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Rainfall Trend Analysis by Mann-Kendall Test and Sen's Slope Estimator: A Case Study Kano Plains, River Nyando Basin, Kenya.

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***Abstract**: Rainfall variability has been a concern for the last few decades globally, regionally and nationally. Efficient planning and designing of required water resources will depend on the rainfall trend analysis of that area. The present study sought to determine rainfall variability within Kano plains in Kisumu County, Kenya. In this present study the rainfall variability was investigated using Mann-Kendall Test for coefficient of variance (CV%) and statistical significance of trends. Daily rainfall data for 40 years (1980-2020) for Ahero Irrigation and Koru Bible Centre stations has been used to analysis Monthly, Seasonal and Annual rainfall trends. The seasonal analysis was done depending on the meteorological seasons of Kano Plains, JF (short dry), OND (short rains), JJAS (long dry), MAM (long rains). The study revealed relationship between the two stations in their monthly rainfall trend. This was evidence on their strong significant increasing correlation coefficient (0.697) and $\tau = 0.02$, p(2-tailed) < 0.05 with a correlation of determinant of 48.6%. Secondly, the study revealed that, there was maximum mean monthly rainfall during MAM (482.5 mm and 526.7 mm) and minimum mean monthly in the JF (164.5mm and 160.6 mm) for Ahero Irrigation and Koru Bible Centre stations respectively. Thirdly, based on the analysis of correlation of variance, MAM (28.1% and 28.2%) rainfall is more predictable than the other seasons for Ahero Irrigation and Koru Bible Centre respectively. Finally, increasing insignificant annual rainfall trend for Ahero Irrigation with correlation coefficient of 0.193 and $\tau = 0.076$, p (2-tailed) > 0.05. However, Koru Bible Centre showed a decreasing significant rainfall trend with correlation coefficient of -0.406 and $\tau = 0.000$, p (2-tailed) < 0.05. Therefore, the study concluded that there was monotonic rainfall trend in all the seasons (monthly, seasonal and annual) in Kano Plains. Furthermore, the study recommends the necessity to formulate adaptation strategies to mitigate impacts of rainfall variability to preserve aquifers to become more productive especially during lean seasons within Kano Plains area. This electronic document is a "live" template and already defines the components of your paper [title, text, heads, etc.] in its style sheet.*

Keywords—Rainfall Variability, Mann-Kendall Test, Lean, Seasonal, Trend analysis)

1. INTRODUCTION

Precipitation forms a great component of water balance of a catchment area and as such water cycle is most sensitive to rainfall variability [1]. Increase in the population numbers in the cities increases the demand for water resource as increased number of industries increases the demand for water and prosperity raises expectations for the quality of water services [2]. Increase of the middle class in cities sometimes lead to increased demand for better governance including improved water services, [3]. Water scarcity in Kenya is mainly due to recurrent droughts, water resource contamination, poor management of water supply and unsustainable demand for available water resource from the increasing population and industries [4]. Rainfall trend analysis is the use of statistical techniques to quantify the extent of changes in long term rainfall series over a given time frame and its purpose is to determine the pattern (increasing or decreasing). The two statistical tests widely used in the detection of trend include parametric and non-parametric. In the parametric test the data needs to be normally distributed, random and independent. This is difficult to achieve with hydrological time series data. However, with non-parametric tests, the outliers are accumulated and the data does require any statistical distribution. One of the widely used non parametric test by researchers Mann Kendall test. The objective of this present study is to interrogate the rainfall trend in the rainfall variability in Kano Plain, Nyando River Basin, Kisumu County. There are limited studies of hydrological data within this area. To achieve the objective monthly, seasonal and annual hydrological rainfall time series were investigated for the presence of trend. According to 2010 constitution, many activities have been devolved to the counties hence increase in groundwater dependence especially in areas with insufficient surface water. Safe and clean water for all citizens is a key social pillar for the country vision 2030. Further more, Kano plains are known to have a series of problems ranging from climatic disasters to poverty with 70% of the households living on less than 2,500 shillings annually [5]. The area is affected mainly by floods and droughts both of which cause economic, social and environmental losses to the community. According to [6] the Kano Plains is characterized by low productivity, erratic rainfall and severe erosion. According to [7], the changing precipitation patterns associated with global warming have showed a strong indication that rainfall changes are already taking place on both the global and regional scale. The study used K-means clustering algorithm which showed 74.6% of rainy pattern and two distinct dry periods. Furthermore, in the study of rainfall variability by [8], the determination of trend and periodicity in the magnitude of rainfall by application of spearman correlation, linear regression, statistical trend analysis (Man-Kendall), Student's t test and Spearman's Rho were carried out. Moreover, for sustainable management and future development of water resources it is prudent to understand the periodicity and rainfall trend [9,10]. Both studies showed rainfall variability trend analysis in Nigeria by applying statistical analysis, trend analysis and linear regression technique. In another study done by [11] applying Remote Sensing and GIS, the study revealed high temporal variation of rainfall; however, the study did not do rainfall trend analysis. In Kenya, a study was carried out in Sondu Miriu River Basin to determine rainfall trend computation based on long term mean variance showed changing precipitation pattern associated with global warming [4]. A previous study to determine rainfall trend in Ruiru location for a period of thirty-one years between 1984 through to 2014- Data was from four stations within Ruiru [12]. Both studies did statistical analyses using Mann-Kendall's procedure, Linear Regression, Spearman's Rho and the Student's t test to determine statistically significant difference among the sampled four stations in the study. A previous study of Nyando catchment, revealed that rainfall variability (flooding/surplus and drought/deficit) is a common occurrence in the area [13]. The study above employed statistical analysis to determine rainfall trend Due to the problems above, this study sort to analyze the rainfall variability using Mann-Kendall test. This would help in proper planning and management of Water Resources in Kano Plains. The specific objective was to determine Kano Plains' temporal and spatial rainfall variability in Kano Plains.

2. Materials and Methods

2.1 Research Site.

Kano Plain relief is subdued ranging from 1135 m to 1170 m and the general slope of the land runs from east-north-east to west-south-west [14]. The relief of the plain ranges between 1152 meters and 1168 meters the former being the mean sea level of Lake Victoria [15]. Two large channels meandering within Kano Plains are the Nyando, and Nyamasaria rivers [16]. It covers three Divisions; Lower-Nyakach, Nyando and Miwani that forms Nyando sub-county in Kisumu County [16]. Nyando Sub- County in Kisumu County falls within the Lake Victoria lowlands and floodplains region. The sub-county lies between latitude 0 0 00' (the equator) and 0 0 25' South, and between longitude 34 0 45' East and 35 0 21' East [16]. The sub-county is surrounded by Lake Victoria and escarpments.

