Use of Mann Kendall Method to Study Annual Rainfall Trends in Narok and Kisii Counties

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***Abstract*:-Rainfall is the main source of water which is an important basic requirement for a living. It is therefore important to have proper planning and water resources management in any county. In this study, the purpose was to study annual trends of rainfall in Narok and Kisii counties. Specifically the study sought to detect trends in the rainfall time series data, to determine the significance and magnitude of the trends and to compare the trends behavior for Narok and Kisii counties. The data used for this study was obtained from the Kenya Metrological Department for the period 1963 to 2015 inclusive for Narok and Kisii counties. Studying trends will help the residents of the two counties to cope with the climate change in the area. Mann Kendall and Sen's Slope were used to analyse rainfall data. The results showed that Kisii County had a significant increasing trend while Narok County had a significant decreasing trend.**

***Key words:* Rainfall trends; Mann Kendall; Yearly**

I. INTRODUCTION

Rainfall is the natural source of water for domestic activities, agricultural practices, construction and many other areas. Deforestation, global warming and some other factors have led to reduced rainfall. This has become a serious issue in the world today. Prolonged drought has led to loss of life and destruction of property (Nyakundi, 2017). Majority of Kenyans makes their living on land as small scale holders who depend on rain fed agriculture.

Rainfall trend analysis has been of great concern for the past century because of the attention that is given to global climate change from the scientific community. (IPCC, 1996), indicated that a large area of the world is characterised by negative trends and small global positive trends. (Kansiime,2013), studied perceived and actual rainfall trends and variability in Eastern Uganda. They found out that there is a significant increasing trend in seasonal and annual rainfall in the highlands but in the low lying areas, there is a decreasing trend. In Kenya, there is generally a decrease in rainfall trend which is accompanied by significant increases in average air temperatures, (USAID,2010).

Narok county practices crop farming for commercial and subsistence and livestock keeping as the main economic activities. Kisii county also practices agriculture as the main economic activity (Tea, Bananas, Maize, Coffee and dairy farming). In both regions, the activities are highly dependent on rainfall. Therefore, there is a need to detect rainfall trend and determine significance and magnitude of the trends. This will guide in advising farmers on how to prepare before and after rainfall and how to adjust with the change in amount of rainfall.

In this research rainfall trend was studied. Mann Kendall test and Sen's slope were used to detect trends of rainfall in Narok and Kisii regions. The magnitude of the trend line explains the behaviour of rainfall. The study has used rainfall data for Narok and Kisii counties.

Narok County is situated in Kenya along the Great Rift Valley. It is named after, Enkare Narok, the river flowing through Narok town. It covers an area of 17,944 square kilometers and has a population of 850,920. The temperature range is 12^0 C to 28^0C and the average rainfall range from 500 to 1,800 mm per annum. The Maasai Mara National Park, an important tourist destination, is located in Narok County. It is home to the Great Wildebeest Migration which is one of the "Seven New Wonders of the World". It constitutes 6 sub-counties namely: Kilgoris, Narok North, Narok South, Narok East, Narok West and Emurua Dikirr. Narok town is the capital Head Quarters of Narok County and stands as the major center of commerce in the county. It is inhabited mostly by the Maasai community. Narok County is livestock farming, practiced in both local and adaptive exotic breeds. Livestock farming in Narok County contribute around 10 % of the county's Gross Domestic Product. (www.narok.go.ke/about-narok)

Kisii County is in the former Nyanza Province in southwestern Kenya. Its largest town is Kisii. The region is inhabited mostly by the Gusii Community. The total area is 1,317.9 km square while the total population is 1,152,282.The maximum temperatures in the region range between 21°C and 30°C while the minimum temperatures range between 15°C and 20°C.

Kisii County is characterized by a hilly topography with several ridges and valleys. It can be divided into three main topographical zones. The first zone cover areas lying below 1,500m above sea level located on the western boundary and include parts of Suneka, Marani and Nyamarambe. The second zone covers areas lying between 1500-1800m above sea level located in the Western parts of Keumbu and Sameta divisions, Eastern Marani and Gucha River basin.

The third zone covers areas lying above 1800m above sea level in parts of eastern and southern Keumbu, Masaba and Mosocho. The major economic activity is farming. (https://en.wikipedia.org/wiki/Kisii)

II. METHODS

Analysis was done using Mann Kendall method and Sen's slope for the yearly rainfall data.

