International Journal of Modern Social Sciences, 2013, 2(3): 169-194

Modern Scientific Press

International Journal of Modern Social Sciences

ISS: 2169-9917

Journal homepage: www.ModernScientificPress.com/Journals/IJMSS.aspx

Florida, USA

Article

Small Scale Farmers' Adaptation to Climate Change Effects in Pangani River Basin and Pemba: Challenges and Opportunities

G. J. Sanga[1], *, A. B. Moshi[2], and J. P. Hella[3]

[1]*Department of Economics and Statistics, The University of Dodoma (UDOM), P. O. Box 395, Dodoma*

[2]*Department of Agriculture Economics and Agribusiness, Sokoine University of Agriculture (SUA), P.O.Box 3007, Morogoro*

[3]*Department of Agriculture Economics and Agribusiness, Sokoine University of Agriculture, P. O. Box 3007, Morogoro*

* Author to whom correspondence should be addressed; E-Mail: godysanga2012@yahoo.com, abmoshi@yahoo.com, jp_hella@yahooco.uk

Article history: Received 29 August 2013, Received in revised form 5 October 2013, Accepted 15 October 2013, Published 14 November 2013.

Abstract: Climate change is a global problem with its effects being severe in developing countries where the majority are poor and depend primarily on rain-fed agriculture. Evidence shows that Africa is more vulnerable because 80% of its population depends on rain-fed agriculture for food and other livelihood needs. Climatic data indicate that the continent experiences decreasing and increasing trends of rainfall and temperature respectively. Considering that agricultural continue to be the main stay of the majority of rural communities in the continent. This study therefore, investigated small scale farmers' perceptions to climate change; farm level adaptation efforts and limitation; and factors influencing adoption adaptation mechanisms in Pangani River Basin and Pemba of Tanzania. Results indicate that farmers in the area perceive that there is change in trends of temperature and rainfall and they are able to link with changes in crop types, cropping patterns, and outbreak of human, animal and crop diseases happening in their respective areas. Results also indicate that farmers are making efforts to adapt to it but shortage of water for irrigation, lack of necessary farm inputs, capital, lack of information on appropriate adaptation mechanisms, and shortage of farm land are the major limitations. Results from Multinomial Logit Model indicate that access to extension services; credit; education level, and location positively condition farmers' choices of climate change coping strategy. These results suggest that there are opportunities and limitation in ensuring small scale farmers fully adapt to climate change that need immediate attention.

Keywords: Climate change, perceptions, adaptation methods, multinomial logit.

---

1. Introduction

Climate change is a global problem, however its associated impacts and vulnerability varies across the globe. Studies indicate that developing countries, of which the majorities are in Africa, are the ones that have severely been affected by climate change (Kurukulasuriya and Mendelsohn, 2008). These countries are more vulnerable to climate change impacts because the majority of the population depends on rain-fed agriculture for food and other livelihoods (Morton, 2007). Tanzania being one of developing countries has not been spared of climate change effects. Currently the climate of Tanzania is highly variable and unpredictable. Climate assessments indicate that the country is prone to extreme weather conditions, including droughts and floods (Shemsanga, 2010).

Climate variability has direct adverse impacts on agricultural production in Tanzania because nearly 80% of agricultural production in the country is rainfall dependent (Thornton, 2011). In recent years the country has experienced crop failure due to low rainfall and emerging animal, crop and human diseases in many parts (Mtalo *et al*., 2005). The effect is more profounding in the country, because the majority of the population is characterized with low means of adapting to climate variation impacts (Agrawala *et al*., 2003).

The fact that climate is changing and mitigation efforts to reduce the sources or enhance the sinks of greenhouse gases will take time as it involve the diverse global community, regional and country initiatives to adapt to changes are imperative and of critical concern in developing countries like Tanzania where vulnerability is high due to low capacity to absorb climate change shocks. Adaptation helps farmers achieve their food, income and livelihood security in the face of changing climatic conditions, extreme weather conditions such as droughts and floods (IISD, 2007; De Wit and Stankiewicz, 2006; Kandlinkar and Risbey, 2000). It is believed that small scale farmers can reduce the potential damage by making tactical responses to these changes (Maddison, 2006; Mano *et al*., 2003). Analyzing perception and adaptation is therefore deemed important for finding ways to help farmers adapt in the context of developing countries rural economies.

Although small scale farmers in developing countries have low capacity to adapt to climate change effects, they have, however, survived and coped in various ways over time (Mano and Nhemachena, 2006). A better understanding of how they are doing it is essential for designing incentives to enhance adaptation. Supporting the coping strategies of local farmers through appropriate public policy, investment and collective actions can help increase the adoption of well-crafted adaptation measures (IISD, 2007). For poor countries like Tanzania this will help to reduce the negative consequences of predicted changes in the coming years, with great benefits to vulnerable rural communities at large (URT, 2007).

A wide range of empirical studies measuring the economic impacts of climate change on agriculture in developing countries (Hassan and Nemachena, 2008; Kurukulasuriya and Mendelsohn, 2006; Seo and Mendelsohn, 2006; Mano and Nhemachena, 2006; Benhin, 2006) show that such impacts can significantly be reduced through adaptation. This paper adds to these analyses by studying: (i) farmers' awareness on climate change and its impacts; (ii) famers ability to associate climate change with the change in type of crops, cropping pattern, outbreak of human, animal and crop diseases in their respective areas; (iii) farmers efforts to cope with climate change and what they perceive as the limitations to their efforts, and (iv) the determinants of farmers' choices between alternative adaptation measures available at their disposal. Our analysis is different from the adaptation studies mentioned above, in this study we investigate farmers' *actual* adaptation measures that has been taken by farmers on their own initiatives. The analysis screened only farmers who have taken the initiatives to adopt to climate change effects using the resources they have at their disposal. The analysis begin with investigating farmers' perceptions on climate change basing on the assumption that small scale farmers take adaptation initiatives after realizing that something is not normal with the trends of rainfall and temperature in their respective areas. The study goes ahead with investigating determinants or factors conditioning famers' choices of various adaptations measures. The study employed the Multinomial Logit approach to identify factors conditioning farmers' choices.

The rest of the paper is presented as follows: the next section (2) presents the description of study area, followed by materials and methods describing model and data sources section (3). The empirical results and discussion are presented in section 4 and the last section (5) presents conclusions and policy implications of the results.

2. Description of Study Area

The study was conducted in Pangani River Basin and Pemba Island. The Pangani River basin drains a large catchment in the northeastern part of the country along the border with Kenya, extending from Mount Meru and Mount Kilimanjaro down through the Pare and Usambara Mountain ranges

(Figure 1) (PBWO, 1997). The basin has a total catchment area of about 43,650 sq. km with about 3,914 sq. km lying in Kenya (IUCN, 2003). Pangani River Basin is unique in the fact that it begins from the highest pick of Africa Mount Kilimanjaro (which is 5895 m asl) and Mount Meru (which is 4565 m asl) through the Pare and Usambara Mountains to the north and north-east respectively to the low lands of about 900 m asl and 0m asl. The low lands make up about 50% of the basin (Mbonile, 2001).

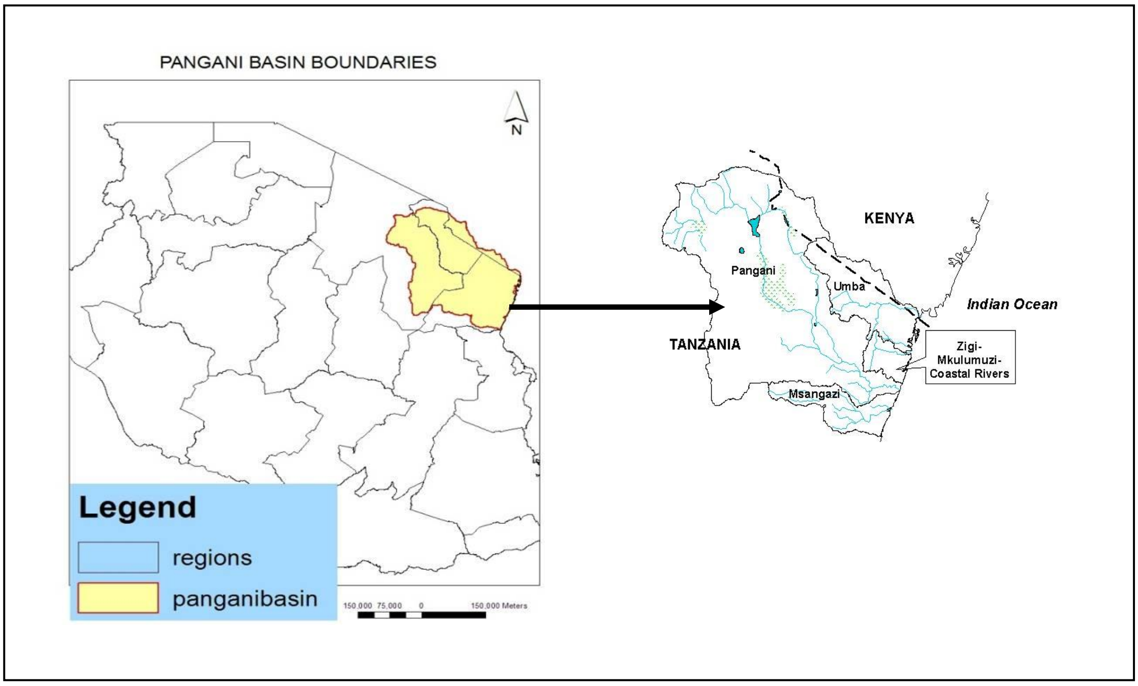


Figure 1: Pangani River Basin location in Tanzania and Boundaries

The basin is characterized by rapid population growth and uneven distribution, the basin is currently a home to 3.7 million inhabitants (IUCN, 2003). Ninety percent of this population lives in the highlands, leading to a population density of up to 300 people per sq. km, compared to 65 people per sq. km in the lowlands (IUCN, 2003). This rapid population growth, high population density coupled with climate change is posing pressure to the basin natural resources. The basin is well known for persisting water conflicts between farmers and pastoralists, shortage of arable land for agriculture and is also hosting precious natural resources such as wildlife which are important to the economy of the country. Nonetheless, the basin is characterized by in-migration of farmers searching for farmland, water and pasture for livestock.