2.2 Research Methods

Figure 1: Map showing Kano Plains

Source: Author (2021).

2.2 Climate

The climate of Kano Plains, Nyando basin is diverse and ranges from humid to sub humid. The mean annual rainfall varies from 1,000mm near the shores of Lake Victoria to over 2,000mm in the highlands of Mau [17]. The annual rainfall pattern for Kano is bi-modal with peaks during the long rains (March-May) and short rains in October-November. The first rainy season is the most pronounced and is experienced throughout the basin from March to May. This is normally followed by a long dry spell, which starts in June and ends in August. The short rainy season starts in October and lasts for two months until November, followed by the long dry spell which starts in December through to February [18].

2.3. Hydrology

The hydrology of the catchment is strongly influenced by the north-south movement of the Inter-Tropical Convergence Zone and local winds (lake/land breezes), which influence the spatial and temporal variations of hydro-meteorological parameters [14]. The source of Nyando River is the Mau Forest complex found in Rift Valley. It transverses through Kano Plains and ends up in Wanam Gulf of Lake Victoria. Other sources of water include direct precipitation, runoff from upstream areas, recharge from aquifers, inflow from rivers and backflow from Lake Victoria. However, rainfall over this region has some remarkable anomalies and every year farmers depend on precipitation has a determinant of the success or failure of their produce [14].

2.4. Data Analysis.

This study was carried out through descriptive research also known as statistical research. The following steps guided this study- First step was data acquisition of daily rainfall data (1980-2020). Historical daily rainfall data was obtained from Ministry of Water, JICA reports, WRA and KMD. Available stations include Ahero Irrigation Station and Koru Bible Center. Next step was to verify the quality of data, where single mass curve was used to illustrate the quality of the data. The result revealed that there was no missing and outliers' data, the curve was a straight line. This showed that the data quality was good and could be used for analysis. According to (Gao *et al*. 2017), mass curve assessment generates a straight-line graph if the data are proportional; however, any break along the line of the graph is indication of inconsistency in sampling procedure and departure from linearity. Notably, all the graphs showed almost straight lines and strong coefficient of determination ($0.9 < R^2 < 0.9$) confirming the data to be of good quality and consistency. The next step was to prepare data for analysis (Monthly, seasonal and annually). The seasonal analysis was done depending on the meteorological seasons of Kano Plains, JF (short dry), OND (short rains), JJAS (long dry), MAM (long rains). Furthermore, the appropriate data analysis method was applied, for instance this study applied Mann-Kendall test. It was realized that visual determination of trend from graphs a lone is very subjective and it will depend only on individual judgement. For that reason, an objective statistical approach (Mann Kendall test) was employed to further investigate the trend.

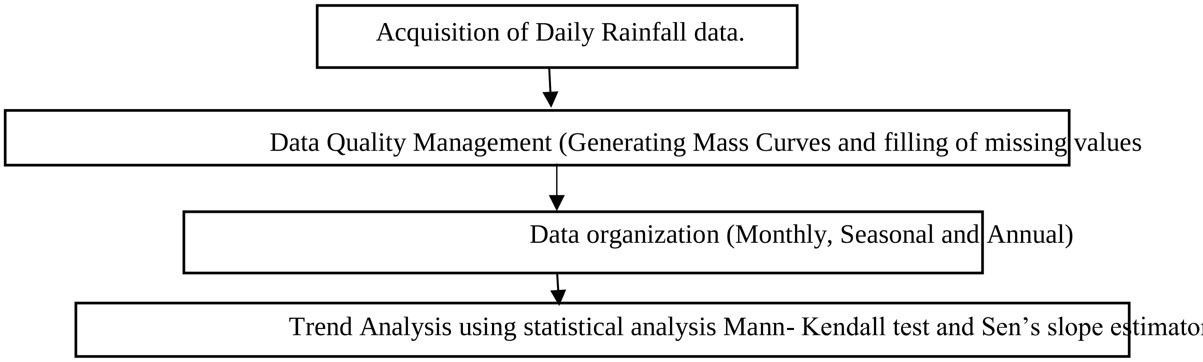

Figure 2: Methodology flowchart.

2.5 Mann Kendall Test

The Mann-Kendall test is a non-parametric technique used in identifying trends in time series data. The Mann Kendall test has been approved to detect the presence or absence of significant trend in data series (Mann, 1945). The main advantage of the test is that the data does not need to conform to any particular distribution and statistically checks the trends (upward and downwards) in precipitation data series over a period of time. Another advantage is that when the data consists of multiple data points for one single time period, then the median value is applied. The MK technique was used to check and investigate the null hypothesis of no trend (H_0) "there is no monotonic trend in the data series" versus the alternative hypothesis (*Ha*) "there is a monotonic trend in the data series." of the existence of the increasing or decreasing trend. The confidence level of null hypothesis was tested at 95% for both rainfall and water table. Again, statistic was obtained through Kendall tau (τ)/correlation coefficient, p value and coefficient of variation. Kendall tau is used to measure the relationship of two variables by establishing the strength.

For the time series $x_1, ..., x_n$, the MK Test uses the following statistic:

$$S = \sum_{i=1}^{n-1} \sum_{j=k+1}^{n} sign\left(x_j - x_i\right) \qquad (1)$$

Note that if $S > 0$ then later observations in the time series tend to be larger than those that appear earlier in the time series, while the reverse is true if $S < 0$.

The variance of S is given by

$$var = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_t f_t(f_t - 1)(2f_t + 5)\right] \qquad (2)$$

where t varies over the set of tied ranks and f_t is the number of times (i.e., frequency) that the rank t appears.

The MK Test uses the following test statistic:

$$z = \begin{cases} (S-1)/se, & S > 0 \\ 0, & S = 0 \\ (S+1)/se, & S < 0 \end{cases} \qquad (3)$$

where se = the square root of var. If there is no monotonic trend (the null hypothesis), then for time series with more than 10 elements, $z \sim N(0, 1)$, i.e., z has a standard normal distribution.

If p- value is less than the significance level 0.05 then the hypothesis is rejected. R squared is the correlation coefficient (x & y) and R squired range from 0-1. 1 is the stronger relation (correlation) and 0 the weaker relation (correlation). 0-0.3- weak. 0.- 0.7 moderate while 0.7 – 1 (strong). According to (Kothari, 2004) A threshold of R squired value of 0.5, is acceptable.

After the data were evaluated, the statistical analysis was done using coefficient of variation (CV) to show the rainfall variability and the significance of the trend analyzed using Mann-Kendall (MK) as check. The greater the CV value, the larger spatial variability, and vice versa. This was done for Ahero irrigation and Koru Bible Centre stations to investigate spatial and temporal rainfall variability between the two stations within different times. To achieve the goal, the methodology flowchart in Figure 2 was developed to aid the exercise.

