	166.78
Dry	156.34	0	346	102.36
Wet	167.25	10	536	116.32
HH size	5.29	1	13	2.12
Primary occupation	2.43	0	1	0.45
Number of years lived in the area	4.87	1	6	1.18
Access to extension services	0.73	0	1	0.45
Farm size	3.04	0.5	10	2
Access to crop failure subsidies	0.73	0	1	0.45
Access to credit	0.73	0	1	0.45

Table 4.8: Descriptive statistics: Variable for the regression model

The estimated marginal effects and P-levels from the Multinomial Logit Model and the estimated coefficients are presented in Table 4.9. The results show that most of the explanatory variables are statistically significant at 10 percent or lower which are described and discussed below. The chi-square results show that likelihood ratio statistics are highly significant ($P<0.00001$), suggesting that the model has a strong explanatory power. Specifically, the results in Table 4.5 show that the age of the head of household positively influences the probability of adopting all the alternatives, and also significantly influences the probability of adopting soil conservation mechanisms and adopting mixed cropping adaptation alternatives as opposed to the base alternative. The results also indicate that the education level of the household head positively influences the probability of adopting all climate change adaptation alternatives and significantly influences the probability of adopting early planting, applying soil water conservation mechanisms, growing crops that take a short period to mature (mature faster), turning to non-farming activities and practicing mixed cropping adaptation alternatives as opposed to the base alternative.

Furthermore, results in Table 4.9 indicate that the location of a farmer in the basin and the Island i.e. upper, middle, lower, wet or dry influence farmers' probability of adopting adaptation alternative as opposed to the base alternative differently. The upper locations of the basin, for example, appears to influence negatively the probability of increasingly adopting use of inorganic fertilisers, irrigation of farm plots, applying soil and water conservation mechanisms, turning to non-farming activities, and practicing mixed cropping adaptation alternatives as opposed to the base alternative. On the contrary, the middle parts of the basin appear to influence positively the probability of increased adoption of the use of inorganic fertilisers, planting of drought-resistant crops, planting trees, turning to non-farming activities and practicing mixed cropping adaptation alternatives as opposed to the base alternative. The locations also appear to influence positively the probability of adopting irrigating farm plots, early planting and applying soil and water conservation adaptation alternatives as opposed to the base alternative.

The lower locations of the basin appear to have a negative influence on the probability of increased adoption of the use of inorganic fertiliser adaptation alternatives as opposed to the base alternative. On the other hand, these locations appear to have a positive influence on the probability of adopting planting of drought-resistant crops, irrigation of farm plots, early planting, use of mulching as soil and water conservation mechanisms, turning to non-farming activities and practicing mixed cropping adaptation alternatives as opposed to the base alternative. Other factors determining the type of adaptive strategy include ownership of livestock, permanency nature of crops grown and genders. It is more likely that farmers owning large number livestock will migrate to other areas. Similarly, out-migration is common to farmers who cultivate annual crops and men.

The wet areas appear to have negative influence on adaptive strategies and, conversely, dry areas appear to have positive effect. In fact, farmers living in areas with relatively lower climatic stress are reluctant to adapt to climate change than those in areas with more stress.