On the other end of the spectrum, Pemba Island is located on the eastern side of Pangani River Basin (Figure 2). The Island has a total of 984 square kilometers with a population of 362,000 people. The Island is characterized by two major climatic conditions which are also used to demarcate the Island into two side; the wet and dry side. Similarly, it is characterized by in-migration of people from dry to wet side creating conflicts over land and other resources. Realizing the economic importance of the basin and the island, and the challenges posed by climate change, it is therefore, deemed important to find a better way to mitigate climate change impact so as to mimic migration towards these precious resources.

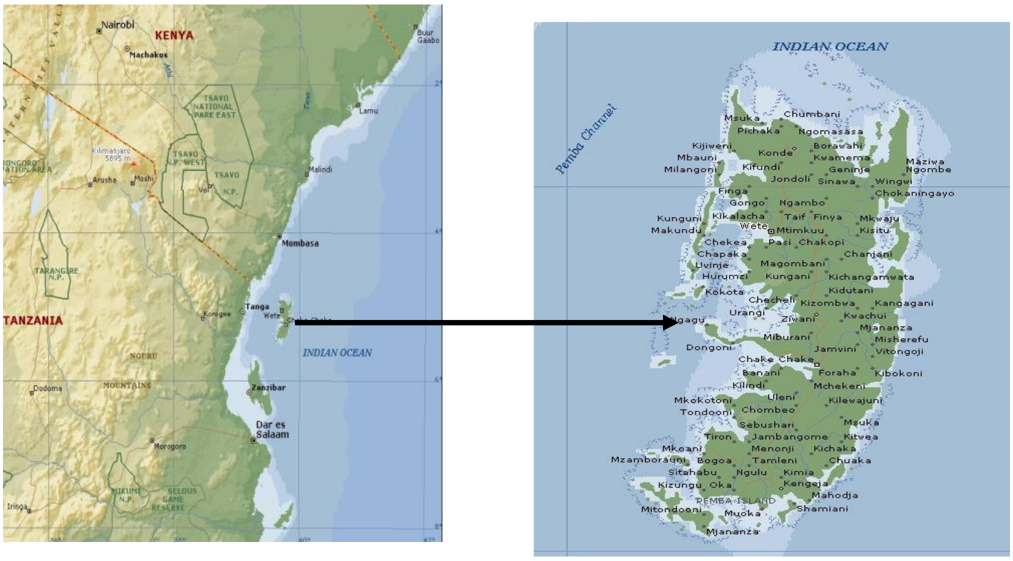


Figure 2: Pemba Island location in Tanzania

3. Materials and Method

3.1. Type of Data and Collection

The study employed both secondary and primary data. Primary data used for this study were collected from eleven (11) villages found in Pangani river basin and Pemba through a cross sectional survey of small scale farmers. The villages were purposively selected to include different climatic variations in the basin and Pemba. Following this the study area was therefore, categorized into three scenarios: (i) upper; (ii) middle; (iii) lower; (iv) wet and (v) dry. These categories were established basing on the assumption that the five areas have different rainfall and temperature, hence differences in perception and adaptation. From each of the eleven villages an average of 35 farmers were randomly selected basing on the assumption that they all practice agriculture and therefore face climate change negative challenges. To get the trend of rainfall, temperature, change in crop types and cropping pattern, outbreak of both plant and animal diseases the study also collected data from key people aged between 40 years and above through focus group discussion. The study also used secondary data on trends of rainfall and temperature; these were collected from a Tanzania metrological Agency (TMA) for a span of 51 and 37 years for Pangani River Basin and Pemba respectively.

3.2. The Analytical Framework and Empirical Model

The study employed both descriptive and empirical analytical framework. Descriptive analysis was used to establish farmers' awareness on climate change and its impacts; their ability to associate climate change with the change in type of crops, cropping pattern, outbreak of human, animal and crop diseases in their respective areas; their efforts to cope with climate change; and what they perceive as the limitations to their efforts.

Empirical framework was used to assess factors influencing farmers' choices of adaption measures. The framework was selected basing 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. The analytical approaches that are commonly used in an adoption decision study involving multiple choices are the Multinomial Logit (MNL) and Multinomial Probit (MNP) models (Green, 2000; Long, 1997). Both the MNL and MNP are important for analyzing farmer adaptation decisions as these are usually made jointly. These approaches are also appropriate for evaluating alternative combinations of adaptation strategies, including individual strategies (Wu and Babcock, 1998; Hausman and Wise, 1978). In this paper we used Multinomial Logit Model (MNLM) to analyze 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 i.e. the MNP.

The advantage of using a MNL model lays on its computational simplicity in calculating the choice probabilities that are expressible in analytical form (Tse, 1987). This model provides a convenient closed form for underlying choice probabilities, with no need of multivariate integration, making it simple to compute choice situations characterized by many alternatives (Long, 1997). In addition, the computational burden of the MNL specification is made easier by its likelihood function, which is globally concave (Hausman and McFadden, 1984). The main limitation of the model is the independence of irrelevant alternatives (IIA) property, which states that the ratio of the probabilities of choosing any of the two alternatives is independent of the attributes of any other alternative in the choice set (Long, 1997; Tse, 1987).

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 (Greene, 2003):

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

Where β_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 $\beta_0 = 0$ and the probabilities can be estimated as:

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

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

$$\ln\left(\frac{P_{ij}}{P_{ik}}\right) = x_i'(\beta_j - \beta_k) = x_i'\beta_j, \text{ if } k = 0 \qquad (3)$$

The dependent variable is therefore the log of one alternative relative to the base alternative. The MNL coefficients are difficult to interpret, and associating the β_j with the *jth* outcome is tempting and misleading. To interpret the effects of explanatory variables on the probabilities, marginal effects are usually derived as (Greene, 2008):

$$\delta_j = \frac{\partial P_j}{\partial x_i} = P_j\left[\beta_j - \sum_{k=0}^{J} P_k \beta_k\right] = P_j\left(\beta_j - \bar{\beta}\right)$$

Therefore, the full model is specified as follows:

$$y = \beta_i x_i + \varepsilon_{ij} \qquad (4)$$

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

4. Results and Discussion

4.1. Results

This section provides the results derived from the survey designed to understand farmers understanding about climate change, their perception and how do they link changes in the cropping pattern, disappearance of some crop and breakout of diseases in their areas to climate change. It also provides results on their strategies to cope with adverse climate change stresses, the barriers to adapt various strategies they think are appropriate and the factors influencing their adaption strategies choices. During the survey farmers were asked about their understanding and perceptions of temperature and rainfall changes over the last 30 years, and how they link these changes in cropping pattern, type of crops, and outbreak of diseases to climate change over the same period of time. Farmers were also asked how they cope with climate change stresses and what they think are the barriers to adopting various climate change adaptation strategies.

4.1.1. Farmers' perception of climate change and its impacts

Results from a comprehensive household survey conducted from 11 villages in Pangani River Basin and Pemba, it is clear that farmer perceive that there is changes in the trends of temperature and rainfall in their respective areas. Results in table 1 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. According to them this changes has been characterized by change in the start and end of rainfall, amount, intensity and frequency during the rain season; 30.9 percent admitted that there have been erratic rain in their areas, 62.8 percent pointed out that there has been small amount of rainfall which rain for a very short period of time.

Table 1: Farmers perceptions of long term change in climatic variables (temperature and rainfall)

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	High 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
Number of respondents		**375**

Farmers' perceptions are in accordance with the climatic parameters trends in Pangani River Basin and Pemba. The data for temperature and rainfall trends shows that temperature is increasing and rainfall decreasing over time (See figures in appendix 1).

Farmers were also asked to report on the changes happening in their respective areas and what they think could be the reason. Results in table 2 show that 86.9 percent perceive that crop failure in their areas is a result of climate change, 70.8 percent believe that change in cropping pattern is a result of climate change, 72.8 percent believe that disappearance of crops that used to be produced in their areas is a result of climate change, 41.3 percent associate the outbreak of crop diseases to climate change and 56.1 percent associate the outbreak of diseases such as malaria to climate change. According to them the increase in temperature and reduced rainfall has favored growth of some micro organisms and pests which cause human and plant diseases.

Table 2: Farmers link of the climate change to the experienced change in agriculture cycle and health in their respective areas

Climate change effect	**% of farmers**
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
Number of respondents	**375**

4.1.2. Farmer adaptation strategies

To cope with the climate change effect at least in a short-term some farmers in the area expressed that they have increased the use of inorganic fertilizers(see table 3). Farmers living in areas where water is relatively available pointed out that they use irrigation to cope with climate change stresses; 45.1 percent of the farmers admitted to employ this mechanism to overcome the stresses (see table 3). A significant proportion of farmers in the area admitted to use soil and water conservation mechanisms; 10.7 percent of farmers said that they use these mechanisms to cope with climate change stresses (see table 3).