2.6. Sen's Slope Estimator Test.

Sen's slope estimator can be used to estimate the magnitude of the trend in meteorological time series (Ali & Abubaker, 2019).

$$\beta i = median\ \left(\frac{x_{j-}x_k}{j-k}\right)\ for\ i = 1, 2, 3, \dots., n, j\ > k \quad (4)$$

Where β is Sens's slope estimator. $\beta > 0$ indicates increasing trend in time series data. On the other hand, $\beta < 0$ presents decreasing trend. While, x_j and x_i denote values data at time j and k respectively, and time k (k < j).

3. Results and Discussion.

3.1 **Statistical Analysis**.

In the preparation of the trend analysis, these fundamental parameters were first computed to lay down the foundation for the exercise as shown in Table 1.

Table 1. Rainfall Statistics.

Ahero Irrigation Station (1980-2020)							
Season	Minimum	Maximum	Mean	Standard Deviation (SD)	Coefficient of Variation (CV)	Skewness	Kurtosis
JF	10.3	520.3	164.5	105.8	0.643	1.1	1.981
MAM	259.6	771.4	492.9	135.3	0.274	0.402	-0.489
JJAS	102.9	767.8	367.0	140.3	0.382	1.163	1.351
OND	95.3	689.6	315.5	129.6	0.411	0.749	0.620
Annual	261.1	2241.7	1311.7	355.3	0.20	0.576	2.604
Koru Bible Centre Station (1980-2020)							
JF	15	372.6	159.5	85.9	0.530	0.145	-0.569
MAM	248.1	904.9	537.3	147.9	0.274	0.47	0.695
JJAS	205.3	824.2	449.6	166.3	0.373	0.539	-0.475
OND	165.6	841.1	344.2	154	0.447	1.335	1.904
Annual	956.3	5019.9	1587.9	619.7	0,390	4.381	24.233

Table 1. Shows the statistical parameters (Mean rainfall, Standard Deviation, Coefficient of variance, M-K trend (z) and significance levels) for both Ahero Irrigation and Koru Bible Centre Stations. The computation was done for monthly, seasonal and annual seasons for the period of (1980-2020). Skewness which is a measure of the degree of asymmetry observed in a probability distribution around the mean. This distribution can either exhibits right (positive) or left (negative) skewness to varied degrees. All the values for the skewness are positive (0.402-1.163) for Ahero Irrigation station and (0.145-4.381) for Koru station, this indicating that the precipitation within the period was asymmetric and it lies to the right of the mean over the two stations. Kurtosis is a statistical measure used to describe the degree to which scores cluster in the tails or peak of a frequency distribution. Where the peak is the tallest part of the distribution, and the tails are the ends of the distribution. It varied from -0.47-24.233 with predominantly positive values of skewness. In order to investigate the spatial pattern, coefficient of variation (CV) which is the measure of dispersion of data points around the mean was computed for the two stations. The findings revealed that the season with enhanced rainfall (MAM) recorded least variability 0.274 for the two stations. On the other hand, season with least precipitation (JF), recorded the most rainfall variability of 0.643 and 0.530 for Ahero Irrigation and Koru Bible Centre stations respectively for the period (1980-2020). The monthly rainfall of Ahero Irrigation and Koru Bible Centre for a period of 40 years is illustrated in Figure 3 and Figure 4 was used to investigate the rainfall trend for both Ahero Irrigation and Koru Bible Centre stations. Both stations showed increase in the mean monthly rainfall totals in the months of (March, April, and in May) and declined in the months of (June and July) with a slight increase in the months of August, another slight decline in the month of September and gradual increase in the month of October and peaks in the month of November, then a decline in the month of December. January and February recorded relatively low monthly mean rainfall values as compared to other remaining months. This conforms to the water year of meteorological seasons of Kano Plains. JF (dry), OND (wet), JJAS (dry), MAM (wet).

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To investigate the trend further, 2-tailed Mann Kendall test was applied. The test revealed a perfect unison between the two stations, with a strong increasing correlation coefficient (0.697) and $\tau = 0.02, p(2 - tailed) < 0.05$ showing correlation of determinant of 48.6%. The highest mean monthly rainfall was recorded in the month of April (227.5 mm and 185.1 mm) for Koru Bible Centre and Ahero Irrigation stations, being 30.9% and 30.8% rainfall variability respectively. While, the minimum amount of mean monthly rainfall was recorded in the month of July (120.8 mm and 71.8 mm) for Koru Bible Centre and Ahero Irrigation stations, being 48.3% and 44.5% rainfall variability respectively. The overall mean monthly minimum rainfall variability ranges between 30.9% - 30.9%, while the maximum rainfall variability ranges from 81.2% - 76.1% for Ahero Bible and Koru Bible Centre stations respectively. The first rainfall season being (MAM) long rains, with more rainfall amount than the second rainfall season (OND) short rains separated with dry seasons JJAS and JF. Mean annual rainfall for (MAM), was revealed to be 482.5 mm and 526 mm for Ahero Irrigation Koru Bible Centre stations respectively. This being 28.1% and 28.2% rainfall variability for both Ahero Irrigation and Koru Bible Centre stations respectively. The rainfall variability smaller in the seasonal and annual periods as compared to the monthly rainfall variability. This implies that, the monthly rainfall pattern is hard to predict than the seasonal and annual rainfall pattern**.**

Figure 3 &4 also revealed double maxima in the months of April and November, with April recording the highest mean rainfall totals followed by November. Moreover**,** it was worth noting the similarity in the monthly rainfall pattern; however Koru Bible Centre had enhanced rainfall amount compared to Ahero Irrigation station. Both stations peak in the month of April and October forming a bimodal rainfall pattern with two dry seasons separating them. These findings are in consistence with the study done by (Khisa, et al., 2013) that showed bimodal seasonal pattern of rainfall variability for (MAM) and (OND).

