TREND ANALYSIS OF HYDROCLIMATIC CHARACTERISTICS

BY

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BEING

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DECLARATION

I, Okanlawon Kunle, hereby declare that this project was undertaken and written by me. It has not been presented before for any degree, diploma or certificate at any university or institution. The information derived from personal communications, published, and unpublished works were duly referenced in the text.

Okanlawon Kunle

02-03-2012

Date

CERTIFICATION

This project entitled "Trend analysis of Hydro-Climatic Characteristics" by Okanlawon Kunle meets the regulations governing the award of the degree of Bachelor of Engineering (B. Eng.) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This project is dedicated to the Almighty God, who, in His infinite mercies saw me through the moments of disappointment and moments of joy throughout this period. I praise His holy name for all His benefit and goodness toward me. To Him alone are all the glory, honour and adoration.

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Kunle Okanlawon

Abstract

Identification of the precise nature and attributes of the time series of climatological data is very important and is usually the first step of water resources planning and management, The major objective of this study is to determine the presence or otherwise of trend over time for some selected Hydroclimatic components of Kaduna, Nigeria, and deduce (if trend is detected) it's magnitude. To this end this study employed statistical approaches used to investigate the presence and extent of persistence, trend analysis in Hydroclimatic time series. The study investigated spatial distributional pattern (i.e. Trend) of the indicative Hydroclimatic variables based on Mann Kendall test, twenty six years of hydroclimatic data for Kaduna, Kaduna state were used. The non-parametric Man-Kendall test was used to detect monotonic trends, and the Mann-Kendall slope estimator was used to estimate the magnitude of trend on the variables. The study showed that there is an evidence of trend on all variables, The Temperature and Evaporation variables showed a positive and significant trend over time, while rainfall and stream flow have negative trend though not of significant at the 95 or 99% level of confidence. Thus, it could be concluded that the trend of change in temperature around river Kaduna is on the increase, with no significant increase in change of rainfall. This is not favourable for streamflow management and other related hydrological processes. Based on the results it is strongly recommended that proper water resource management strategy be put in place to avoid the water drying off; tests should be carried out on other hydroclimatic variables to ensure better management since there is strange independence among hydroclimatic characteristics.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Generally, the study of the weather and climatic elements of a region is vital for sustainable development of agriculture and planning, particularly, rainfall and temperature. Temporal analyses for trends, fluctuations and periodicities are deemed necessary as such can indirectly furnish the "health" status of an environment. A declining and/or rising trend, etc may be quite instructive for different segments of the human and natural systems. Impending long or short term weather – related natural disasters for instance may be predicted and better adaptive actions initiated through the analysis of the fluctuations and return periods of the series. Extreme weather events that can lead to drought and prolonged heat spell, flooding, etc., can be accessed through the statistical analysis of a region's temporal rainfall regime. The global concern on the apparent deterioration in all of the earth's natural systems, particularly the weather and climate sub-system and global warming with attendant climate change pandemic renders credence to trend and periodicity analyses of weather elements. Climate is the most important driving parameter that causes year-to-year variability in socio-economic and environmental systems including the availability of water resources .It affects the development and planning of water resources schemes such as flood prevention and control, drought management, food and fibre production, etc. Further, change in climate will increase the uncertainty in water resources planning. Apart from this, changes in climatic pattern will have profound effects and consequences for natural and agricultural ecosystems and for society as whole. These changes could even alter the location of the major crop production regions on the earth (Reddy and Hodges, 1980). The shifting from 'normal weather', with its associated extreme events will surely change the zones of crop adaptation and cultural practices required for successful crop production. Climate and weather induced instability in food and fibre supplies will alter social and economic stability and regional competitiveness (Reddy and Hodges, 1980). Therefore, the analysis of hydroclimatic variables such as rainfall, potential evapotranspiration, sreamflow, temperature, etc becomes a prerequisite task to understand climatic changes.

In recent years, there has been a considerable concern about the possibility of climatic changes. Alteration in our climate is governed by a complex system of atmospheric and oceanic processes and their interactions. Atmospheric processes such as humidity, solar radiation, evaporation etc, also result in increase in surface-level ultraviolet radiation and changes in temperature and rainfall pattern. Human activities on the other hand are responsible for changes in ecosystem due to increased emission rates of CO_2 and other green house gases. The evidence using state-of-art computer models incorporating as much of the theoretical understanding of the earth's weather suggests that global warming is occurring along with shifting patterns of rainfall and incidents of extreme weather events (Solomon and Qin, 2007).

It was demonstrated that global surface warming has been taking place at the rate of 0.74 ± 0.18 °C over the period of 1906-2005 (Solomon and Qin, 2007) and it was expected more in the next century than what has occurred during the past 10,000 years (IPCC, 2007). The increased atmospheric moisture content associated with warming might be expected to increase the global mean precipitation. Global annual land mean precipitation showed a small, but uncertain, upward trend of approximately 1.1 mm per decade (uncertainty ±1.5 mm) over 1901-2005. During the 20th century, precipitation has generally increased from latitudes 30° to 85°N over land; but notable decreases have occurred between latitudes 10 °S and 30°N in the last 30-40 years. In western Africa and southern Asia the linear trends in rainfall decrease during 1900-2005 were 7.5% per century (significant statistically at <1%

level), whereas over much of northwest India shows increase in the rainfall with more than 20% per century (NOAA, 2007). At lower latitudes, especially seasonally dry and tropical regions, crop productivity is projected to decrease for even small local temperature increases (1-2 °C), which would increase the food risk (IPCC, 2007).

Considering all the issues involved herein, it can be stated that the study of hydroclimatic variables such as rainfall, potential evapotranspiration, temperature, humidity, etc becomes a prerequisite task to understanding climatic changes. Therefore, for water resources planning, it seems to be logical to analyze hydroclimatic variables at small scale for proper appreciation of their spatio-temporal variability. However, the change in climate is governed by the complex system of atmosphere and oceanic processes and their interaction, but due to limitation on availability of wide variety of atmospheric data, this study focus on the analysis of indicative hydroclimatic parameters to demonstrate the climate change or changes in weather patterns.

1.2 Statement of Problem.

The question of whether climate change has had an impact on extreme rainfall and flooding viz-a-viz other related hydrological variables has lately become an issue of serious concern among the hydrological community. Hydrological variables are traditionally treated as random, stationary with some probability distribution. If for instance, change in rainfall and flow patterns are evident, they will have significant impact on existing infrastructure, current practice and future strategies in flood deference. Because change of hydro climatic pattern in both temporal and spatial, there is absolute need for recent information on this change, but at present in the country, such data are seemingly not available and if available not continuous at all. Changes in climatic pattern will have profound effects and consequences for natural and agricultural ecosystems, and for the society as a whole. The shifting from normal weather, with its associated extreme events will sure change the zones of crop adaptation and cultural practices required for successful crop production. A very basic analysis in this context for an effectual appreciation of any seeming change is the analysis of trend; it provides a preliminary basis for any further explanatory study on dynamical variability of hydroclimatic characteristics.

1.3 Objectives of study

1. To determine the presence or otherwise of long range trend over time for some selected hydroclimatic components
2. To establish, based on the trend analysis carried out whether climate change has already altered hydroclimatic process of rainfall, temperature, relative humidity, stream flow.

1.4 Justification of Study.

The assessment of possible trends in hydroclimatic characteristics can be an important scientific task in the support of water resources planning and management of water bodies. The presence or absence of trends over time in key hydroclimatic variables is a good indication of the degree to which the variables are responding to changes. This information, in turn, provides a basis for predictive models in the development and planning of water resources scheme. Formal statistical trend provides a rational scientific basis for addressing concerns that may arise due to natural variation in climate changes. For example, citizen who is involved in agricultural production may be distressed about undesirable "changes" in the hydro climatic characteristics that may be due to entirely natural variations. Seasonal trend of hydro climatic characteristics program could provide estimates of the likelihood that the observed "changes" reflect natural variability or real trends overtime. This helps in citizen education, and in turn, may suggest alternative management actions that may be directed at either reversing trends in hydro climatic characteristics or reducing the hydro climatic variability. It is expected that at the end of the completion of this study, whatever information obtained on the subject will provide an objective preliminary basis for further research in this area, and largely, constitute preliminary data base for water resources planning.