Table 3: Adaptation strategies employed by farmers

Copping strategy	**% of respondents**
Increase use of inorganic fertilizers	1.6
Migrating from dry to wet, river banks and wetlands	1.6
Irrigating farm plots	45.1
Applying soil and water conservation mechanisms	10.7
Change planting dates (i.e. planting at first rain)	8.3
Grow crops that mature faster	18.1
Planting drought resistant crops	10.1
Mixing crops on the same plot	16.8
Focus more on non-farm activities	8.8
Planting trees around the farm plots for shading and litter production for mulching	15.7
Number of respondents	**375**

Other farmers especially those found dry areas in Pangani River Basin and Pemba, expressed that they have changed planting dates by planting at first rains, planting crops which mature faster, planting drought resistant crops and mixing crops on the same plot; about 8.3, 18.1, 10.1, and 16.8 percent admitted to employ these mechanism respectively. Some farmers mentioned that they have left agriculture to non-farming activities; about 8.8 percent of 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 3).

On the other hand, a significant proportion of farmers believe that the long term solution to climate change challenges is to increase efforts to plant trees, which will help in absorbing greenhouse gases that are major causes of climate change. They also admit that planting trees improve shading, shelter and produce litter which is important for mulching and making farmyard manure. Survey results in table 3 show that 15.7 percent of farmers practice tree planting around their farm plots and river banks for the aforementioned purposes.

4.1.3. Constraints to farmers farm level adaptation strategies

The study also asked farmers' about barriers to using various farm level climate change adaptation strategies. Results in table 4 show that, 9.6 percent pointed out that shortage of farm land is the main barrier to adopt the coping mechanisms. Others pointed out that shortage of water for irrigation is a limiting factor for adaptation in the area; about 47.7 percent pointed out that this is the barrier for adopting the mechanism. Also lack knowledge or information about proper adaptation mechanisms was pointed out as the one of the limiting factor in area; about 14.7 percent mentioned it as the main limiting factor. Lack of timely forecasting 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.

Table 4: Farmers constraints to adaptation methods

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

Other factors pointed out by farmers include lack of necessary farm inputs such crop varieties tailor made for coping with extreme climatic condition as the main constraint to use 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 pointed out as the major limiting factors; about 8 percent pointed out that these as the major limiting factors.

4.1.4. Factors conditioning farmers' adaptation choices

This section provides the results on farmers' *actual* adaptation measures or the main practices actually used by farmers at farm level. It is important to note that many of the measures identified by the farmers are grouped into nine categories (Table 5). These strategies, however, are mostly used in combination with other strategies. The various combinations of measures and practices may be grouped into the following categories: Increase use of inorganic fertilizer (INCUSEINOFERT); Planting drought resistant crops (DROURESCROPS); Irrigating farm lots (IRRIGATEFARMPLOTS); Early planting (EARLYPLANTING); Use mulching (USEMA); Grow crops that mature faster (GROWCROPMATFAST); Plant trees (PLANTTREES);Focus more or turn to non-farming activities (FOCUSNONFARMACT); and Practice mixed cropping (MIXEDCROPPING).

To capture the effect of various factors to the probability of adopting various climate change adaptation alternatives at the farmers' disposal, we used *migration to river banks 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 5 for instance, compares the probability of adopting increase in use inorganic fertilizers (INCUSEINOFERT) as opposed to no adaptation. The marginal effects and their signs reflect the expected change in probability of preferring to increase use of inorganic fertilizers 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.

Table 5 presents the estimated marginal effects and P-levels from Multinomial Logit model and the estimated coefficients are given in Appendix 2. The results show that most of the explanatory variables are statistically significant at 10% 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 results in table 5 shows that age of the head of household positively influence the probability of adopting all the alternatives, but significantly influence the probability of adopting soil conservation mechanisms and practicing mixed cropping adaptation alternatives as opposed to the base alternative. The results also indicate that education level of the household head positively influence the probability of adopting all climate change adaptation alternatives and significantly influence the probability of adopting early planting, applying soil water conservation mechanisms, growing crops that take 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 5 indicate that location of a farmer in the basin influence farmers' probability of adopting adaptation alternative as opposed to the base alternative differently. The upper locations of the basin for example appear to influence negatively the probability of adopting increase use of inorganic fertilizers, irrigate farm plots, applying soil and water conservation mechanisms, turn 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 adopting increase use of inorganic fertilizers, planting 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 positively influence 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 negative influence on the probability of adopting increase use of inorganic fertilizers 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, irrigate 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.

As noted in above, the study also investigated the dry and wet areas of Pemba Island, results in table 5 indicate that dry locations have negative influence on the probability of adopting increase use of inorganic fertilizers and irrigating the farm plots alternatives as opposed to base alternative. The areas also appear to have positive influence on the probability of adopting planting of drought resistant crops, early planting, applying soil and water conservation mechanisms, turning to non-farming activities and practicing mixed cropping adaptation alternatives as opposed to the base alternatives. While this is the case with dry locations of Pemba, the wet locations on the other hand appear to have a negative influence on the probability of adopting soil water conservation mechanisms, turning to non-farming activities and practicing mixed farming adaptation alternatives as opposed to the base alternative.

Table 5: Marginal effects of explanatory variable from Multinomial Logit climate change adaptation model

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*
Household level of education (years)	0.0331	0.0007	0.0179	0.0276*	0.0146*	0.0166*	0.0019	0.0389*	0.0026**
Upper	-0.0389*	-0.0489	-0.0920*	-0.0672	-0.0156*	-0.0582	-0.0151	-0.0223***	-0.0154*
Middle	-0.0426*	-0.0327*	0.0597***	0.0026***	0.0318*	-0.0217	-0.0054***	-0.0453*	-0.0355***
Lower	-0.0327*	0.0126**	0.0422***	0.0087***	0.1468***	0.0067	-0.0364	0.0342*	0.0253***
Dry	-0.0254	0.0253*	-0.0476*	0.0025**	0.0324*	0.0224	-0.0045	0.0525***	0.0433**
Wet	0.0263	-0.0057	-0.0064	-0.0013	-0.0516***	0.0012	-0.0065	-0.0415*	-0.0526*
Household size	-0.1682***	0.0091	0.0108	0.0351**	0.0733*	0.0241*	0.0042	0.0232***	0.0343*
Primary Occupation	0.0324	0.0222	0.0012	0.0332*	0.0622*	0.0232	-0.0022	-0.0325	0.0232**
Number years lived in the area	-0.0513*	-0.0402*	0.0263	0.0380*	0.0432*	0.0270	-0.0131	0.0242**	0.0432***
Access to extension services (1/0)	0.0853	0.0752	0.1129*	0.1533***	0.0356*	0.1634***	0.0246	-0.0436**	0.0257*
Farm size (ha)	0.0214*	0.0214*	-0.0349*	0.0048*	0.0253*	0.0018	0.0152*	-0.0163*	0.0352*
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*
Access to credits (1/0)	0.2236***	0.1235***	0.1211***	0.0848***	0.0947***	0.0958***	0.1488*	0.1210**	0.0467***

Size of the household seems to have a strong and significant influence on the probability of adopting all early planting, applying soil and water conservation mechanisms, growing crops that mature faster, turning to non-farming activities and practicing mixed cropping alternatives instead of migrating to river banks and wetland areas. Similar strong influence is observed if agriculture is the primary occupation of the household. The factor seems to strongly and significantly influence the probability of adopting early planting, applying of soil and water conservation mechanisms and practice mixed cropping alternatives as opposed to the base alternative.

Number of years the household head has lived in the location appears to negatively and significantly influence the probability of adopting increase use of inorganic fertilizers and planting trees as opposed to the base alternative. However, the factor appears to positively and significantly influence the probability of adopting early planting, practicing soil and water conservation mechanisms, and practicing mixed cropping as opposed to base alternative.

Better access to extension and credit services seems to have a strong positive influence on the probability of adopting irrigation of farm plots, early planting, practicing soil and water conservation mechanisms, growing crops which need short time to mature, and practicing mixed cropping and negatively influence probability of turning to non-farming activities as opposed to the base alternative. Access to credit services seems to have a strong positive influence on the probability of adopting all adaptation measures and abandoning the base alternative. On the contrary to this, access to crop failure subsidies appears to negatively influence the probability of adopting all the adaptation mechanisms as opposed to the base alternative. At the same time, Size of land owned by a household appear to have a strong positive influence on the probability adopting increasing the use of inorganic fertilizer, planting the drought resistant crops, early planting, practicing soil and water conservation mechanisms, planting trees, and practicing mixed cropping alternatives as opposed to the base alternative. However, the factor appear to have a negative influence to the probability of adopting irrigation of farm plots and turning to non-farming activities as opposed to base alternatives.

4.2. Discussions

4.2.1. Farmers' perception on climate change and adaptation strategies

The results suggest that there is a good level understating among small scale farmers about climate change occurrence and effects in their respective areas. The results are in line with trends of annual mean temperature and rainfall established from climatic data gathered from meteorological stations over the period of 51 and 37 for Pangani basin and Pemba respectively. Along with perception, results also indicate that farmers are making efforts to adapt to climate change in their respective areas. However, their efforts are hindered by a number of obstacles. Again this conforms to the fact that poor countries are more prone to climate change effects than developed countries due to lack of capital to invest on adaptation mechanisms among the majority of its population (Maddison, 2006).

