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# Drought Trends in Areas Above Latitude $8^0$ N of Nigeria

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**Abstract**
This study is on the trends and decadal analyses of drought characteristics in areas above latitude $8^0$ N of Nigeria. Analysing tools such as Von Neumann ratio, Cramer $t_k$ test, Students t-test and Mann-kendall rank statistics were used to identify the drought characteristics between 1941 and 2010. This is with the aim of making recommendations in order to minimise the adverse effects of those characteristics on the populace, community and environment. Results showed that the area is witnessing increase in drought occurrence trend. Apart from this other findings were discussed in this study.
**Keywords:** Decadal, Drought, Latitude, Randomness and Trend.

## 1.Introduction

Drought occurrences and reoccurrences have been reported in Nigeria for decades (Abaje *et al*, 2011; Aremu, 2011; Oladipo, 1993; Ayoade, 1988; Adefolalu, 1986; James, 1973; Mortimore, 1973). However of recent, the occurrences have increased, while gradually the occurrences have spread southward especially to the Sudan zone of Nigeria. At the sametime it seems the severity of drought in the Sahel zone has increased (Abaje et al, 2011; Olatunde, 2011a&b; Oladipo, 1993). This means drought occurrence is a constant hazard and reality for people in this area. Therefore, there is the need to constantly look into its characteristics overtime. The essence of this study therefore is to look at the trend of drought over the recent years (1941 to 2010) and suggest appropriate measures to curtail its effects.

The study area is located north of latitude $8^0$ of the equator (Olaniran, 1987) (Fig 1) The Tropical Hinterland climate dominates in the Sudan zone, while Tropical Continental climate prevail in the Sahel zone of the study area. The vegetation of the study area has been grouped into the Sudan Savanna and Sahel Savanna (Olaniran, 1987). Occupations of the people of the study area apart from agricultural activities include fishing, mining, leather works, pottery works, brass and silver works. Other people work in offices, industries and in the informal sector of the economy like driving and trading.

## 2.Methodology

This study is based on the drought series for the period 1941-2010 at eight stations (Fig.1) which have rainfall data for upwards of seventy (70) years. The drought series were derived using Bhamle and Mooley drought index (Bhalme and Mooley,1980). These stations are located north of latitude $8^0$ (Fig.1). The data used were sourced from Nigerian Meteorological Agency (NIMET). The following statistical tools; Von Neumann ratio, Mann-Kendall rank statistic, the students' t-test were used in the analyses for trends. The Cramer $t_k$ for decade was also used.

The Von Neumann ratio for trend against randomness in the series was computed for the stations as follows:

$V= (N/N-1)\{ \sum \mathbf{[X – X + 1]^2} \} / \{\sum Xi^2 – [1/N] ( \sum Xi^2)\}$ ..................................(1)

Where:

Xi = the seasonal drought index.

The value of V is compared with a test statistic (v)t, equal to

$(V)t = (2N\text{-}2tg(N\text{-}2)^{1/2} ) / ( N\text{-}1)$ ...........................................................................(2)

Where tg is defined as 1.65 for one tailed test at the 0.95 confidence level. If V is greater than (V)t we accept the null hypotheses that the time series is random. If V is less than (V) t, we conclude that a source of non-random variance exists in the data (Mitchell *et al*, 1966).

Because it is considered that the most likely alternative to randomness is some form of trend (linear or non linear), we used the Mann-Kendall rank statistic to test for trend and are computed as:

$R= \{4(\sum ni) / N (N\text{-}1)\} – 1$ ...............................................................................(3)

Where:

Ni = represents the number of subsequent values (from Xi + 1 to XN) in the time series that exceed Xi.