Variable	INCFERT USE	DROURES CROPS	IRRIGATE FARMPLOTS	EARLY PLANTING	USEMA	GROWCROP MATFAST	PLANTTREES	FOCUS NON FARMACT	MIXED CROPPING
Household head age (years)	0.0315	0.0015	0.0044	0.0025	0.0036*	0.0026	0.0004	0.0044	0.0044*
	(0.53)	(0.63)	(1.46)	(1.16)	(1.57)	(1.17)	(0.29)	(0.38)	(1.69)
Household level of education (years)	0.0331	0.0007	0.0179	0.0276*	0.0146*	0.0166*	0.0019	0.0389*	0.0026***
	(0.97)	(0.07)	(1.24)	(1.67)	(1.78)	(1.57)	(0.32)	(1.63)	(2.32)
Upper	-0.0389*	-0.0489	-0.0920*	-0.0672	-0.0156*	-0.0582	0.0151	-0.0223***	-0.0154*
	(-1.54)	(-1.04)	(-1.56)	(-1.10)	(-1.63)	(-1.20)	(0.62)	(-2.10)	(-1.62)
Middle	-0.0426**	-0.0327*	0.0597***	0.0026***	0.0318*	-0.0217	-0.0054	-0.0453**	-0.0355***
	(-1.85)	(-1.65)	(2.34)	(3.44)	(1.54)	(-1.14)	(-0.48)	(-1.88)	(-2.48)
Lower	-0.0327*	0.0126**	0.0422***	0.0087***	0.1468***	0.0067	-0.0364***	0.0342**	0.0253***
	(-1.51)	(1.01)	(2.53)	(2.60)	(2.60)	(0.60)	(-3.11)	(1.95)	(3.21)
Dry	-0.0254	0.0253*	-0.0476*	0.0025**	0.0324*	0.0224	-0.0045	0.0525***	0.0433***
	(-1.27)	(1.46)	(-1.54)	(1.95)	(1.55)	(1.25)	(-0.05)	(2.82)	(2.10)
Wet	0.0263	-0.0057	-0.0064	-0.0013	-0.0516***	0.0012	-0.0065	-0.0415*	-0.0526*
	(1.18)	(-0.42)	(-0.33)	(-0.23)	(-2.06)	(0.10)	(-0.06)	(-1.66)	(-1.66)
Household size	-0.1682***	0.0091	0.0108	0.0351**	0.0733*	0.0241**	0.0042	0.0232***	0.0343*
	(-2.42)	(0.72)	(0.64)	(1.83)	(1.53)	(1.93)	(0.53)	(2.53)	(1.53)
Primary Occupation (1/0)	0.0324	0.0222	0.0012	0.0332*	0.0622*	0.0232	-0.0022	-0.0325	0.0232***
	(1.14)	(1.15)	(0.05)	(1.56)	(1.70)	(1.30)	(-0.17)	(-0.16)	(2.17)
Number years lived in the area	-0.0513**	-0.0402*	0.0263	0.0380*	0.0432*	0.0270	-0.0131	0.0242**	0.0432***
	(-1.88)	(-1.71)	(0.83)	(1.64)	(1.93)	(1.14)	(-0.93)	(1.93)	(2.43)

Access to extension services (1/0)	0.0853	0.0752	0.1129*	0.1533***	0.0356*	0.1634***	0.0246	-0.0436*	0.0257*
	(1.32)	(1.23)	(1.51)	(3.68)	(1.74)	(3.27)	(0.74)	(-1.74)	(1.74)
Farm size (ha)	0.0214*	0.0214*	-0.0349*	0.0048*	0.0253*	0.0018	0.0152*	-0.0163*	0.0352*
	(1.87)	(1.77)	(-1.85)	(1.64)	(1.68)	(0.14)	(1.78)	(-1.68)	(1.78)
Access to crop failure subsidies (1/0)	-0.0325***	-0.0317	-0.1863**	-0.0047**	-0.0525*	-0.0913	-0.0633	-0.0533	-0.0435*
	(-2.61)	(-0.41)	(-1.93)	(1.99)	(-1.65)	(-0.99)	(-1.15)	(-0.15)	(-1.75)
Access to credits (1/0)	0.2236***	0.1235***	0.1211*	0.0848***	0.0947***	0.0958***	0.1488**	0.1210***	0.0467***
	(2.02)	(2.03)	(1.64)	(-2.18)	(2.19)	(2.19)	(1.87)	(2.17)	(2.17)

Table 4.9: Marginal effects of explanatory variables from multinomial Logit climate change adaptation model

Note: *Values in brackets are z-values.*

5.0 Implications of the lessons learnt for REDD+ process and climate change mitigation and adaptation in general

The United Nations Framework Convention on Climate Change (UNFCCC) conference agreed in Bali in 2007 that a comprehensive approach to climate change mitigation should include the reduction of emissions from deforestation and forest degradation (REDD) in developing countries (UNFCCC, 2007). REDD+ is a financial mechanism compensating countries for the prevention of deforestation and forest degradation that could otherwise occur. The 2009 Copenhagen Accord of the UNFCCC recognised REDD+ as a valid mitigation strategy and has increased interest in and funding of it. An international accord on REDD+ emphasises alongside effective greenhouse gas mitigation its environmental co-benefits such as biodiversity protection, sustainable forest management, provision and quality of soil and water, as well as socioeconomic co-benefits, pro-poor development, protection of human rights, and improved forest governance (UNFCCC, 2007).

