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TREND ANALYSIS OF CLIMATE CHANGE AND ITS IMPACTS ON CROP PRODUCTIVITY IN THE LOWER TANA RIVER BASIN, KENYA

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Abstract: Impacts of Climate change and the associated vulnerabilities have increasingly become significant environmental issues of concern across the globe. Climate change is one of the greatest impediments to the realization of the first Millennium Development Goal of reducing poverty and food insecurity globally since it directly influences agricultural production and community livelihoods. Africa is highly vulnerable and especially the arid and semi arid lands which have low adaptive capacities. Approximately 80% of the African population is dependent on agriculture which it is currently facing myriad of challenges ranging from climate change to technology adoption. The sector therefore needs better support from policy makers, service providers and/or development agencies to remain the engine for economic growth and rural development. Analysis of climate trends in relation to regional production sectors such as crops using available scientific tools would create opportunities to incorporate relevant adaptation measures from the planning stages. This study found that the return periods for extreme climatic events such as drought as decreased from approximately 4 to 5 years before the year 2000 to about 2 years or less at present in the lower Tana River basin. Maize production in the region remains climatically undermined and farmers need to upscale the production of mangoes and cassava which grows and have good yields in the region. There is need to maximize the production opportunities of better yielding crops and encourage cross border trades in the country.
Keywords: Climate change; Climate variability; Crop yields; Tana River basin.

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INTRODUCTION

Climate variability and change, its impacts and the associated vulnerabilities is a growing environmental issue of concern across the globe. It is believed to be one of the greatest impediments to the realization of the first Millennium Development Goal of reducing poverty and food insecurity globally. Scientific studies projects a global increase in the frequency and impact of climate related natural disasters (Pelling, 2003; DFID, 2011; IPCC, 2012), a trend that is likely to continue as climate change increases the threat of disasters such as droughts and floods (IPCC, 2012). Many parts of the world including the Sub-Sahara Africa (SSA) are already experiencing changes in seasonal patterns and timing, and in particular the distribution and intensity of rainfall (CARE, 2012). Rainfall and temperature remains the most important weather variables in agricultural production systems of the Sub-Sahara Africa (Hulme et al., 2005). Year-to-year variability of rainfall is a significant constraint to the sustainability of rainfed farming systems in the region (Unganai, 2000) and farmers therefore need to be empowered to face this climate uncertainty that will manifest in every season including the occurrence of other catastrophic events.

Agricultural production remains the economic back bone of most developing countries with an estimated 70%of the world's poor relying on agriculture for their primary source of food, livelihoods and rural development (Suarez et al., 2012). Therefore, the increasingly unpredictable climatic conditions are impacting on livelihoods and food security of millions of people. Kenya's climate condition has been changing in many parts of the country and it is becoming more unpredictable every season and year. Global warming induces these changes which have profound impact on agriculture, the driver of the economic growth in Kenya (McCarthy et. al., 2001). Incidence of extreme floods and droughts, which are largely aggravated by climate change and its variability are been experienced more frequently than ever before in many parts of Kenya with serious consequences in arid and semi-arid regions. The uncertainty of rainfall and uneven temporal and spatial distribution is posing huge challenges to decision makers. Majority of farmers in the arid and semi-arid areas of Kenya grow crops and keep livestock under the mixed farming system and are highly susceptible to variations in the climate. It is anticipated that crop production would be extremely vulnerable under the projected climate change scenarios which indicate that climate variability will lead to increased droughts and more uncertainties in rainfall particularly on the onset, distribution and cessation (Washington et al., 2004; IPCC, 2007). As a result, food security will be at risk and increased community vulnerability (Karim et al., 1996). Communities and decision makers in these regions require detailed climate information regarding the climate change trends and their potential impacts so as to incorporate appropriate agricultural adaptation measures. Presently, development efforts both at national and regional levels aims at increasing food production through the revival and expansion of irrigation schemes, flood protection embankments/dykes, and adoption of modern farming technologies in order to achieve self-sufficiency in food grains. These strategies need to be mainstreamed with appropriate climate information as a pillar to sustainability. Threats from undefined climate change can terribly hinder this national target and initiatives if information on the trend of climate together with future projection is ignored or inaccessible during the planning stage (Karim et. al., 1994). The objective of this study was to assess the extent of climate variability and change (particularly rainfall and temperature) in the lower Tana River basin and how it is impacting on crop yields (tons/acre) of the widely grown food crops which influence the food security of the region. The motivation is to inform policy makers on the need to incorporate appropriate climate change adaptation measures to rain fed agricultural production systems against the increasing climatic shocks.

EXPERIMENTAL

Historical climatic variables -rainfall (mm) and temperature (°C) from as early as 1960s to 2010 for the lower Tana River region were collected from the Kenya Meteorological Department (KMD) field stations. The annual mean rainfall and temperature as well as number of raining days were computed from the observed climatic data. Agricultural production data (crop yields) specifically for the widely grown crops in the region namely maize, mangoes, rice, cassava and green grams for a period of at least 20 years (1989 to 2009) were collected from Ministry of Agriculture offices in the sites. Descriptive and inferential statistics were used to analyze the data. Correlation and regression analyses were to establish the relationship between climatic data and crop yields.

RESULTS AND DISCUSSION

Rainfall Variability

Rainfall is an extremely important climatic variable to the economic development of a region. In agriculture, for example, it dictates how land can be utilized. The analysis of six weather recording stations sparsely distributed mainly along River Tana (Figure 1) reveals variability in the frequency and intensity of rains from one area to another and also from season to season (Figure 2). The year-to-year variability is a significant constraint to the establishment and sustainability of rain-fed farming systems particularly in the ASALs. Historically, many of the biggest shortfalls in crop production are observed during droughts caused by anomalously low precipitation (Sivakumarv et al, 2005). As in many parts of the country, the region receives a bimodal rainfall seasons namely March-May (often refereed as MAM) and October-December (OND) with the peak rainfall periods received in April (100 day) and November (325 day) respectively (Figures 3 and 4). Annual rainfall totals in the lower Tana River basin varies from slightly over 1100 mm in Witu to about 400 mm in Bura (Figure 5). Kipini and Witu areas receive relatively large annual rainfall of above 1000 mm. The short rains season (OND) is more enhanced and reliable in Garissa, Bura, and Tana areas as compared to the long rains (MAM) season (Figure 5).