N = the number of values in the series.
Its test statistic is equal to:
$(r)t = 0 \pm tg[( 4N + 10) / 9N ( N-1)]^{1/2}$ ..............................................................(4)
Where tg is the two- tailed probability of the Gaussian distribution, equal to 1.96 at the 95% confidence level. If R lies outside the bounds of (r)t, we may conclude that some form of trend exists in the data ( Kendall and Stuart, 1966).
The students't –test was also used to determine if the sub-period means of the drought index series have shown significant changes through time. The td statistic is given as:
$td =( X_1-X_2) / ( [ N_1S_22 + N_1S_2^2] / [N_1 + N_2 -2]) .( [1/ N_1] + [1/N_2])^{½}$ ................(5)
With $N_1 + N_{2-2 \text{ degree}}$ of freedom.
Where:
$(X_1 - X_2)$ represents the differences in group means
$N_1$ and $N_2$ are the number cases in the sub samples.
Thus, when td is outside the bounds of the two-tailed values of tg, a significant shift in the mean is assumed.
The Cramer $t_k$ test (Mitchell *et al,* 1966) was also used. It was used to compare the mean of the sub periods with the mean of the whole period. In this test, the mean (X) and the standard deviations (S) were calculated for each station for the total numbers of years (N) under investigation. The purpose of the test was to measure the difference in terms of a moving t –statistic between the mean, XK for each successive n-year period and the mean X for the entire period. This statistic is computed as follows:
$t_k = \{n(N-2) /N-n(1+ Lk^2) Lk$ .........................................................................(6)
Where Lk is a standardized measure of the difference between means given as
$\frac{( XK – X )}{S}$ ..................................................................................................(7)
S is the standard deviation of the entire series. The $t_k$ values were computed and tested against the t – distribution table with N-2 degree of freedom. When $t_k$ falls outside the t – distribution table at 0.95 confidence level appropriate to a two – tailed form of test, it is accepted that the difference between the over all mean and the mean of certain parts of the records are significant.

## 3.Results and Discussion

The Von Neumann ratio (ratio of the mean square successive difference to the variance) was used to test for randomness. In analysing the data (Table 1.) it was found that the values of V, when compared to the test statistic (V)t at 0.95 confidence level were greater for Bauchi, Bida, Kaduna, Kano and Sokoto. Maiduguri, Nguru and Katsina had values of V that were lesser than their test statistics (Table 1). Therefore, it can be suggested that a source of random variance exist in the first (5) five stations except for Maiduguri, Nguru and Katsina in which sources of non random variances exist. These stations are in the sahelian area, suggesting this area is witnessing increasing trend in drought occurrence.
Trend (linear or non linear) being the most likely alternative to randomness in the data, Mann-Kendall rank statistic "r" was calculated as a test of trend. At the 95% confidence level the test showed that some form of trend exists in the random variance structure of Sokoto, Nguru and Katsina (all in the Sahelian zone).The drought series of these stations showed significant tendency towards increasing trend of drought with negative values of their "r" lying outside the bounds of (r)t ($\pm$0.96) . On the other hand, the series for Bauchi, Bida, Kaduna, Kano and Maiduguri have values that did not indicate any significant trend (Table 1).
The students't-test was also applied to the data to determine whether there was a significant shift in the trend from one sub-period (1941 to1975) to another (1976 to 2010). This was done by checking whether or not their td lie outside the bounds of the two tailed value of tg (1.96) at 95% confidence level. It indicated that there exists a significant shift towards increasing trend in the series for Bauchi, Sokoto, Nguru and Katsina.Therefore for these stations, the last thirty or more years appeared to be drier than the preceding years (Table 1).

## TRENDS IN DECADES

Values of $t_k$ as shown in Tables 1 to 6 for decadal (over lapping and non-lapping) were subjected to the students't-test with N-2 degree of freedom at 50% level of significance in an attempt to indentify trend. The following were observed in the decadal analyses of the stations using zones.

## SUDAN ZONE

In the decade 1941-1950, it was observed that two stations Bida and Kaduna were with negative values (Table 2). In the decades 1951-1960 and 1961-1970, no station has a negative value. Bauchi being the only station with negative value in the decade 1971-1980 .All the three stations in this zone (Bida, Bauchi and Kaduna) have negative values in the decade 1981 -1990 indicating that decade to be a very dry one for the zone. For this zone, Bida and Kaduna had negative values for the decade 1991-2000 suggesting a slightly dry decade. Bauchi had a value of 1.31 suggesting a wet decade. Between 2001 and 2010, Bauchi and Bida had values indicating period of drought.