Many agricultural and forestry practices emit GHGs into the atmosphere. According to Seeberg-Elverfeldt (2010), using fertilisers release N_2O from the soil and burning agricultural residues gives rise to CO_2 levels. Also, CH4 is set free in the digestion process of livestock, as well as when rice is grown in flooded conditions. When land is converted to cropland and trees are felled,CO_2 emissions result. Based on the study findings in Pangani river basin and Pemba, small farmers' adaptive strategies and mitigation against climate change have both positive and negative implications for GHG formation and thus somehow in conflict with REDD+ initiatives in Tanzania. The implications summarised in six points below are also mentioned in the National Climate change adaptive strategies (see URT, 2007):

a) Evidence of change in type crops cultivated from permanent tree crops such as coffee, tea and banana to short maturing annual crops contradict REDD+ initiatives which is against the reduction of emission and deforestation.

b) Evidence of increased non-farm activities such as charcoal-burning and cutting down of mangrove forest as an adaptive strategy against declining income from crops due to climate change exerts pressure on forest reserves, hence further contradicting the spirit of REDDS initiatives.

c) Evidence of increased use of inorganic fertiliser and farm yard manure in response to declining land productivity due to, among other things, climate change-related factors increases the GHG emission thus in contradiction with REDD+ initiatives.

d) Increased evidence of farmers and livestock outmigration in search of pastures in marginal and forested areas, thus destroying highly needed carbon sink as addressed by REDD+ initiatives.

e) Evidence of declining yield climate related challenges in the context of population growth makes smallholder farmers expand production to marginal and forest reserves and they practice shifting cultivation. These measures have high a impact on REDD+ initiatives.

f) Isolated evidence of tree planting as adaptive strategies for mitigating the impact of climate change has been reported. This initiative increases carbon since within the REDD+ initiatives.

The empirical results from the study which are the basis of this chapter posit that smallholder farmer' activities, their adaptive strategies climate change in Pangani basin and Pemba compromise in many ways the REDD+ initiatives. Whereas REDD+ initiatives are long-term, the adaptive strategies for mitigation resource-poor farmers employ against the impact of climate are short-term strategies. This observation implies that efforts for sustaining REDD+ initiatives must go hand in hand with assisting farmers to meet short-run basic needs such as food in addition to the provision of services which can stop them from turning to natural resources (carbon sink). This approach can facilitate their meeting of their immediate survival needs and co-opt them into the long-term REDD+ initiatives.

Acknowledgement

Research, which is the basis of this chapter, was funded by the CCIAM project. It is part of a larger study on the Economic Assessment of Climate Change Impacts, Vulnerability and Adaptation in Tanzania: Case of Pangani Basin and Pemba coordinated by Sokoine University of Agriculture (SUA), Tanzania.

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Appendices

	Age	educat	Upper	Middle	Lower	dry	wet	hhsize	yearliving	farmsize
age	1.000									
educat	-0.1438	1.000								
Upper	0.1855	0.0671	1.000							
Middle	-0.0372	-0.1499	-0.3226	1.000						
Lower	-0.2506	0.0422	-0.311	-0.3874	1.000					
dry	0.0952	0.0979	-0.1633	-0.2034	-0.196	1.000				
wet	0.048	-0.1372	-0.1131	-0.1887	-0.206	-0.1082	1.000			
hhsize	0.089	0.0877	-0.0577	-0.0708	-0.1501	0.2197	0.1274	1.000		
yearliving	0.3405	0.0228	-0.209	0.0214	-0.0781	0.1113	0.0202	0.204	1.000	
farmsize	0.0013	0.0052	-0.2176	0.0904	0.1019	0.0156	0.0531	0.1585	0.1325	1.000

Appendix 4.1: Correlation analysis of continuous explanatory variables

Variable	VIF
Upper	3.40
Middle	3.13
Lower	2.93
dry	2.56
wet	2.12
age	1.68
educat	1.45
hhsize	1.30
primocupat	1.24
yearliving	1.35
extservices	1.01
farmsize	1.03
credit	1.02
Mean VIF	**1.86**

Appendix 4.2: Variance inflation factor (VIF) test for multicollinearity among variables included in the analysis