1.5 Scope of the Study

Considering data collection problem in the country at present, the study is only limited the one of hydro climatic data (i.e., rainfall, temperature, evaporation, sreamflow) for the presence of trend or otherwise and estimating the magnitude of the trend for River Kaduna. To this end, analysis and conclusion shall be limited to the extent of data available only and the period covered by data set.

CHAPTER TWO

2.0 Review of Related Literature

2.1 Hydroclimatic Characteristics

The Earth's climate is dynamic and naturally varies on seasonal, decadal, centennial, and longer timescales. Each "up and down" fluctuation can lead to conditions, which are warmer or colder, wetter or drier, more stormy or quiescent (Reddy and Hodges, 1980). These changes in climate may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use (Bates et al., 2008). Perhaps, the most well understood occurrence of climate variability is the naturally occurring phenomenon known as the El Niño-Southern Oscillation (ENSO), an interaction between the ocean and the atmosphere over the tropical Pacific Ocean that has important consequences for weather around the globe (Reddy and Hodges, 1980).

Pronounced long-term trends from 1900 to 2005 have been observed in precipitation amount in some places: significantly wetter in eastern North and South America, Northern Europe and Northern and Central Asia, but drier in the Sahel, Southern Africa, the Mediterranean and Southern Asia. Widespread increases in heavy precipitation events have been observed, even in places where total amounts have decreased. These changes are associated with increased water vapour in the atmosphere arising from the warming of the world's oceans, especially at lower latitudes (Trenberth et al., 2007).

One of the most significant climatic variations in the African Sahel since the late 1960s has been the persistent decline in rainfall (Kanji, 2006). The Sahel is characterized by strong climatic variations and an irregular rainfall that ranges between 200mm and 600 mm with coefficients of variation ranging from 15 to 30% (Fox, 2003 and Kanji, 2006).

According to Intergovernmental Panel on Climate Change (IPCC), a rainfall decrease of 29-49% has been observed in the 1968-1997 period compared to the 1931-1960 baseline period within the Sahel region (McCarthy et al., 2001). The West Africa region has experienced a marked decline in rainfall from 15 to 30% depending on the area (NOAA, 2007). The trend was abruptly interrupted by a return of adequate rainfall conditions in 1994. This was considered to be the wettest year of the past 30 and was thought to perhaps indicate the end of the drought. Unfortunately, dry conditions returned after 1994 (McCarthy et al., 2001).

Statistical tools commonly used to detect significant trends in climatic and hydrological time series is both the non-parametric test either such as Mann-Kendall or Spearman's rank correlation and the parametric test such as student's t-test. The non-parametric test is considered better because it is a function of the ranks of observation and it displays much insensitivity to outliers unlike the parametric counterpart. In this regard, statistical tools have been used extensively. Hydro climatology provides a systematic structure for analysing how the climate system causes time and space variations (both global and local) in the hydrologic cycle. Changes in the relationship between the climate system and the hydrologic cycle underlie floods, drought and possible future influences of global warming on water resources (Ayoade, 1986). Land-based data, satellite data, and computer models contribute to our understanding of the complex time and space variations of physical processes shared by the climate system and the hydrologic cycle. Blending key information from the fields of climatology and hydrology - which are not often found in a single volume, can provide useful reference for academic researchers in these fields (Ayoade, 1986). These characteristics are;

- Evaporation and Transpiration (E)
- Precipitation (P)
- Run-off (F)
- Sreamflow
- Temperature (T)

2.2. TREND ANALYSIS

A trend is the general pattern of fluctuation of data over time (Okoko, 2001). To define the climatic fluctuations exhibited in the hydroclimatic time series is an important aspect of the analysis .From a statistical point of view, the study of climatic fluctuations is a problem of time series analysis. Statistical evidence of persistence in such time series is equated with evidence of bonafide climatic fluctuations and said to be dependent. In many instances, a time series is generally not statistically independent but is comprised of persistence, cycles, trends or other non-random components. A steady and regular movement in a time series through which the values are on average either increasing or decreasing is termed a trend. This type of behaviour can be local, in which case the nature of the trend is subject to change over short intervals of time, or, on the other hand, it can be visualized as global trend that is long lasting. If a trend in a hydrologic time series appears, it is in effect, part of a low frequency oscillatory movement induced by climatic factors or through change in land use and catchment characteristics.

Trend analysis determines whether the measured values of a climate variable increase or decrease during a time period. In statistical terms, has the probability distribution from which they changed over time. It would be useful to describe the amount or rate of that change, in terms of changes in some central value of the distribution such as mean or median (Hirsch *et al.*, 1982). Based on the inconsistent nature of the climate variables, which are affected by factors such as industrial activities, human activities, hydrological factors, natural phenomenon like rock weathering, plant decomposition and greenhouse effects, etc., the quality of any water body at anytime need to be ascertained and as more data are made available, the trend which these data follow needs to be understood to establish a behavioural pattern and to be able to estimate the extent to which this influencing factor have impact variation.

The essence of trend analysis is to identify the precise nature and attributes of the time series of the climatological data for water resources planning and management, which is very important for the hydroclimatic extremes. Impending long or short-term weather – related natural disasters for instance may be predicted and better adaptive actions initiated through the analysis of the fluctuations and return periods of the series. Extreme weather events that can lead to drought and prolonged heat spell; flooding, etc, can be accessed through the statistical analysis of a region's temporal rainfall regime. The global concern on the apparent deterioration in all of the earth's natural systems, particularly the weather and climate sub-system and global warming with attendant climate change pandemic renders credence to trend and periodicity analyses of weather elements. When carried out with the exponential growths in the human population, industrialization and urbanization, etc., the picture is always threatening for man on earth. (WMO, 1988).

2.2.1 CATEGORIES OF TREND ANALYSIS

There are several approaches for detecting the trend in the time series. These approaches can be either parametric or non-parametric. Parametric methods assumed the data should be normally distributed and free from outliers. On the other hand, non-parametric methods are free from such assumptions.

2.2.1.1 Mann-Kendall

The most popularly non-parametric tests for detecting trend in the time series is the Mann-Kendall (MK) test. It is widely used for different climatic variables. For original Mann-Kendall test, the time series must be serially independent in nature. However, in many real situations, the observed data are serially dependent (i.e. auto correlated). The autocorrelation in the observed data will results in misinterpretation of trend test results. (Burn DH, 2002) states that "positive serial correlation among the observations would increase the chance of significant answer, even in the absence of a trend". A closely related problem that has been studied is the case where seasonality exists in the data. By dividing the observations into separate classes according to the season and then performing the Mann-Kendall trend test on the sum of the statistics from each season, the effect of seasonality can be eliminated. This modification is called the seasonal Mann Kendall test.

2.2.1.2 Kendall's Rank Correlation Test

Here, the Kendall's rank correlation test is used to test the significance for the presence of trend component in the annual flow series. This test, which is also referred to as the τ test, is based on the proportionate number of subsequent observations which exceed a particular value. For a sequence $x_1, x_2, \cdots, x_N$, the standard procedure is to determine the number of times, say, p, in all pairs of observations $(x_i, x_j, j > i)$ is greater than x_i; the ordered (i, j) subsets are (i = 1, j = 2, 3, 4, ..., N), (i = 2, j = 3, 4, 5, ..., N), (i = N-1, j = N).

The maximum possible number of such pairs occurs for a continuously increasing sequence. This is a rising trend where succeeding values are throughout greater than preceding ones and p is given by (N-1) + (N-2) + ...+ 1 which is the sum of an arithmetic progression and is given by (N-1) N/2. If the observations are totally reversed, p = 0 and hence, it follows that, for a trend-free series, E(p) = N(N-1)/4. It is important to stress that if p is close to N(N-1)/2 or 0, it indicates the presence of a rising or falling trend, respectively. Generally, the test statistic is based on $\tau = 4p/N(N-1) - 1$, and $\text{var}(\tau) = 2(2N+5)/9N(N-1)$, and is calculated as $\tau/\text{var}(\tau)^{1/2}$.

2.2.2 REASONS FOR USING NON-PARAMETRIC TEST

The non-parametric test is used with seasonal data which are suspected of being serially correlated and where one or more of the following conditions exist in the data set.

1. The data are non-normal. Many types of hydrologic data are distinctly non normal (Usually positive skewed), in particular, discharge, and variables related to wash off phenomena (biomass, bacterial counts, and chlorophyll). Dissolved constituent concentrations are distinctly non normal in some cases but not in others. Among all the common measured variables, only temperature, pH and dissolved oxygen can be considered to be typically normal or near normal. When data sets are small, as is often the case with data, the test for normality will only reveal the most extreme violations. Using a test that relies on an assumption of normality, even when the hypothesis of normality cannot be rejected, should probably be done only with considerable caution by checking for undue influence of extreme values on the outcome of the test.