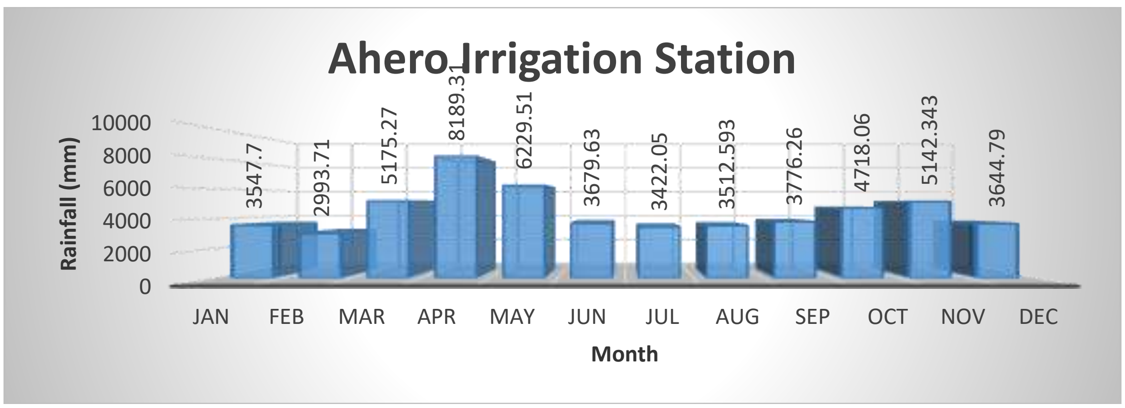

Figure 3: Mean Monthly rainfall for Ahero Irrigation Station.

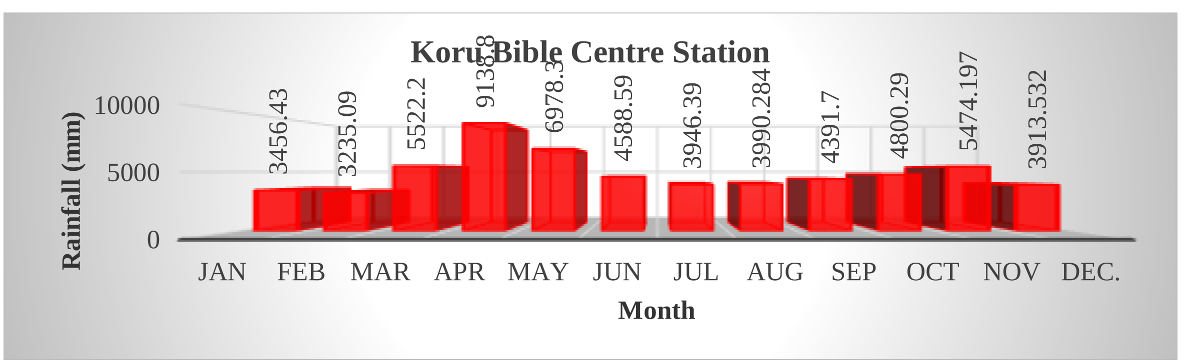

Figure4: Mean Monthly Rainfall for Koru Bible Centre station

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3.2 Annual Rainfall Analysis.

Figure 5 shows annual rainfall trend for Ahero Irrigation Station for the year 1980 to 2020. Ahero Irrigation Station recorded the highest mean annual rainfall of 2241.7 mm in the year 2001 and the lowest mean annual rainfall of 261.09 mm was received in the year 2005. There seems to be a rise in the amount of rainfall around the year 1997-1998 and this is explained by the fact that El-Nino rains occurred during that period which caused severe flooding problems in the entire Lake Victoria Basin ((Awange, et al., 2008, (Kizza et al, 2009, Millman, 1973; Mistry & Conway, 2003, Ongwenyi et al., 1993). According to (Opere, 2013) in April/May 2003 there was excessive rain that resulted in complete inundation of Nyando River flooding plain downstream of Ahero town as a result of breaching of the dykes. This again confirms the rise in the amount of annual rainfall in the year 2003. Rainfall deficit (drought) years include 1981(974 mm), 1984 (1010 mm), 1992 (1059 mm), 2005 (261.09 mm), 2010 (1019.88 mm) and 2017 (1076.4 mm). While enhanced (wet) years include 1982 (1326.5 mm), 1986 (1309.5 mm), 1989 (1422.1 mm), 1996 (1575.1 mm), 1998 (1477.1 mm), 2001 (224.7 mm), 2002 (2081.5 mm), 2003 (2203.4 mm), 2004 (1950.1 mm), 2006 (1612 mm), 2011 (1371 mm), 2015 (1409.5 mm), 2018 (1481.7 mm), 2019 (1463.9 mm) and 2020 (1465.5 mm). The minimum amount of rainfall (956.3 mm) was received in the year 2008 and the highest rainfall amount of 2300 mm in the year 1995.There was enhanced annual rainfall totals in the following years: - 1988 (1956.8 mm), 1994 (2158.4 mm), 1999 (1747.1 mm), 2006 (1798.23 mm) and 2012 (5019.9 mm). The following years 2001 (1255.5 mm), 2008 (956.3 mm) and 2010 (990.837 mm) recorded relatively low rainfall as compared to Ahero Irrigation Station.The 2-tailed Mann Kendall test applied for trend analysis revealed increasing trend in annual rainfall for Ahero Irrigation station though not significant with correlation coefficient of 0.193 and $\tau = 0.076$, p (2-tailed) > 0.05. However, in figure 6**.** Koru Bible Centre the Mann Kendall showed a decreasing correlation coefficient of -0.406 and $\tau = 0.000$, p (2-tailed) < 0.05. Meaning there was declining statistically significant annual rainfall trend for Koru Bible station. This study shows downward significant rainfall trend for Koru Bible Centre and upward rainfall trend for Ahero Irrigation station which is in consistent with the study done by (Khisa, *et al*., 2013).