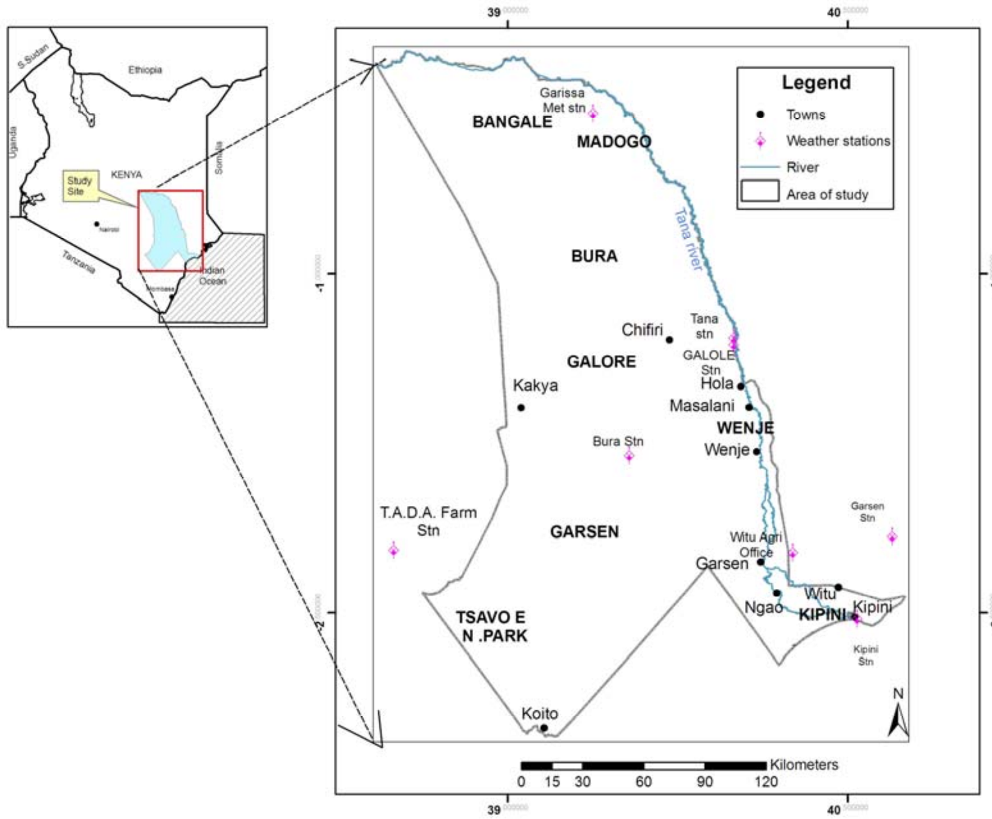


Figure 1. Location of Six weather stations in the lower Tana River basin

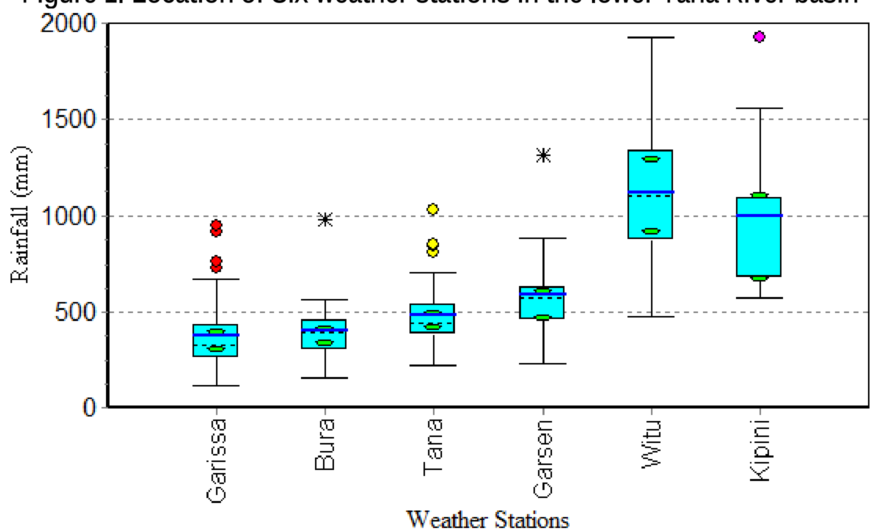


Figure 2. Distribution of Rainfall within sites in lower Tana River basin

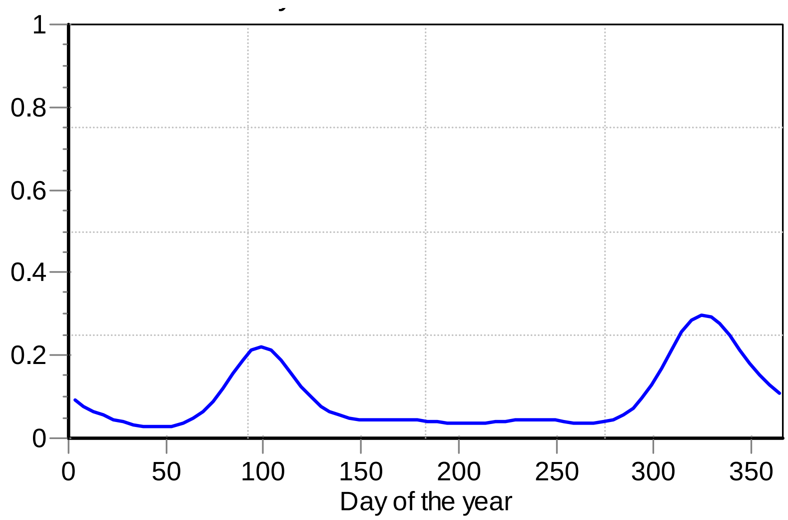


Figure 3. Probability function of rain in Garissa station

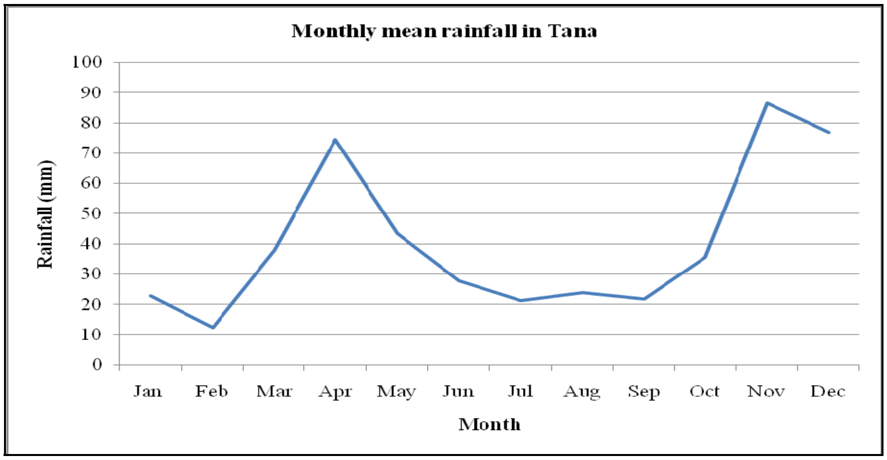


Figure 4. Seasonal Rainfall distributions in Tana weather station

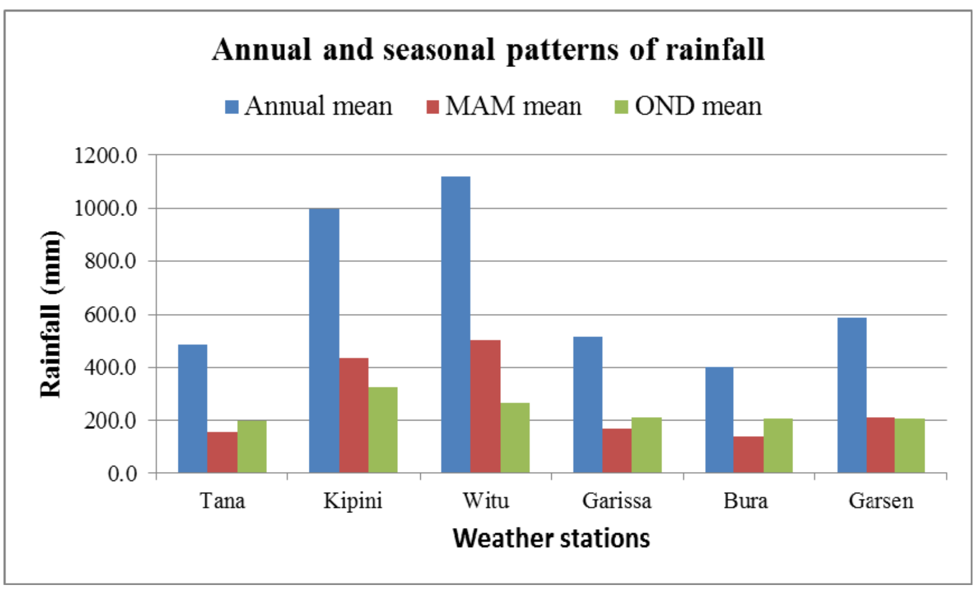


Figure 5. Lower Tana basin annual and Seasonal rainfall

This implies that only Kipini and Witu areas in the region can successfully grow maize within the MAM rainfall seasons while the production of maize in other areas is undermined and would require incorporation of some adaptation strategies such as supplementation of water through irrigation. This is because a normal agricultural season for maize production (the most commonly grown crop in Kenya) requires precipitation levels of between 500 and 800 mm (FAO, 1986). In Garsen the rainfall seasons (MAM and OND) are almost the same. Similarly, the study reveals that areas closer to the Indian Ocean have enhanced rainfall exceeding a mean of 1000mm as compared to areas away from the Ocean such as Garissa, Bura and Tana that receive a depressed rainfall with a mean of about 350 mm. These areas can therefore be intensively utilized to produce food for the region and farmers need to be facilitated to access improved planting seeds and fertilizers. The region experiences extreme flood events in approximately 10 year return period such as in 1967, 1977, 1988 and 1997 with a maximum ever received rainfall totals exceeding 2000 mm around Kipini and Witu in 1997 (Figure 6). Similarly, the study revealed a general rainfall decrease in the recent years indicating that the region is becoming drier. Analysis of rainfall anomalies for example in Tana site reveals both alternating floods and drought extreme climate events (Figure 7). The return period of a devastating flood in the region is about 10 years and about 4 years for drought. Nonetheless, the frequency of droughts in recent years has increased to about 1 to 2 years (Figure 7).