2. There are missing values in the data. The parametric procedures for trend detection, used when serial correlation exists (Box and Tiao, 1975), depend on uniform sampling. Techniques exist to deal with a few isolated data gaps (Lettenmaier, et al., 1994; Astous and Hipel, 1979) by estimating values for the missing data. However, if there are a lot of missing values, one or more long gaps exist, the effect of data fill in on the identification of the stochastic process and the ultimate trend testing becomes very problematic; Harned et al., (1981) have employed various method of aggregating season data into annual summary values. This has the advantage that such annual series typically have only minimal serial dependence, and thus testing for trend can be carried out in straightforward fashion (either, parametrically or nonparametrically). However, in the presence of missing values (for any irregular sampling schedule) and seasonality, these annual summary values will be biased and

trends may be detected which are simply artefacts of year-to-year variations in the sampling schedule.(Astous and Hipel, 1979)

3. The data are censored. Censored data are those observations reported as being "less than" or "greater than" some specific value. Typical examples include concentration values for metals, or organic compounds which fall below the limit of detection (LD) of the analytical procedure and are then reported as "less than LD". Censoring may also exist in flood data when long historical records are used. But this case would generally involve annual series data rather than seasonal data. Where "less than LD" observations arise in a data set, parametric methods require substituting some numerical value for "less than LD" observations. Whatever numerical value is used, it will make the parametric test inexact and will severely violate the assumption of normality. Provided that the LD has not changed over the period of record, non parametric tests such as the one described here may be used with no difficulty. All "less than LD" (Lettenmaier, et al., 1994) values are considered tied with each other and are considered to be lower than any numerical value at or above LD. If LD has changed over the record from LD_1 to LD_2 where $LD_2 < LD_1$, then all data indicated as "less than LD_2", as well as any numerical values less than LD_1, must be recorded to "less than LD_1" and then the test maybe run as described.

2.2.3 Semi-non-parametric Trend Analysis

If the hypothesis of monotonic trend is reduced to a hypothesis of linear trend, a semi-non-parametric method which could be applied is the rank-based linear models approach. For a review, Hettmansperger and McKean (1998). Application of this method for the detection of trends in hydro climatic variables was studied by van Belle and Hughes (1984). They based their work on Farell (2008) who used an aligned rank test of Sen. (1968). This method requires estimation of missing values, independence, and no censoring, and it does not adjust for flow. However, for ideal conditions this method slightly outperforms the seasonal Kendall method of Hirsch et al., (1982) in terms of asymptotic efficiency because aligned rank tests generally have better asymptotic power properties than intra-block procedures (van Belle and Hughes, 1984). A lot of work has been done using semi-non-parametric methods with censored data in survival studies. For example, see Harrington and Fleming (1982), and Wei et al., (1990). This work could possibly be applied in the hydro climatic quality context. Solutions still need to be extended to allow dependent data although some yet to be published, but work of McKean's (1998) may shed some light on this subject.

2.3.0 Mann-Kendall Test for Annual Flow Series

This test is popularly known as the Mann-Kendall's (MK) test. In using this method, it is advisable to pre-whiten the time series by removing the impact of serial correlation from the series through $m_i = x_i - \phi x_{i-1}$ (Wang et al., 2005, Otache, 2008), where m_i is the pre-whiten series value, x_i is the original series value, and ϕ is the estimated lag 1 serial correlation. The pre-whitening is necessary because it has been found that positive serial correlation inflates the variance of the MK statistic S thereby increasing the possibility of rejecting the null hypothesis of no trend (Von, 1995). In order to test for the presence or non-existence of trend in the flow sequence, for instance annual series, the mean daily flow values are aggregated to annual mean values. The null hypothesis H_0 for this test usually is that a flow series $\{x_1, \ldots\ldots\ldots, x_N\}$ come from a population where the random variables are independent and identically distributed.

The Mann-Kendall (MK) test statistic S is expressed as

$$S = \sum_{i=1}^{N-1} \sum_{k=i+1}^{N} \operatorname{sgn}(x_k - x_i) \qquad \textbf{2.10}$$

where

$$\operatorname{sgn}(x) = \begin{cases} +1 & x > 0 \\ 0 & x = 0 \\ -1 & x < 0 \end{cases}$$

(Hirsch et al., 1982)

Mann-Kendall test statistic tau, τ is computed as

$$\tau = \frac{2S}{N(N-1)} \qquad 2.11$$

and

$$\sigma_s^2 = \frac{1}{18}[N(N-1)(2N+5) - \sum_{i=1}^{m} P_i (P_i - 1)(2P_i + 5)] \qquad 2.12$$

where m is the number of tied groups in the data set and p_i, the number of data points in the ith tied group. Similarly too, under the null hypothesis, the quantity z is taken to be standard normally distributed. Based on this,

$$z' = \begin{cases} (S' - 1)/\sigma_{s'} & S' > 0 \\ 0 & S' = 0 \\ (S' + 1)/\sigma_{s'} & S' < 0 \end{cases} \qquad 2.13$$

2.4.0 Seasonal Kendall method

Mann (1945) presented a nonparametric test for randomness against time which constitutes a particular application of Kendall's test for correlation (Kendall, 1975) commonly known as the Mann-Kendall or the Kendall t statistic, Letting x_1, x_2 . . . x_n, be a sequence of measurements over time, Mann (1945) proposed to test the null hypothesis, H_0, that the data come from a population where the random variables are independent and identically distributed. The alternative hypothesis, H_1, is the data follow a monotonic trend over time. Under H_0, the Mann-Kendall test statistic is

$$S_i = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\left(x_{ji} - x_{ki}\right) \qquad \textbf{2.14}$$

where n= number of years

i= number of season

$$\operatorname{sgn}(x) = \begin{cases} +1 & x > 0 \\ 0 & x = 0 \\ -1 & x < 0 \end{cases}$$

Kendall (1975), showed that S is asymptotically normally distributed and gave the mean and variance of S, for the situation where there may be ties in the x values, as

$E(S) = 0$

$$Var(S) = \frac{1}{18}\left[n(n-1)(2n+5) - \sum_{i=1}^{m} t_i\,(t_i - 1)(2t_i + 5)\right] \qquad \textbf{2.15}$$

where m is the number of tied groups in the data set and t_j is the number of data points in the ith tied group.

When using Equation 2.10, a positive value of S indicates there is an upward trend where the observations increase with time. On the other hand, a negative value of S means that there is a downward trend. Because it is known that S is asymptotically normally distributed and has a mean of zero and variance given by Equation 2.15, one can check whether or not an upward or downward trend is significantly different from zero. If S is significantly different from zero, based upon the available information H_0 can be rejected at a chosen significance level and the presence of a monotonic trend, H_1, can be accepted.

A problem, which can arise when using the Mann-Kendall trend test, is how to summarize information when there are several values for a given year. Van Belle and Hughes, (1984) suggest four possible approaches for accomplishing this. A simple procedure, for example is to simply replace the set of values by the median or mean before calculating the test statistic. An alternative to calculating a mean or median within a given year, is to consider these values as tied in the time index and then to compute the test statistic along with a modified variance. Van Bell and Hughes (1984) present the formulae for carrying this out. The exact distribution of S for n≥10 was derived by both Mann (1945) and Kendall (1975), They showed that even for small values of n, the normality approximation is good provided one employs the standard normal variate Z given by

$$z' = \begin{cases} (S'-1)/\sigma_{s'} & S'>0 \\ 0 & S'=0 \\ (S'+1)/\sigma_{s'} & S'<0 \end{cases} \qquad \textbf{2.16}$$

The seasonal Kendall analysis works as follows; the data are first blocked by some time division so that values from different time divisions will not be compared. This blocking prevents the seasonality of the data from invoking a trend and reduces variability when there is a seasonal effect. Often months are used as blocks. Within each season k, a Mann-Kendall statistic, S_i, and its variance are computed. The trend hypothesis is then tested by invoking a fairly good normality approximation to the distribution of the standardized test statistic (Mann 1945 and Hirsch et al, 1982). Another good quality of this test is that missing values do not invalidate the test as long as the pattern of missing values is random. Two important values related to the statistic S are the non-parametric correlation coefficients: Kendall's tau and modified Kendall's tau.