Across the decadal periods in the zone, Bauchi experienced drought in three out of the seven decades (1971 to 1980, 1981 to 1990 and 2001 to 2008).That is about 43% of the decades studied, with a significant drought period in the decade 1981 to 1990 (-2.37). Bida also had three decades out of seven being drought (43% of decades studied) with none being significant. Kaduna, however, experienced four decades out of seven being drought prone that is 52% of the decades studied (Table 3).

The interesting feature about the drought prone decades of the zone is that they were concentrated towards the end of the study period (latter decades) starting from the 1981 decade. This is with the exception of 1991 to 2000 in Bauchi and 2001 to 2008 in Bida that were wet (Tables 2 and 3). For the three stations in the zone (Sudan) about 10 decades altogether were drought prone out of a possible 21 decades. This means about 48 % (close to 50%) of the study decades in the zone were affected by drought (Table 3). This shows the Sudan zone is not drought free rather it tends to be in a flux between wet and dry periods.

**Sahel zone**

The decadal characteristics of the five stations used in the study were as follows:

In the decade 1941 to 1950, two of the five stations (40%) experienced low intensity drought as their values were not significant (Kano (-1.06) and Maiduguri (-0.45)). Other stations were with positive values and were not significant. In the next decade (1951 to 1960), all the stations in the zone indicated positive values, in fact two stations; Nguru (2.29) and Katsina (2.38) had values that were significant (Table 4). Therefore, this decade must have been a wet period as it was also wet in Sudan zone with positive values. The next decade (1961 to 1970) probably continued in this path of wetness in the zone as only Kano gave a negative value that was not significant (-0.78). All other stations indicated positive values meaning wetness, though the values were not significant (Table 4 and Figs. 2 to 9). The decade 1971 to 1980 had all the five stations used in the zone being negative with values that were not significant but nonetheless indicating drought. This drought trend continued into the next decade with all stations possessing negative values. In fact, Kano (-2.22), Maiduguri (-2.56), Sokoto (-2.28) and Nguru (-2.46) had significant negative values indicating intense drought periods. Katsina is the only station without a significant negative value in this decade in the zone but still with a high value of -1.94 (Table 4 and Figs.2 to 9).

The decade 1991 to 2000 had Maiduguri (-0.10), Nguru (-1.47) and Katsina (-2.56) with negative values with Katsina value being significant. The other two stations (Kano and Sokoto) were with positive values with that of Kano being significant. This positive significant value of Kano indicating wetness continued into the last decade of study 2001 to 2008. Kano in this decade had a value of 2.40. Other stations also had positive values indicating recovery from drought and wet decade with the exception of Nguru with a negative value that was not significant but nonetheless signified the continuation of drought from the previous decade for the zone (Table 4 and Figs 5 to 9).

The Kano station in this zone had four decades that are negative therefore they were drought decades. This means about 57% of the decades were drought prone. The situation (four negative decades and 57% of study period being dry) also occurred for Maiduguri though with the decades not being exactly the same as those of Kano. Sokoto had two decades with drought (negative values) (1971 to 1980 and 1981 to 1990), that is about 29% of the study decades was affected by drought (Table 5.20). The last four decades of study in Nguru were also affected by drought meaning about 57% of the study decades as in Kano were drought prone. Katsina had three decades affected by drought (that is about 43% of the study decades) out of a possible seven decades. In this zone the station with the least drought decades being Sokoto with two decades (Table 5).

The total number of decades in the zone with drought was 17 out of a possible 35. This means that about 49 % of the study decades were affected by drought in the zone. The occurrence of the drought decades were however more dispersed than those of the Sudan zone as they were not concentrated towards the latter decades studied (Tables 3 and 5). These percentages of drought prone decades (48% for Sudan zone and 49% for Sahel zone) (almost 50%) indicates that the zones were always at the mercy of drought and its consequences as the stations have been slipping in and out of drought during the study period.