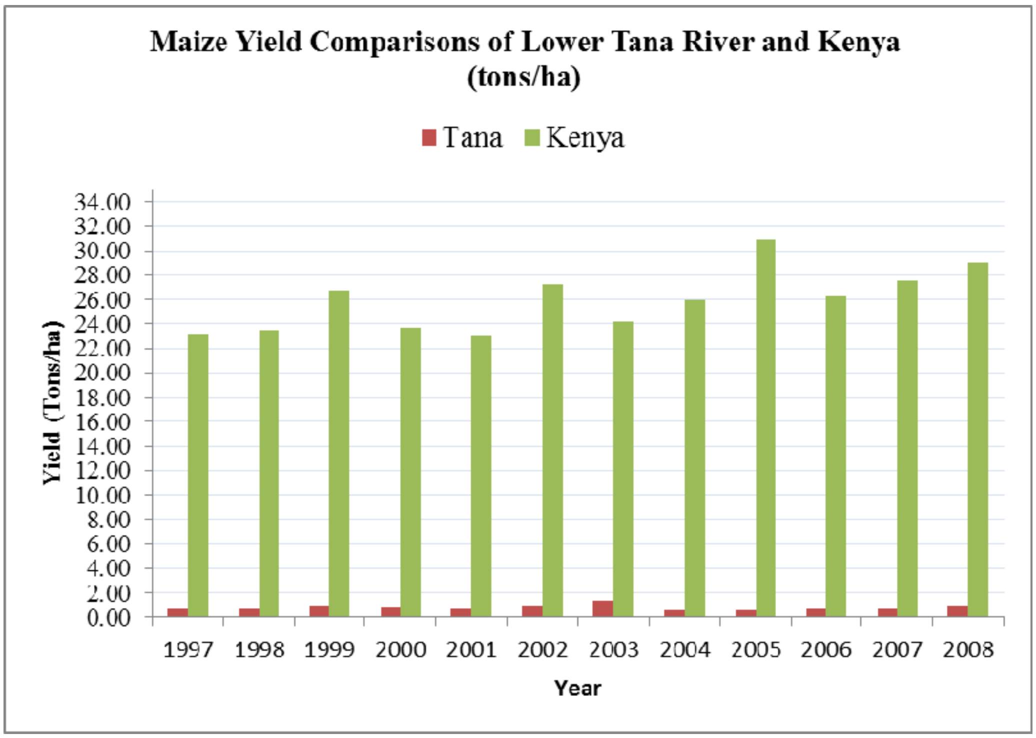


Figure 6. Mean maize yield comparisons of Tana with the national production (tons/ha)

The inter-annual variability of rainfall across the six stations (Figures 7-11) is high and this may often be associated with the frequent climate hazards experienced in the region, especially floods and droughts, with devastating effects on food production, associated calamities and human suffering. The study also reveals that most weather stations were established in late 1970s and collapsed in the early 2000s.

Temperature changes

The changes in temperatures over years were noted. Highest maximum temperatures were recorded between 1982 and 1984 (Figure 12). The minimum temperature has been increasing and was highest in 2010 (Figure 13).

Crop production in the lower Tana River basin

The yield of crops is central to the well-being of a community and is influenced by both regional and local climate. Rainfall is the most important climatic factor and determines the spatial yield distribution of crops. The region predominantly produces high quantities of cassava and mangoes per unit area of land (above 5 tons/acre) as compared to other crops whose yields are less than 2 tons/acre (Figure 14). This indicates their resilience to the regions climatic conditions.

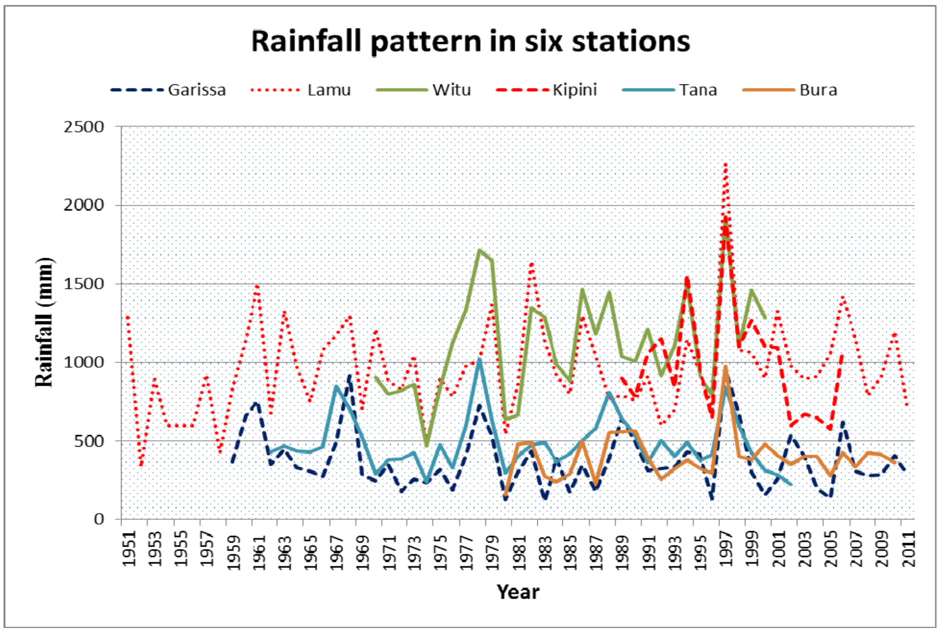


Figure 7. Seasonal pattern of rainfall within the lower Tana basin (1951-2011)

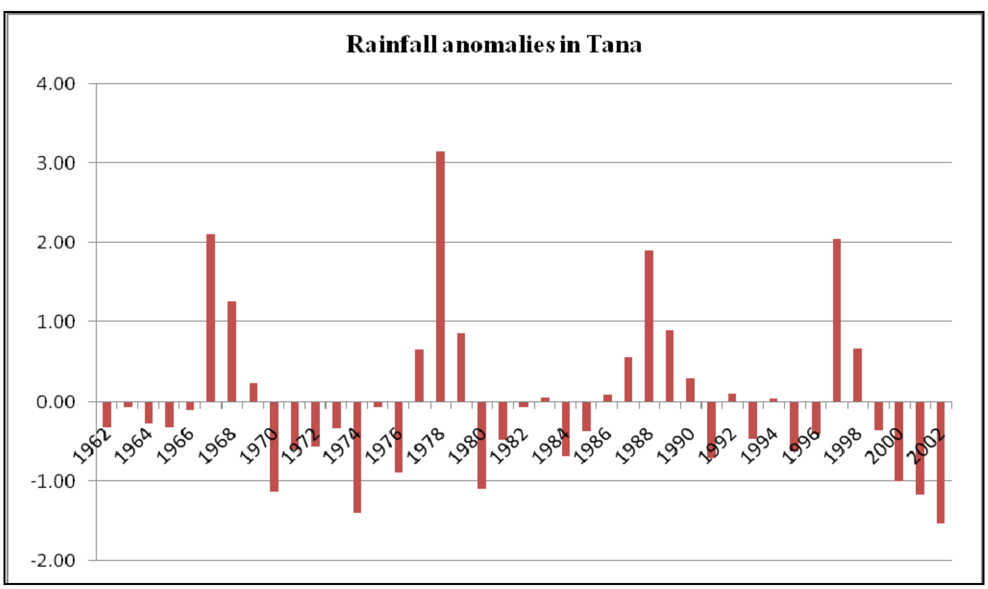


Figure 8. Rainfall anomalies indicating extreme floods and drought periods in Tana River basin between 1962 and 2002