The analysis of barriers to adaptation to climate change in the Pangani River Basin and Pemba indicates that there are seven major constraints to adaptation. Most of these constraints are associated with poverty. For instance, lack of information to adaptation options could be attributed to the fact that farmers outreach programs are not well coordinated, therefore, some of the farmers are lagging behind. Lack of capital to invest on adaptation mechanisms and labour hinders farmers from getting the necessary resources to adapt to climate change. As noted by Deressa and Hassan (2008), adaptation to climate change is costly and this is more profounding in mechanisms that need materials and intensive labour. Thus, if farmers do not have sufficient family labour or the financial means to higher labour, they cannot adapt.

Shortage of land has also been pointed out as a barrier to adaptation. Literatures have associated it with high population pressure that force farmers to intensively farm over a small plot of land and make them unable to use the plots for other practices they are not sure of (Mendelson, 2004). Adaptation studies indicate that farmers begin by trying new technologies before they fully adopt (Maddison, 2006), similarly to climate change adaptation. Therefore, if farmers are not having enough land, they cannot adapt to climate change. On the other hand, despite the fact that Pangani River Basin and Pemba are relatively rich in water resources, the terrain (topography) couple with poverty can probably be the reason for this appearing as a barrier for using irrigation as an adaptation strategy. Farmers in area in general are very poor and cannot afford to invest on irrigation technology not only to adapt to climate change but also to sustain their livelihood during climatic extremes such as drought and heavy rain.

4.2.2. Factor influencing farmer's choices of adaptation strategies

The terrain where the farmer is located has been found to influence the choice of adaptation mechanisms. This conforms with the assertion that climate change effects are not uniform, they vary from one area to another depending on the topography (Nhemachena and Hassan, 2007; Kurukulasuriya and Mendelsohn 2006). Pangani basin is characterized with varying terrain ranging from high altitude which includes Mount Kilimanjaro which is 5980 m above sea level through Usambara mountain ranges to low lands of 0m above sea level. Similarly, Pemba is characterized by a unique terrain which demarcates the Island into two distinct climatic conditions, the wet and dry. The results show a clear effect of the two climatic differences on influencing the probability of adopting climate change adaptation alternatives as opposed to the base alternative.

Better access to education, extension and credit services seems to positively influence the probability of adopting almost all of the climate change adaptation measures as opposed to base alternative. These results are in line with augment that education and extension services improve awareness of potential benefits and willingness to participate in local natural resource management and conservation activities (Dolisca *et al*., 2006). They are also in line with augment that with more financial and information about adaptation mechanisms at their disposal, farmers are able to make use the information to change their management practices in response to changing climatic and other conditions (Tizale, 2007). Contrary to this, better access to crop failure subsidies seems to have a strong negative influence to the probability adopting almost all of the climate change adaptation measures. The probable reason for this could be derived from the fact that assurance of getting help in incidence of crop failure due to climatic variability does not encourage farmers in adopting climate change adaptation mechanisms (Anley *et al*., 2007).

Household size seems to influence the probability to adopt climate change adaptation alternatives. This result is in line with the argument which assumes that family size determine with labour endowment, which would enable a household in accomplishing various agricultural tasks especially during peak seasons (Croppenstedt *et al*., 2003). Similar observation is shown by size of land owned by household and the probable reason for this could be the fact that the choice of adaptation measure depends on factor endowments at the disposal of farming households (Seo and Mendelsohn, 2006).

5. Conclusion and Policy Implications

As noted throughout the paper, this study based on the analysis of farm level climate change perceptions, types of adjustments small scale farmers are making in their farming practices in response to the changes, constraints they face in doing so and factors influencing the probability of choosing adaptation mechanism at their disposal. Perception results indicate that farmers in Pangani River Basin and Pemba perceive that their respective areas are getting warmer and drier over time, and that there are changes in starting, length, intensity and end of rainfall. This creates an opportunity for policy and practitioners on the ground to make use of this advantage in enhancing climate change adaptation in the area. Instead of investing on creating awareness about climate change in the area, they should focus more in facilitating adaptation.

The study has also revealed a number of important adaptation options being used by small scale farmers in the area. Small scale farmers practice mixed cropping, soil and water conservation measures, plating more trees for shading and litter for mulching, using more inorganic fertilizers, change planting dates, planting drought resistant crops and irrigating their farm plots. However, in so doing they face a number of limitations which include shortage of water for irrigation, lack of necessary farm inputs, lack of proper information on the appropriate adaptation mechanism, shortage of farmland, lack of capital and shortage of water for irrigation. Based on this analysis different policy options can be suggested and these include, facilitating the availability of credit; farm inputs and information on proper adaptation mechanisms, investment on constructing irrigation infrastructures that cater for the terrain differences in basin and Pemba, research on inventing new crop varieties that are more suited to drier conditions and yield more in small piece of land.

Empirical results from multinomial discrete choice model confirm the role of knowledge acquired through extension services and formal education, and financial capacity through credits in enhancing farmers' awareness and adopting climate change adaptation measures. Combining access to extension, formal education and credit services ensures that farmers have the necessary information for decision making and the means to take up adaptation measures. Therefore, policies and intervention programs aimed at promoting farm-level climate change adaptation need to invest more on providing formal education and extension services, and the means to implement adaptations through affordable credits. Provision of affordable credit may provide farmers' ability to meet the costs associated with various adaptation measures. Hence, this is an important policy area to exploit for stimulating farm-level climate change adaptation.

The results from the empirical model also demonstrates the importance of taking into account geographical and topographical differences in designing policies and strategic investment plans for supporting farm level climate change adaptation. This is derived from the fact that climate change effect is not uniform, it varies across geographical and topographical features.

Acknowledgement

This paper was funded by 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.

References

Agrawala, S.; Moehner, A.; Hemp, A.; Aalst, M.; Hitz, S.; Smith, J.; Meena, H.; Mwakifwamba, S.; Hyera, T.; and Mwaipopo, O., (2003). *Development and Climate Change in Tanzania: Focus on*

Mount Kilimanjaro. Organisation for Economic Co-operation and Development (OECD), Paris, France.

Anley, Y.; Bogale, A. and Haile-Gabriel, A. (2007). Adoption decision and use intensity of soil and water conservation measures by smallholder subsistence farmers in Dedo district, Western Ethiopia. *Land Degradation and Development*, **18**: 289-302.

Benhin, J.K.A. (2006). *Climate change and South African agriculture: Impacts and adaptation options*. CEEPA Discussion Paper No. 21. Centre for Environmental Economics and Policy in Africa, University of Pretoria.

De Wit, M.; and Stankiewicz, J. (2006). Changes in surface water supply across Africa with predicted climate change. *Journal of Science*, **311**:1917-21.

Dolisca, F.; Carter, R.D.; McDaniel, J.M.; Shannon, D.A.; and Jolly, C.M. (2006). Factors influencing farmers' participation in forestry management programs: A case study from Haiti. *Forest Ecology and Management*, **236**: 324-31.

Green, W. (2008). *Econometric Analysis,* 6th ed., Prentice Hall.

Greene, W.H. (2000). *Econometric analysis. Fourth edition*. Prentice Hall, New Jersey.

Greene, W.H. (2003). *Econometric analysis. Fifth edition*. Prentice Hall, New Jersey.

Hassan, R.; and Nhemachena, C. (2008). Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *AfJARE*, **2**(1): 83-104.

Hausman, J and McFadden, D, (1984). Specification tests for the multinomial logit model. *Journal of Econometrica*, **52**(5): 1219-40.

Hausman, J. and Wise, D, (1978). A conditional probit model for qualitative choice: Discrete decisions recognizing interdependence and heterogeneous preferences. *Journal of Econometrica*, **46**: 403-26.

International Institute for Sustainable Development (IISD). (2007). *Community based adaptation to climate change Bulletin*. A Summary of the Second International Workshop on Community-Based Adaptation to Climate Change. IISD Reporting Services.

IUCN (2009). *The Pangani River Basin: A Situation Analysis*. 2nd Edition, 82pp.

IUCN Eastern Africa Programme. (2003). *Pangani basin: A situation analysis.* Nairobi, Kenya: IUCN. The World Conservation Union. Available online at http://www.iucn.org/themes/wani/pub/SituationPangani.pdf

Kandlinkar, M.; and Risbey, J. (2000). Agricultural impacts of climate change: If adaptation is the answer, what is the question? *Journal of Climatic Change*, **45**: 529-39.

Kurukulasuriya, P.; and Mendelsohn, R. (2008). *A Ricardian analysis of the impact of climate change on African crop land.* CEEPA Discussion Paper 8.

Kurukulasuriya, P.; and Mendelson, R. (2006). *Crop selection: adapting to climate change in Africa*. CEEPA Discussion Paper No. 26. Centre for Environmental Economics and Policy in Africa. Pretoria, South Africa: University of Pretoria.

Long, J.S. (1997). *Regression models for categorical and limited dependent variables: Advanced quantitative techniques in the social science*. Series 7. Sage, Thousand Oaks, California.

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

Mano, R.; and Nhemachena, C. (2006). *Assessment of the economic impacts of climate change on agriculture in Zimbabwe: A Ricardian approach*. CEEPA Discussion Paper No. 11. Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Mano, R.; Isaacson, B. and Dardel, P. (2003). *Identifying policy determinants of food security response and recovery in the SADC region: The case of the 2002 food emergency*. FANRPAN Policy Paper, FANRPAN.

Mbonile, M. J. (2001). Rural population mobility in the Pangani basin, Tanzania. In J.O. Ngana (Ed.), *Water resources management in the Pangani basin: Challenges and opportunities*. Dar es Salaam, Tanzania: University of Dar es Salaam Press.