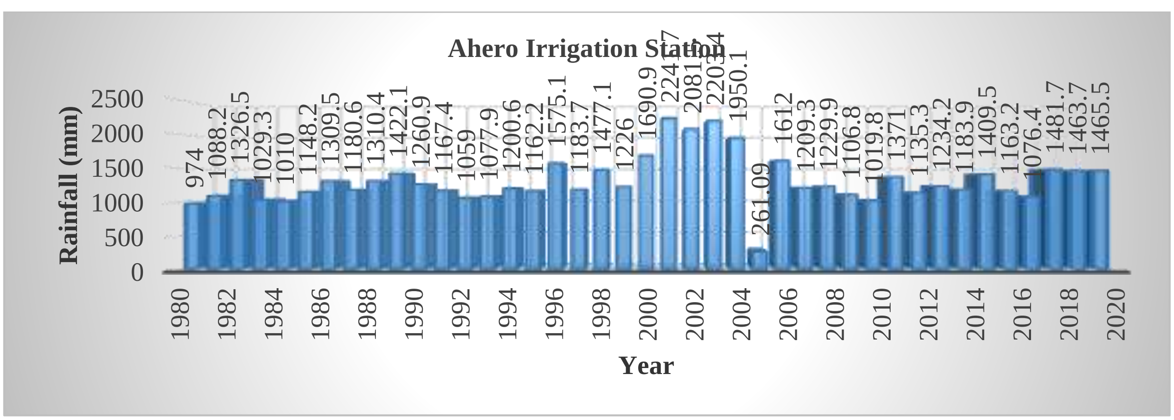


Figure 5: Annual Rainfall (1980-2020) for Ahero Irrigation Station

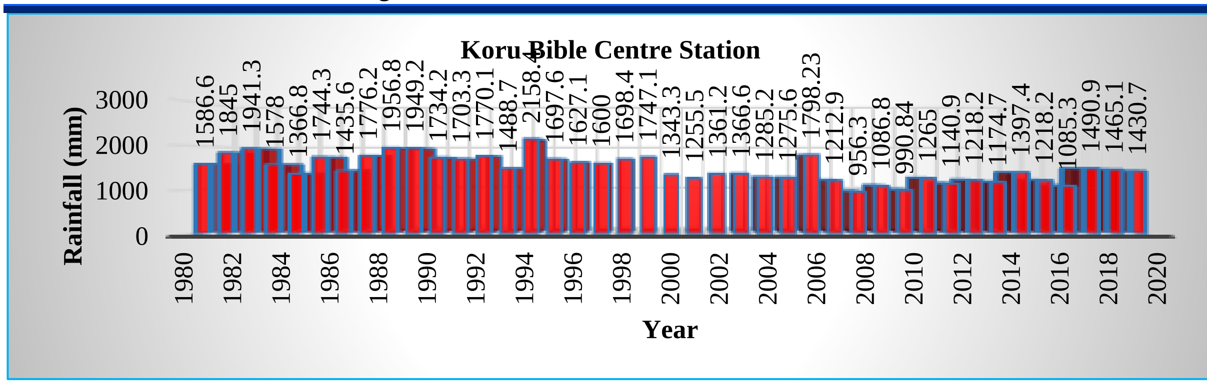
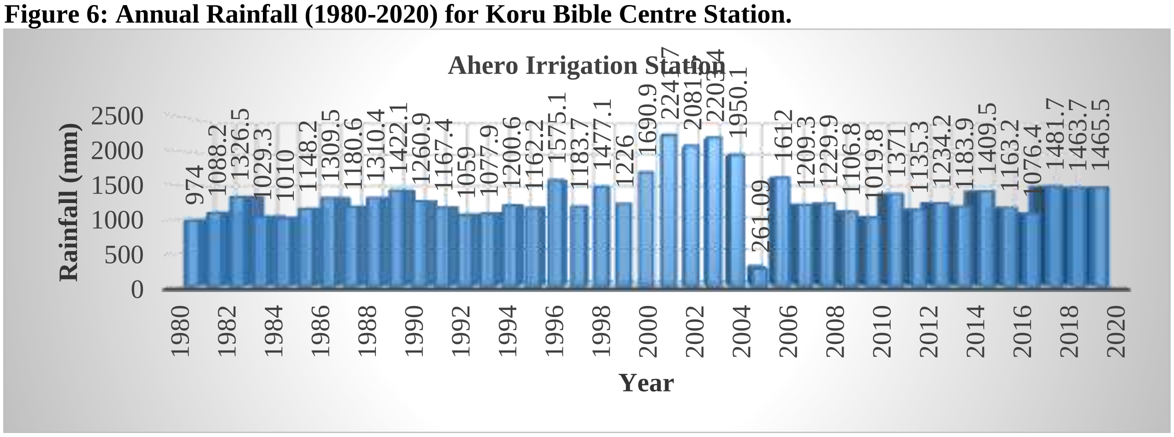


Figure 6: Annual Rainfall (1980-2020) for Koru Bible Centre Station.



3.2 Trend analysis for monthly.

The present study analysed rainfall trend in monthly rainfall data using Mann Kendall (MK) for both Ahero Irrigation and Koru Bible Centre stations. Table 2 contains the Mann-Kendal statistics and corresponding significance levels of the trend analysis.

Table 2. Trend Analysis for Monthly Rainfall.

Month	Ahero Irrigation station				Koru Bible Centre station			
	Correlation coefficient	Sens's slope (S)	Significance level		Correlation coefficient	Sens's slope (S)	Significance level	
January	-0.101	4.461	0.357	NS	-0.078	-1.339	0.477	NS
February	0.064	-0.826	0.056	NS	0.291	-2.375	0.008**	S
March	0.182	0.458	0.098	NS	0.031	-0.645	0.78	NS
April	0.104	3.476	0.345	NS	0.041	-0.074	0.709	NS
May	-0.030	6.035	0.37	NS	0.259	3.417	0.019*	S
June	-0.099	3.922	0.37	NS	0.097	-0.561	0.376	NS
July	0.005	3.943	0.963	NS	0.159	2.846	0.149	NS
August	-0.003	5.234	0.981	NS	0.221	0.931	0.045*	S
September	-1.830	3.596	0.098	NS	0.154	0.098	0.168	NS
October	0.110	3.503	0.316	NS	0.254	2.458	0.021*	S
November	0.003	3.791	0.981	NS	0.030	1.886	0.789	NS
December	-0.145	1.965	0.188	NS	-0.126	2.047	0.126	NS

* Shows (S) significance at α =0.01 **Indicates (S) significance at α = 0.05 NS – Not Significant.

Ahero Irrigation Station recorded non - Significant trend at 5% or 1% levels of Significance for all the Monthly. Moreover, insignificant trends were observed both increasing (six months) and declining (months) for monthly rainfall trends for the period (1980-2020).

On the other hand, Koru Bible Centre station, the analysis detected both Significant and Insignificant trends for monthly rainfall, majority of which are Insignificant (January, March, April, June, July, September, November and December). The remaining months recorded Significant rainfall trends (February, May, August and October).

Figure **7** was also used to investigate the monthly rainfall trends for both Ahero Irrigation and Koru Bible Centre stations using Mann Kendall statistics (Z_C) values. The result revealed that majority of the months recorded increasing rainfall trends. However, in the months of January and December both stations recorded declining rainfall trend. It is worth noting that Ahero Irrigation station recorded statistically insignificant rainfall trends for all the months.