The other way to use the Mann-Kendall test for trend with seasonality is to first adjust for seasonality, i.e. deseasonalize the data, and then perform the Mann-Kendall test on the resulting time series. Deseasonalization is accomplished by subtracting seasonal means or medians from all the observations in that season and also, sometimes, dividing by seasonal standard deviations (Hirsch et al, 1982). This method has a tendency to be liberal for small samples because of negative correlation added to the data by deseasonalization (Harcum et al, 1992). It is also not easy adjusted to handle serial correlation as is the blocking-on-seasons approach. In power studies with independent seasons, the seasonal Kendall analysis has been shown to be a powerful choice for a general procedure when overall monotonic trend is of interest (Hirsch et al., 1982, Harcum et al., 1992, Loftis et al., 1989, Taylor and Loftis, 1989). However, when the seasons are not independent, this method does not maintain appropriate alpha levels.

The covariance sum test (Hirsch and Slack, 1984), covariance inversion test (Dietz and Kileen, 1981), and the covariance eigen value test (Lettenmaier 1988) all takes this dependence into account. The covariance sum test is the most powerful of these for overall monotonic trend when analyzing a single variable (Hirsch and Slack 1984, Lettenmaier, 1988, Thas et al., 1998). Unfortunately, when the observations are in fact independent and especially for small sample sizes (e.g. ten years or less of data), it is much less powerful than the seasonal Kendall method described above which assumes independence (Loftis et al, 1991). The covariance inversion test and the covariance Eigen value test are capable of detecting trends that have varying signs among seasons with the covariance Eigen value being the more powerful of the two (Lettenmaier,1988). All three of these methods have low power with small sample sizes (Hirsch and Slack 1984, Taylor and Loftis 1989, Loftis et al., 1991, and Harcum et al., 1992).

The covariance sum, inversion, and eigen value tests can also be applied in a multivariate manner (Smith et al., 1993, and Dietz and Killeen, 1981). Thus, a multivariate trend could be detected that would not be detected by looking at any one of the individual variables in a univariate manner. The statistic based on the covariance sum test is asymptotically chi-squared. Approximate p-values can be obtained for the covariance inversion and eigen value tests via a three parameter gamma distribution (Rheem, 1992). An alternative to using Kendall's tau based tests for trend is the use of Spearman's rho as a basis for tests. Alvo and Cabilio, (1994) give a method for using Spearman's rho to test for trend that allows missing observation from a regularly sampled time series with independent observations. In Alvo and Cabilio (1995), they extended their ideas to Kendall's tau, however, they again require observations that are missing randomly from a regularly sampled time series and that the observations be independent.

2.5. Detection Limits

Hirsch et al., (1982) and Gilliom, et al., (1984) suggested treating as tied all the observations smaller than the largest reported lower detection limit. This is consistent with "Kendall's tau, Breslow-type" (Brown et al., 1974) from survival analysis. Hughes and Millard (1988) give a method for dealing with detection limits that does not throw out as much information and has better power properties. They compute an "expected rank vector" by averaging the ranks for each observation from all possible rankings consistent with the observed data. Lower detection limits are considered to be upper ends of the intervals which could possibly contain the true data values. They then use these ranks to compute the Mann-Kendall statistic as described above. A problem is that these types of conditional statistics no longer have the same null distribution as the standard case. With Hughes and Millard's method, the new statistic has less variability. A further complication is that their method of obtaining an approximate normal test requires that the pattern of censoring be random. This is unlikely to be the case. When the censoring mechanism is dependent on time, the null distribution for the test statistic must be estimated by generating random permutations of the expected rank vector, storing the value of the statistic computed from that configuration of ranks if it agrees with the censoring pattern, and repeating a large number of times to estimate the null distribution. This quickly develops in computational difficulty. One final problem with this method is the unlikely assumption that all possible rankings are equally likely. Another method for dealing with censored data is Tobit regression (Judge et al., 1985 and Helsel and Hirsch, 1992). This is a maximum likelihood parametric method and requires the assumption that the dependent variable is normally distributed. Thus, it is not an ideal method for water-quality data. Tobit estimates are slightly biased so bias corrections should be used (Cohn 1988). With normal data, this method can be used to estimate and test a linear trend. Perhaps some modification can be made to Tobit regression to make it more applicable in the data context.

2.6. The Multiple-Observation-Problem

All the non-parametric methods for trend analysis named above in the preceding sections require one observation per season in every year. This is not always the case when there are no observations in a particular season within a given year; the above methods are all still valid assuming that values are missing randomly. Another problem occurs when a season within a year has multiple observations. In this case, Helsel and Hirsch (1992) suggested taking the median of the observations within the same season when the variations in the sampling frequency are random and sub-sampling by using the value closest to the centre of the season when there is a systematic trend in the sampling frequency. They recommended sub-sampling in the latter case because using the median would induce a trend in the variance. Using the median can also induce a trend in the data if many values are lower detection limited. This recommendation was verified by a Monte Carlo study performed by Darken (1998).

Other possible solutions to the multiple-observations-per-season problem exist:

(i) Using a mean,

(ii) Treating observations in the same season and month as tied in time with an adjustment to the variance formula (van Belle and Hughes, 1984, Gilbert, 1987),

(iii) Expanding the time variable to include days so as to eliminate ties in time.

(iv) Using a weighted median, the mean is inferior to the median because of skew and detection limits.

Using all the original data weights years with more observations more heavily and values within the same season in the same year are quite likely to be highly correlated. Because these observations are assumed to be independent for the adjustment to the variance and the hypothesis test, implementing (ii) is a bad idea. The use of a weighted median seems like a compromise between using the value closest to the centre and using the median, but it is probably unnecessarily complicated. In the simulation study of Darken (1998), using a Gaussian kernel for the

weights, the weighted median was better at maintaining alpha(α) levels than the median but not as good as the sub-sampling method. The weighted median solution was generally more powerful than the sub-sampling method but less powerful than using the median. So, the weighted median was in fact a compromise between the uses of the median and the sub-sampling method, but for optimal results, it appeared that the extreme cases of the weighted median were needed. Namely, with a systematic variation in the sampling frequency, the weighted median that assigns all the weight to the value closest to the centre appeared to be

best, while with random variation in the sampling frequency, the weighted median with uniform weights performed best, (Darken 1998). An interesting side note from this Monte Carlo study was that even under extremely mild levels of serial correlation, like 0.05 for observations one month apart, when months were used as seasons, the seasonal Kendall analysis assuming independence did not maintain appropriate alpha (α) levels. This justifies the need for tests that allow dependence between seasons.

2.7. Testing Homogeneity of Trend and Median Levels between Seasons

To test for homogeneity of trend between seasons, van Belle and Hughes (1984) gave a method that requires seasons to be independent. Letting m be equal to the number of seasons, an approximately chi-squared statistic with m degrees of freedom is decomposed into a one degree of freedom overall-trend component and an m-1 degree of freedom remainder. This remainder is used to test the hypothesis that the trend is homogeneous across seasons. Smith et al., (1993) extended this test to allow dependent seasons by using the covariance matrix of the test statistics from the different seasons. Testing for homogeneity of median levels between seasons is not as easy as it sounds. To test this hypothesis, years need to be blocks to eliminate the effect of an overall trend. This suggests the use of a non-parametric ANOVA-like analysis, specifically, Friedman's test (Friedman, 1937). Even with independence, however, Friedman's test cannot be used with missing values. Although several ad-hoc solutions come to mind, the missing-value-problem with Friedman's test has not been solved because of the countless ways to assign ranks to missing values and the lack of a good method for concluding, which is best. If season effects can be ordered in the alternative hypothesis, then Alvo and Cabilio (1995) give a method to handle missing values that outperforms, simply ignoring blocks (years) with missing values. However, their method still requires independent errors. In reality, seasons are likely to be dependent, so the problem becomes more difficult.