Morton, J. (2007). The impact of climate change on smallholder and subsistence agriculture. *Proceedings of the National Academy of Sciences*, **104**: 50.

Nhemachena C.; and Hassan, R. (2007). *Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa*. IFPRI Discussion Paper No. 00714. International Food Policy Research Institute. Washington DC.

Pangani Basin Water Office (PBWO). (1997). *Pangani Basin Authority annual report.* Tanga, PBWO. Tanzania.

Seo, N.; and Mendelsohn, R. (2006). *Climate change impacts on animal husbandry in Africa: A Ricardian analysis*. CEEPA Discussion Paper No. 9. Centre for Environmental Economics and Policy in Africa, University of Pretoria.

Shemsanga, C. (2010). The Cost of Climate Change in Tanzania: Impacts and Adaptations. *Journal of American Science*, **6**(3): 182-196.

The United Republic of Tanzania (URT). (2007). *National Environmental Policy*. Vice President's Office. Government printers, Dar es Salaam, Tanzania. 159pp.

Thontorn, N. (2011). *Climate Change Financing and Aid Effectiveness*. Tanzania Case Study. [http://www.oecd.org/htm/M0053.htm] site visited 13/9/2012.

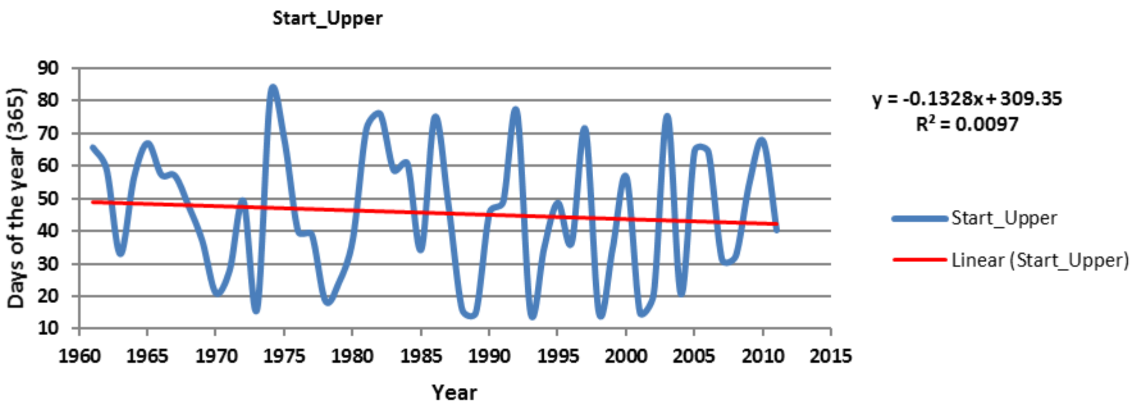
Tizale, C. Y. (2007). *The dynamics of soil degradation and incentives for optimal management in the Central Highlands of Ethiopia*. PhD thesis, Department of Agricultural Economics, Extension and Rural Development, Faculty of Natural and Agricultural Sciences, University of Pretoria.

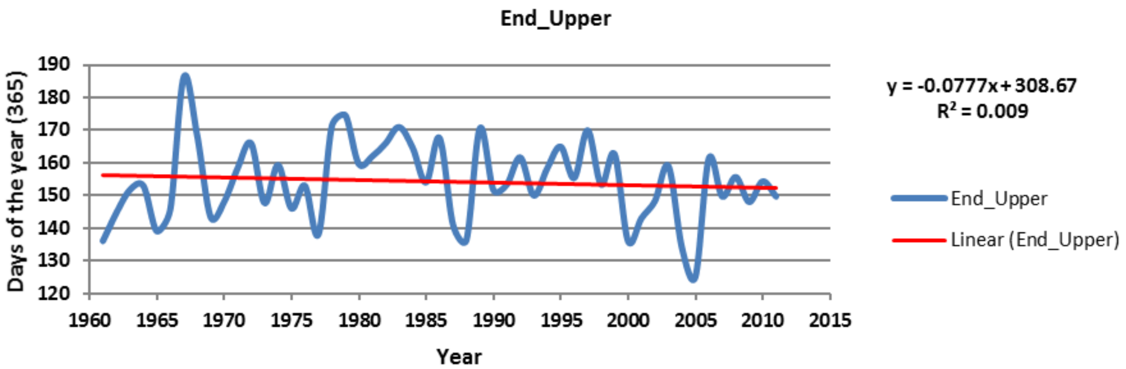
Tse, Y.K. (1987). A diagnostic test for the multinomial logit model. *Journal of Business and Economic Statistics,* **5**(2): 283-86.

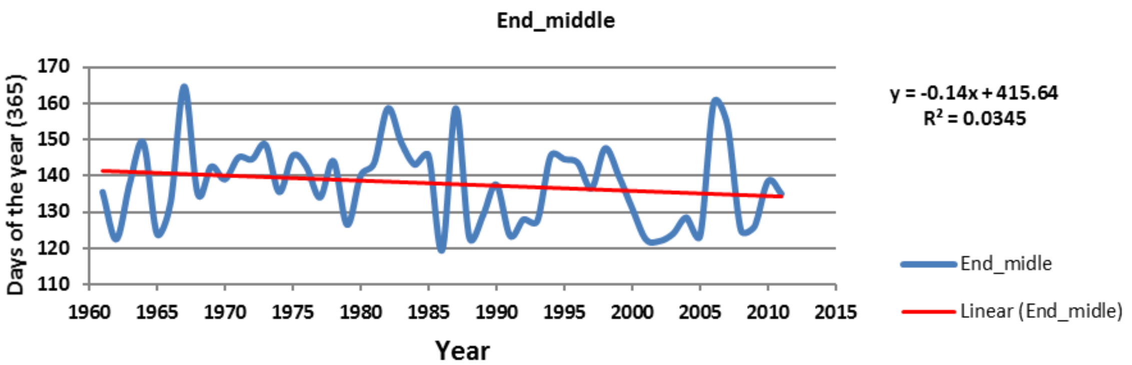
Wu, J.; and Babcock, B.A. (1998). The choice of tillage, rotation, and soil testing practices: Economic and environmental implications. *American Journal of Agricultural Economics*, **80**: 494-511.

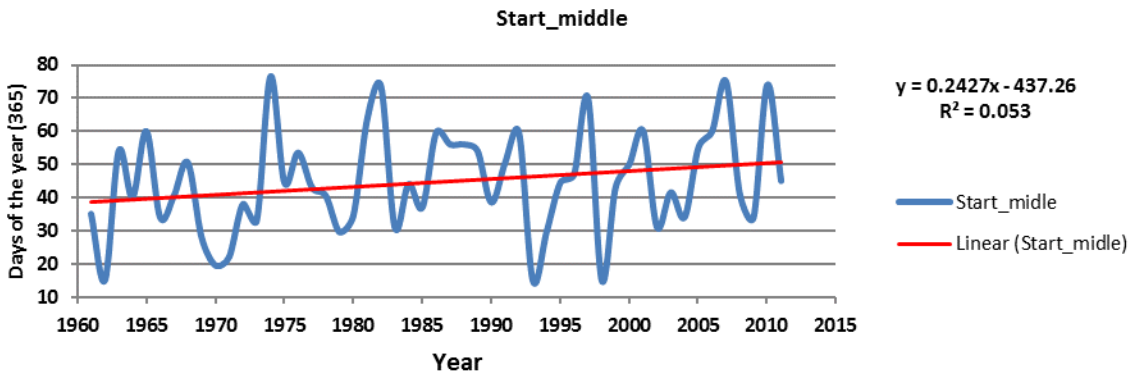
Appendices

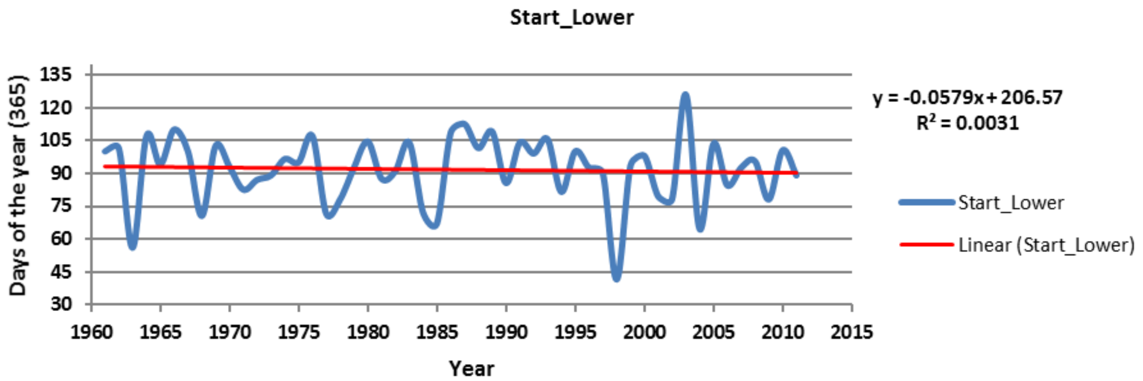
Appendix 1: Pangani River Basin and Pemba rainfall trends showing start, end, length and estreme events

