Climate Scenario and location substitution approach in analyzing the Impacts of Climate Change in Smallholder farming systems: Case study of Pangani river basin and Pemba, Tanzania

Joseph P. Hella[1Ω1], Ruth Haug[2], Hidaya Senga[3] M. Haji[4], S. Mboya[5], M. Bakar[5]

[1] Sokoine University of Agriculture Department of Agric Econ & Agribusiness, P. O. Box 3007,
Morogoro. Tel +255784582110; Email jp_hella@yahoo.co.uk

[2] Norwegian University of Life Sciences, P.O. Box 5001, 1432 Ås, Norway Tel:
+4764965336/4797167976, Fax: +4764965201, Email: ruth.haug@umb.no

[3] Tanzania Meteorological Agency P. O Box 3056, DSM.; Mobile: +255-754 388968: Email:
mamaadam@yahoo.com

[4] Department of Environment, P. O. Box 2808, Zanzibar, Email: Mobile +255-777-42763
makamehaji2000@hotmail.com,

[5] Directorate of Research and Postgraduate Studies, Sokoine University of Agriculture, P.O. Box
3151, Morogoro, Tanzania. Tel +255 765611156 and +255 777324050 respectively

ABSTRACT

Most studies analyzing the impacts of climate change are centered on the use of sophisticated data manipulation and complicated models not easily understood by smallholder farmers and planners in developing countries. This study use meteorological data collected from three climate phenomenon; high, medium and low rainfall locations and farm level data collected through Focus Group Discussions (FGD) in the corresponding 11 villages in Pangani river basin (PRB) and Pemba in Tanzania to explain the cost effective methodology for analyzing the impacts of climate change. Using mult-criteria method and substitution approach that switches across locations, this method can be used to establish the most likely situation in smallholder farming communities the case of climate changes. The paper conclude that although the model cannot be used to generalize the outcomes across wide planning horizons but its simplicity make it ideal to planners and smallholder farmers in developing countries.

Key words: Climate change, smallholder farmers, climate scenario, Climate change impacts and Tanzania.

---

[1] Corresponding Author: Email jp_hella@yahoo.co.uk; Tel +255 784 582110; Fax +255 23 260 1390

Introduction

Climate change refers to any change in climate over time, whether due to natural variability or as a result of human activity. The United Nations Framework Convention on Climate Change (UNFCCC), puts more emphasis on the human activities and therefore defines 'climate change' as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods (IPCC, 2001).

In recent years there has been a growing concern over the phenomena of Climate change and its effects on agriculture, environment and energy sources that are based on water resources. In Tanzania, just as in a number of other countries, climate changes have manifested themselves by extreme fluctuations in patterns and magnitudes with respect to atmospheric temperatures, precipitation, or wind. In recent years, Eastern Africa and Pangani river basin has suffered various climate-related disasters, ranging from persistent and prolonged drought (e.g. Same and Micheweni) to devastating rains that have triggered landslides and floods (e.g. Mamba Miamba). These have ravaged farmlands, destroyed crops and livestock pastures, and consequently threatening the survival of millions of people. Changing rainfall patterns, resulting from global warming, have rendered hectares of arable land useless and resulted in emergence of evasive pests and diseases, compounding the threat of food insecurity (Shemsanga, 2010). With the growing population the experts envisage even more devastating effects for the area.

The effects of these fluctuations have included changes in the range and distribution of plants and animals, trees blooming earlier, lengthening of growing seasons, extreme periods of heat and cold, storms, and increased prevalence of climate-sensitive diseases such as malaria and wilts to crops (Agrawala *et al*., 2003). According to Vervoort (2012), the future is highly complex and uncertain. There are many different stakes at play and conditions change quickly; economy, politics, climate need to face uncertainty without being pacified by it. This paper reviews the possibility of using scenario approach in Pangani river basin and Pemba to study the impact of climate change on smallholder farming systems.

Theoretical concept and framework

Agriculture is sensitive to climate. All types of farming, from highly mechanized capital intensive farming, to manual subsistence agriculture have the potential to be significantly impacted by current climate variability, as well as by future climate change. In Pangani river basin and Pemba, farming is impacted by a multitude of environmental issues that influence agricultural production at present and in the future. These include:

- Temperature – Higher temperatures and less frost days mean that some crops benefit. However, other crops may suffer from higher temperatures. The shifts in temperatures may change the ideal planting and harvesting times for some crops or shift the type of crop varieties which can be grown. Temperature can also have a direct impact on livestock health and reproduction.

- Precipitation and soil moisture – an increase in average global temperatures will also mean an increase in the intensification of the global water cycle. Higher temperatures will mean more evaporation, and possibly more intense rainfall in some regions – which can lead to flooding. Other regions may however experience longer spells of drought. The changes to the water cycle are critical to consider when examining the agricultural sector.

- Climate variability and extreme events – while long-term changes in the average climate may require adaptation measures, greater risks to food security may be posed by changes in year-to-year variability and extreme events. Extreme temperatures, droughts and floods may result in greatly reduced productivity, and in some cases crop failure.

- CO_2 fertilization – higher levels of CO_2 should, in principle, stimulate greater photosynthetic activity in plants, thereby increasing agricultural productivity. However, some crops will respond better than others and limiting factors such as nutrient and water availability may further limit increases in productivity.

- Weeds, pests and pathogens – conditions may also become more favorable for unwanted species and diseases in the future. Just as the climatic conditions of crops may change, the climate envelopes of weeds, pests and pathogens may also shift to new areas.

- Geographical extent of agriculture – as average temperatures increase, especially in high latitude areas, new areas will become available for agriculture. However, in contrast, changes in rainfall patterns and more extreme summer temperatures may result in some areas no longer being viable for agriculture (PWBO/IUCN, 2008).

Smallholder farmers could be the most vulnerable group to the impacts of climate change. Traditional crops may fail in the future due to climate-related shifts in agro-ecological zones, meaning that adaptation measures might need to be considered. For example, farmers may need to plant crops that are not traditionally part of their cultural history, or more research into drought resistant varieties of traditional crops may be required.

In whatever situation, the challenges of analysis of climate present a major hurdle in modern sciences of climate change. There are so many factors that are uncertain about what is perceived as climate change. Climate change could bring effects in ways we do not understand, global prices and economies could go in all kinds of unexpected directions and political situations could change unexpectedly. To attempt to project the future is really quite a challenge. Reliance on meteorological data and efforts to extrapolate what is happening on the ground is offering little help especially in the developing countries. Steiner (2006) suggests that adaptation to and coping with climate change is complex and will involve a range of social and economic factors including education and literacy as well as creative financial and technological solutions including a better understanding and application of indigenous knowledge and traditional coping strategies.

The estimate of climate change impacts can be complicated and requires a complex interaction between future socio-economic, climate change scenarios, and the valuation of effects that are not easily valued (such as human life, endangered species, etc.). For years, the methodology for determining the impact of climate change on agriculture broadly contains four types of quantitative estimates; agronomic studies, farm yield studies, agro-economic models, and Ricardian models (UNDP, 2010). *Agronomic studies* utilize crop models which are calibrated to each location. These models are generally available for major grain crops. The models can be used to forecast changes in yields associated with change in climate holding everything else constant. The economic damage is assumed to be crop yield change multiplied by the current price. Major limitation is based on the fact that the broad scope of such a study requires making many assumptions, and introduces potentially large uncertainties into the analysis (UNDP, 2010). Economic markets are known for their unpredictability, and may be influenced in the future by currently unknown factors.

Farm *yield studies* regress observed yields from farms on climate, soils, and other control variables. In developing these studies, it is important to include variables that affect yields that might vary over the sample – especially if they are correlated with climate. These models then forecast how farm yields change if the same crop is grown. The *Agro-economic models* – emphasize market mechanisms and treat agriculture as an industry. These models use projections of yield from crop models to predict the economic costs of changing patterns of production. However, its use is limited by the fact may not be most effective to carry out without an advisor who has already carried out similar model development

The Ricardian models – use a top-down approach by making observations of farm revenue or farmland values at local or regional scales and observations of regional climate and other environmental factors to create a model for predicting the spatial variation of farm revenues (Ouedraogo *et al.,* 2006). This model is applied to projections of climate change, in order to calculate future farm incomes under different climate change scenarios. If climate change causes shifts in production patterns, food prices will also fluctuate. Furthermore early studies focused entirely on physical impacts of climatic conditions on natural processes (Arnell, 1998; Stakhiv, 1998; CCIRG, 1996; Harrison *et al.*, 1995; Glantz, 1992; Bentham and Langford, 1995). In general, these studies examined a few exposure units and climate change scenarios.