A new idea of how to approach this problem is to analyze the problem as repeated measures in a split-plot design; year would be the whole plot treatment while season would be the split-plot treatment. Due to the typical nature of the data, a non-parametric analysis should probably be used. Older non-parametric methods do not seem optimal. Some of these methods are based on reducing the longitudinal part (the observations within each given year in the set up here) to one or two numbers. Ghosh et al., (1973) fit polynomials to the longitudinal part of the data and used those parameter estimates as the raw data for performing a non-parametric analysis. This is really a semi-non-parametric method and might be hard to implement in the context because of the dependence between observations one season apart and the detection limits. Perhaps a sinusoid would work better then a polynomial in this context. With some sort of robust fit, this is one possible solution. Other methods, like those presented in Koch (1970), would not work without replication which generally does not exist in the water-quality data context. Replication is necessary to estimate the covariance matrix. Koch's methods were called non-parametric because the analysis is performed on rank transformed data. More recent ideas are not ideal either. Agresti and Pendergast (1986) gave a method that requires compound symmetry, an assumption that does hold in the water-quality data context. Possibly the best methods currently available are those given in Akritas and Arnold (1994) which are based on performing rank transformations to the data. Even in this context, the issues created by missing values and censoring still need to be dealt with. Currently, an optimal method has not been found.

2.8 THE SEASONAL KENDALL SLOPE ESTIMATOR

In addition to identifying time series that exhibit trend, it may be desirable for some applications to estimate the magnitude of such a trend. We have chosen to express this magnitude as a slope (change per unit time), but this does not imply any belief that the trend takes the form of linear trend in the process mean. In an overview of many stations, one may wish to identify those stations for which trend slope is large with respect to mean value. One may also want to identify those stations where extrapolation of an existing trend would suggest that frequent violations of some relevant water quality criterion might occur in the near future. The estimator we defined is an extension (to account for seasonality) of one proposed by Sen (1968).

We define the seasonal Kendall slope estimator B by the following computational algorithm. Compute $d_{ijk} = (x_{ij}-x_{ik})/(j-k)$ for all (x_{ij}, x_{ik}) pairs i=1, 2, ...,1 2; $1\leq k< j\leq n_i$. The slope estimator B is the median of these d_{ijk} values. The estimator is related to the seasonal Kendall test statistic S' such that if $S'>0$, then $B\geq 0$ ($B>0$ if one or no $d_{ijk}=0$), and if $S'<0$, then $B\leq 0$ ($B<0$ if one or no $d_{ijk}=0$). This is because S' is equivalent to the number of positive d_{ijk}'s minus number of negative dijk's and B is the median of these d_{ijk}'s .By using the median of these individual slope d_{ijk} values, the estimate B is quite resistant to the effect of extreme values in the data. It is also unaffected by seasonality because the slope are always computed between values that are multiples of 12 months apart.

CHAPTER THREE

3.0 MATERIALS AND METHODS

To carry out this proposed trend analysis, data would be needed and specific procedures would be followed. This chapter spells out the kind of data used in testing for trend in the specified Hydroclimatic variables and the methods/approach used in detecting the presence and magnitude of it.

3.1 MATERIALS

3.1.1 Study Location

For this study, Hydroclimatic data were collected from Kaduna. Kaduna state is located on the southern end of the high plains of northern Nigeria, bounded by parallels 9^0 03' N and 11^0 32' N, and extends from the upper River Mariga on 6^0 05' E to 8^0 48' E on the foot slopes of the scrap of jos plateau. Stream valley incisions and dissections of the high plains are evident in several areas, especially in the Zaria region; they are due more to anthropogenic influences and climatic factors than regional geologic instability. The state experiences a typical tropical continental climate with distinct seasonal regimes, oscillating between cool to hot dry and humid to wet. These two seasons reflect the influence of tropical continental and equatorial maritime air masses which sweep over the entire country. However, in Kaduna state, the seasonality is pronounced with the cool to hot dry season being longer, than the rainy season. Again, the spatial and temporal distribution of rain varies, decreasing from an average of about 1530mm in Kafanchan and Kagoro areas in the southeast to about 1015mm in Ikaramakarfi districts in the northeast. High storm intensities (ranging from 60mm hr 1 to 99mm hr 1) plus the nature of surface runoff build up the good network of medium sized river systems. High Evaporation during the season, however, creates water shortage problems especially in Igabi, Giwa, Soba, Makarfi and Ikara LGAs.

3.1.2 Data used

Hydroclimatic characteristic (i.e. rainfall in mm, evaporation in mm, stream flow in m^3/s, and temperature in °C) Data of 26 years were collected for this study.

3.2 METHODS

A non-parametric procedure was used to test for the presence of trend in the data collected; prior to the analysis, the entire data was pre-whitened to eliminate the seasonality implications and then followed by the adoption of Mann-Kendall and Mann-Kendall slope estimator for the tests.

3.2.1 Data preparation

The data used for this analysis were not the raw data collected from the study location because of the messy nature of it, because of this the data was processed by pre-whitening hereby removing the impact of serial correlation from the series through $m_i = x_i - \phi x_{i-1}$ (Wang et al., 2005, Otache, 2008), where m_i is the pre-whitened series value, x_i is the original series value, and ϕ is the estimated lag 1 serial correlation.

For serial autocorrelation (ϕ)s

ϕ (i) =C (k) / C (0)

where

$$C(K) = \frac{1}{n}\sum_{i=1}^{n-k}(x_i - \overline{mean})(x_{(i-k)} - \overline{mean}) \qquad 3.10$$

and k = 0, 1, 2. . . k

3.2.2 Mann-Kendall Trend Test (S)

$$S_i = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn\left(x_{ji} - x_{ki}\right) \qquad 3.11$$

where **n**= number of years, **i**= number of season

$$sgn(x) = \begin{cases} 1 & x > 0 \\ 0 & x = 0 \\ -1 & x < 0 \end{cases}$$

$E(S) = 0$

$$Var(S) = \frac{1}{8}\left[n(n-1)(2n+5) - \sum_{i=1}^{m} t_i\,(t_i - 1)(2t_i + 5)\right] \qquad 3.12$$

The parameters are defined according as;

S: This parameter is called the Mann Kendall slope statistic, the mean value of this parameter E(S) = 0, when a positive value is gotten, the trend is said to be positive and when a negative value is gotten then the trend is said to be negative

n: Number of years

i: Number of season

x_i: are data's collected for analysis

Var(S): This is the variance of S

Z: Standard normal variant

Using the equations above, all hydroclimatic components under study was tested for seasonal trend (monthly) and annually trend (yearly) except for the stream flow component, which was tested for daily trend because of the availability of daily data set.

3.2.3 Mann-Kendall slope estimator (*B*)

In addition to identifying time series that exhibit trend, it may be desirable for some applications to estimate the magnitude of such trend.

$$d_{ijk} = \frac{x_{ij} - x_{ik}}{j - k} \qquad 3..13$$

where d_{ijk} is the various slope for the individual season; daily, seasonal or annually, i is the number of seasons, x_{ij} and x_{ik} are the set of data to be analysed, where $1 < j < k \leq n_i$. The Mann-Kendall slope estimator (B) is the median of all the slopes calculated, which is used to estimate the magnitude of the trend detected whether positive or negative. Using the equation 2.19, does not imply any belief that the trend took the form of a linear trend in the process. By using the median of these individual slope d_{ijk} values, the estimated B is quite resistance to the effect of extreme values in the data. It was also unaffected by seasonality because the slopes were always computed between values that are multiple of 12 months apart.Using a visual basic computer program, the various slopes were computed and the aggregate Kendall slope estimated by estimating the median of the various slopes.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 RESULTS

Based on the analysis done, the results of each test are presented in Table 4.1 through to table 4.8. In this regard, this chapter details the results and explanation or discussion of same. This is done to bring to the fore the salient issues as itemized in the objectives.