**Sudano-Sahel Region**

On regional basis, the decade 1941 to 1950 had four stations (50% of the study stations/ areas) out of a possible eight with drought (Table 6). The next decade, 1951 to 1960 was drought free and was wet. The 1961 to 1970 decade had only one station, Bauchi which covers about 13% coverage of study area, out of possible eight (8) stations with drought. Six stations out of these eight stations were with drought in the decade from 1971 to 1980.That is about seventy-five percent (75%) of the study stations/ areas during the period of study was affected by drought. The next decade, 1981 to 1990 of had all stations with negative values and with drought. This means that the region (100%) entirely suffered from drought during the decade (possibly with various intensities).The decade of 1991 to 2000 had five stations which made up about 63% of the study stations/ areas being affected with drought during the study period (Table 6).The last decades of the study period (2001 to

2010) had three stations with negative values and therefore were affected by drought. This means about thirty-eight (38%) percent of the studied stations/ areas during the study period was infested with drought (Table 6).

**4.Conclusion**

In this study though it has being shown that drought re occur frequently in the region, but as shown in the decadal analysis the intensity of the drought has reduced drastically in the last two decades. This study therefore confirmed that there is no coherent time pattern to the occurrence of drought. It also confirmed the high intensity of droughts in 1980's. The analysis showed some stations to be on what can be termed recovery (Kano, for example) to wet situations in the last two decades. This study proves the need to put measures in place that are likely to be used to tackle and ameliorate the impact of drought when they next reoccur.

**5.Reccommendations**

* Water recycling plants should be established to recycle water from toilets and from other household usages.
* The use of Green Infrastructure (G.I) in cities, towns and villages in the study region will help to reduce the actual and potential impact of radiation especially in reducing evaporation of water from soils and water bodies. This will reduce the drying effect of drought.
* Discouraging bush burning and tree cutting that exacerbate land degradation in this region. This practises also reinforce drought occurrence and re occurrence.
* There is the need to further construct more dams, boreholes and wells in order to be able to have enough water for periods of droughts.
* There is the need to encourage the use of local technology like the shadoof system of irrigation. This is because such technology cost less as most locals can not afford the expensive and modern forms of technology.
* Strategic irrigation that includes installing drip irrigation that directs water to the roots of crops and irrigation of land being done in the morning to ensure that the water does not evaporate.
* Also there is the need to accelerate the rate of establishing the proposed national commission for drought and desertification, control and management.
* The mitigation of drought effects need to implement these recommended and other measures collectively and should also be multi-disciplinary in nature

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**Table 1: Values of Stations for Von Neumann, Mann-Kendall and Students't-test.**

| ZONE/STATION | V | (V)t | (r) | td |
|---|---|---|---|---|
| **SUDAN ZONE** | | | | |
| **Bauchi** | 1.78 | 1.46 | -0.15 | -2.3 |
| **Bida** | 2.32 | 1.79 | -0.16 | -0.3 |
| **Kaduna** | 1.67 | 1.55 | -0.14 | 0.75 |
| **SAHEL ZONE** | | | | |
| **Kano** | 1.47 | 1.34 | -0.17 | -1.92 |
| **Maiduguri** | 1.41 | 1.52 | -0.14 | -0.76 |
| **Sokoto** | 1.76 | 1.53 | -0.27 | -2.79 |
| **Nguru** | 2.19 | 2.22 | -0.50 | -3.3 |
| **Katsina** | 1.47 | 1.77 | -0.41 | -4.39 |

**Source:** Fieldwork, 2012

**Table 2 : $t_k$ Values for Decadal Periods in Stations (Sudan Zone)**

| Station | 1941-50 | 1951-60 | 1961-70 | 1971-80 | 1981-90 | 1991-2000 | 2001-2010 |
|---|---|---|---|---|---|---|---|
| **Bauchi** | 1.33 | 1.11 | 0.07 | -0.25 | -2.37 x | 1.31 | -0.63 |
| **Bida** | -1.33 | 0.36 | 1.81 | 0.49 | -1.11 | -0.47 | 0.10 |
| **Kaduna** | -0.30 | 1.60 | 0.49 | 1.08 | -1.69 | -0.15 | -1.09 |