This paper reviews the possibility of using scenario approach in studying climate change impacts in Tanzania. Scenario planning is different in that it tries to step outside the project box. It encourages thinking in generational terms, rather than in the two or three years of most project plans. It is an open-ended process whose outcome is unknown. And it perhaps works best when it is completely divorced from any prospect of subsequent support. One implication of scenario planning for development organisations is therefore that they must be prepared to let go of the predictability of project cycles and project frameworks

Methodology

3.1.1. Description of the study area

This paper is based on project currently implemented in Pangani basin and Pemba Island. The basin is shared by Tanzania and Kenya extending from northern highlands comprised of mt Meru, Kilimanjaro and Taita hills to the north-eastern coast of the Indian Ocean. Pemba Island is located few nautical miles east of the point where Pangani river enters the Indian ocean. The basin lies between latitude 03^o 05’ 00 and 06^o 05’ 00 South and longitude 30^o 45’ 00 and 39^o 00 East. The basin covers an area of 56300 km^2 out of which 5% lies in Taita- Taveta district of Kenya (Figure 1). In Tanzania the basin is distributed among the Kilimanjaro, Manyara, Arusha and Tanga administrative regions. To improve our analysis, Pemba Island has been included in the study

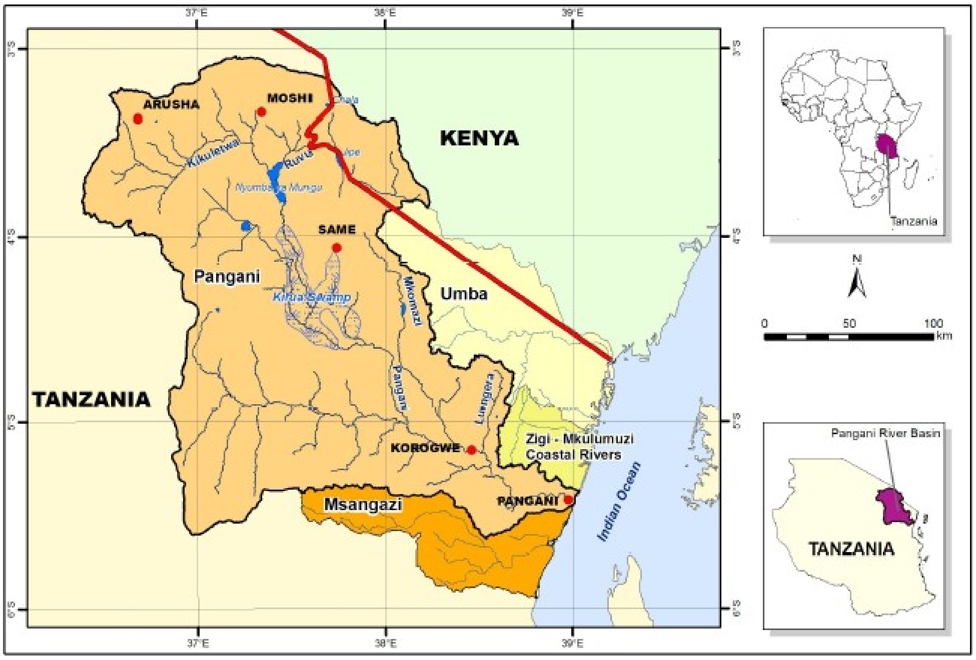


Figure 1: Location of the study (Pangani river basin and Pemba)

Topographically, the basin is not uniform, its altitude ranges between 700-5825m above sea level; the ice cap of Mount Kilimanjaro forms the highest point not only of the basin but of Africa. This altitude has a significant influence on the basin climatic conditions. The temperature ranges between 14ºC to 25ºCin Kilimanjaro and 17 to 29ºC in south-eastern part of the basin and Pemba Island (Sanga *et al*., 2013). On the other hand precipitation varies considerably.

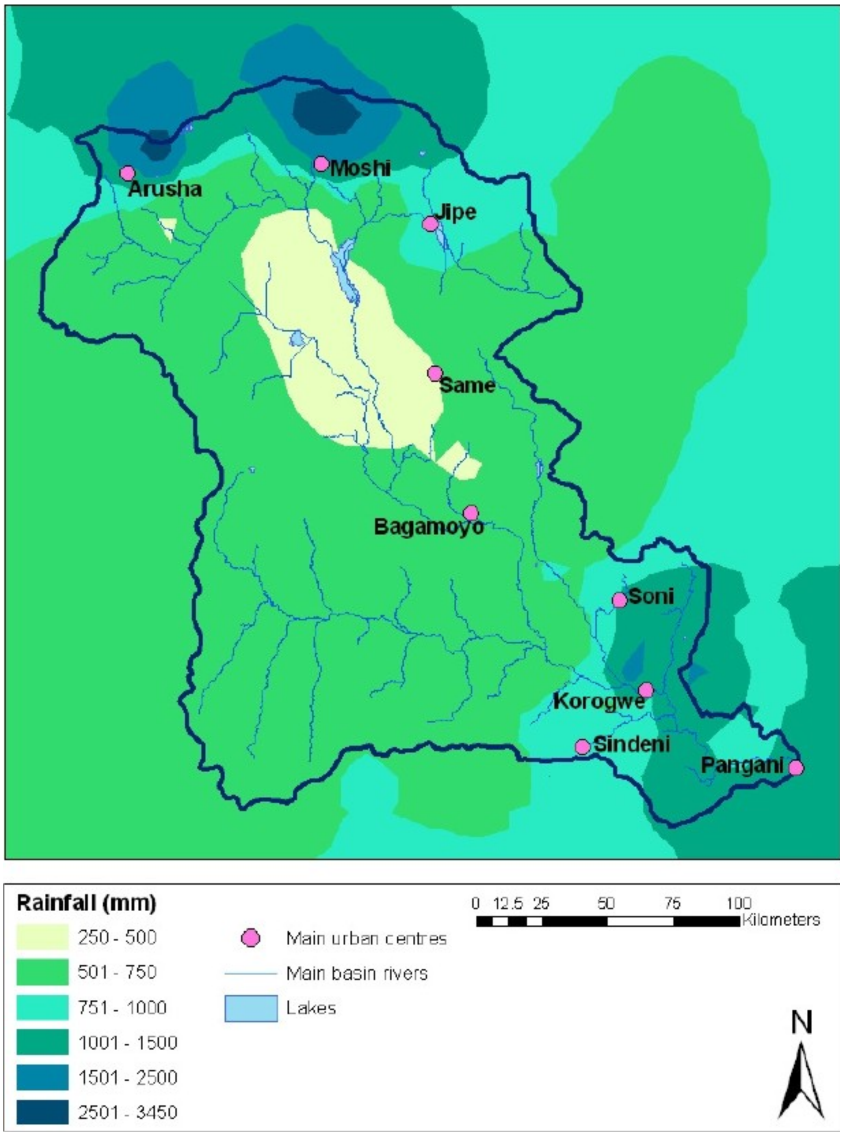


Figure 2: Rainfall pattern in Pangani River Basin (Source PBWB/IUCN, 2007)

The basin is characterized 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. Also the basin is characterized by minimal seasonal variation of temperature. The moderate rainfall zone which receives rains between 800-1200mm per year, the zone 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. The zone covers the low lands of the basin in all districts of Meru, Simanjiro, Same, Mwanga, Korogwe, Handeni, Muheza and Pangani. In this reports, Pemba Island is also included in this zone

The results were related to the changes in crop type, cropping patterns and emergence of crop diseases. Data on these were collected through focus group discussion (FGD) with farmers, opinion leaders, elders, village leaders and other influential people aged 40 years and above from 11 villages: 9 and 2 villages from Pangani River Basins and Pemba respectively. Lyamungo Kilanya (Hai), Baga (Lushoto) and Bungu (Korogwe) are located in high altitude, high rainfall and low temperature while Lekitatu (Meru), Mabilioni (Same) Kigurusimba (Pangani), Micheweni and Makangale (Pemba North) are in lower altitude, high temperature and low rainfall. The intermediate between high and low altitudes Mahoma (Maoshi rural), Ngwasi (Same) and Mafuleta (Korogwe) were selected (Table 1).

