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Climate Change Detection across All Livelihood Zones in Tharaka Nithi County

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Abstract

Kenyan agriculture is largely rain-fed and principally dependent on rainfall. According to FEWS NET report for Kenya in August 2010 based on historical data from 70 rainfall stations and 17 air temperature stations to interpolate the long-rains precipitation and temperature trends for all of Kenya from 1960 to 2009 (Funk et al, 2010). The FEWS NET report indicates that in Kenya long-rains traditionally occur between March and June and short rains in October to December. The authors report that Kenya has experienced trend of decreasing rainfall and rising temperatures as Sudan. In Central Kenya, one of the country's key agricultural regions, the area receiving adequate rainfall to support reliable rain-fed agriculture has declined by roughly 45 per cent since the mid 1970s (Funk et al, 2010). This study investigates change in temperature and rainfall pattern across all livelihood zones in Tharaka Nithi County. Data was collected for 39 years (1976 - 2015) period for the area of Study and in addition divisions were made to three non overlapping climate period of 30 years (1982 - 1991, 1992 – 200 and 2002 - 2012). The data were subjected to Gaussian kernel analysis, moments, regression, and non-parametric approaches based on Mann-Kendal statistics to justify any change in the average monthly and annually rain fall and temperature trend. The results indicate common change points and transitions from wet to dry (upward shift). The test indicates rainfall variation over the study area is significant (p= 0.05).The study recommended on the use of the information for Agricultural development and general socio-economic improvement.

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1. Introduction

Kenya economy and population are connected to Rainfed agriculture. A thoughtful insight of historical rainfall and temperature trends and variation is predictable to future development particularly in agriculture sector. It is vital to understand different climate systems and their impact on the cryosphere (Oguntunde et al. 2012). According to FEWS NET report for Kenya in August 2010 based on historical data from 70 rainfall stations and 17 air temperature stations to interpolate the long-rains precipitation and temperature trends for all of Kenya from 1960 to 2009 (Funk et al, 2010), in Kenya the long-rains traditionally occur between March and June and short rains in October to December. The authors report that Kenya has experienced trend of decreasing rainfall and rising temperatures as Sudan.

In Central Kenya, one of the countries key agricultural regions, the area receiving adequate rainfall to support reliable rain-fed agriculture has declined by roughly 45 per cent since the mid 1970s (Funk et al, 2010).This present study differs from the prior one in the following perspective; to begin with, ground study data used was extended to the year 2014. Secondly, statistical approach analysis was based on one County data.

2. Area of Study

Location and Description

Tharaka-Nithi County is located in the Eastern Kenya and lies between latitude 00^0 07' and 00^0 26' South and between longitudes 37^0 19' and 37^0 46' E. It borders Embu County to the South West, Meru County to the North East, Kirinyiga and Nyeri Counties to the West and Kitui County to the South East.

The Study coverage includes Tharaka North and Tharaka South Sub-Counties which are semi-arid and cover an area of 1,569 square kilometres (km^2) with a total population of 158,023 people (KNBS Projections 2013). The Sub-Counties have three main livelihood zones (LZ). These are Marginal Mixed Farming (MMF), Mixed Farming (MF) and Rain-fed Cropping (RF) with population proportion of 52 percent, 38 percent and 10 percent respectively. The area experiences a bimodal rainfall pattern; the long rains (March–July) and the short rains (August-October). The annual rainfall is unreliable and poorly distributed ranging between 300mm and 500 mm. (CIDP, 2014).

3. Methodology

The present study aims to detect change in rainfall and temperature pattern over Tharaka using Gaussian kernel analysis, moments, regression, and

Figure 1: Map of Kenya Highlighting Tharaka Nithi County (Source: CIDP, 2014)

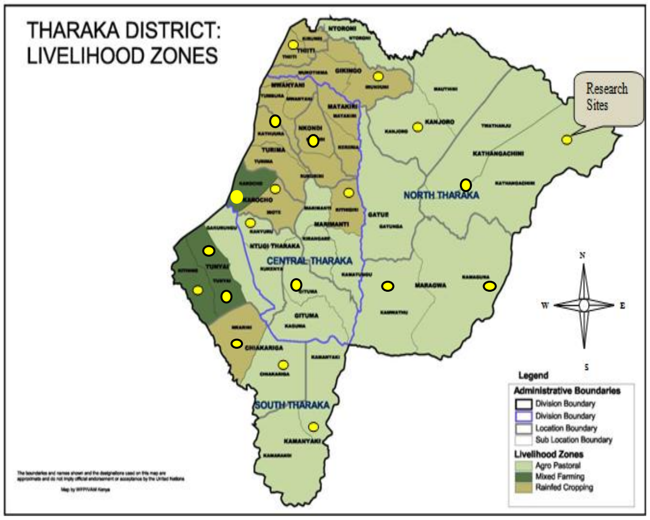


Figure 2: Map of Tharaka Sub Counties (Source: NDMA, 2014)

non-parametric approaches based on Mann-Kendal statistics. This was performed on the average zonal rainfall to show transition three non overlapping climate periods of 30 years (1982 - 1991, 1992 – 2001 and 2002 - 2012). This enables the observation of increase or decrease in rainfall and temperature received to be established.