**Source:** Fieldwork, 2012
x: negative dry condition and significant

**Table 3: Drought Percentages using $t_k$ Decadal values for Stations (Sudan Zone)**

| Station | Decades with drought | Total frequency of occurrence | As %age of Decades (Seven) |
|---|---|---|---|
| **Bauchi** | 1971 to 1980,1981 to 1990,2001 to 2010 | 3 | 43 |
| **Bida** | 1941 to 1950, 1981 to 1990, 1991 to 2000 | 3 | 43 |
| **Kaduna** | 1941 to 1950, 1981 to 1990, 1991 to 2000, 2001 to 2010 | 4 | 52 |

**Source:** Fieldwork, 2012

**Table 4: $t_k$ Values for Decadal Periods in Stations (Sahel Zone)**

| Station | 1941-1950 | 1951-1960 | 1961-1970 | 1971-1980 | 1981-1990 | 1991-2000 | 2001-2010 |
|---|---|---|---|---|---|---|---|
| **Kano** | -1.06 | 0.33 | -0.78 | -1.77 | -2.22 x | 2.22 x x | 2.40 xx |
| **Maiduguri** | -0.45 | 1.97 xx | 1.00 | -0.26 | -2.56 x | -0.10 | 1.26 |
| **Sokoto** | 1.70 | 1.94 | 0.04 | -1.61 | -2.28 x | 0.12 | 0.46 |
| **Nguru** | 1.84 | 2.29 xx | 1.25 | -0.44 | -2.46 x | -1.47 | -1.04 |
| **Katsina** | 1.18 | 2.38 xx | 1.64 | -0.82 | -1.94 | -2.56 xx | 0.69 |

**Source**: Fieldwork, 2012
X: negative, dry condition and significant.
XX: positive, wet condition and significant.

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**Table 5: Drought percentages using $t_k$ Decadal values for Stations (Sahel Zone)**

| Station | Decades with Drought | Total frequency of occurrence | As %age of Decades (Seven) |
|---|---|---|---|
| **Kano** | 1941-1950,1961-970,1971-1980,1981-1990 | 4 | 57.14 |
| **Maiduguri** | 1941-1950,1971-980,1981-90,1991-2000 | 4 | 57.14 |
| **Sokoto** | 1971-1980,1981-1990 | 2 | 28.57 |
| **Nguru** | 1971-1980,1981-990,1991-2000,2001-2010 | 4 | 57.14 |
| **Katsina** | 1971-80,1981-1990,1991-2000 | 3 | 42.86 |

**Source:** Fieldwork,2012

**Table 6: $t_k$ Values for Decadal Periods (Region)**

| **SUDAN ZONE** | **1941-50** | **1951-60** | **1961-70** | **1971-80** | **1981-90** | **1991-2000** | **2001-2010** |
|---|---|---|---|---|---|---|---|
| **Bauchi** | 1.33 | 1.11 | 0.07 | -0.25 | -2.37 x | 1.31 | -0.63 |
| **Bida** | -1.33 | 0.36 | 1.81 | 0.49 | -1.11 | -0.47 | 0.10 |
| **Kaduna** | -0.30 | 1.60 | 0.49 | 1.08 | -1.69 | -0.15 | -1.09 |
| **SAHEL ZONE** | | | | | | | |
| **Kano** | -1.06 | 0.33 | -0.78 | -1.77 | -2.22 x | 2.22 x x | 2.40 xx |
| **Maiduguri** | -0.45 | 1.97 xx | 1.00 | -0.26 | -2.56 x | -0.10 | 1.26 |
| **Sokoto** | 1.70 | 1.94 | 0.04 | -1.61 | -2.28 x | 0.12 | 0.46 |
| **Nguru** | 1.84 | 2.29 xx | 1.25 | -0.44 | -2.46 x | -1.47 | -1.04 |
| **Katsina** | 1.18 | 2.38 xx | 1.64 | -0.82 | -1.94 | -2.56 xx | 0.69 |