Table 1: The locations for defining climatic scenarios in studying climate change in Pangani basin

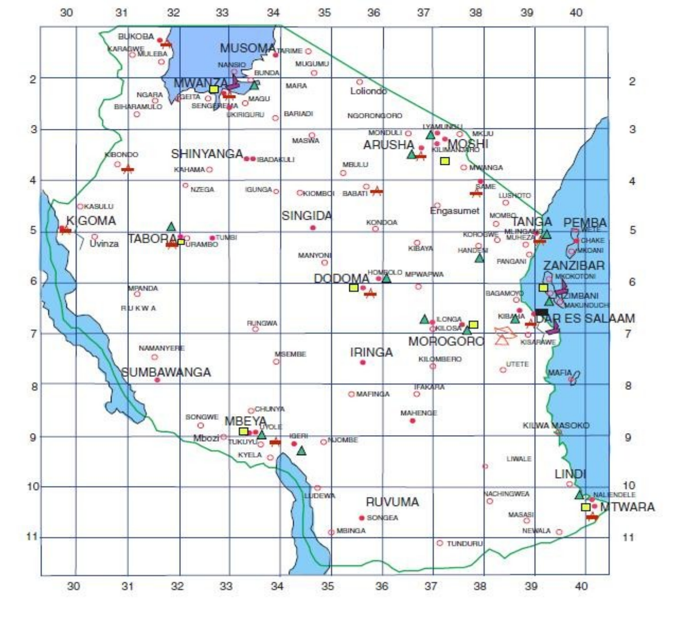
		Climate scenarios (I, II, III) & study locations		
		High rainfall & low temperature (I)	*Medium rainfall & medium temperature (II)*	*Low rainfall & high temperature (III)*
Basin position (L1, L2, & L3) & study locations	L_1 (Upper basin)	**Hai** ✓ Lyamungo Kilanya	**Moshi rural** ✓ Mahoma	**Meru** ✓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

***NOTE**: for Pemba scenarios will be based on rainfall pattern instead of elevation as in PRB*

In addition to the three hypothetical scenarios mentioned in table 1, the project has chosen the location which is comprised of seven main tribes (the Meru, Maasai, Chaga, Pare, Sambaa, Bondei, Digo and Pemba) with differing socio-culture practices hence different outlook in understanding and adapting to climate scenarios. This is crucial in deepening our understandings of the dynamics of achieving the long run climate change mitigation measures such as Reduced Emission from Deforestation and Degradation (REDD) in the basin.

Climate data in Pangani river basin and Pemba

Time series rainfall and temperature data were obtained from Tanzania Meteorological Agency (TMA) for a period of 30 years (i.e. between 1981 and 2010 inclusively) the period which is long enough for change detection and trend correlation analysis. The monthly rainfall and temperature data from 16 rainfall stations and 6 synoptic stations respectively were collected, covering high to lower altitudes of Pangani basin and Pemba (See Figure 3). Initially there were 31 rainfall stations; others were rejected due to insufficient data. All stations with amount of missing monthly data equivalent to 5 or more years (that is around 15% of the data) were rejected (PWBO/IUCN, 2008). Pangani basin and Pemba areas are characterized by bimodal rainfall patterns, in which two rainy seasons exists. These data were analyzed using INSTAT statistical computer package (Stern, 1991; Kihupi *et al.*, 2007), and missing data were replaced by long term mean values. Total annual rainfall, highest maximum temperature and lowest minimum temperatures were computed and linear trend were carried out for each parameter. Results of computations were crosschecked physically by viewing the raw data in spreadsheet format and necessary adjustment were made (Kihupi *et al.*, 2007).



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

Economic Activities

Crop production is the biggest economic activities in Pangani basin and Pemba. This includes large commercial estates (mainly coffee, also sugar), flower farming and small-scale mixed cropping. Small-scale farmers have plots of about 0.1 – 0.2 ha in the highlands, increasing to 0.8-1.5 ha in the lowlands. Coffee is Tanzania’s second largest export crop. It is produced on large estates and by small-holder farmers. Production is strongly correlated with rainfall and irrigation inputs. Sugar production is mostly on large scale, but small-scale farmers also grow it.

According to Turpie *et al*. (2008) and Focus Group Discussions (FGD) conducted in 11 villages in the basin, over 20 different crops are grown by small-holders in the basin, with most farmers growing a variety of fruits and vegetables. There is high correlation between the type of crop produced and climate related variable such as rainfall and temperature.

Turpie et at (2008) found out that maize is the most ubiquitous crop, both in irrigated and non-irrigated areas. Coffee is grown by most households on Mount Kilimanjaro and Mount Meru and tea is dominant in high altitude areas of Lushoto and Korogwe districts. This is usually grown in association with maize and bananas by almost 90% of households in this area. Bananas are also grown by about one third of households in the lowlands. Tomatoes are grown in all areas, but tend to be more frequent in irrigated areas, particularly in the highland areas. Beans are very commonly grown in the upper basin and in highlands, but not in the lowlands. While the highlands are too cool for rice production, rice is a major crop of irrigated areas in the upper basin, and to a lesser extent in the lowlands under irrigation or in close proximity to flooded areas.

Farmers in the highlands and upper basin that do not have access to irrigation concentrate their efforts on maize, beans and onions, as well as a variety of fruits and vegetables. Sugarcane is a minor crop on smallholder farms, but is grown throughout the basin. Cassava is only grown in the lowlands, as are peri-peri, paprika and fiwi. Okra is more commonly grown in the lowlands. Around the Pangani estuary, farmers concentrate on coconuts, betelnuts, cassava, sweet potato and pumpkin, as well as maize and bananas, but there is very little irrigation.

Survey data from a small sample of households throughout the basin (see Turpie *et al*., 2008) suggests that gross income from crops is typically in the range of Tsh 350,000 – 600,000 per household per year. However, much higher incomes have been reported from traditional furrow systems in the upper basin, in some cases higher than that of improved irrigation schemes. Nevertheless, it is easily demonstrated that irrigated areas produce higher incomes per ha than fields without irrigation in the upper basin.

Livestock are kept throughout the basin. In the highland and upper basin areas, households keep small numbers of cattle and goats and sometimes sheep. In the densely-populated highland and upper basin areas, most cattle are stall-fed (‘zero-grazing’) dairy cattle, but a few households in the upper basin have larger herds (up to 32), which are grazed. In the lowlands, cattle and goat herds are much bigger, and are almost all associated with the Maasai community, who are also the only community keeping donkeys. Other tribes in this area keep very few livestock, mainly small numbers of goats. Very few households close to the keep livestock.