Table 4.1 Mann-Kendall tests for Annual Series

Hydro-climatic component	Statistics				
	τ	Z	S	p Value	Trend/significance
Evaporation	0.34	2.21	108.00	0.0271	+s (*)
Stream flow	-0.02	-0.13	-7.00	0.8966	-s (-)
Temperature	0.78	5.32	251.00	< 0.0001	+s (**)
Rainfall	-0.14	-0.97	-45.00	0.3320	-s (-)

+s – positive trend, -s – negative trend, (-) – no trend, (*) – 95% significance level, (**) – 99% significance level

Table 4.2 Mann-Kendall test for Seasonal Evaporation at Kaduna

Variable	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
S	-63.00	-53.00	8.00	98	101.00	128.00	122.00	20.00	36.00	-23.00	-4.00	-42.0
τ	-0.19	-0.16	0.02	0.30	0.31	0.39	0.38	0.06	0.11	-0.07	-0.01	-0.13
Z	-1.37	-1.15	0.15	1.96	2.20	2.80	2.67	0.42	0.77	-0.48	-0.07	-0.90
P Value	0.1707	0.2501	0.8808	0.05	0.0278	0.0051	0.0076	0.6745	0.4413	0.6312	0.9442	0.368
Trend/ significance	-s (-)	-s (-)	+s (-)	+s (-)	+s (*)	+s (**)	+s (**)	+s (-)	+s (-)	-s (-)	-s (-)	-s (-)

+s – positive trend, -s – negative trend, (-) – no trend, (*) – 95% significance level, (**) – 99% significance level

Table 4.3 Mann-Kendall test for Seasonal Rainfall at Kaduna

Variable	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
S	0.00	-30.00	-20.00	73.00	-6.00	95.00	55.00	29.00	29.00	-27.00	-95.00	14.00
τ	0.00	-0.09	-0.06	0.22	-0.02	0.29	0.17	0.09	0.09	-0.08	-0.29	0.04
Z	0.00	-0.64	-0.42	1.59	-0.11	2.07	1.19	0.62	0.62	-0.57	-2.07	0.29
P Value	1.0000	-0.64	0.6745	0.1118	0.9124	0.0385	0.2340	0.5353	0.5353	0.5687	0.0385	0.7718
Trend/ significance	-	-s (-)	+s (-)	+s (-)	-s (-)	+s (*)	+s (-)	+s (-)	+s (-)	-s (-)	-s (*)	-s (-)

+s – positive trend, -s – negative trend, (-) – no trend, (*) – 95% significance level, (**) – 99% significance level

Table 4.4 Mann-Kendall test for Seasonal Temperature at Kaduna

Variable	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
S	81.00	148.00	121.00	135.00	91.00	85.00	-52.00	173.00	133.00	111.00	170.00	126
τ	0.25	0.46	0.37	0.42	0.28	0.26	-0.16	-0.53	-0.41	0.34	0.52	0.3
Z	1.76	3.24	2.64	2.95	1.98	1.85	-1.12	-3.79	-2.91	2.42	3.73	2.7
P Value	0.0784	0.0012	0.0083	0.0032	0.0477	0.0643	0.2627	0.0002	0.0036	0.0155	0.0002	0.0
Trend/ significance	+s (-)	+s (**)	+s (**)	+s (**)	+s (*)	+s (-)	-s (-)	-s (**)	-s (**)	+s (*)	+s (**)	+s

+s – positive trend, -s – negative trend, (-) – no trend, (*) – 95% significance level, (**) – 99% significance level

Table 4.5 Mann-Kendall test for Seasonal Streamflow at Kaduna River

Variable	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
S	-65.00	-42.00	43.00	-14.00	5.00	44.00	66.00	32.00	-1.00	91.00	55.00	54.0
τ	-0.20	-0.13	0.13	-0.04	0.02	0.14	0.20	0.10	0.00	0.28	0.17	0.17
Z	-1.41	-0.90	0.93	-0.29	0.09	0.95	1.43	0.68	0.00	1.98	1.19	1.17
P Value	0.1585	0.3681	0.3524	0.7718	0.9283	0.3421	0.1527	0.4965	1.0000	0.0477	0.2340	0.24
Trend/ significance	-s (-)	-s (-)	+s (-)	-s (-)	+s (-)	+s (-)	+s (-)	+s (-)	-	+s (*)	+s (-)	+s (

+s – positive trend, -s – negative trend, (-) – no trend, (*) – 95% significance level, (**) – 99% significance level

Table 4.6 Mann-Kendall test for Daily Streamflow at Kaduna River

Hydro-climatic component	τ	Z	S	P value	Trend/significance
Stream flow	0.02	2.53	778736.00	0.0114	+s (*)

+s – positive trend, -s – negative trend, (-) – no trend, (*) – 95% significance level, (**) – 99% significance level

Table 4.7 Slope Estimates for Annual Series

Hydro-climatic component	Series (Estimated slopes)		
	Annual series	Monthly series	Daily series
Evaporation	1.34	0.08	-
Rainfall	-0.17	-0.02	-
Stream flow	-0.22	-0.01	-0.01
Temperature	3.58	0.37	-

Table 4.8 Pearson Correlation test

Correlations variables		Rainfall	Evaporation	Temperature
Evaporation	Pearson Correlation	0.531**		
	Sig. (2-tailed)	0.005		
Temperature	Pearson Correlation	0.515**	0.663**	
	Sig. (2-tailed)	0.007	0.000	
Stream Flow	Pearson Correlation	0.934**	0.470*	0.486*
	Sig. (2-tailed)	0.000	0.015	0.012

*****Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).***

4.1.1 Graphical representation of data's

Presented below are graphs which show the physical implication of the data presented above.

4.1.2 Graphical representation of decadal segment (monthly series)

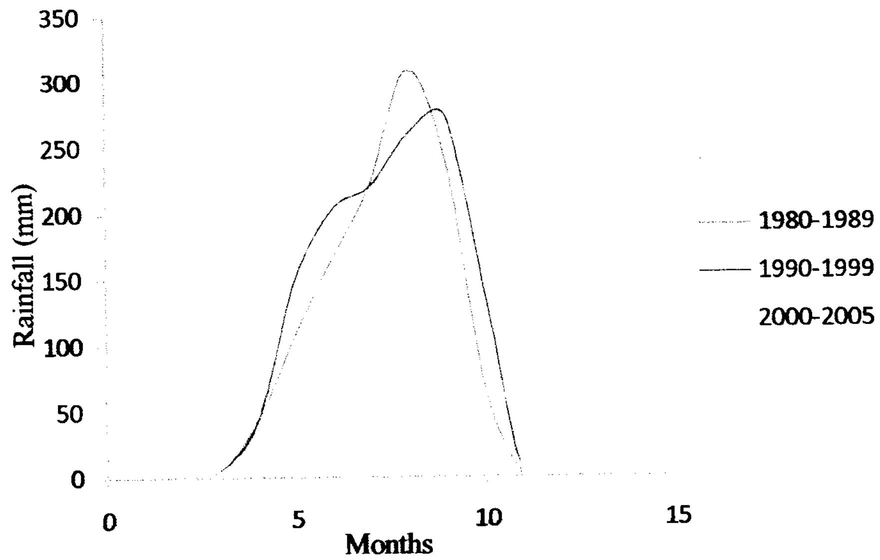

Fig 4.1 Decadal Segmentation of Rainfall Variable (Monthly Series)

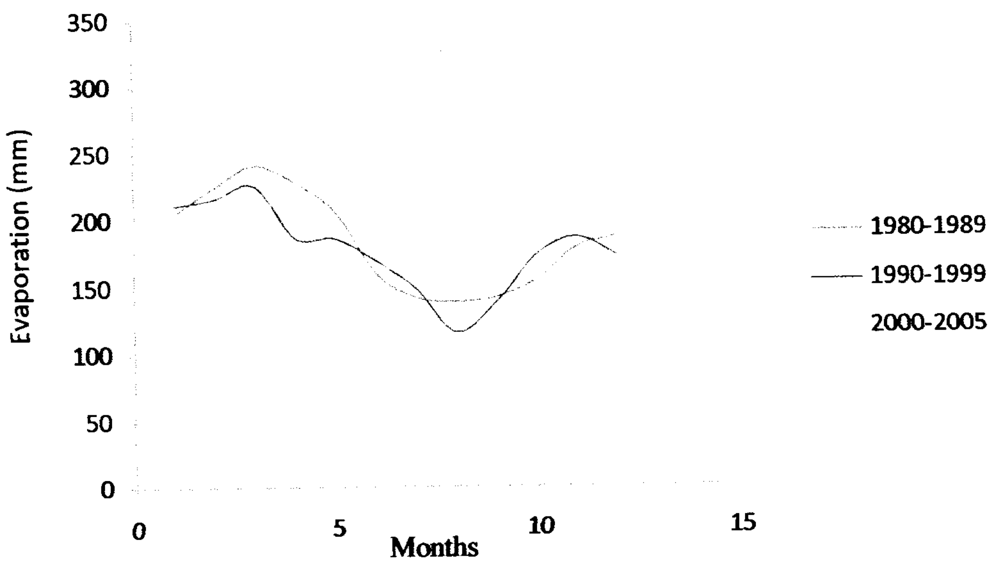

Fig 4.2 Decadal Segmentation of Evaporation Variable (Monthly Series)