Mann Kendall test is a statistical test widely used for the analysis of trend in climatologic (Mavromatis T., Stathis D., 2011) and in hydrologic time series (Yue S., Wang, C., 2004.)There are two advantages of using this test. First, it is a non parametric test and does not require the data to be normally distributed. Second, the test has low sensitivity to abrupt breaks due to inhomogeneous time series (Tabari, H., Marofi, S., Aeini, A., Talaee, P.H., Mohammadi, K., 2011). Any data reported as non-detects are included by assigning them a common value that is smaller than the smallest measured value in the data set (Blackwell Publishing 2012). According to this test, the null hypothesis H0 assumes that there is no trend (the data is independent and randomly ordered) and this is tested against the alternative hypothesis H1, which assumes that there is a trend (Onoz, B., Bayazit, M., 2012).

The computational procedure for the Mann Kendall test considers the time series of n data points and T_i and T_j as two subsets of data where i = 1, 2, 3, …, n-1 and j = i+1, i+2, i+3, …, n. The data values are evaluated as an ordered time series. Each data value is compared with all subsequent data values. If a data value from a later time period is higher than a data value from an earlier time period, the statistic *S* is incremented by 1. On the other hand, if the data value from a later time period is lower than a data value sampled earlier, *S* is decremented by 1. The net result of all such increments and decrements yields the final value of S (Drapela, K., Drapelova, I., 2011)

According to IPCC (2007), statistical approach to climate change studies was proposed and this is the basis for the attempt to study temperature and rainfall distribution in Tharaka. Data was collected for 39 years from the Kenya metrology (1976 - 2015) period for the area of

The annual values were calculated as per equation (1):

$$\sum_{i=1}^{12} R_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where R is the monthly rainfall amount at each station, i is the months of the year, and A is the annual rainfall amount at that station.

In addition divisions were made to three non overlapping climate period of 30 years (1982 - 1991, 1992 - 2001, and 2002 - 2012). The data were subjected to Gaussian kernel analysis and non-parametric approaches based on Mann-Kendal statistics to justify any change in the average monthly and annually rain fall and temperature trend.

Variation exists in rainfall received even between stations that fall in the same climatic zone, hence, for stations that fall in the same zone, zonal averages of rainfall were obtained for stations (1 to j) using equation (2).

$$\bar{R}_z = \frac{\sum_j^n A_j}{n} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where $\bar{R}_z$ represents the average annual rainfall for the area at any given year, and n is the number of meteorological stations in that area. The probability density function (PDF) describes the relative likelihood for any random variable to occur at a given point. The probability for the random variable to fall within a particular region is given by the integral of this variable's density over the region. The probability density function is non-negative everywhere, and its integral over the entire space is equal to one. A random variable X has density f, where f is a non-negative Lebesgue - integrable function, if

$$P(a \leq x \geq b) = \int_a^b f(x)dx \ldots\ldots\ldots\ldots\ldots (3)$$

The uniform distribution on the interval (0, 1) has probability density f(x) = 1 for 0 ≤ x ≤ 1 and f(x) = 0. Elsewhere the standard normal distribution has probability density.

$$f(x) = \frac{1}{\sqrt{(2\pi)}} e^{\left(\frac{-x^2}{2}\right)} \ldots\ldots\ldots\ldots\ldots\ldots (4)$$

If a random variable X is given and its distribution admits a probability density function f, then the expected value of X (if it exists) can be calculated as

$$E(x) = \int_{-\infty}^{\infty} x f(x) d(x) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