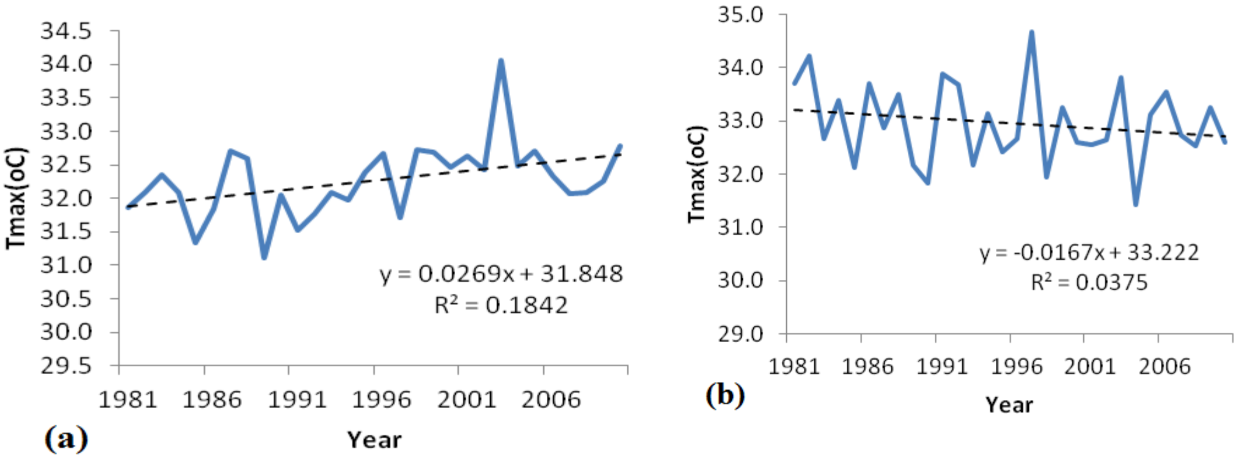
As mentioned earlier, most studies on climate change view holistically the problem without taking into consideration the most likely climate scenarios which dictate the level of impact, vulnerability and adaptation in any area of interest. This study hypothesize that the basin is divided into three scenarios; the high rainfall low temperature, medium rainfall medium temperature and low rainfall high temperature scenarios. Each of these scenarios has got unique characteristics in terms of type of land use, cropping patterns, climate change impact, vulnerability and adaptation. Categorizing the area under consideration into scenarios is crucial because it determine the likely change of scenario one towards the other under prevailing change. For example scenario one is more likely to change to scenario two under climate change. Therefore, nine areas as indicated in the table (1) have been chosen for this study within the basin

Results and discussion

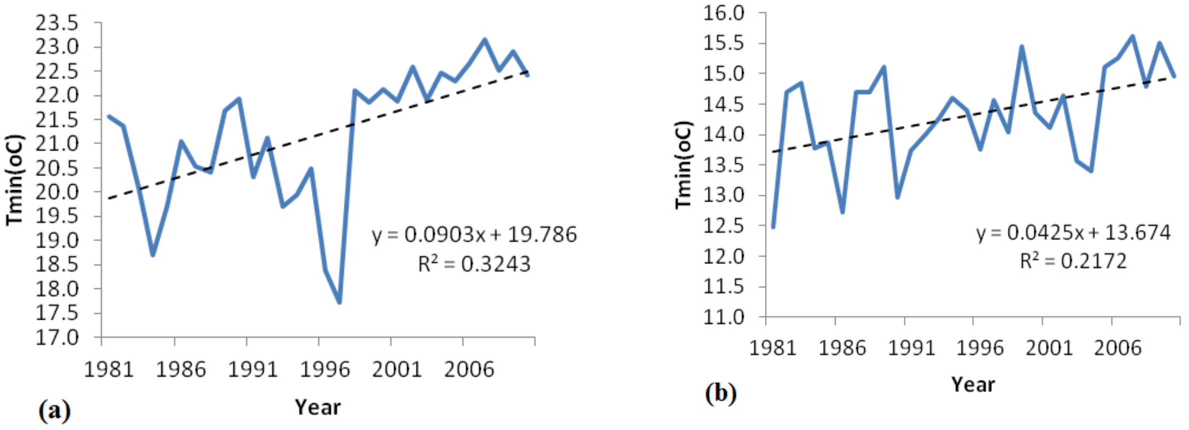
Meteorological data and evidence of changing climate

Temperature

The results on temperature trends indicate that the annual highest maximum and lowest minimum temperature has been increasing over the period of 30 years in the entire area of the basin and Pemba Island. Slight increase of maximum temperature has been observed in Kilimanjaro airport, Moshi and Tanga, and Pemba showing the highest increasing trend (Figure 4a). On the other hand, decreasing trends of maximum temperature has been observed some areas of Arusha and Same (Figure 4b). Highest maximum value of temperature recorded during the period is 35.9^{0}C at Kilimanjaro airport and lowest maximum value is 28.2^{0}C over Arusha. Similarly, the results indicate that the lowest minimum temperature has been increasing at a higher rate over the period of 30 years in the basin and Pemba. Highest minimum value of temperature recorded during the period is 23.2^{0}C at Pemba (Figure 5a) and lowest minimum value is 11.4^{0}C at Arusha (Figure 5b).



Figures 4: Showing maximum temperature trends ((a) increasing in Pemba and decreasing (b) in Same in middle of Pangani Basin



Figures 5: Showing minimum temperature increasing trends ((a) in Pemba and (b) in Arusha in upper altitude of Pangani Basin

Results presented in Figure 4 &5 suggest that there is strong evidence that there is a major shift that both minimum and maximum temperature are increasing in most areas in Pangani river basin and Pemba. Increase of maximum temperature to about **0.8 - 1^{0}C** in most station and of **1.2^{0}C** over KIA. Significant increase of minimum temperature of about **1.5^{0}C** prevails over Pemba and Moshi. These changes have significant impact on the type of crops to produce, livestock to keep, and general husbandry practices common in Pangani river basin and Pemba.

Rainfall

The results in appendix 1 show that there is a general decrease of rainfall in the area over the period (i.e. 30 years). There are high variations of rainfall within the area, a detailed analysis show great variation in the start and end of rainfall in the area. Higher rainfall decreases are shown in Maua seminary and Kilema chini in Moshi rural which are found in upper altitude of the basin. The trend is also seen in Pemba Island, Pangani and Korogwe district, which are found in lower altitudes of the basin. Slight decreasing trend in rainfall is observed in Arusha, Lyamungo, Moshi and Same. On the other hand, slight increase in rainfall, is observed in Lushoto, Shingatini (Mwanga) and Kibong'oto (Hai), which are found in high altitudes of the basins. Highest value recorded during the period is 4551mm at Maua Seminary and lowest value is 265mm over Same which are higher and lower altitude respectively implying that the higher the altitudes the more the rainfall. Constant rainfall trend is observed in Mazinde, Figure 7b, which is found in highest altitude of the basin.

General rainfall trend shows significant decrease in most station especially those in high altitude and upper upper basin of Pangani river (See appendix 1). In some places drops up to about 500mm over have been recorded over Hai only slight increase of rainfall over Lushoto. As indicated above this change is correlated with crops and livestock keeping methods as well as changes in livelihood of the smallholders farmers in the study area. In farming farmers cultivate crops varieties that take short time with respect to available rainfall and crops that are resistance to draught. In livestock farmers have to change grazing system due to unavailability of pastures.

Modeling scenarios to establish climate change impacts based on location substitution

Meteorological data collected in study areas differ from each other by altitude and position along the Pangani river basin and Pemba. When combined with some socio-economic data, the metrological data be used to establish the most likely impacts of the climate change in the most simplified manner based on the perceived scenario. The intergovernmental Panel for Climate Change (IPCC) defines climate impacts as being '…differences…between socio-economic conditions projected to exist without climate change and those projected with climate change' (Carter *et al*., 1994). This climate impact assessment requires a clear picture of two intimately interrelated processes: socio-economic change and climate change. By combining the two it is possible to evaluate the exposure to harm from climate change, and how future societies may cope and adapt to these impacts. The observed change on climate variables for selected station is presented in (Table 2)