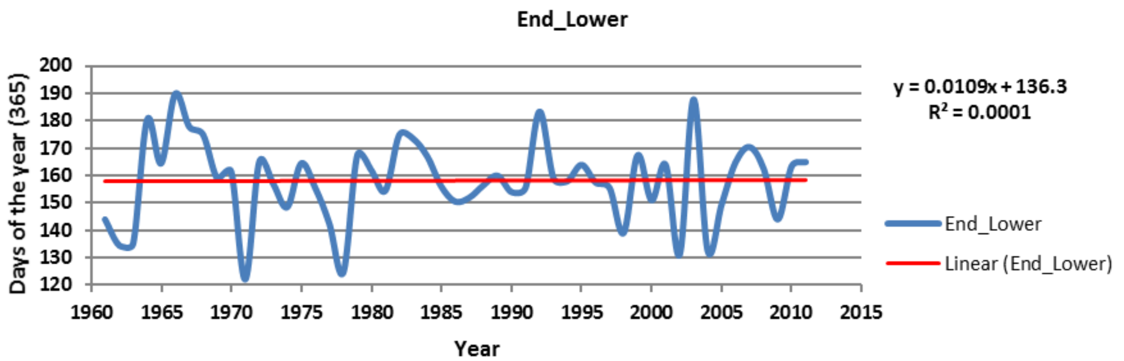


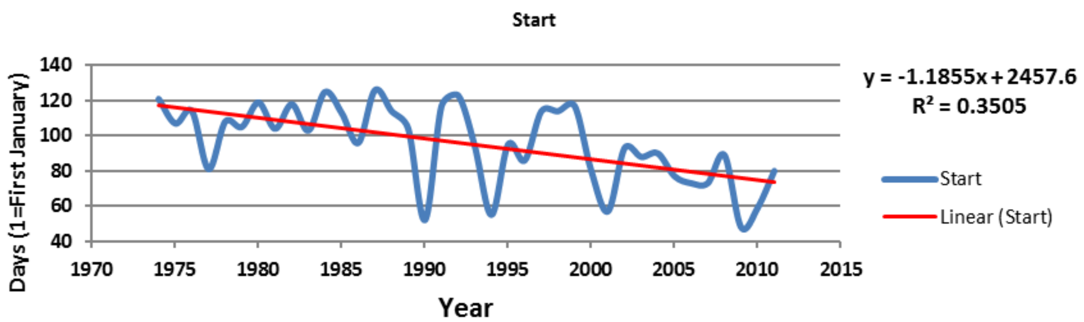


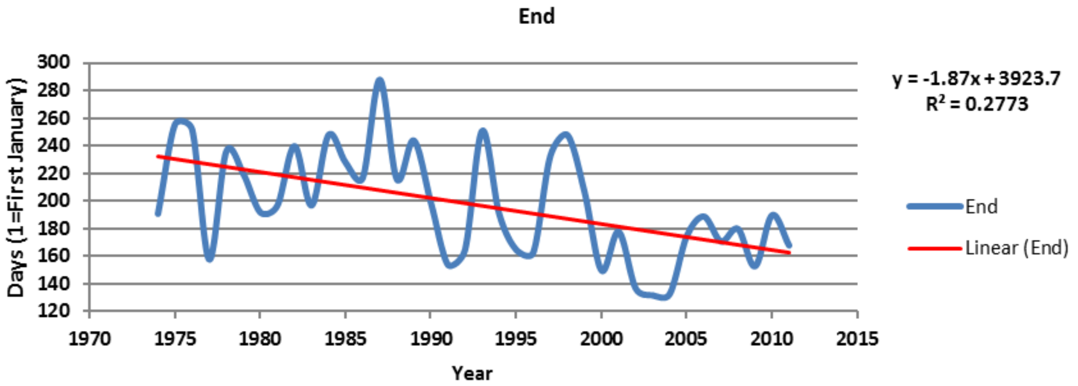


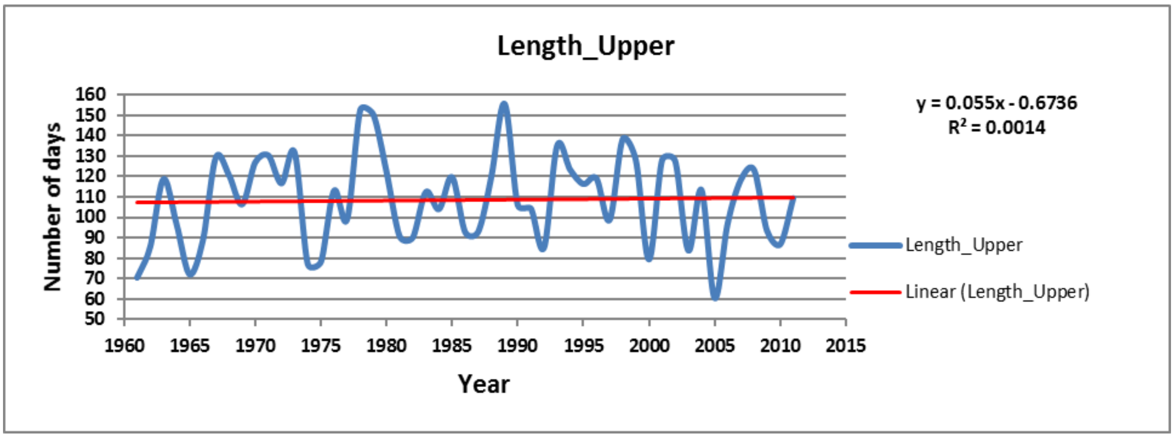

Start_middle
Days of the year (365)
Year
y = 0.2427x - 437.26
R² = 0.053
Start_midle
Linear (Start_midle)

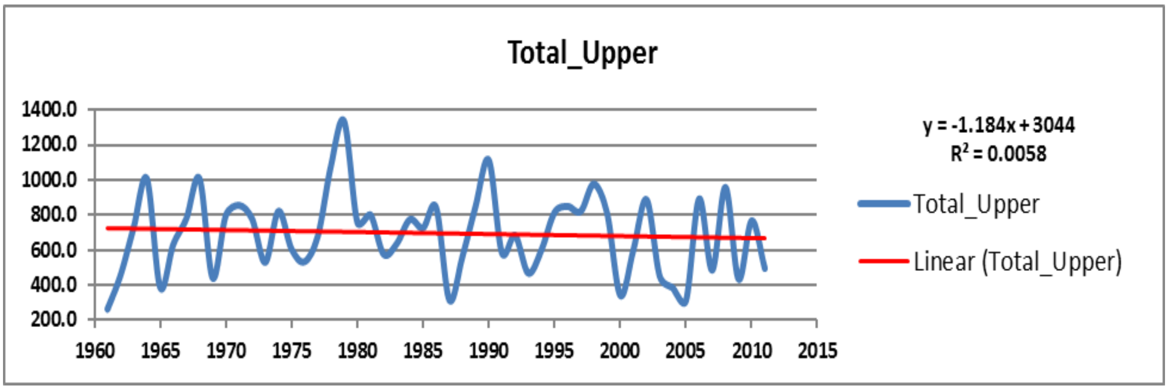

Start_Lower
Days of the year (365)
Year
y = -0.0579x + 206.57
R² = 0.0031
Start_Lower
Linear (Start_Lower)

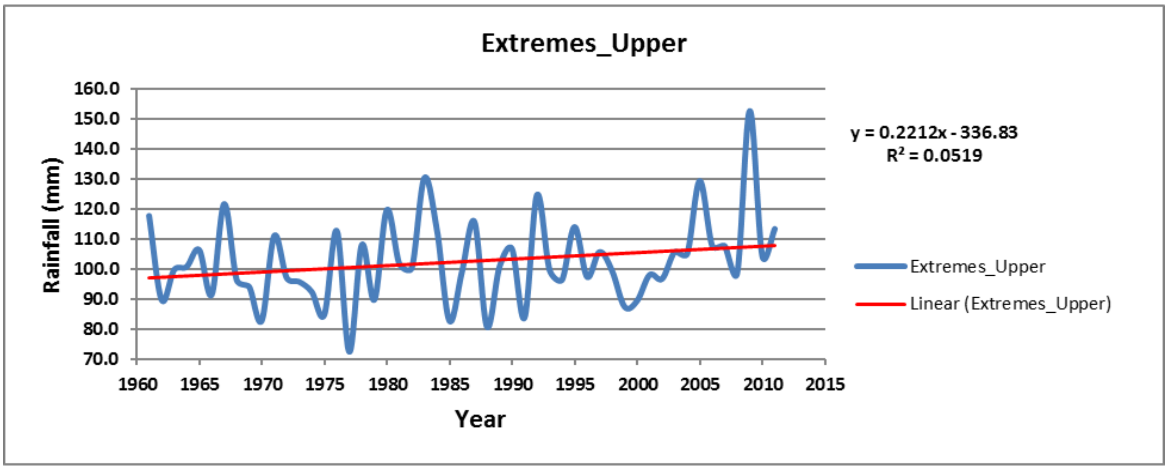

End_Lower
Days of the year (365)
Year
y = 0.0109x + 136.3
R² = 0.0001
End_Lower
Linear (End_Lower)