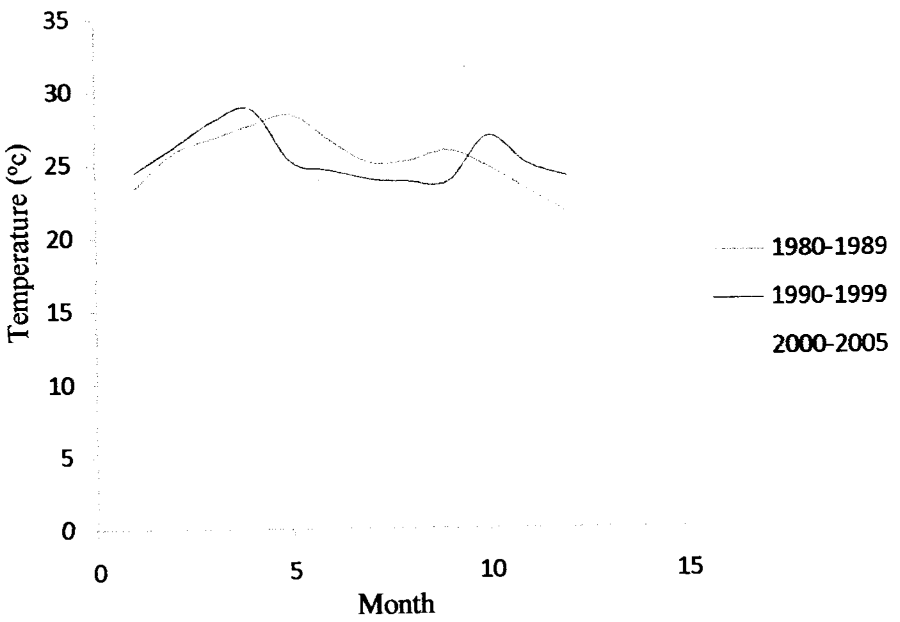

Fig 4.3 **Decadal Segmentation of Temperature Variable (Monthly Series)**

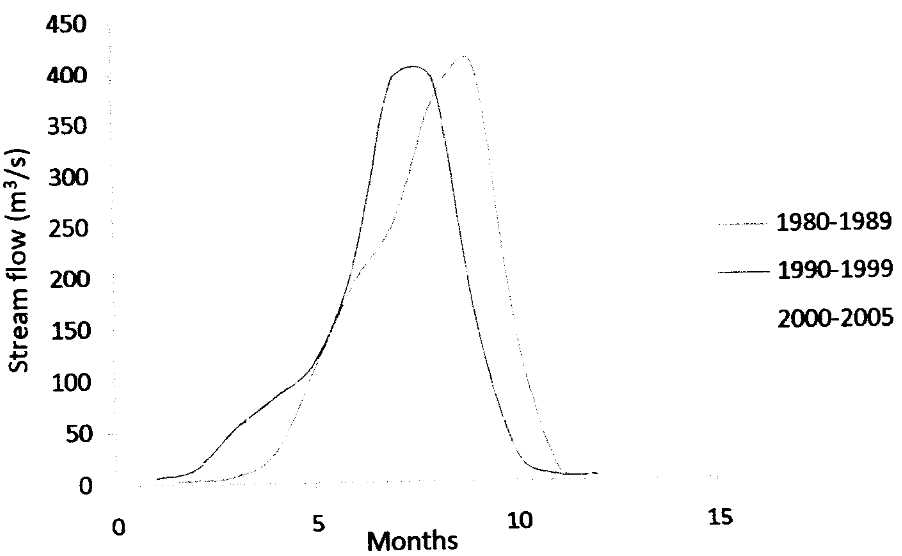

Fig 4.4 **Decadal Segmentation of Streamflow Variable (Monthly Series)**

4.1.3 Graphical representation of decadal segment (Annual series)

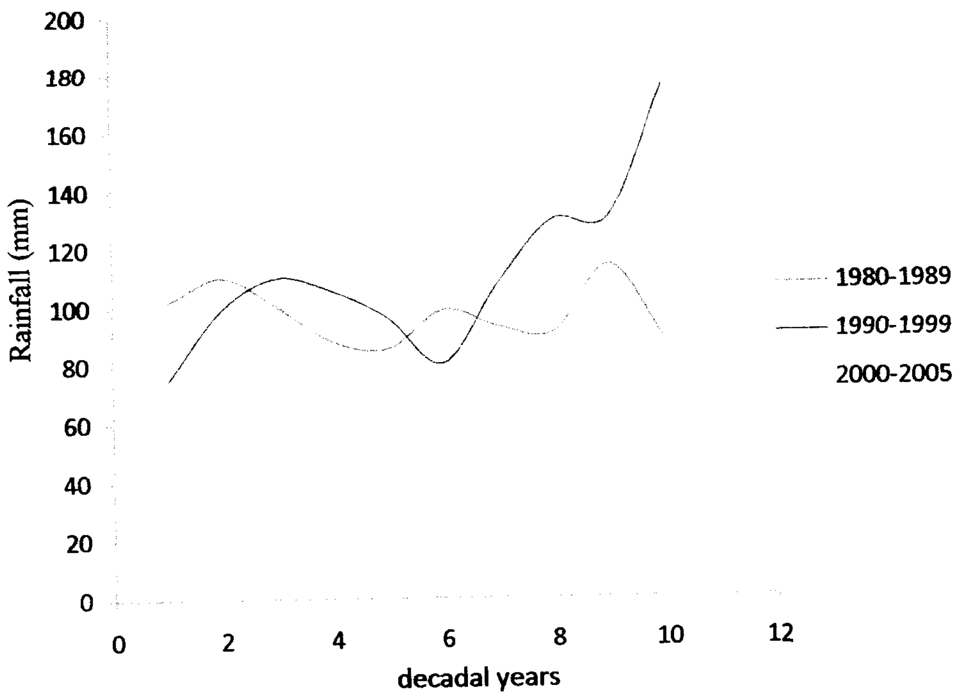

Fig 4.5 Decadal Segmentation of Rainfall Variable (Annual Series)

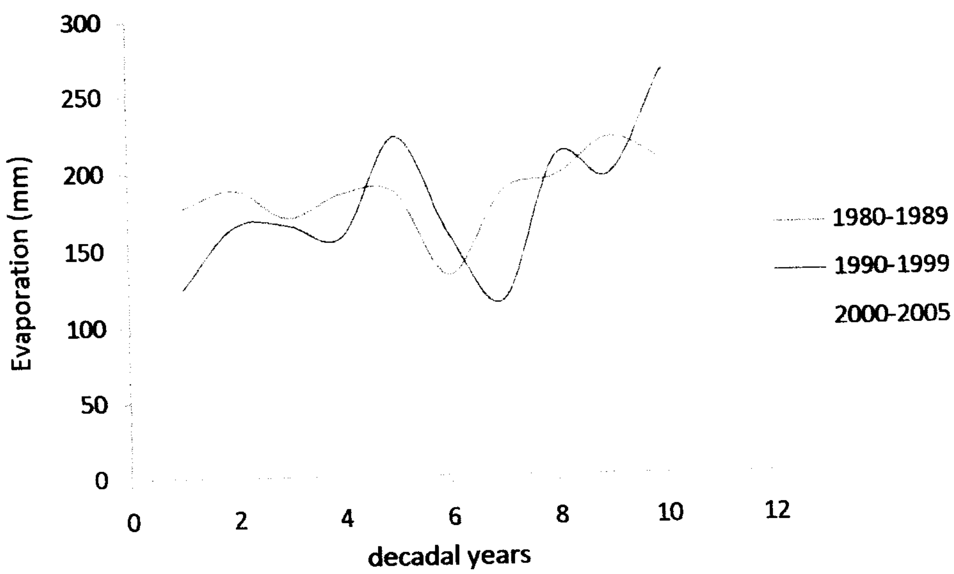

Fig 4.6 Decadal Segmentation of Evaporation Variable (Annual Series)