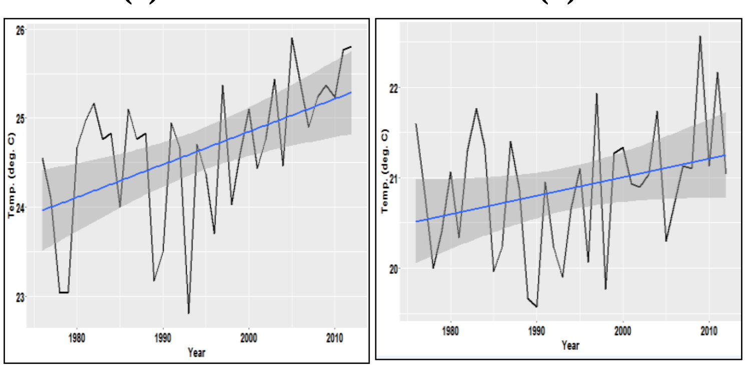
4. Results and Discussions

The Kendall package has a function named Mann-Kendall which implements the non-parametric test for monotonic trend detection known as the Mann-Kendall test. (A monotonic trend can be either an upward trend or a downward trend). On running the Mann-Kendall test on temperature data, the following results in Table 1 were obtained for Tharaka. If the p value is less than the significance level α (alpha) = 0.05, H_0 is rejected. Rejecting H_0 indicates that there is a trend in the time series, while accepting H_0 indicates no trend was detected. On rejecting the null hypothesis, the result is said to be statistically significant. Table 1 indicates that the Null Hypothesis was rejected for DJF, MAM and SON and accepted for JJA for Temperature maximum, while for temperature minimum Hypothesis was rejected for DJF, MAM and JJA and accepted for SON.

Temperature

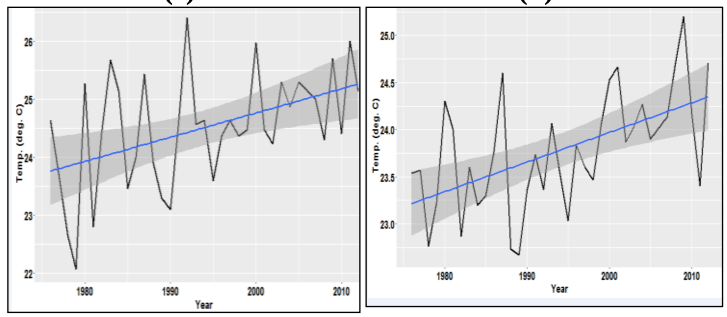
Figures 3 (a, b, c and d) are the graphs for the 12-month average temperature observations for each of the season (DJF, JJA, MAM and SON) for the time period, (1982 - 1991, 1992 - 2001 and 2002 - 2012). On plotting the linear trend line for the Tharaka, the following results were obtained.

(a) **(b)**



DJF **JJA**

(c) **(d)**



MAM **SON**

Figures 3: Linear Trend Line for the Tharaka

Linear trend line corresponding to temperature data for each of Season data indicating there is a trend in the time series as illustrated in Figure 3 above.

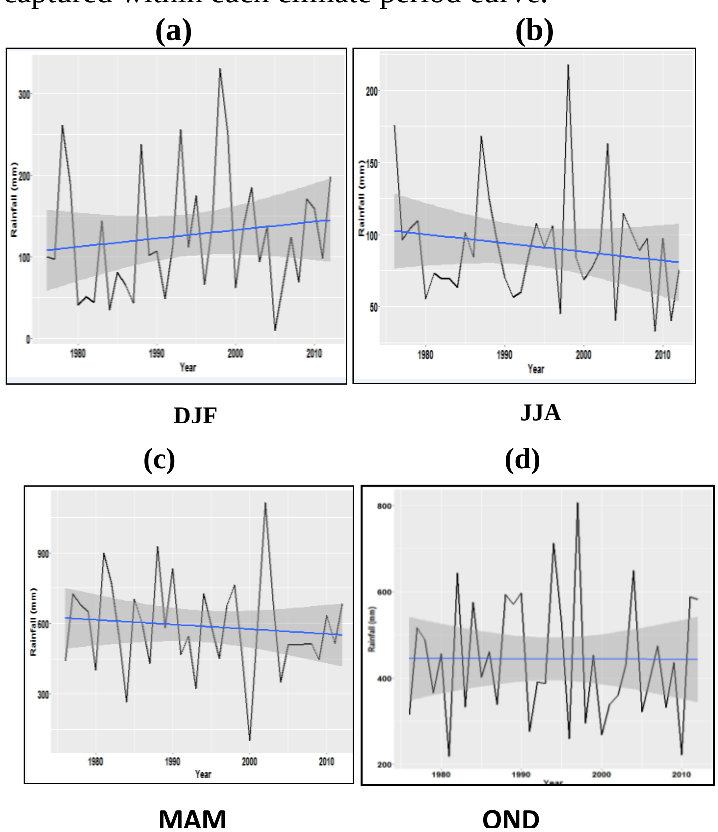
Table 1: Seasonal Mann-Kendall Test on Temperature Data and Rainfall Data