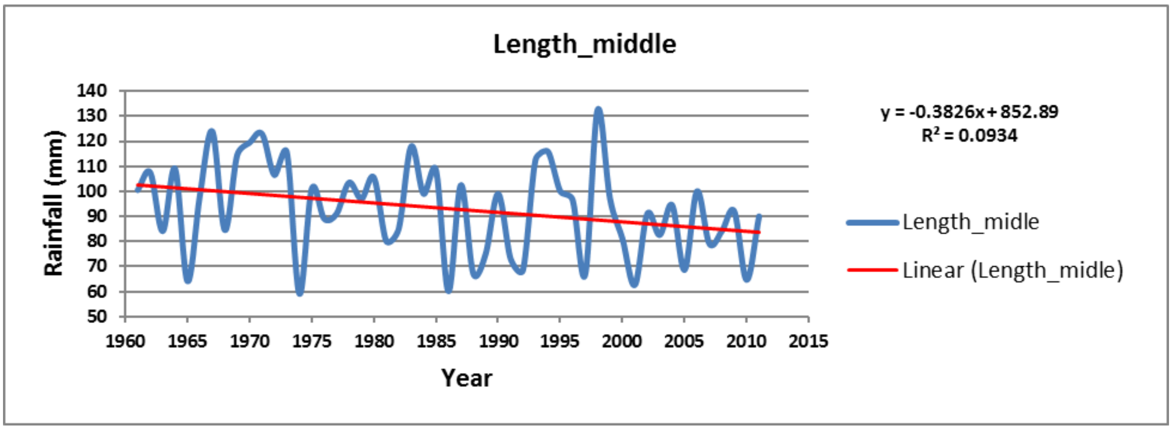

Start
Days (1=First January)
Year
y = -1.1855x + 2457.6
R² = 0.3505
Start
Linear (Start)

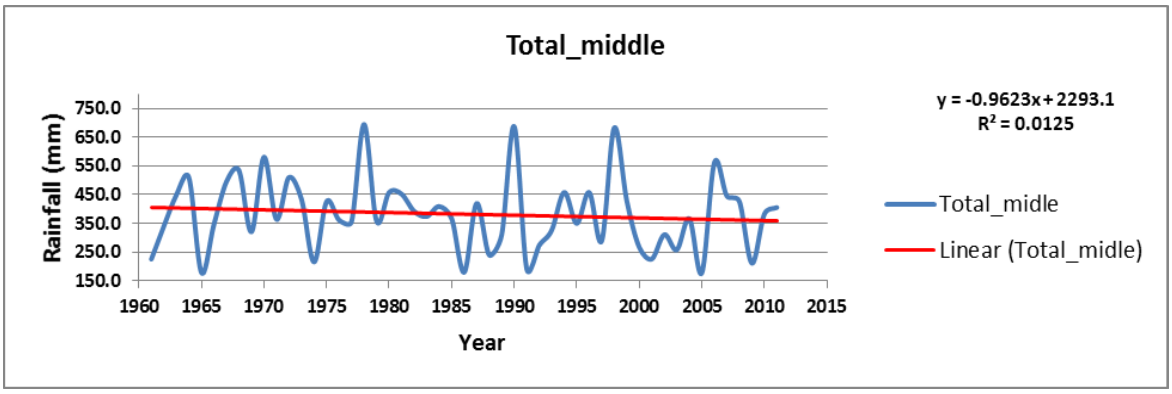

End
y = -1.87x + 3923.7
R² = 0.2773
End
Linear (End)
Days (1=First January)
Year

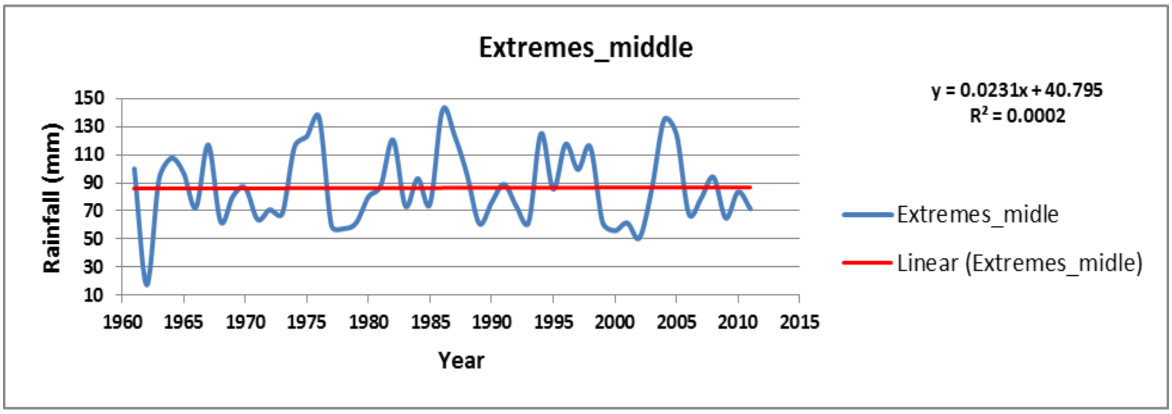

Length_Upper
y = 0.055x - 0.6736
R² = 0.0014
Length_Upper
Linear (Length_Upper)
Number of days
Year

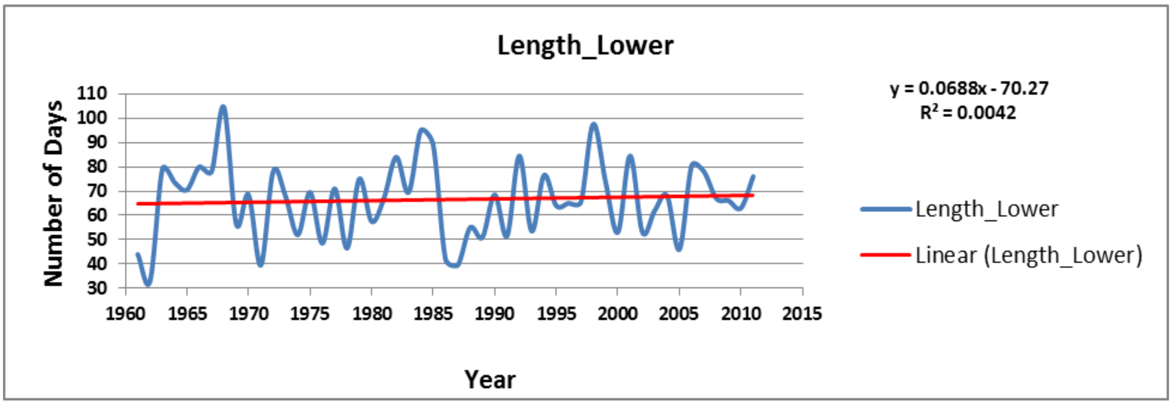

Total_Upper
y = -1.184x + 3044
R² = 0.0058
Total_Upper
Linear (Total_Upper)

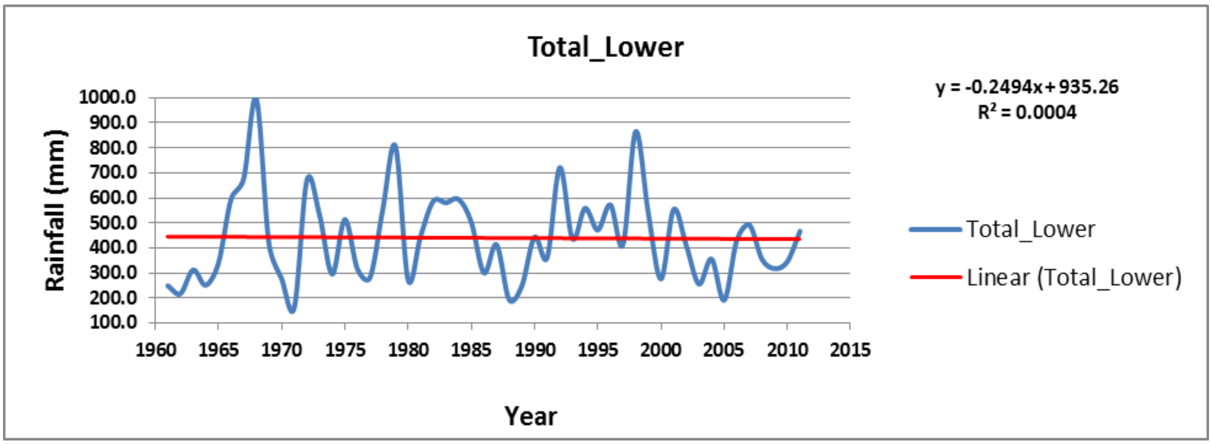

Extremes_Upper
y = 0.2212x - 336.83
R² = 0.0519
Extremes_Upper
Linear (Extremes_Upper)
Rainfall (mm)
Year

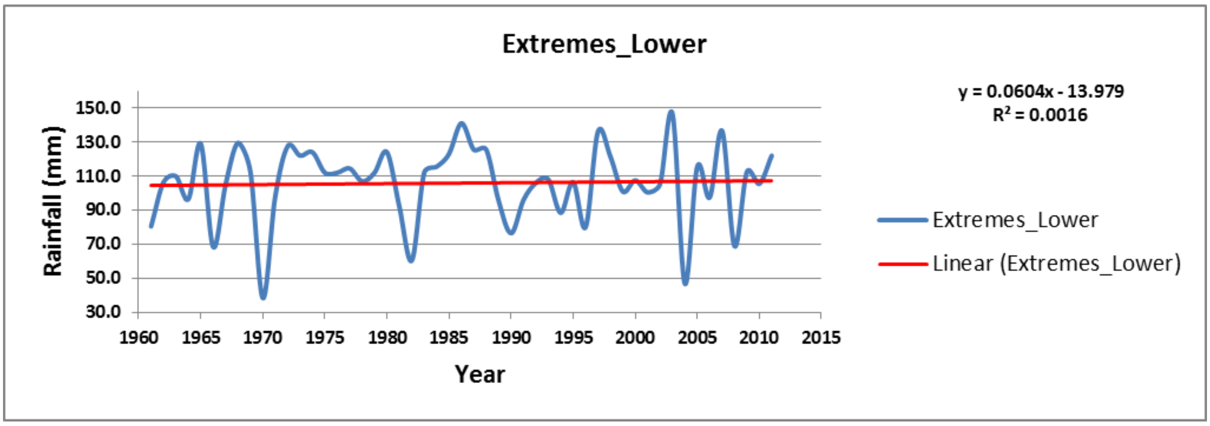

Length_middle
y = -0.3826x + 852.89
R² = 0.0934
Rainfall (mm)
140
130
120
110
100
90
80
70
60
50
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
Length_midle
Linear (Length_midle)