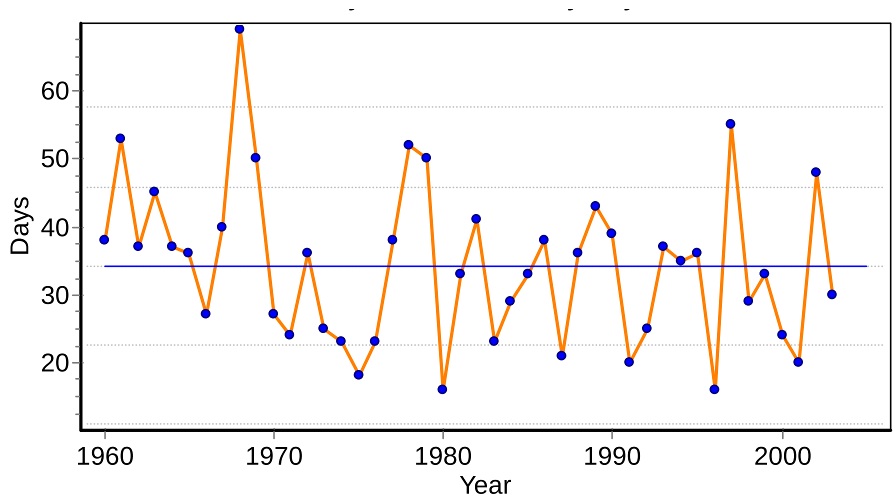


Figure 9. Trend of Rainy days

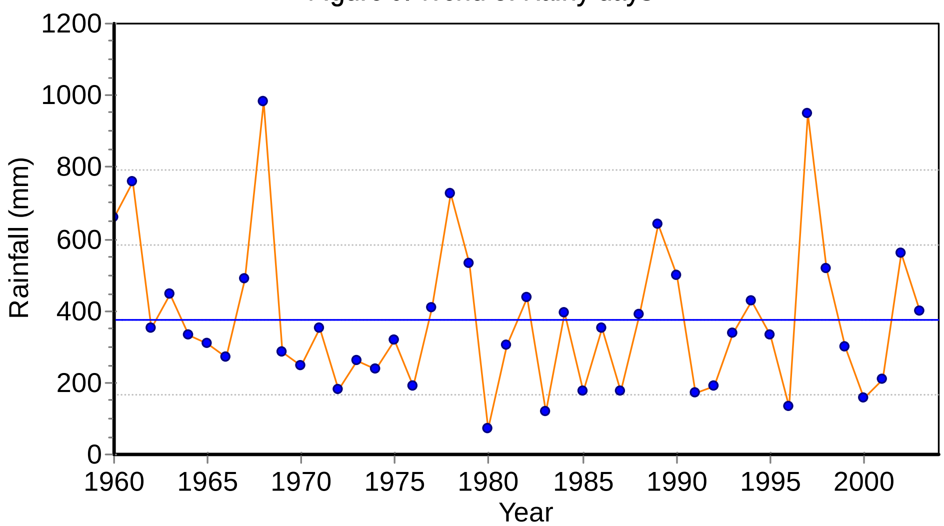


Figure 10. Garissa Annual Rainfall totals

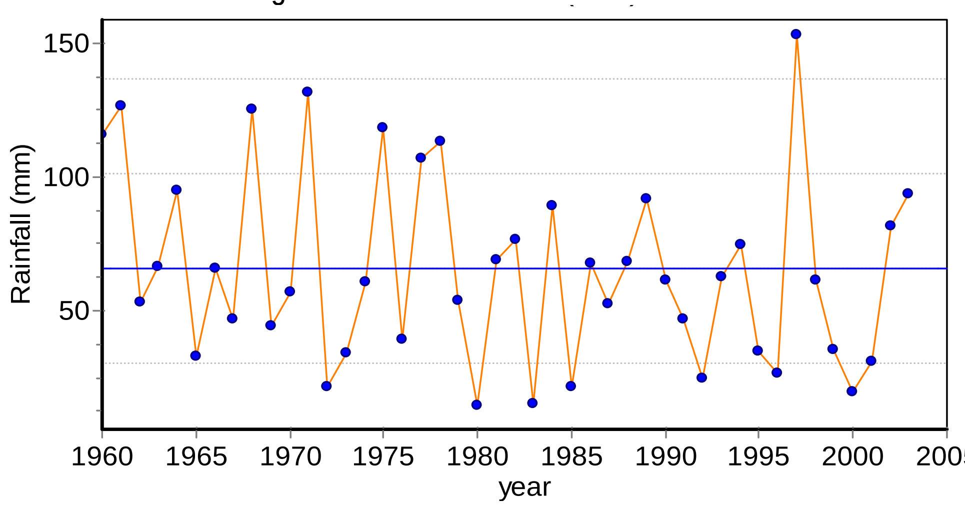


Figure 11. Maximum Rainfall records (mm) in Garissa station

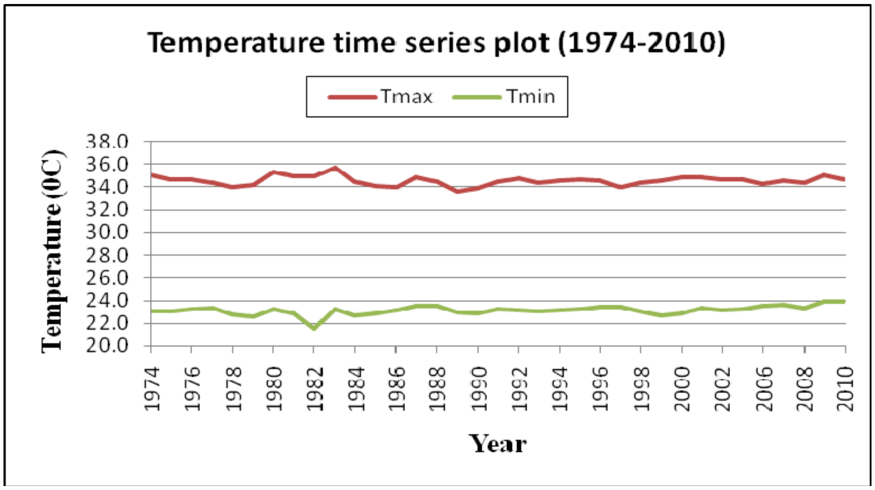


Figure 12. Plot of temperature (Tmax and Tmin)

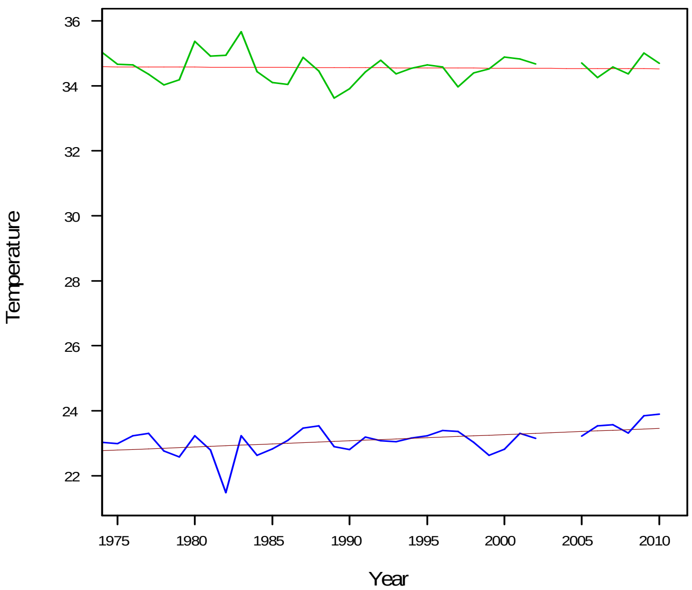


Figure 13. Maximum and minimum temperature trends (1974-2010)

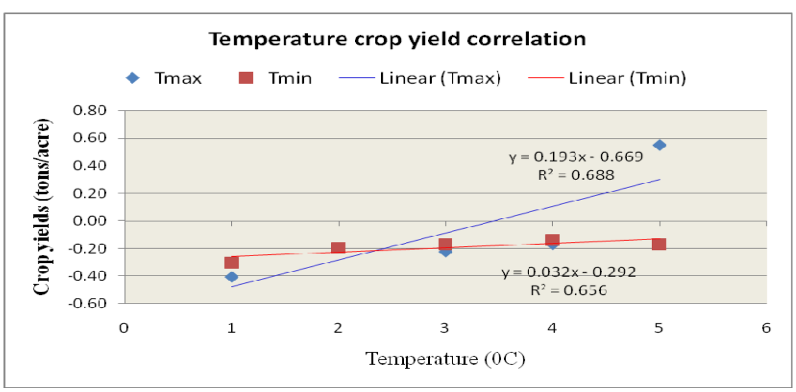


Figure 14. Plot of temperature (Tmax and Tmin) and crop yields correlation

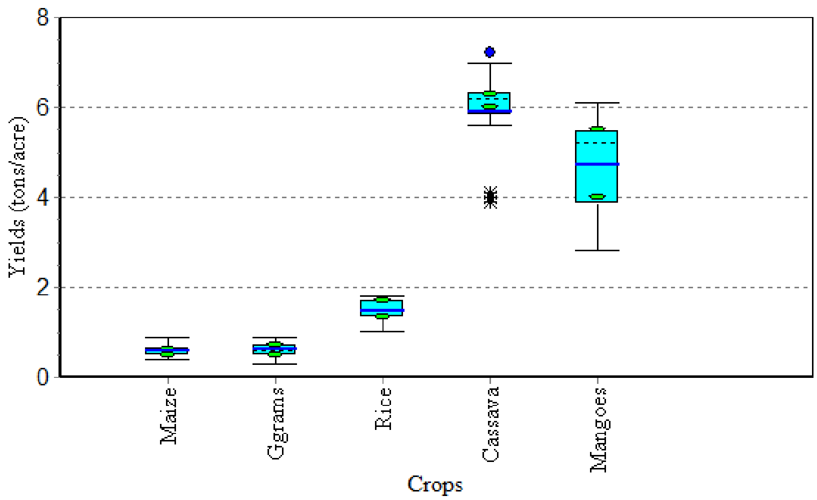


Figure 15. Widely grown crops and their yields per unit area in the study region

The yield levels and variability of the five (5) major food crops viz. maize, green grams, rice, cassava and mangoes from the region shows high and non-stationary variability in cassava and mangoes yields in 1990s as compared to the 2000s period (Figure 15). This may be attributed to the various technological interventions adopted by the farmers over time which includes the use of better crop varieties and improved agronomic practices. The non-linearity of the crop-yield plots in the region concurs with the results of other studies (Challinor et al., 2004) that the productivity of crops in tropical regions is highly vulnerable to inter-annual and sub-seasonal climate variability (Figure 16). The yield production for most crops except cassava and mangoes is below the normalized averages by 2009 reflecting the serious threats to food security of the region (Figure 17).