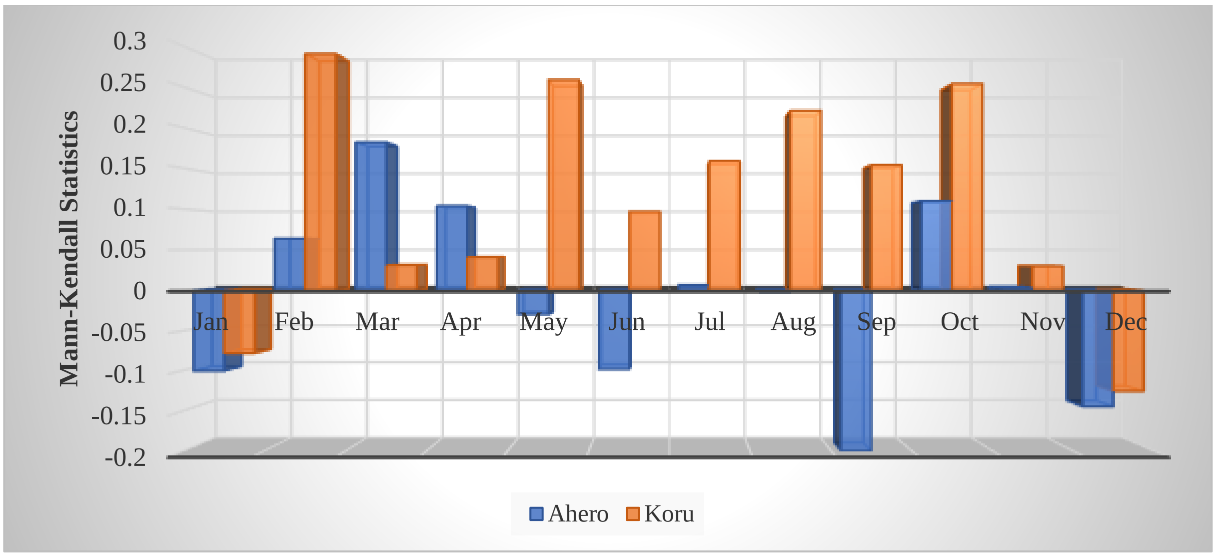


Figure 7: Monthly rainfall trend analysis.

Source: Author (2020).

4.3 Trend Analysis for Seasonal and Annual Rainfall.

The study used four seasons for analysis based on the studies that has been done on the area, according to [7]. The seasons are; JF (short dry season), MAM (long rainy season), JJAS (long dry season), and OND (short rainy season). The Mann Kendall's statistic and Significance were computed for seasonal and annual rainfall trend analysis as shown in table 3.

Table 3: Trend Analysis for Seasonal and Annual Rainfall.

Season	Ahero Irrigation station				Koru Bible Centre station			
	Correlation coefficient	Sen's slope estimator	Significant level		Correlation coefficient	Sen's slope estimator	Significant level	
MAM	0.032	1.316	0.770	NS	-0.205	-5.124	0.059	NS
JJAS	-0.017	0.29	0.875	NS	-0.489	-9.383	0.000**	S
JF	-0.256	-0.529	0.736	NS	-0.037	-2.556	0.018*	S
OND	0.249	4.255	0.024	NS	0.008	0.915	0.944	NS
ANNUAL	0.193	4.753	0.076	NS	-0.41	-14.57	0.000**	S

NS – Non-Significant trend S – Significant trend at 5% and 1% level of Significance.

Long Rainy Season (MAM).

The present study investigated the seasonal rainfall trend analysis for MAM by applying 2-tailed Mann- Kendall test, that showed that there was increasing rainfall trend for Ahero Irrigation Station, that recorded correlation coefficient of (0.032) and $\tau = 0.770$, p (2-tailed) >0.05. Implying there was increasing rainfall trend for Ahero Irrigation Station even though not statistically significant.

However, Koru Bible Centre Station recorded decreasing rainfall trend with correlation coefficient of (-0.198) and $\tau = 0.069$, p (2-tailed) >0.05, showing a weak correlation determinant of 3.9%. Meaning there has been decreasing rainfall amounts during (MAM) even though not statistically significant.

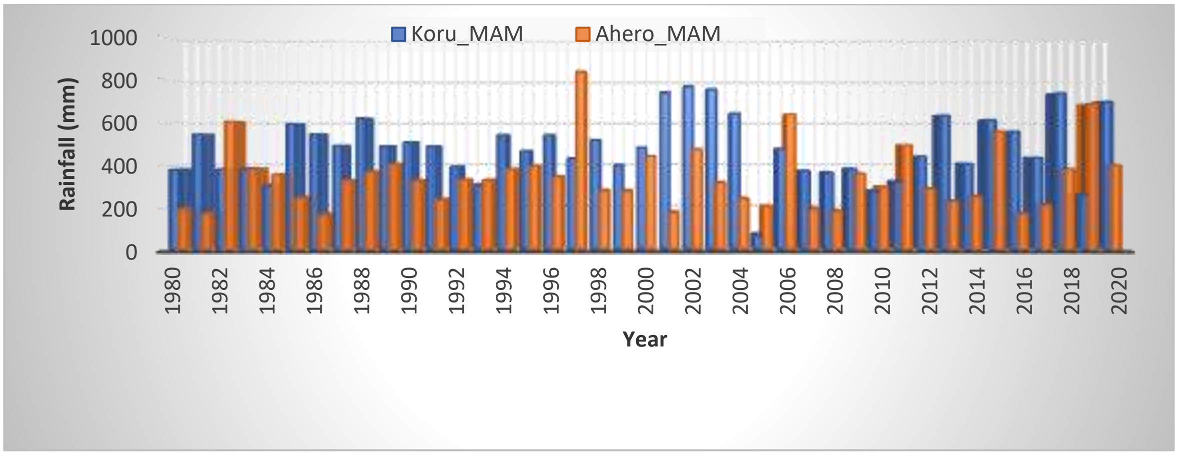


Figure 8: Long rainy season

Long Dry Season (JJAS).

Ahero Irrigation Station recorded decreasing correlation coefficient of (-0.017) with $\tau = 0.875$, p (2-tailed) > 0.05. Meaning there has declining rainfall trend for Ahero Irrigation station even though not statistically significant during this season. However, Koru Bible Centre experienced statistically significant declining rainfall trend over the period (1980-2020) with correlation coefficient of (-0.489) with $\tau = 0.000$, p (2-tailed) < 0.05. Meaning the trend of rainfall has been increasing during (1980-2020) for the JJAS period.