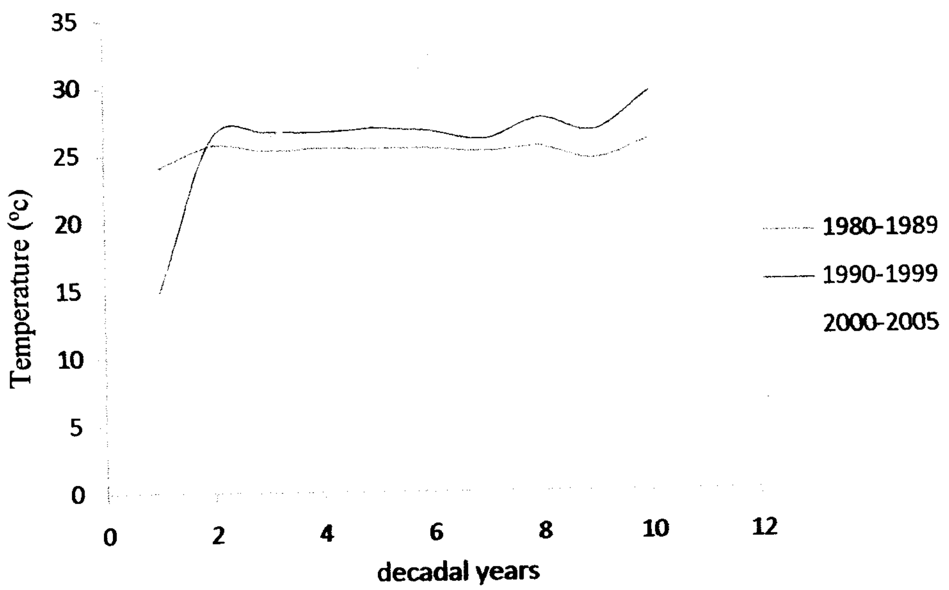

Fig 4.7 **Decadal Segmentation of Temperature Variable (Annual Series)**

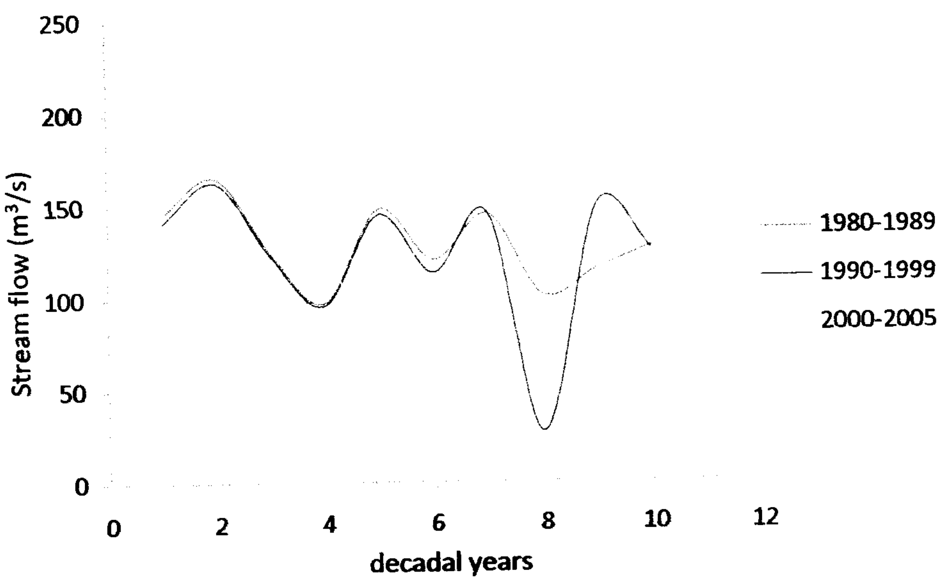

Fig 4.8 **Decadal Segmentation of Streamflow Variable (Annual series)**

4.2 DISCUSSION OF RESULTS

Result of the Mann-Kendall trend test are as presented in Table 4.1 - 4.7 and the Pearson correlation test in Table 4.8 for the Hydroclimatic variables (i.e. rainfall, evaporation, temperature and streamflow) considered.

Having in mind that, a positive S value indicate an upward trend (increasing value with time) and a negative value of S indicates a downward trend and also that the test statistic Z follows a normal distribution which values were tested at 95% ($Z_{0.025}$±1.96) and ($Z_{0.001}$±2.58) level of significance. The trend is said to be decreasing if Z is negative and the absolute value is greater than the level of significance, while it is increasing if Z is positive and greater than the level of significance. If the absolute value of Z is less than the level of significance, there is no trend (Khambhammettu et al., 2005). The analysis of the annual series reveals a significant positive trend in temperature over the 26 years period. The temperature trend is significant over 95 and 99% level of significance, thus indicating a significant rise in temperature, the Mann-Kendall statistic S=251, Mann-Kendall slope estimate B=5.48 and Z value of 5.32 shows that the trend is highly significant. A Mann-Kendall statistic S of 108 and a positive Mann-Kendall slope estimate accompanied by a positive Z value of 2.21 also showed that evaporation around Kaduna has been in a significant positive trend over the 26 years period analysed. The rainfall has been in a downward trend for the 26 years of available data analysed. However a Z value of -0.97 indicates that the trend though negative is not significant at the 95 and 99% level of significance, also the analysis of the stream-flow at revealed a non-significant decrease in the stream-flow trend at Kaduna with a Mann-Kendall statistic S=-7.00 and Z value of -0.13.

With this variables having a high level of relationship, increase in temperature and evaporation might be having effect on the rainfall and stream-flow, however the effect is not significant. A review of a work by Salami et al., (2010) on the impact of climate change on water resources reveals that there is tendency for high increase in evaporation, temperature and sunshine hour while there is no much/no change in rainfall.

The analysis of the monthly series for trend on various hydro-climatic variables brings to the fore that some month has positive trend and some months has negative trend on different level of significance. April, May, June, July, August and September shows a positive trend, while January, February, March, October, November and December shows a negative trend in evaporation, but only May, June and July are of significance. Analyzing the rainfall variable for trend on the monthly series, February, March, May, October and November shows a negative trend while April, June, July, August and September shows a positive trend although significant trend was only noticed in the month of June and November and no trend at all in January because no rainfall was recorded for January during the 26 years period analysed. Most of the months indicate the presence of positive and some indicate negative trend when the temperature variable was analysed, most of the trend detected were of high significance at both 95 and 99% level of significance except for January, June and July. Most of the monthly trends detected on the hydro-climatic variable (stream flow) are of no significance except for the trend detected on the month of October, which is only significant on the 95% level of significance, January, February and April indicate a negative trend, while March, May, June through to December indicate a positive trend. All the spatial distribution in trend in the monthly series can be attributed to the effect of the climate change phenomenon, which played a major role in the fast changing trends of hydro-climatic variables. The analysis of the daily series of the stream flow variable reveals that like the annual series the daily series of the stream flow indicate a decreasing/downward trend, though not significant. To show a clearer picture of the behavioral trend of these Hydroclimatic variables, figure 4.1 to 4.4 shows a graph of the average values of the variables plotted against the months, in a decadal segment. While figure 4.5 to 4.8 shows the graph of the average values of the variables plotted against the various years

From the result presented and explain above, the effect of climate change cannot be left out as the cause of the rapid or increasing trend in temperature over the years, this effect on temperature has significantly affected the rainfall, and this is made more visible in the Pearson correlation test, which shows the significance in relationship of the various Hydroclimatic variable tested.

These results shows that the increased in temperature caused by the phenomenal "Climate change" has had an adverse effect on the rainfall and same on evaporation, which in one way or the other has affected the stream flow over time, even though the test show that it not of significance.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

After careful trend analysis of the streamflow, rainfall, temperature and evaporation, the following conclusions are deduced namely:-

1. There were presence of trend on all the variable analysed, though at different level of significance, temperature and evaporation showed trend of high significance while the other (rainfall and stream flow) even though the presence of trend was detected, was seemingly insignificant
2. In addition, it could be strongly asserted that testing daily series for trend would not produce a significant result; as the time scale increases, i.e., monthly and annual presence of trend was strongly noticeable.
3. The increasing trend on the temperature caused by the phenomenal climate change has a significant effect on the other hydroclimatic variables tested.

5.2 RECOMMENDATIONS

The act of determining the nature of the trend in any natural occurring process helps in better planning and management of agricultural, Industrial and water resource planning, etc. Based on the findings of the study it is recommended that:

- Trend testing should be carried out on other hydroclimatic process that might be of greater relevance, such as; relative humidity, runoff, solar radiation, etc., because of the inter play of these characteristics both in time and space.
- For objective conclusion to be drawn, substantial and continuous length of data should be used. Because of the implications of seasonality, for any trend analysis, data pre-processing should be carried out to eliminate the associated serial dependence and volatility of the data series.

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