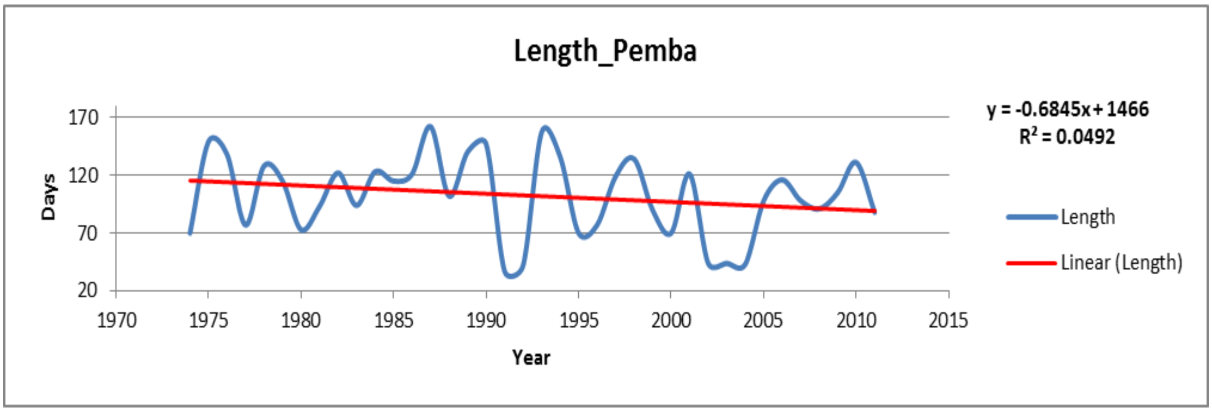

Total_middle
y = -0.9623x + 2293.1
R² = 0.0125
Rainfall (mm)
750.0
650.0
550.0
450.0
350.0
250.0
150.0
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
Total_midle
Linear (Total_midle)

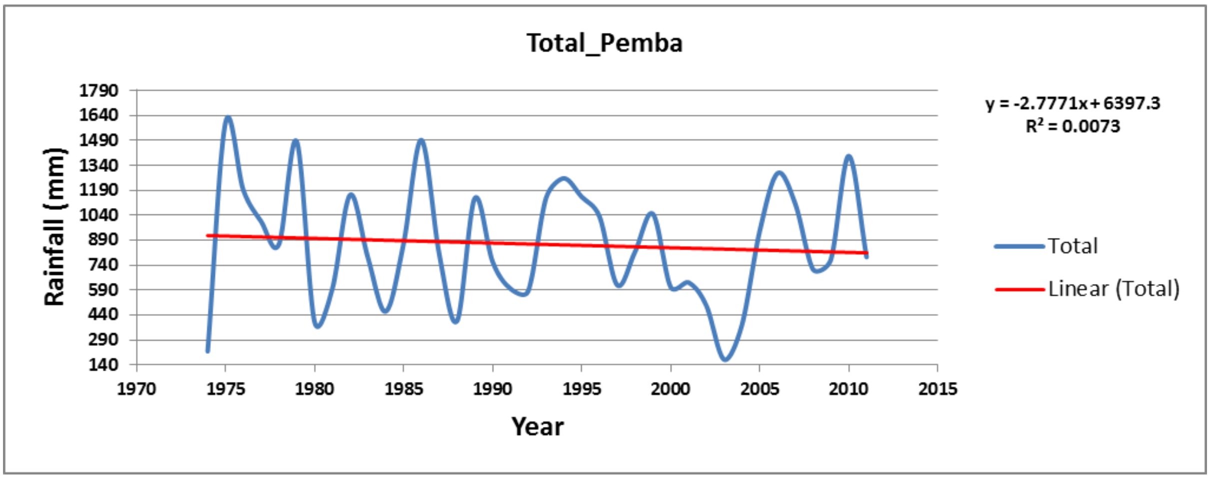

Extremes_middle
y = 0.0231x + 40.795
R² = 0.0002
Rainfall (mm)
150
130
110
90
70
50
30
10
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
Extremes_midle
Linear (Extremes_midle)

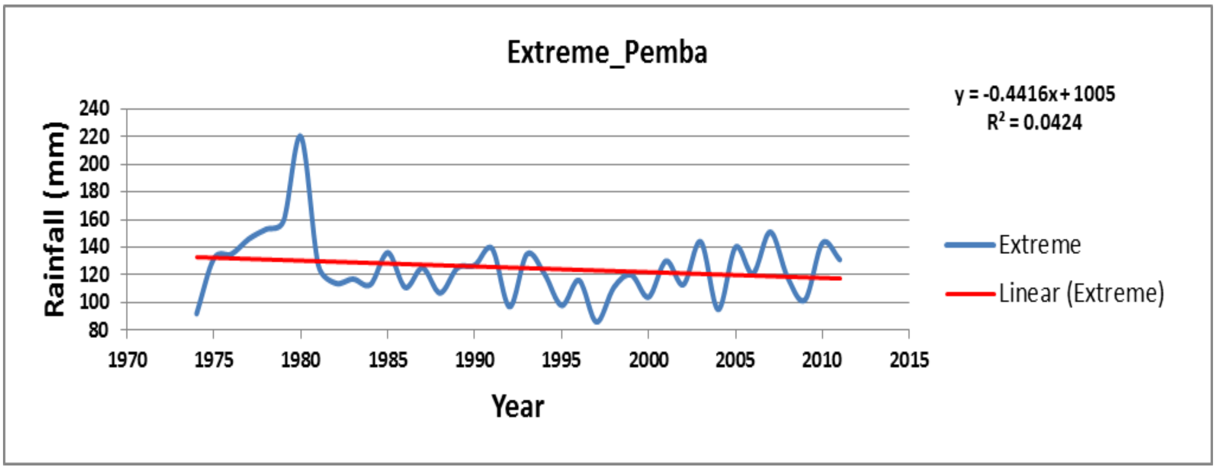

Length_Lower
y = 0.0688x - 70.27
R² = 0.0042
Number of Days
110
100
90
80
70
60
50
40
30
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
Length_Lower
Linear (Length_Lower)


Total_Lower
y = -0.2494x + 935.26
R² = 0.0004
Rainfall (mm)
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
Total_Lower
Linear (Total_Lower)


Extremes_Lower
y = 0.0604x - 13.979
R² = 0.0016
Rainfall (mm)
150.0
130.0
110.0
90.0
70.0
50.0
30.0
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
Extremes_Lower
Linear (Extremes_Lower)


Length_Pemba
y = -0.6845x + 1466
R² = 0.0492
Days
170
120
70
20
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
Length
Linear (Length)


Total_Pemba
y = -2.7771x + 6397.3
R² = 0.0073
Rainfall (mm)
1790
1640
1490
1340
1190
1040
890
740
590
440
290
140
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
Total
Linear (Total)


Extreme_Pemba
y = -0.4416x + 1005
R² = 0.0424
Rainfall (mm)
240
220
200
180
160
140
120
100
80
1970
1975
1980
1985
1990
1995
2000
2005
2010
2015
Year
Extreme
Linear (Extreme)

Appendix 2: Parameter estimates from Multinormial Logit Model (MNLM)

Variable	INCRE FERT USE	DROUGH RESISTCROPS	IRRIG FARMPLOTS	EARLY PLANTING	USESWC	GROWCROPS MATFAST	PLANT TREES	FOCUSNON FARMACT	MIXED CROPPING
Household head gender (1/0)	-6.843***	0.077	0.890	0.871	1.636	-0.118	0.870	-0.393	2.212*
Household head age (years)	-0.022	-0.005	-0.022	0.025	0.035	0.002	-0.011	-0.017	-0.025
Household level of education (years)	0.068	0.086	0.111	0.026	0.243*	-0.031	0.060	-0.374**	0.030
Upper	-3.200**	2.626***	2.673***	-1.896*	2.543*	6.219***	6.675***	-1.651**	2.661***
Middle	-6.531***	5.884*	6.196***	5.584**	4.710*	5.952***	6.038***	6.408*	5.986***
Lower	-7.180***	0.449*	0.601***	-6.490**	-7.211*	0.577*	0.125	0.617*	0.532*
Dry	2.178***	0.204	-0.039	0.347	-0.379	0.189	0.038	0.525*	-4.777*
Wet	-0.141	0.169	0.122	0.385*	-0.115	0.140	0.126	-4.224*	-4.402*
Household size	0.641	0.007	-0.035	-0.032	0.257	-0.215	-0.006	-0.132	-0.080
Primary Occupation	-0.239	-0.221	-0.074	-0.068	0.018	0.080	-0.101	-0.010	-0.346
Number years lived in the area	0.154	-0.614	-0.308	-0.995*	-1.035*	-0.169	-0.497	-0.171	-0.097
Access to extension services (1/0)	-1.956	0.912	0.631	0.934***	1.263	-0.874	0.148	-0.225	-0.340
Farm size (ha)	0.036	-0.016	-0.214*	-0.008	-0.182	-0.169	0.014	-0.364*	-0.639***
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*
Access to credits (1/0)	1.664	2.786***	2.260*	1.281	2.757**	1.282	-0.176	2.644*	1.006

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	