Variable	INCRE FERT USE	DROUGH RESISTCROPS	IRRIG FARMPLOTS	EARLY PLANTING	USESWC	GROWCROPS MATFAST	PLANT TREES	FOCUSNON FARMACT	MIXED CROPPING
Household head age (years)	-0.022	-0.005	-0.022	0.025	0.035	0.002	-0.011	-0.017	-0.025
	(-0.29)	(-0.14)	(-0.61)	(0.69)	(0.79)	(0.07)	(-0,29)	(-0.31)	(-0.64)
Household level of education (years)	0.068	0.086	0.111	0.026	0.243**	-0.031	0.060	-0.374**	0.030
	(0.27)	(0.75)	(0.98)	(0.26)	(1.91)	(-0.25)	(0.49)	(-1.94)	(0.21)
Upper	-3.200**	2.626***	2.673***	-1.896*	2.543**	6.219***	6.675***	-1.651**	2.661***
	(-1.75)	(2.57)	(3.73)	(-1.57)	(1.88)	(3.52)	(3.72)	(-1.69)	(8.65)
Middle	-6.531**	5.884*	6.196***	5.584***	4.710**	5.952***	6.038***	6.408*	5.986***
	(-1.69)	(2.00)	(3.03)	(2.29)	(1.78)	(2.15)	(2.39)	(1.57)	(12.13)
Lower	-7.180**	0.449*	0.601***	-6.490**	-7.211	0.577**	0.125	0.617*	0.532**
	(-1.89)	(1.50)	(2.03)	(-1.58)	(-1.01)	(1.92)	(0.38)	(1.50)	(1.74)
Dry	2.178***	0.204	-0.039	0.347	-0.379	0.189	0.038	0.525*	-4.777**
	(2.85)	(0.78)	(-0.15)	(1.22)	(-0.36)	(0.72)	(0.14)	(1.54)	(-1.89)
Wet	-0.141	0.169	0.122	0.385*	-0.115	0.140	0.126	-4.224**	-4.402**
	(-0.22)	(0.72)	(0.54)	(1.56)	(1.23)	(0.60)	(0.54)	(-1.86)	(-1.69)
Household size	0.641	0.007	-0.035	-0.032	0.257	-0.215	-0.006	-0.132	-0.080
	(0.14)	(0.04)	(-0.23)	(-0.21)	(0.06)	(-1.27)	(-0.04)	(-0.54)	(-0.43)
Primary Occupation	-0.239	-0.221	-0.074	-0.068	0.018	0.080	-0.101	-0.010	-0.346

	(-0.31)	(-0.86)	(-0.31)	(-0.28)	(0.06)	(0.31)	(-0.38)	(-0.03)	(-1.18)
Number years lived in the area	0.154	-0.614	-0.308	-0.995**	-1.035*	-0.169	-0.497	-0.171	-0.097
	(0.11)	(-1.22)	(-0.63)	(-1.87)	(-1.82)	(-0.33)	(-0.98)	(-0.25)	(-0.19)
Access to extension services (1/0)	-1.956	0.912	0.631	0.934***	1.263	-0.874	0.148	-0.225	-0.340
	(-0.79)	(1.00)	(0.72)	(1.98)	(0.91)	(-0.90)	(0.16)	(-0.19)	(-0.33)
Farm size (ha)	0.036	-0.016	-0.214*	-0.008	-0.182	-0.169	0.014	-0.364**	-0.639***
	(0.09)	(-0.12)	(-1.51)	(-0.07)	(-0.97)	(-1.11)	(0.10)	(-1.62)	(-2.62)
Access to crop failure subsidies (1/0)	-1.961***	2.200***	1.245***	2.163***	1.213***	2.232***	2.238***	-3.265**	2.237*
	(-2.53)	(2.40)	(3.17)	(3.49)	(2.18)	(3.10)	(2.52)	(1.67)	(1.59)
Access to credits (1/0)	1.664	2.786***	2.260**	1.281	2.757***	1.282	-0.176	2.644**	1.006
	(0.58)	(2.20)	(1.81)	(1.00)	(2.00)	(1.00)	(-0.13)	(1.79)	(0.76)
Number of observations	364	* significant at 10%							
Log Likelihood	-465.848	** significant at 5%							
LR χ^2 (135)	744.590	*** significant at 1%							
Prob > χ^2	0.0000								
Pseudo R2	0.4442								

Appendix 4.3: Parameter/coefficient estimates from Multinormial Logit Model (MNLM)

Note: Values in brackets are z-values.