Season	Kendall tau	2-sided p-value	Slope Score	Denominator	var (Score)
Seasonal_MannK_Test_Tmax					
DJF	0.362919	0.002062	227	625.4838	5380.333
MAM	0.289843	0.014093	181	624.4758	5376.333
JJA	0.175441	0.13741	110	626.9928	5384
SON	0.412752	0.000438	259	627.495	5385
Seasonal_MannK_Test_Tmin					
DJF	0.425614	0.000303	266	624.98	5379.333
MAM	0.409684	0.000409	271	661.4847	5837
JJA	0.26018	0.027233	163	626.4902	5382.333
SON	0.474381	5.73	296	623.9711	5375.333
Seasonal_MannK_test_Rainfall					
DJF	0.155556	0.186426	98	629.9999	5390
MAM	-0.08102	0.495803	-51	629.4998	5389
JJA	-0.10476	0.375963	-66	629.9999	5390
SON	-0.0127	0.92404	-8	629.9999	5390

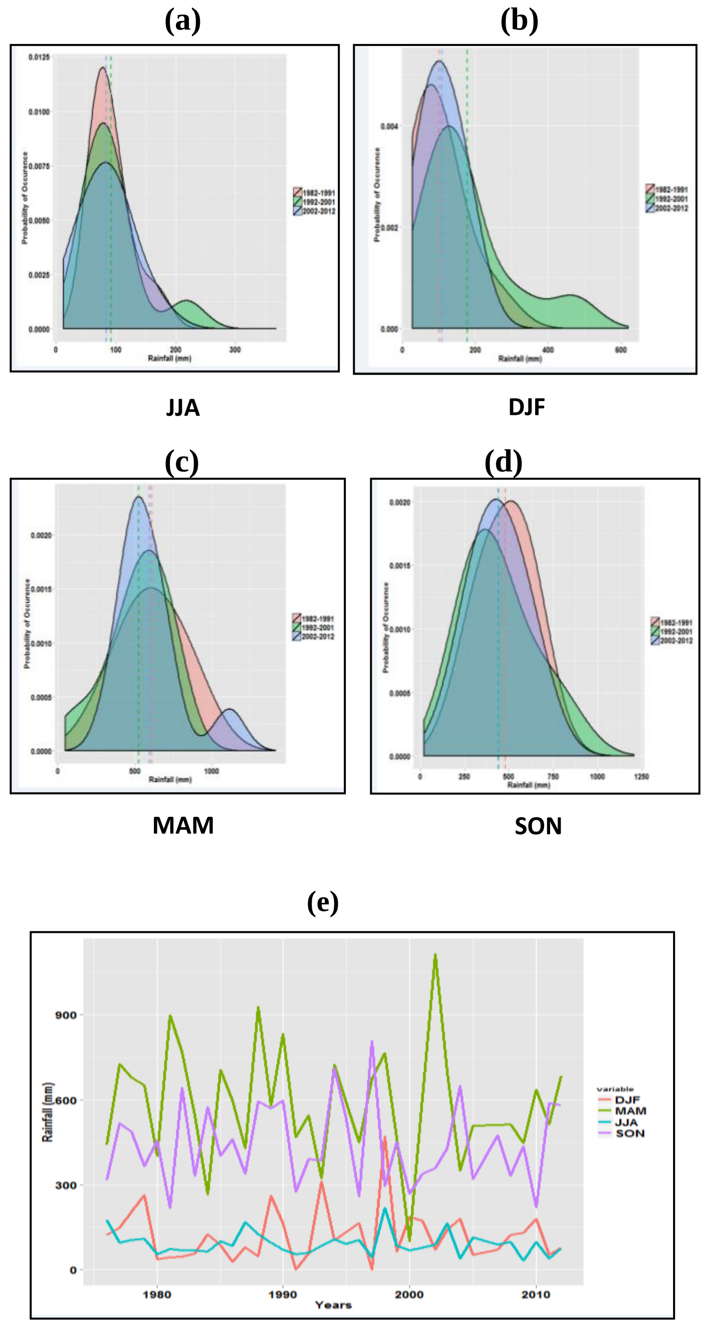
Precipitation

Figure 4 are the graphs for DJF, JJA, MAM and SON precipitation accumulation observations for each of for the time period (1982 - 1991, 1992 - 2001 and 2002 - 2012). On running the Mann-Kendall test on precipitation data, the results in Table 1 were obtained. If the p value is less than the significance level α (alpha) = 0.05, H_0 is rejected.