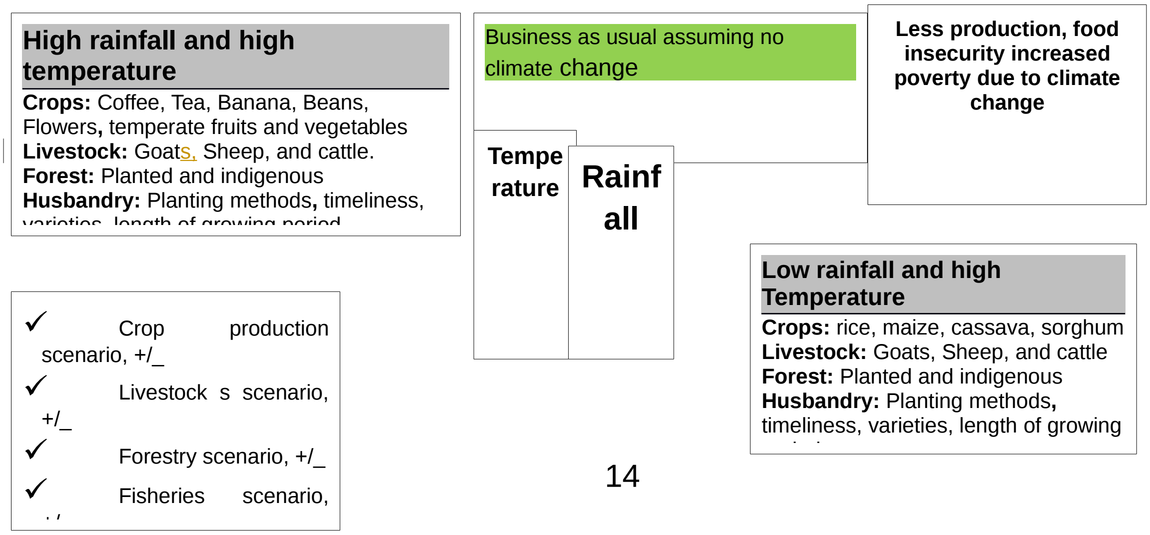
Table 2: Summary of long term rainfall and Temperature trends in selected weather stations in Pangani river basin and Pemba

STATION	Rainfall trend	Temperature	
		Minimum	Maximum

Arusha	Decreasing	Increasing	Increasing
Hai	Decreasing	-	-
KIA	-	Increasing	Increasing
Moshi Rural	Decreasing	Increasing	Increasing
Mwanga	Decreasing	-	-
Same	Slight decrease	-	-
Lushoto	**Slight increasing**	-	-
Korogwe	Decreasing	-	-
Pangani	Decreasing	-	-
Tanga	-	Increasing	Increasing
Pemba	Decreasing	Increasing	Increasing

After obtaining socio-economic data, scenarios can be established based on the interpolation of locations within the catchment. Socio-economic scenarios can be used to respond to the challenges discussed above. According to the IPCC, a scenario is a coherent, internally consistent and plausible description of a possible future state of the climate (Parry and Carter, 1998). Scenarios are planning and communication tools used to explore uncertain futures. They do not aim to predict, but are designed to give representations of possible futures. Typically, futures scenarios include a narrative component as well as quantitative illustrative indicators. Rotmans and van Asselt (1998, cited in Greeuw *et al.*, 2000) define scenarios as:'…archetypal descriptions of alternative images of the future, created from mental maps or models that reflect different perspectives on past, present and future developments.'

Based on this concept farmers in high altitude villages who have been enjoying cool climate, high rainfall, and limited crop pest and diseases, with the climate change (decreasing rainfall and increasing temperature) they are more likely to follow a numbers scenario pathways such as to limit production of some crops, keeping certain type of livestock and practicing some husbandry practices. Alternatively some new crops will be grown leading to increased income and food security to the household.



High rainfall and high temperature
Crops: Coffee, Tea, Banana, Beans, Flowers, temperate fruits and vegetables
Livestock: Goats, Sheep, and cattle.
Forest: Planted and indigenous
Husbandry: Planting methods, timeliness,

Business as usual assuming no climate change

Less production, food insecurity increased poverty due to climate change

Temperature

Rainfall

Low rainfall and high Temperature
Crops: rice, maize, cassava, sorghum
Livestock: Goats, Sheep, and cattle
Forest: Planted and indigenous
Husbandry: Planting methods, timeliness, varieties, length of growing

- ✓ Crop production scenario, +/_
- ✓ Livestock s scenario, +/_
- ✓ Forestry scenario, +/_
- ✓ Fisheries scenario,

Figure 8: Resulting scenario plans in Pangani river basin and Pemba

Based on relationships presented in figure 8, it is now possible to present scenario plans which can help crop farmers, livestock keepers, agriculture experts, policy makers, etc. to take advantage of emerging opportunities and mitigate potential threats arriving from climate change. Farmers in the highlands (e.g. Lyamungo Kilanya) have several scenarios, continue business as usual, or plan to adapt livelihood patterns of those in low altitude villages (e.g. Lekitatu) which actually portray the direction to which the climate is changing. In similar manner, farmers in high rainfall Makangale village in Pemba threatened by declining rainfall the best planning scenario should emulated those in Micheweni (low rainfall and threats of raising sea level). The approach can be used at many levels, thus giving all stakeholders the means to influence some of the driving forces that affect their lives. Examples of some planning scenario include;

- ✓ Farmers continue with their activities as if no climate changes
- ✓ Farmers adopt crops/livestock which were dominant in high temperature and low altitude areas
- ✓ Change production methods to cope with the changing climate
- ✓ Coping with declining volume of water for irrigation
- ✓ Policy dialogue and technical changes and support systems
- ✓ Out migration or alternative job creation

Small farmers in developing countries without sophisticated equipment to model climate change, the use scenario planning approach offers a simplified opportunity to establish the most likely impact resulting from climate change.

Determining economics of the impacts based on established scenario on climate change and location

After establishing the optimal scenario, then suitable farm management decision tools can be employed to ascertain for economic suitability of each adopted scenario. Farm Management tools such as Partial budget, linear programming, and gross margin analysis as specified below

For example, the net income effect of the proposed change can be calculated by comparing the advantages (new benefits and cost saved) to the disadvantages (benefits foregone and new costs) of say changing from the dominant to new crop or cropping pattern (without climate change) to possible new crop (induced by climate change). The producer will be able to make effective decisions resulting from the equations for Benefit-Detriment analyses as presented in Table 3. For the change to be economically feasible and financially undertaking (scenario), the equation should be greater than zero to indicate positive change (economic advantages). A negative difference will indicate that the change is less profitable.

Table 3: Standard layout of partial budget for adopting climate smart farming

Benefits (Gains)	**Detriments (Costs)**
a) Additional benefits (new benefits): benefits from using seeds that take short time to harvest.	c) High cost of production because production techniques which are new to farmers since earlier ones are not good for current climate.
b) Increased level of yield due to use of climate smart farming technique example use of manure, crop choice and irrigation system.	d) Additional costs (new costs): expenses from the use of new climate smart farming technical
Total benefits: $a + b$ $a + b$	**Total costs:** $c + d$ $c + d$
Difference: Net change in benefit (net gains or net losses) = $\pm[a + b - (c + d)]$ $\pm[a + b - (c + d)]$	

Adapted from Kay *et al*. (2008)

Similarly linear programming can be used to establish the most optimal combination of physical and natural resources resulting from adopting climate friendly scenario.

Conclusion and recommendations

The climate is an integral part of many of the economic systems within Pangani river basin and Pemba farming community. Climate change will have impacts on the physical systems which underpin the economies of the area. Researchers and analysts in the last 3 years have begun to look at methodology which will tell the likely future impacts of climate change as well as the current impacts of climate on the socio-economic systems of the small farmers in developing countries

This paper has attempted to develop a procedure which we are employing to study the impact of climate change in Pangani River Basin and Pemba. While the objective is not to replace the earlier approaches in studying climate change impacts, we believe that scenario planning is different. It encourages thinking in generational terms, rather than in the two or three years of most project plans. It is an open-ended process whose outcome is unknown like climate change itself. It is participatory which can easily be understood by farmers. And it perhaps works best when it is completely divorced from any prospect of subsequent support. One implication of scenario planning for development organizations is therefore that they must be prepared to let go of the predictability of project cycles and project frameworks.

Reference

Arnell, N.W. (1998). Climatic change and water resources in Britain. *Climatic Change*, 39, 83-110

Bentham, G. and Langford, I.H. (1995). Climate change and the incidence of food poisoning in England and Wales. *Int. J. Biomet*., 39, 81-86.