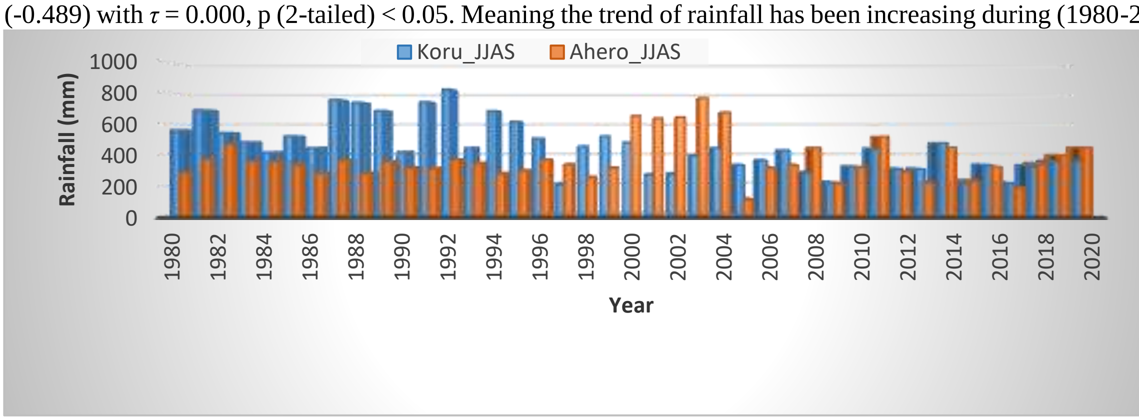


Figure 9: Long Dry Season

Short Dry Season (JF).

Ahero Irrigation and Koru Bible Centre Stations detected a declining rainfall trend with correlation coefficient of -0.256 and -0.037 respectively. Again, Ahero Irrigation and Koru Bible Centre stations recorded Insignificant $\tau = 0.736$, p (2-tailed) >0.05, and $\tau = 0.18$, p (2-tailed) >0.05**,** respectively. Meaning, even though the rainfall trend is declining, its not statistically significant for the two stations.

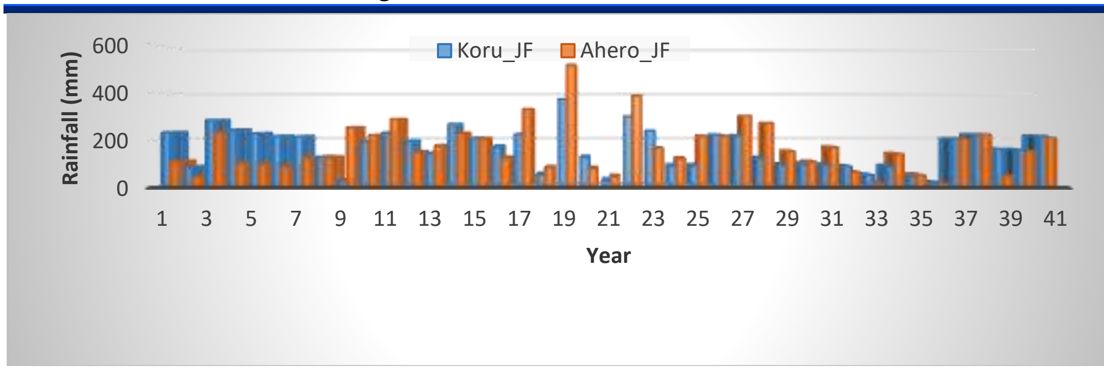


Figure 10: Short Dry Season

Short Rainy Season (OND).

To further understand the seasonal trend analysis, 2-tailed Mann Kendall test analysis was carried out and the findings revealed positive Z_C values of (0.249 and 0.008) for Ahero Irrigation and Koru Bible Centre respectively. Ahero Irrigation Station recorded statistically significant rainfall trend with $\tau = 0.024$, p (2-tailed) < 0.05. While, Koru Bible station on the other hand recorded $\tau = 0.944$, p (2-tailed) > 0.05, meaning statistically insignificant.

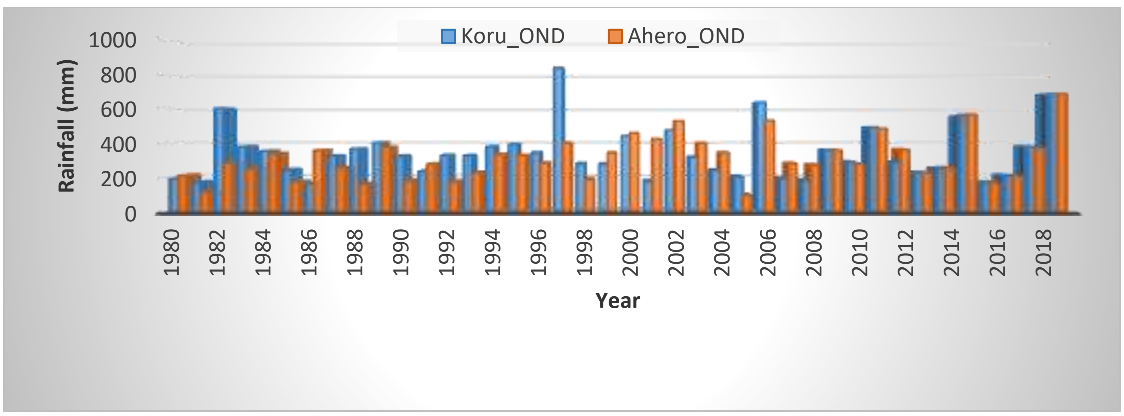


Figure 11: Short Rainy Season

Annual Rainfall.

The 2-tailed Mann Kendall test applied for trend analysis revealed increasing trend in annual rainfall for Ahero Irrigation Station though not significant with correlation coefficient of 0.193 and $\tau = 0.076$, p (2-tailed) > 0.05. However, for Koru Bible Centre the Mann Kendall showed a decreasing correlation coefficient of -0.406 and $\tau = 0.000$, p (2-tailed) < 0.05. Meaning there was declining statistically significant annual rainfall trend for Koru Bible station. This study shows downward significant rainfall trend for Koru Bible Centre and upward rainfall trend for Ahero Irrigation station which is in consistent with the study done by [19] confirming the result to be true.

3.4 Coefficient of variation (CV%)

Correlation coefficient (CV%), was used to show the extent of variability of rainfall within Kano Plains.

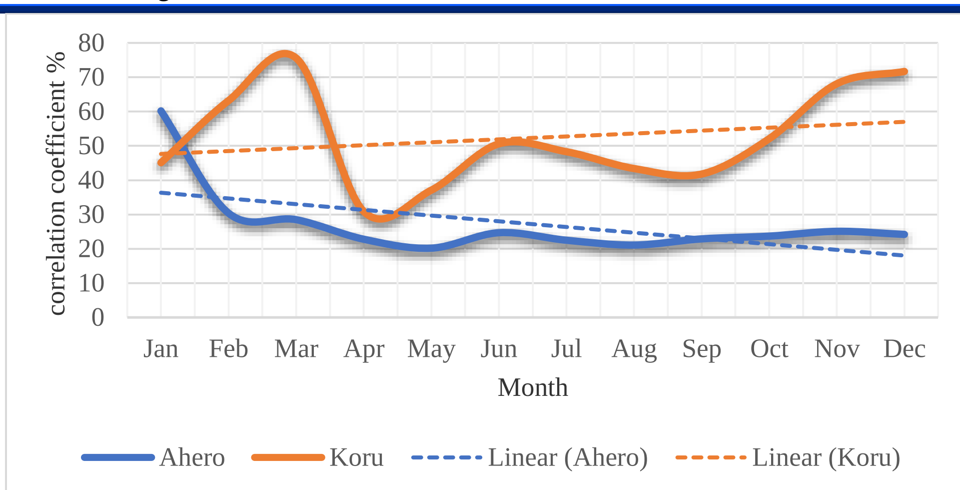


Figure 12: Comparison of coefficient of variation of Ahero and Koru

Source: Author (2021).