The Mann Kandall method (M-K method) was used to analyse data collected over time for consistently increasing or decreasing trends (monotonic trend) in the rainfall values

https://www.statisticshowto.datasciencecentral.com/mann-kendall-trend-test)

It can be used where the data doesn't show a pattern of a known distribution. Hence, it can be used where the data is not linear but with no serial correlation.

Before running it, it was ensured that, data point was only one per time period .Where there were multiple points, the median was used.

M-K method was used to detect trend in the rainfall data and to test the significance of the trend.

One of the benefits of this method is that the data does not need to conform to any particular distribution.

Using M-K method, yearly rainfall time series data was used in the order in which they were collected over time; $x_1, x_2, ..., x_n$ these denote the measurements obtained at year $1, 2, ,......., n$, respectively.

Then the sign of all n(n-1) possible differences $(x_j - x_k)$, where $j > k$. These differences were

$$x_2 - x_1, x_3 - x_1, ..., x_n - x_1, x_3 - x_2, x_4 - x_2, ..., x_n - x_{n-2}, x_n - x_{n-1}$$

Let $sign(x_j - x_k)$ be an indicator function that takes on the values 1, 0, or -1 according to the sign of $x_j - x_k$, that is,

$$\text{sgn}(x_j - x_k) = \begin{cases} -1 \text{ if } & x_j - x_k < 0 \\ 0 \text{ if } & x_j - x_k = 0 \\ 1 \text{ if } & x_j - x_k > 0 \end{cases}$$

For example, if $x_j - x_k > 0$, that means that the rainfall time series data at time j, denoted by x_j, was greater than the rainfall time series data at time k, denoted by x_k.

The statistic S was computed.

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} \left(\text{sgn}(x_j - x_k) \right)$$

Where S is summation of the indicator functions. Note that S is positive when positive signs are more than negative signs, S is negative if negative signs are more than positive signs and S is 0 if positive signs are equal to negative signs. That is, if S was a positive number, observations obtained later in time tend to be larger than observations made earlier. If S is a negative number, then observations made later in time tend to be smaller than observations made earlier.

If S has a positive value it shows that it's an increasing trend and if S is negative value it shows that it's a decreasing trend. If S is zero it shows there is no trend.

It was however necessary to compute the probability that is associated with S that statistically quantify the significance of the trend.

Since n>10, the variance of S was computed as follows

$$Var(S) = \frac{1}{18}[n(n-1)(2n+5) - \sum_{p-1}^{g} t_p (t_p - 1)(2t_p + 5)]$$

Where n was the data points, g was the number of tied groups and t_p was the number of rainfall time series data in the P^{th} group.

The normalized test statistic Z_{MK} was computed as:

$$Z_{MK} = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & \text{if S>0} \\ 0 & \text{if S=0} \\ \frac{S+1}{\sqrt{Var(S)}} & \text{if S<0} \end{cases}$$

The level of confidence was set at 90%.

It was noted that, a positive value of Z_{MK} indicated that the trend increased and the trend was significant if the probability computed was less than the significance level, a negative value of Z_{MK} indicated that the trend decreased and the trend was significant if the probability computed was less than the significance level. If Z_{MK} was zero then there is no trend.

Sen's slope was used to calculate the magnitude of the significant trend. This test computes both the slope (i.e. linear rate of change) and intercept according to Sen's method. It was also called the Theil–Sen estimator, or Sen's slope estimator. It is named after Henri Theil and Pranab K. Sen (https://en.wikipedia.org/wiki/Theil–Sen estimator) .

If the trend was significant, then, the rate of change can be calculated using the Sen Slope estimator denoted by β is given by

$$\beta = median(\frac{x_j - x_i}{j - i})$$

For all i <j and i = 1, 2, n-1 and j = 2, 3, n. The median of those slopes was the Sen's Slope estimator. The median was the slope of the trend.

III. RESULTS AND DISCUSSION

Trend detection for the yearly rainfall data was analyzed using Mann Kendall test for both Narok and Kisii counties. Mann Kendall test was used to detect trend and to determinethe significance for the yearly rainfall data.