**Source**: Fieldwork, 2012
X: negative, dry condition and significant.
XX: positive, wet condition and significant.

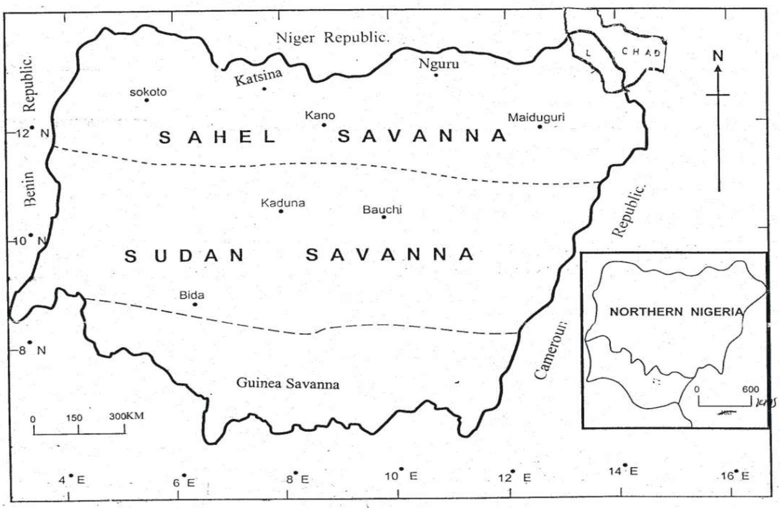


Fig. 1: Stations and geographical regions used in the study.
Adapted from: Olaniran, 1987

 