Figure 12 was used to analyzed the coefficient of variance for the two stations. Ahero Irrigation recorded less than 50% coefficient of variance in all the months except January. On the other hand, Koru Bible Centre recorded more than 50% coefficient of variance in the following six months (January, April, May, July, August, and September). This brings to the conclusion that it was more difficult to predict the rainfall pattern in Koru Bible station than Ahero Irrigation station for the monthly rainfall because of more percentage of CV in Koru station as compared to Ahero Irrigation station. This present study also investigated the seasonal coefficient of variance, and the following results were realized; For JF season, both Ahero and Koru recorded over 50% coefficient of variance while for MAM, JJAS, OND and Annual periods, the CV% were below 50%. This again means that it was not easy to predict the rainfall pattern for JF season compared to the other seasons because of the large disparity from the mean.

4. **Discussion**

The findings were discussed in the light of previous research findings and the available literature, where applicable, in order to identify the similarities and differences between this present study and the previous studies. The monthly results revealed double maxima in the months of April and November, with April recording the highest mean monthly rainfall then declines and peaks again in the month of November for both stations. The bimodal rainfall pattern peaks in April and November, separated with two dry seasons. These findings are in consistence with the study done by (Khisa, et al., 2013). Notably, MAM and OND are the main rainfall seasons that the habitants of Kano Plain rely on for agricultural activities. Based on the analysis of rainfall reliability of the two seasons, MAM revealed 27. 4% for both stations and OND 41.1% and 44.7% Ahero Irrigation and Koru Bible respectively. According to ((Liebmann, et al., 2017; (Becker, et al., 2010) (Ali & Abubaker, 2019) (Khisa P.S, et al, 2013) (Ogalo, Janowiak, & Halpert, 1988) (Kizza, Rodhe, Yu Xu, Ntale, & Haldin, 2009), El Nino Southern Oscillation Index (ENSO) and Indiana Ocean Dipole (IOD) influence short rains than long rains (Conway & Mistry, 2003). Generally, the results revealed negative rainfall trend for MAM in Ahero Irrigation Station and positive trend for Koru Bible Station and positive trend for OND for both stations. This finding is in agreement with the finding by (Liebmann, et al., 2017) and Yang et al (2014) who observed that, there was reduction trend in MAM and Increase trend in OND. However, it can be noted that for this present study Koru Bible Centre recorded increasing trend instead of decreasing trend. This difference is due to the data size used for the analysis. The long rainy season rains (MAM) contribute about 53% while the short rains contribute about 18% of the 1432 mm/year mean annual rainfall. January- June received more rainfall (64%) than July- December (26%) of the total mean annual rainfall received 1432 mm/year.

5. Conclusion

The present study main objective was to analyse the rainfall data for 40 years from (1980-2020) for Kano Plains for determination of rainfall trend. To achieve the goal, daily rainfall data was collected from two reliable rainfall gauge stations of Kano Plains Ahero Irrigation and Koru Bible Centre. The analysis was carried out based on the monthly, seasonal and annual rainfall data series. Data quality was done using mass curve to check the data gaps and outliers. Mann- Kendall test was used to detect the trend in the rainfall variability and coefficient of variance was used to show the extent of trends. The results revealed that Koru Bible centre station received more rainfall compared to Ahero Irrigation station; this could be attributed to its close proximity to Nandi hills that acts like rainfall catchment area. The two stations revealed perfect unison with a strong increasing rainfall trend for annual rainfall. MAM and OND were found to be the main rainfall seasons for the two stations and any change in the rainfall trend could impact negatively on the economy of the area which heavily relies on rain fed agriculture. Again, the result showed insignificant increasing rainfall trend during JF for both stations. Koru Bible Centre station recorded major decreasing rainfall trend in the period of MAM. Contrary, Ahero Irrigation station minor decreasing rainfall trend for the same period of March, April & May (MAM) long rainy season. Koru Bible Centre, showed major rainfall trend in the same season, Ahero Irrigation station however, recorded minor decreasing rainfall trend. Again, in the season of (OND), both stations revealed insignificant decreasing rainfall trends. Finally, for the annual rainfall trend analysis; Ahero Irrigation Station revealed insignificant increasing rainfall trend. However, for the same period, Koru Bible Centre showed major decreasing rainfall trend. From the analysis above (monthly, seasonal and annual), there was evidence upward and downward rainfall trends. "This brings me to the conclusion that, there was monotonic rainfall trend in all the seasons (monthly, seasonal and annul) rainfall occurrence in Kano Plain. From the analysis of extent of variation, Koru Bible Centre station revealed rainfall variation than Ahero Irrigation station. This brings me to the conclusion that it was more difficult to predict the rainfall pattern in Koru Bible station than Ahero Irrigation station for the monthly rainfall. This present study also investigated the reliability of the rainfall where low CV showed very reliable rainfall and high CV indicated unreliable rainfall. The following results were realized; For JF season, both Ahero and Koru recorded over 50% coefficient of variance while for MAM, JJAS, OND and Annual periods, the CV% were below 50%. The high variability in short rains is associated with influence from large scale factors like El Nino Oscillation Index (ENSO) than long rainy seasons like MAM rainfall (Liebmann et al 2014; Ogalo, Janowiak, & Halpert, 1988). Notably, JF, MAM and JJAS rainfall trends has been declining over the years while the OND rainfall trend has been increasing in concurrence with the observation made by (Khisa, 2013; Mutua, et al 2020). This present study will help in the farming practices, management of water resources and other water related activities for sustainable development. However, the present study recommends further study of the hydrological parameters using other trend detection techniques.

6. Author contribution

Author 1: Conceptualization, original draft preparation, writing -review and editing, resources, data curation, methodology and analysis.

Author 2: Conceptualization, validation, methodology, review and editing, analysis and supervision.

Author 3: Conceptualization, validation, methodology, review and editing, analysis and supervision.

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