Table 3.1; Yearly trend detection in Narok County and its significance

S	*Var(S)*	*Z*	*p-value*
-966	*28651389*	*-0.2*	0.085693

The computed values of S and Z were both negative values. This shows that there was a negative trend. The p-value was (0.085693) which was less than the significant level (0.1) thus the trend was significant.

Table 3.2; Yearly trend detection in Kisii County and its significance

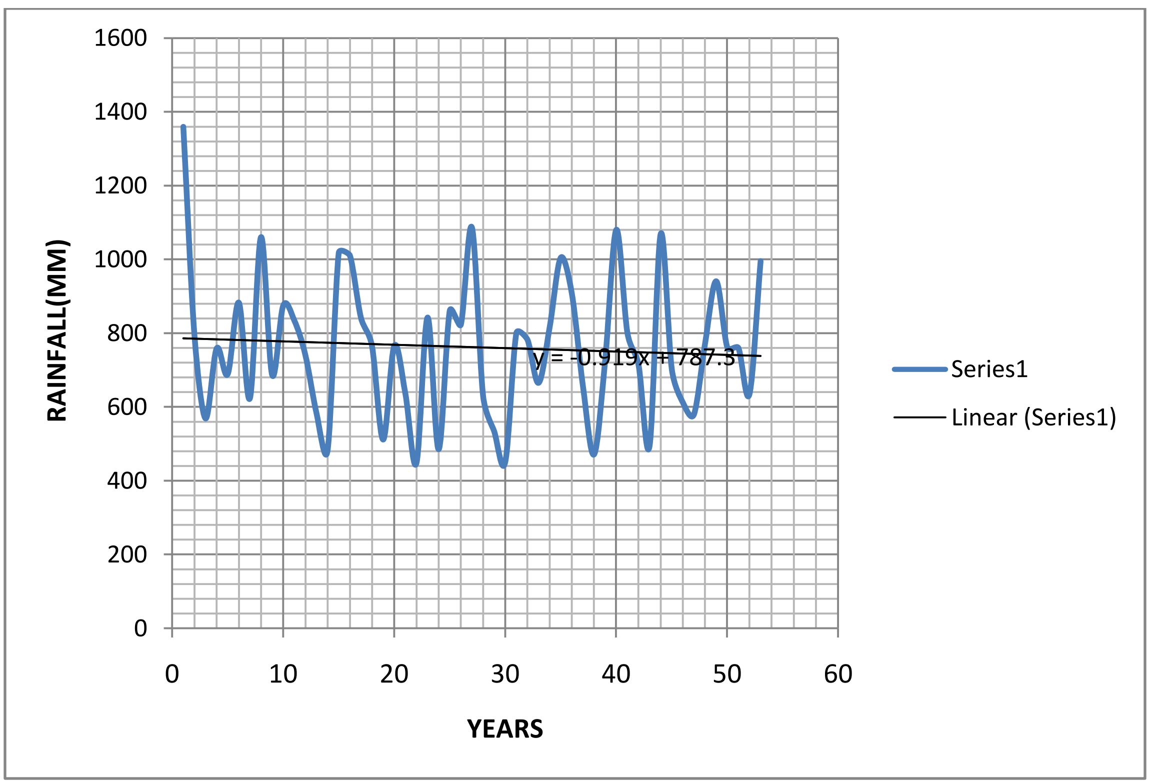
S	Var(S)	Z	p-value
3218	28651555	0.6	0.00384

The computed S and Z were both positive values meaning there exist a trend that is positive. To test the significance of the trend we check the pvalue=0.00384 which is less than the significant level (0.1) hence the trend is significant.

Determination of the magnitude of the trend for the rainfall data was done using sen's slope for both Narok and Kisii counties. Sen Slope was used to determine the magnitude of the significant trend for the yearly rainfall data.

Using Sen Slope , the slope and the intercept of the trend for yearly rainfall data in Narok County were determined. Analysis was performed and the following output of Sen's slope was obtained.