Rejecting H_0 indicates that there is a trend in the time series, while accepting H_0 indicates no trend was detected. On rejecting the null hypothesis, the result is said to be statistically significant. For this test, the Null Hypothesis was rejected. Annual rainfall distribution across Tharaka Gaussian normal distribution (figure 5) shows that annual rainfall ranges from 100 to 1250 mm over the entire 39 years (1976 – 2015) of study in Tharaka Nithi. The first period (1982 – 1991) rainfall ranges between 100 and 1250 mm. the second period (1992 - 2001) rainfall ranges between 150 and 1150 mm, the third period (2002 - 2012) rainfall ranges between 100 and 1100 mm. Further reduction was observed during the third climate period where the minimum to maximum rainfall received falls between 100 mm and 1100 mm. This indicates a northward reduction in annual rainfall as supported by previous studies (Funk et al, 2010). Observational shows that annual rainfall amount is normally distributed over each zone as there was no obvious skewness in the distribution curve. This does not imply that there were no extreme events during the period of study; such extreme cases are being captured within each climate period curve.



Figures 4: Linear Trend Line Corresponding to Precipitation Data



RAINFALL TREND

Figures 5: Annual rainfall distribution across Tharaka Gaussian normal distribution

According to the maximum temperature data, the Mann-Kendall test shows that there is an increasing trend for New DJF, JJA, MAM and SON.

The MK test is statistically significant for DJF, MAM and SON except for JJA for Temperature maximum, while for temperature minimum it is statistically significant for DJF, MAM and JJA except for SON.

The null hypothesis H_0 is accepted for SON minimum and JJA maximum thereby implying that there is no trend. The S statistic recorded for temperature data does not indicate any similarity among the seasons. The linear trend line indicates there is an increasing trend in temperature for all Seasons, even though slopes are small in terms of magnitude. The general noted increase in temperature trend for all the seasons in 39 years time period, it is necessary to note and understand how this may in addition affect the ecosystems and human life if such a trend is maintained. The change in a temperature model could result to a shift in species habitation (Evans A., Perschel R., 2009). In addition the increase in temperature consequently can effect in intense heat that could be demanding for aging and susceptible populations (A., Perschel R., 2009). Kenyan agriculture is largely rain-fed and principally dependent on rainfall hence increase in temperature will basically have an effect on the own farm production.

Regarding the rainfall data the Mann-Kendall test gives attractive results about annual precipitation data for Tharaka. The MK test Statistic (S) test result is weak for DJF, MAM, JJA and SON since the null hypothesis H0 is accepted. This means that there is no trend seen for rainfall. On further analyzing the S statistic for the four seasons, it becomes evident that there is conformity in magnitude of the statistic when a latitudinal factor is taken into consideration (Figure 3). That is, for MAM the S statistic is -51, JJA -66 and SON -8 while the statistics are small in magnitude, but are similar to some extent. Again, on fitting the linear trend line, it is observed that trend is decreasing for all. The slope of the trend line is not very large in magnitude. On taking latitudinal factors into consideration, seasons fall in similar slope magnitude in the range of -66 to 98. It is of great importance to discuss the ecological, economic, and social impacts that could result if decreasing precipitation trends continue in these seasons in the future. The vulnerability to drought might further be increased owing to decrease in rainfall in the future.

Conclusion

In general, there was conformity in the results obtained from the Mann-Kendall test and the linear trend line for the four seasons for the 39 year time period. The linear trend line shows that there is a decrease in precipitation for all four season. For temperature, the trend line indicates that it is increasing for all the seasons. It is critical to understand the changes in temperature and precipitation patterns could be affected seasonally. The study, therefore, offers remarkable insights and new perspective for policy makers and planners in helping them take proactive measures in the context of climate change. Timely measures and institutional changes can certainly help in reducing the irreparable damages that can be caused by climate change, since the trends in 39 year precipitation and temperature data do not deny climate change is occurring.

The study covered a period of 39 years and has revealed the change of rainfall across Tharaka. We observed that temperatures are consistently increasing significantly at all study locations and thus night time temperatures are becoming warmer. The study observed that MAM and SON rainfall had a decreasing trend. Such prolonged variability also extends its socioeconomic importance to the groundwater resources and hydrological sector. Besides reducing over dependence on rain-fed agriculture, it is recommended that farmers should plant drought resistant crops or early maturing crop varieties. This can be achieved by investment and development of agricultural technologies that are environmentally sensitive. Other adaptive measures for climate users include streamlining farming calendars with the changing rainfall climate period or irrigated agriculture. It is believed that these recommendations among others could help avert the impending food insecurity .The findings provide critical climate information that can be adopted in the development of climate change strategic plans for the ASALs areas of Kenya. The government will strengthen and institutionalize early warning systems and mitigate the effects of all disasters.

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