Carter, T.R., Parry, M.L., Harasawa, H., Nishioka, S., (1994). IPCC technical guidelines for assessing climate change impacts and adaptations. Department of Geography, University College London and Center for Global Environmental Research, National Institute for Environmental Studies, London, UK and Tsukuba, Japan

CCIRG (UK Climate Change Impacts Review Group), (1996). Review of the Potential Effects of Climate Change in the United Kingdom, Second Report. HMSO: London

Glantz, M.H. (1988). *Societal responses to regional climate change: forecasting by analogy.* Westview Press: Boulder, Colorado

Greeuw, S.C.H., van Asselt, M.B.A. (2000). Cloudy crystal balls: an assessment of recent European and global scenario studies and models. Prospects and scenarios No 4, European Environment Agency, Copenhagen, November.

Harrison, P.A., Butterfield, R. and Downing, T., (1995). Climate change and agriculture in Europe: Assessment of impacts and adaptations, Research Report No 9, Environmental Change Unit, University of Oxford.

IIED (2008). Planning with Uncertainty: Using planning with African Pastoralists. SOS Sahel International, United Kingdom, 29pp.

Kay, R.D., Edwards, W.M. and Duffy, P.A. (2008). *Farm Management*, 6th Edition. New York, NY: McGraw-Hill Companies

Kihupi, N. I., Tarimo, A. K. P. R., and Dihenga, H. O. (2007). Spatial and Temporal variation of growing season characteristics in Tanzania. Journal of the geographical Association of Tanzania. Vol.32, 32-49

Ouedraogo M, Somé L & Dembele Y, 2006. Economic impact assessment of climate change on agriculture in Burkina Faso: A Ricardian Approach. CEEPA Discussion Paper No. 24, Centre for Environmental Economics and Policy in Africa, University of Pretoria.

PBWB/IUCN (2007). Socio-economic Baseline Assessment Report. Role of river systems in household livelihoods. Moshi, Tanzania. 58pp

Stern, R. (1991). *INSTAT Climatic Guide*. Statistical services Centre, University of Reading, U.K.

Turpie, J. K., Y. M. Ngaga, F. K. Karanja (2008), Preliminary Economic Assessment of Water Resources of the Pangani River Basin, Tanzania

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

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.

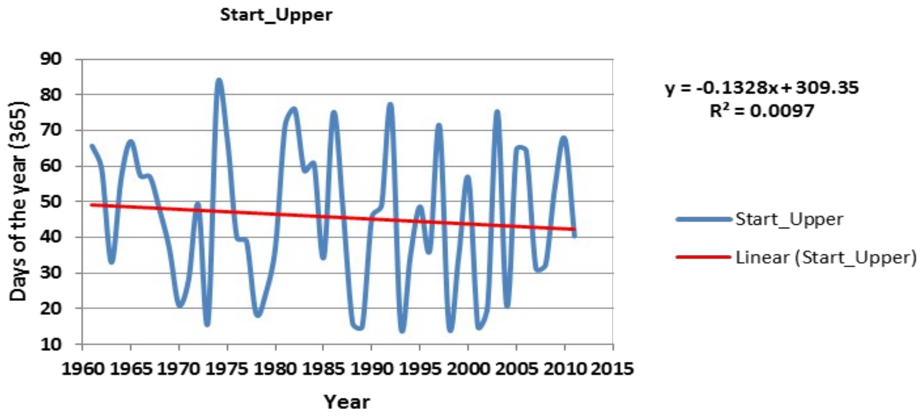
Agrawala, S.; Moehner, A.; Hemp, A.; Aalst, M.; Hitz, S.; Smith, J.; Meena, H.; Mwakifwamba, S.; Hyera, T.; and Mwaipopo, O., (2003). *Development and Climate Change in Tanzania: Focus on Mount Kilimanjaro*. Organisation for Economic Co-operation and Development (OECD), Paris, France.

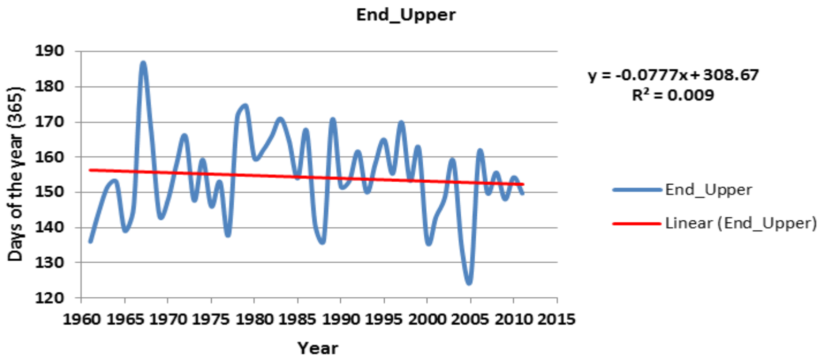
PWBO/IUCN. (2008). Development of Climate change scenarios. Pangani River Basin Flow Assessment. Pangani Basin Water Board, Moshi and IUCN Eastern and Southern Africa Regional Programme. 53 pp.

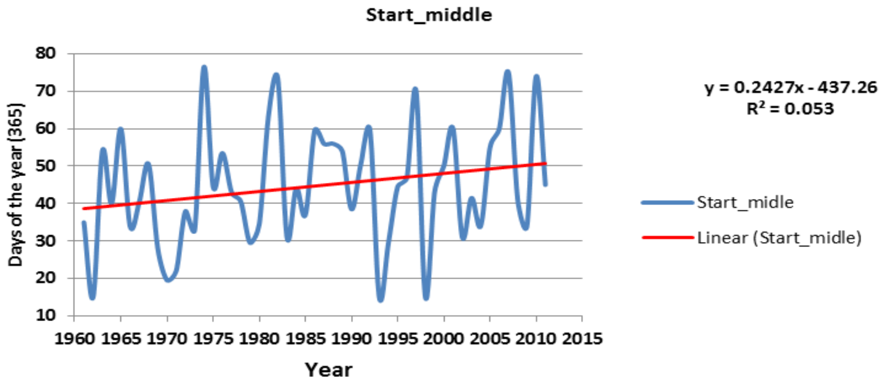
Sanga, J.G., Moshi, A.B., and Hella, P.J. (2013). Small Scale Farmers' Adaptation to Climate Change Effects in Pangani River Basin and Pemba: Challenges and Opportunities. *International Journal of Modern Social Sciences vol.* 2(3): 169-194.

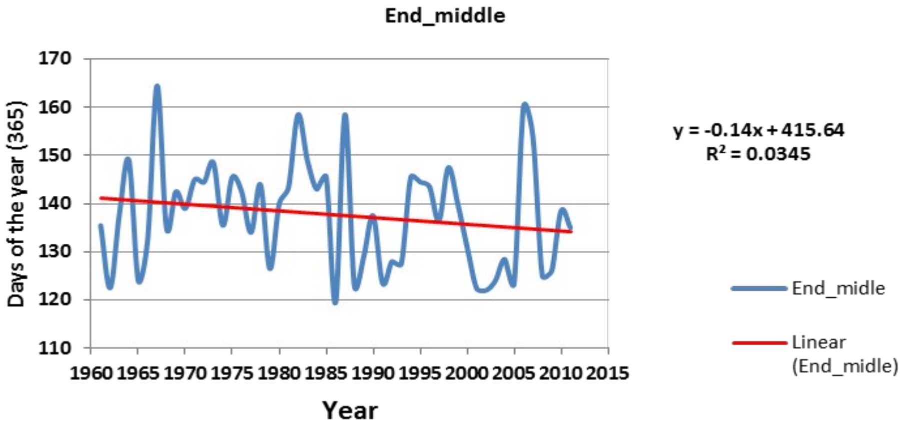
Appendices

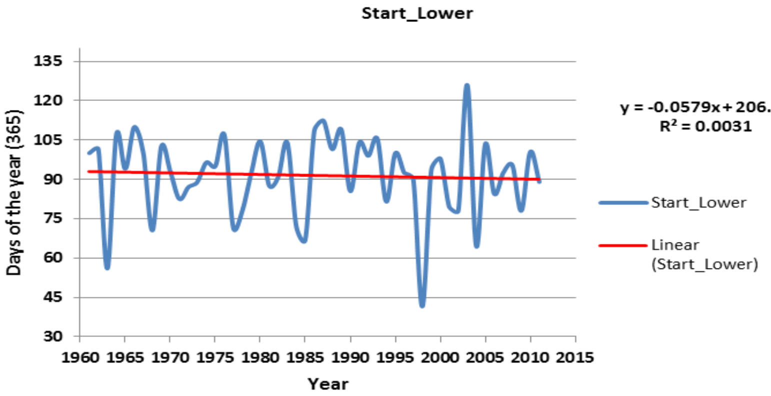
Appendix 1: Pangani River Basin and Pemba rainfall trends showing start, end, length and extreme events