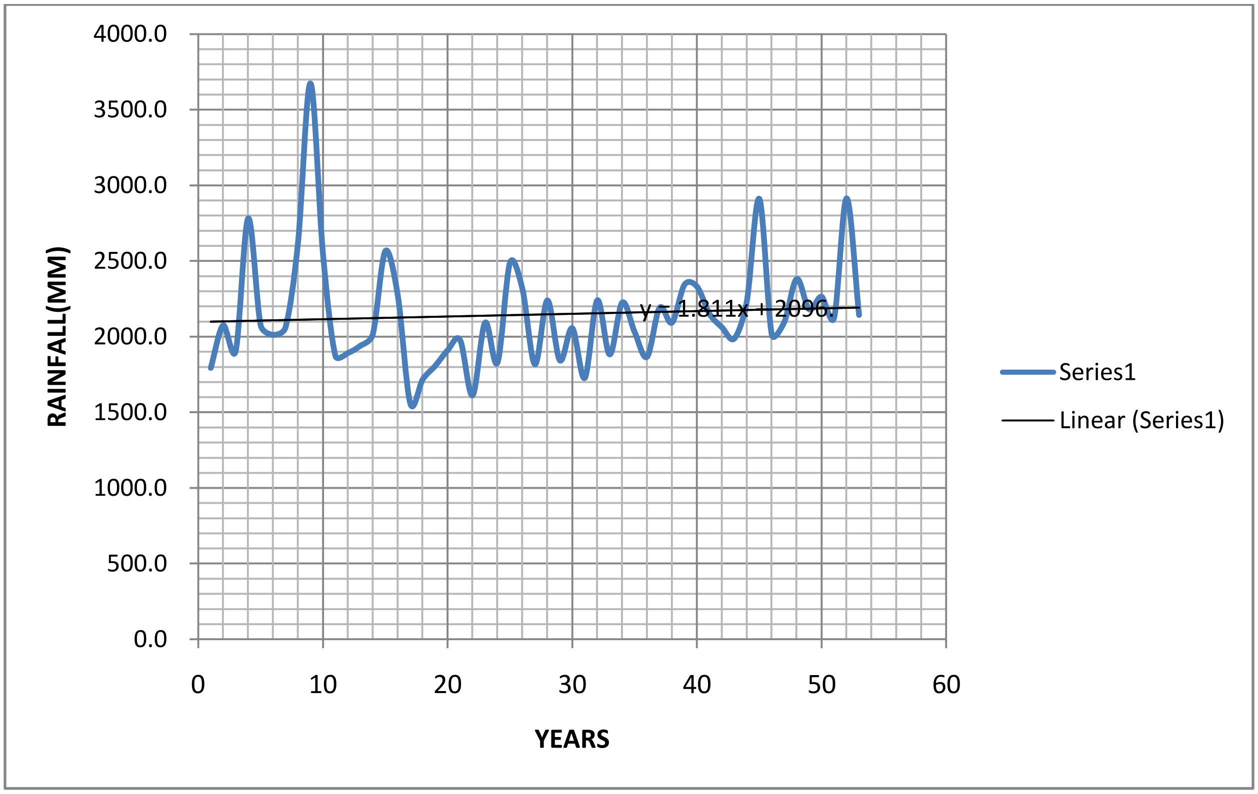
Figure 1.1: Sen'slope for yearly rainfall data in Narok County



The trend decreased monotonically with a magnitude of 0.9.This will help us to know the slope of this data. The intercept of this slope was found to be 787.31.

We again used Sen's Slope to determine the slope and the intercept of the trend for the Kisii county data. Analysis was performed and the following output of Sen's slope was obtained.

Figure 3.2: Sen's slope for yearly rainfall data in Kisii County



The trend increased monotonically with a magnitude of 1.8. This will help us to know the slope of this data. The intercept of this slope was found to be 2096.9. The highest amount of rainfall was in the year 1972 and the least amount of rainfall was in 1980.

In both Narok and Kisii counties there was a trend in yearly rainfall data. In Narok County the trend was negative while in Kisii the trend was positive. In both Counties the trends were significant.

IV. CONCLUSIONS

Kisii county had an annual increasing monotonic trend where as in Narok the trend is decreasing annually. Both counties had annualtrends which are significant.

The magnitude of the trend in Kisii County was 1.8 while in Narok it was -0.9 showing thatKisii County has a steeper slope compared to Narok County.

From the study, there was an increasing monotonic trend in Kisii while in Narok there was decreasing monotonic trend meaning in future the amount of rainfall in Kisii may increase while in Narok it may decrease. This research recommended that people of Narok to plant more trees to attract rainfall and also the county government to help them to dig wells and reservoirs.

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