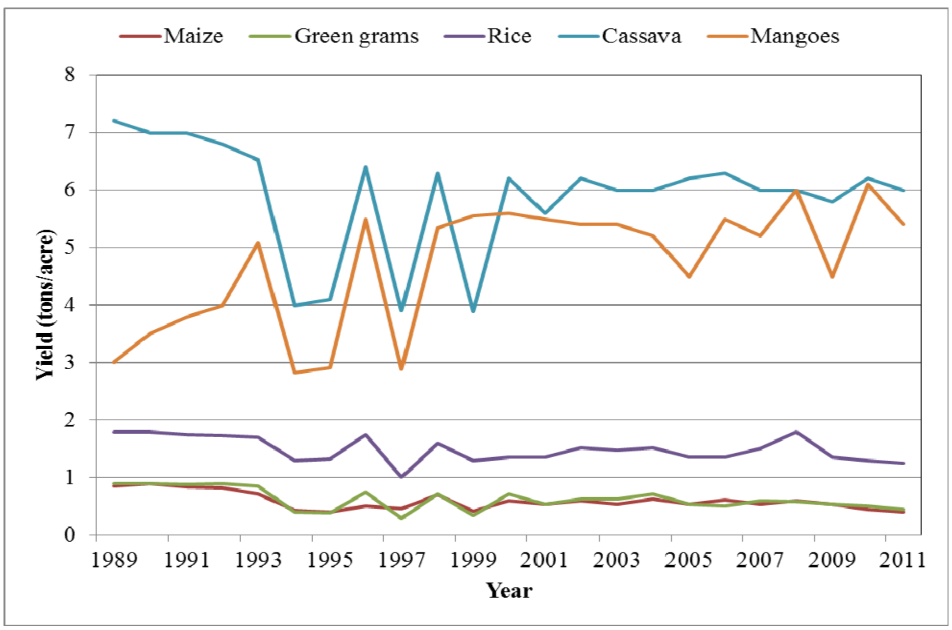


Figure 16. Observed yields for Selected crops in lower Tana River

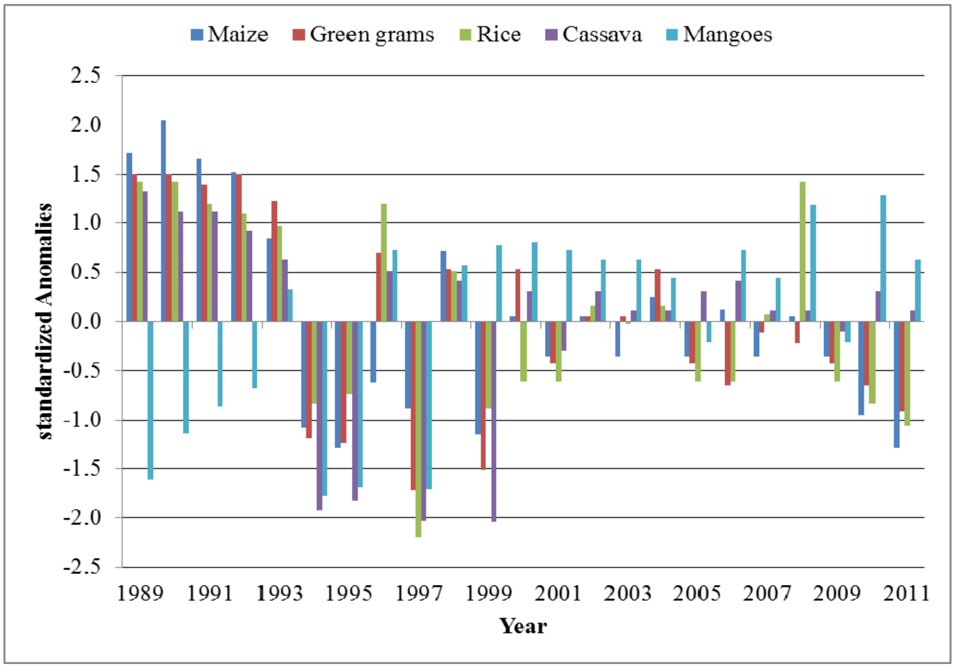


Figure 17. Time series yield anomalies for the key food crops in lower Tana River

Crop Yield – Rainfall relationship

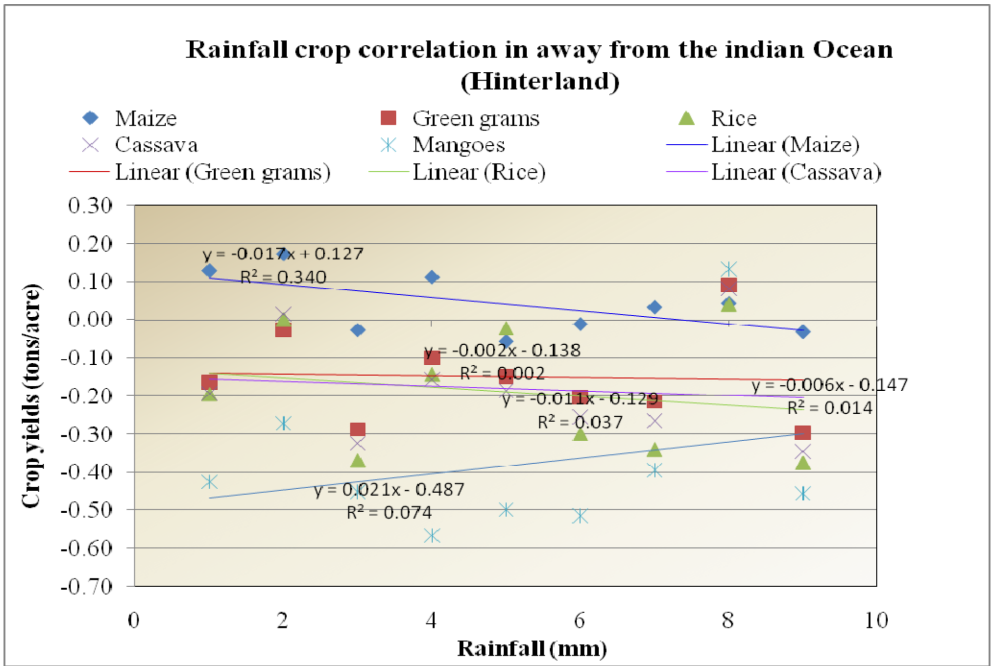
The study revealed significant correlation between crop yields and seasonal rainfall with variability observed among the sites (Tables 1 and 2). In almost all the sites, total and seasonal rainfall is negatively correlated with all crops except some weak positive correlations in Bura on maize, green grams, cassava and mangoes. Rice production has a strong correlation to both total and OND rainfall seasons in Witu and Kipini sites. In the hinterland areas most of the crops had low correlation to rainfall except Mangoes that may be benefiting from the regular floods of River Tana. The relatively low correlation coefficients ($r \leq 0.3$) could be attributed to several factors not climatic such as farm management practices, soil fertility, pests, seed type and quality and planting period.