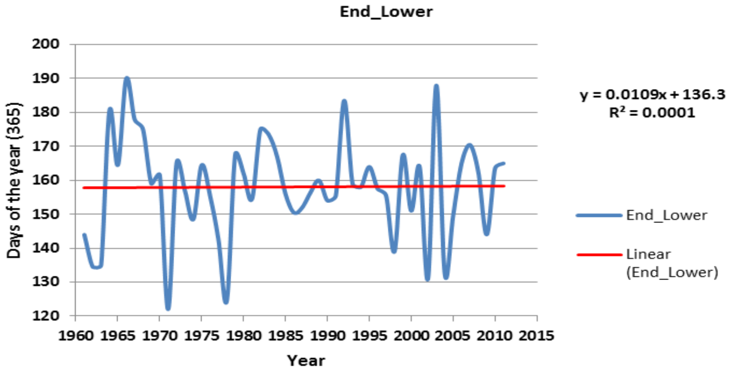


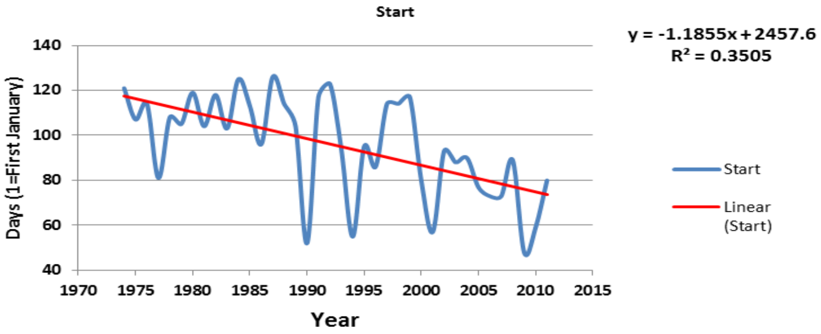


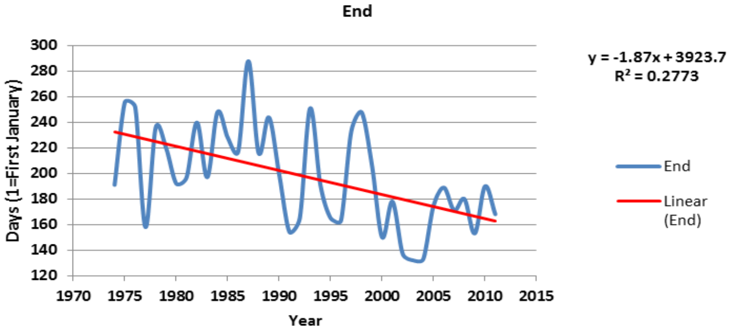


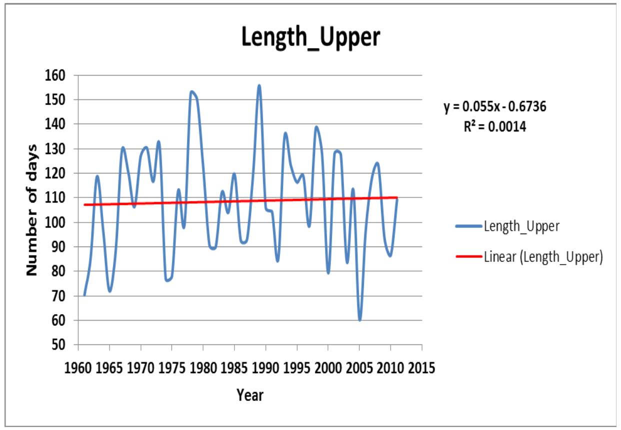


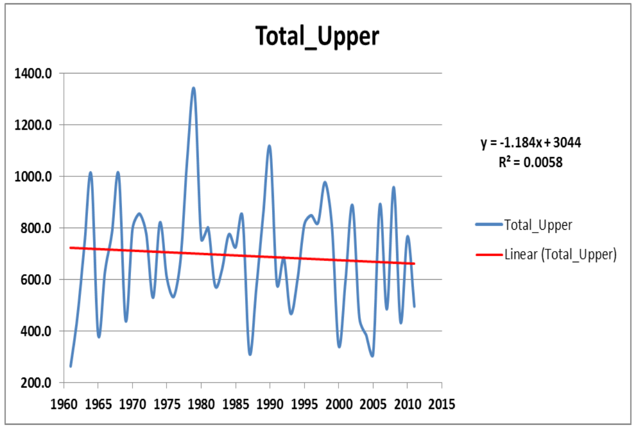

Start_Lower
Days of the year (365)
135
120
105
90
75
60
45
30
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
y = -0.0579x + 206.57
R² = 0.0031
Start_Lower
Linear (Start_Lower)

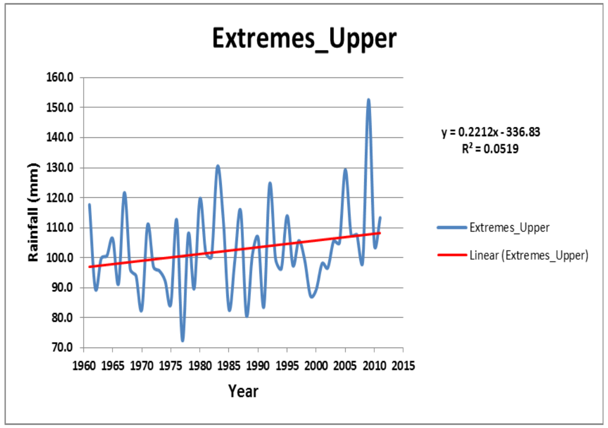

End_Lower
Days of the year (365)
200
190
180
170
160
150
140
130
120
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
y = 0.0109x + 136.3
R² = 0.0001
End_Lower
Linear (End_Lower)

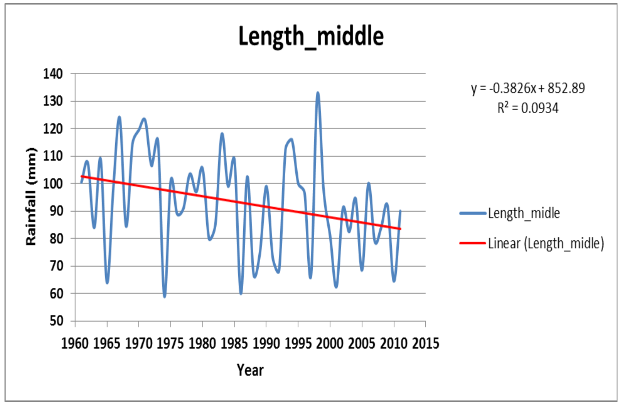

Start
Days (1=First January)
140
120
100
80
60
40
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
y = -1.1855x + 2457.6
R² = 0.3505
Start
Linear (Start)

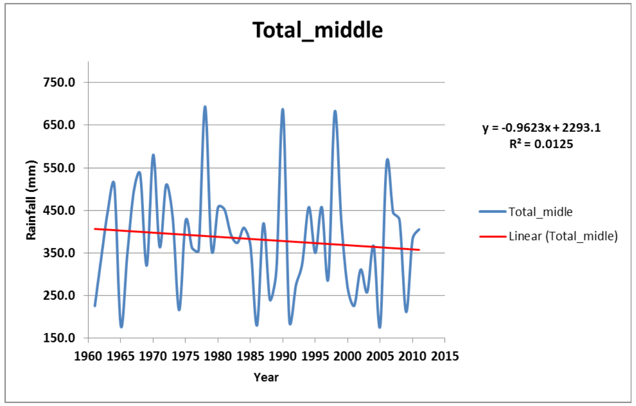

End
Days (1=First January)
300
280
260
240
220
200
180
160
140
120
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
y = -1.87x + 3923.7
R² = 0.2773
End
Linear (End)