Table 1. Correlation analysis with stations closer to Indian Ocean

	Witu Totals	*Witu MAM*	*Witu OND*	*Kipini Totals*	*Kipini MAM*	*Kipini OND*	*Garsen Totals*	*Garesen MAM*	*Garsen OND*
Maize	-0.41	-0.09	-0.43	-0.45	-0.45	-0.19	-0.26	-0.37	-0.29
Green grams	-0.65	-0.03	-0.67	-0.69	-0.46	-0.46	-0.50	-0.55	-0.49
Rice	-0.79	0.04	-0.82	-0.81	-0.56	-0.58	-0.59	-0.48	-0.64
Cassava	-0.63	-0.02	-0.64	-0.68	-0.44	-0.46	-0.49	-0.52	-0.47
Mangoes	-0.22	0.21	-0.40	-0.36	0.05	-0.63	-0.52	-0.41	-0.50

Table 2. Correlation analysis with stations away from Indian Ocean (hinterland)

	Garissa Totals	*Gariss aMAM*	*Garissa OND*	*Bura Totals*	*Bura MAM*	*Bura OND*	*Tana Totals*	*Tana MAM*	*Tan OND*
Maize	0.04	0.22	-0.12	-0.05	0.01	-0.11	0.05	-0.13	-0.06
Green grams	-0.28	-0.08	-0.38	-0.31	0.03	-0.37	-0.20	-0.24	-0.27
Rice	-0.34	-0.04	-0.49	-0.48	-0.10	-0.48	-0.25	-0.08	-0.37
Cassava	-0.23	-0.02	-0.37	-0.24	0.11	-0.34	-0.15	-0.18	-0.25
Mangoes	-0.55	-0.55	-0.57	-0.40	0.20	-0.49	-0.46	-0.39	-0.44



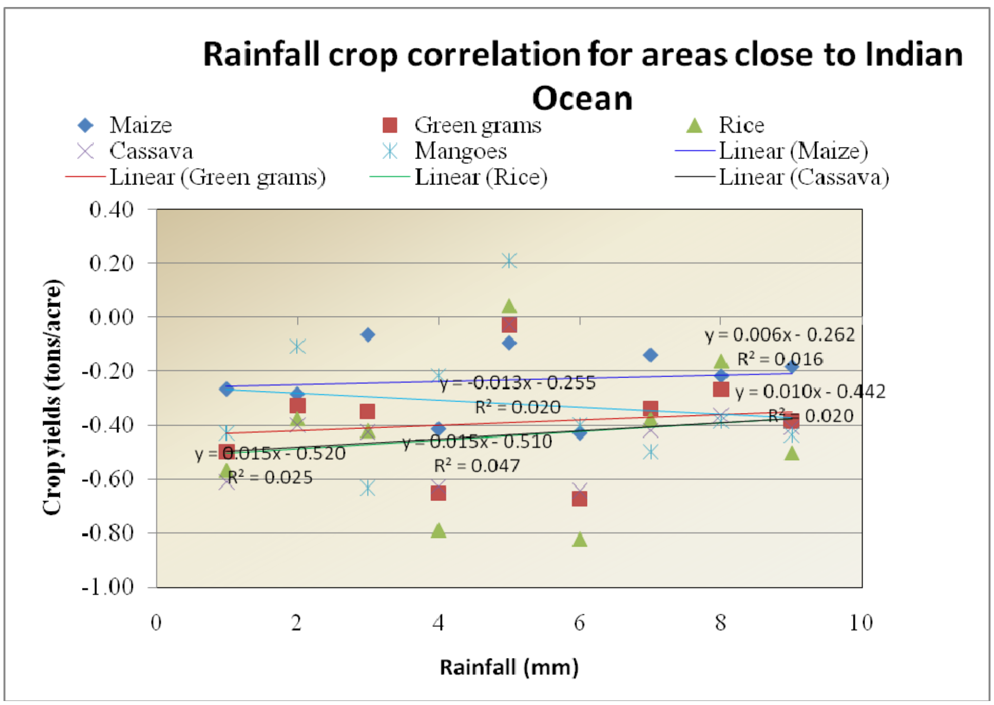


Figure 18. Correlation plots of rainfall and crop yields at different geographical regions of the study area (a) hinterland and (b) close to Indian Ocean

CONCLUSION

The study reveals significant annual and seasonal rainfall variability that influences crop production in the region. Although farmers would do everything possible to grow maize under rainfed production system, the study revealed that the crop remains only possible in Kipini and Witu regions during MAM seasons with expected failure in other sites of the county. Therefore farmers need to upscale the production of mangoes and cassava which grows and yields very well in most parts of the county. The agricultural service providers and policy makers need to utilize the analysis of climate information and advice farmers in the region to maximize the production opportunities of better yielding crops and encourage cross border trades in the country. Trend analysis of rainfall and other climate variables provides answers to some priority concerns of rain-fed agricultural farmers such as when does the rainy season start and what crops can yield well under the current climate conditions.

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CONFLICT OF INTEREST: Nothing