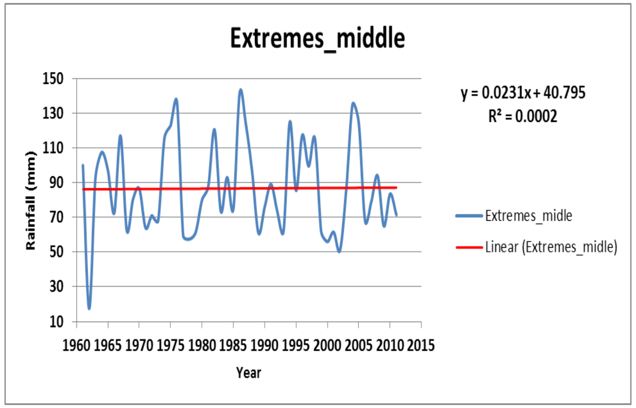

Length_Upper
Number of days
160
150
140
130
120
110
100
90
80
70
60
50
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
y = 0.055x - 0.6736
R² = 0.0014
Length_Upper
Linear (Length_Upper)

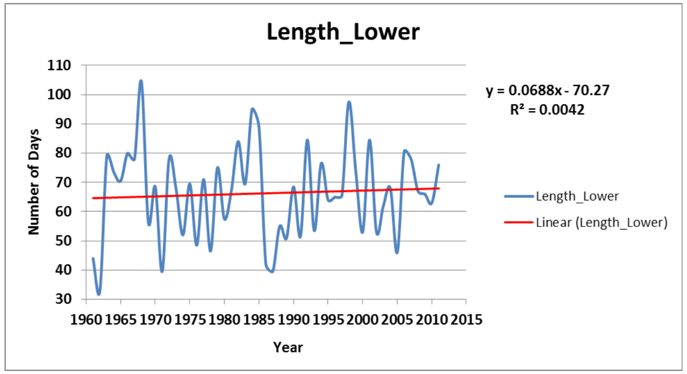

Total_Upper
1400.0
1200.0
1000.0
800.0
600.0
400.0
200.0
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
y = -1.184x + 3044
R² = 0.0058
Total_Upper
Linear (Total_Upper)

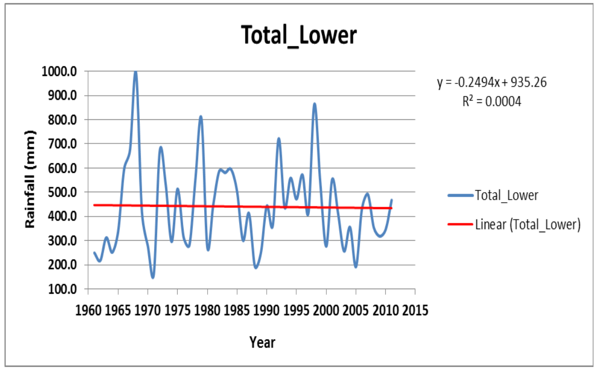

Extremes_Upper
Rainfall (mm)
160.0
150.0
140.0
130.0
120.0
110.0
100.0
90.0
80.0
70.0
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
y = 0.2212x - 336.83
R² = 0.0519
Extremes_Upper
Linear (Extremes_Upper)

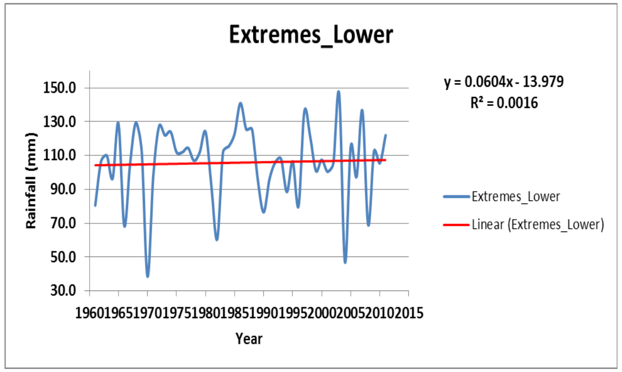

Length_middle
Rainfall (mm)
140
130
120
110
100
90
80
70
60
50
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
y = -0.3826x + 852.89
R² = 0.0934
Length_midle
Linear (Length_midle)

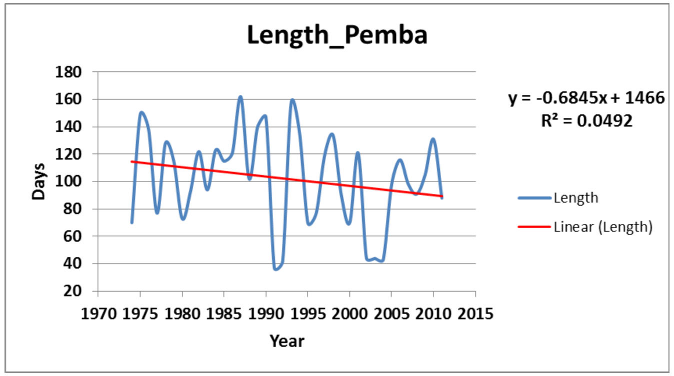

Total_middle
Rainfall (mm)
750.0
650.0
550.0
450.0
350.0
250.0
150.0
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
y = -0.9623x + 2293.1
R² = 0.0125
Total_midle
Linear (Total_midle)

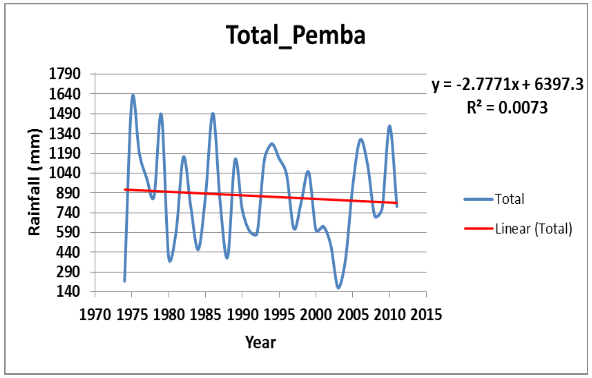

Extremes_middle
Rainfall (mm)
150
130
110
90
70
50
30
10
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
y = 0.0231x + 40.795
R² = 0.0002
Extremes_midle
Linear (Extremes_midle)

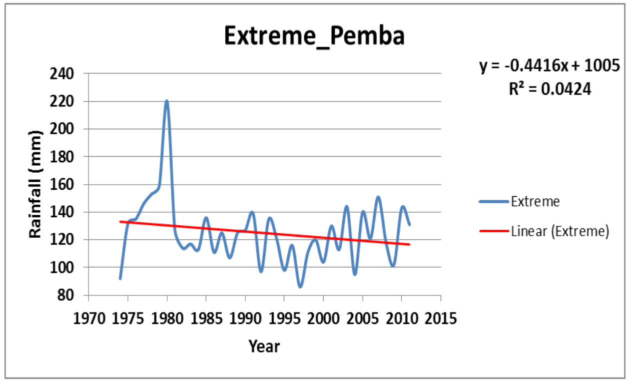

Length_Lower
Number of Days
110
100
90
80
70
60
50
40
30
1960 1965 1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
y = 0.0688x - 70.27
R² = 0.0042
Length_Lower
Linear (Length_Lower)


Total_Lower
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
y = -0.2494x + 935.26
R² = 0.0004
Total_Lower
Linear (Total_Lower)


Extremes_Lower
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
y = 0.0604x - 13.979
R² = 0.0016
Extremes_Lower
Linear (Extremes_Lower)


Length_Pemba
Days
180
160
140
120
100
80
60
40
20
1970 1975 1980 1985 1990 1995 2000 2005 2010 2015
Year
y = -0.6845x + 1466
R² = 0.0492
Length
Linear (Length)


Total_Pemba
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
y = -2.7771x + 6397.3
R² = 0.0073
Total
Linear (Total)


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