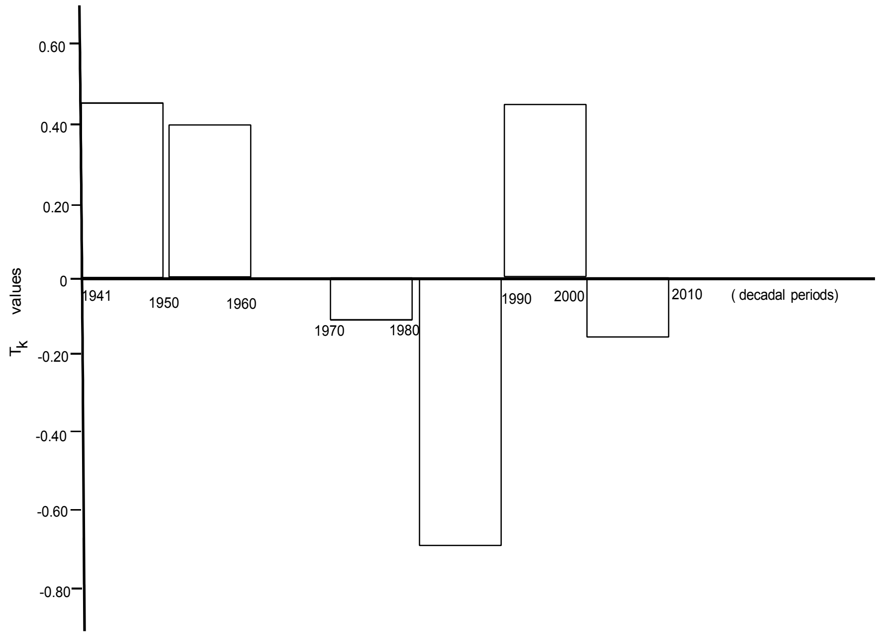


**Fig.2: $t_k$ values indicating decadal fluctuations in rainfall(Bauchi)**
Source:Fieldwork, 2012.

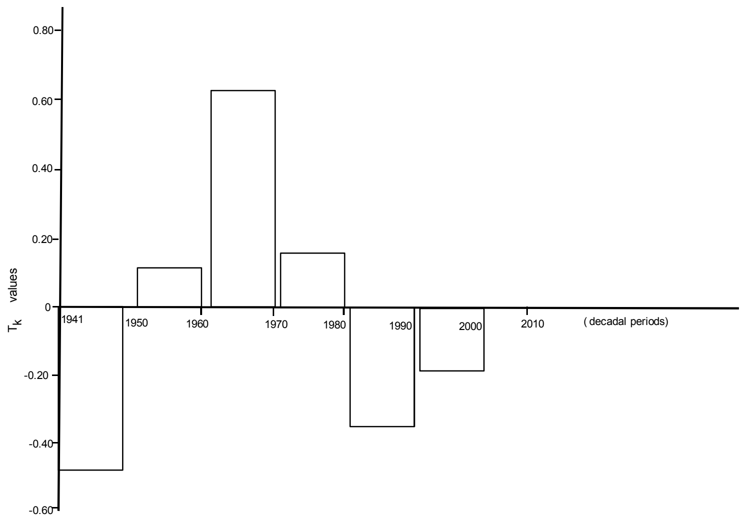


**Fig.3: $t_k$ values indicating decadel fluctuations in rainfall(Bida)**
Source:Fieldwork, 2012.

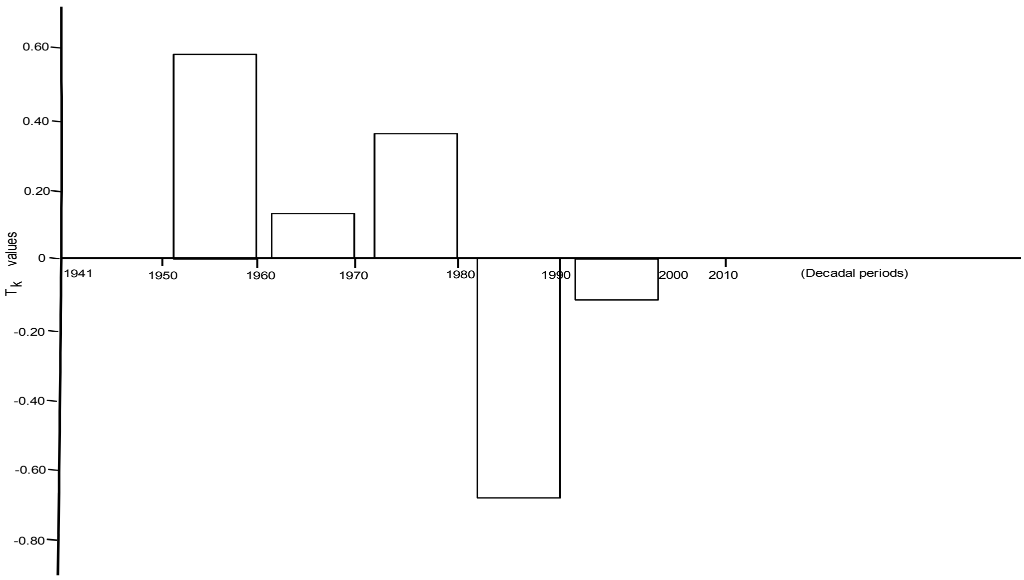


**Fig.4: tk values indicating decadel fluctuations in rainfall(Kaduna)**
Source:Fieldwork, 2012.

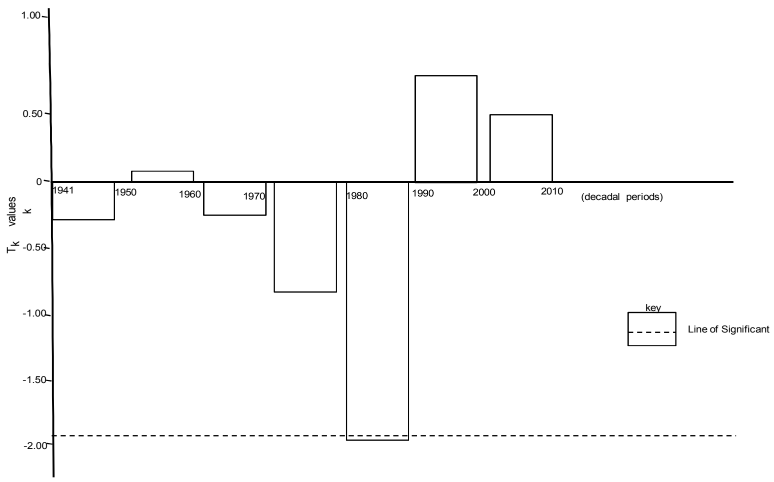


**Fig.5.: t k values indicating decadel fluctuations in rainfall(Kano)**
Source:Fieldwork, 2012.

 

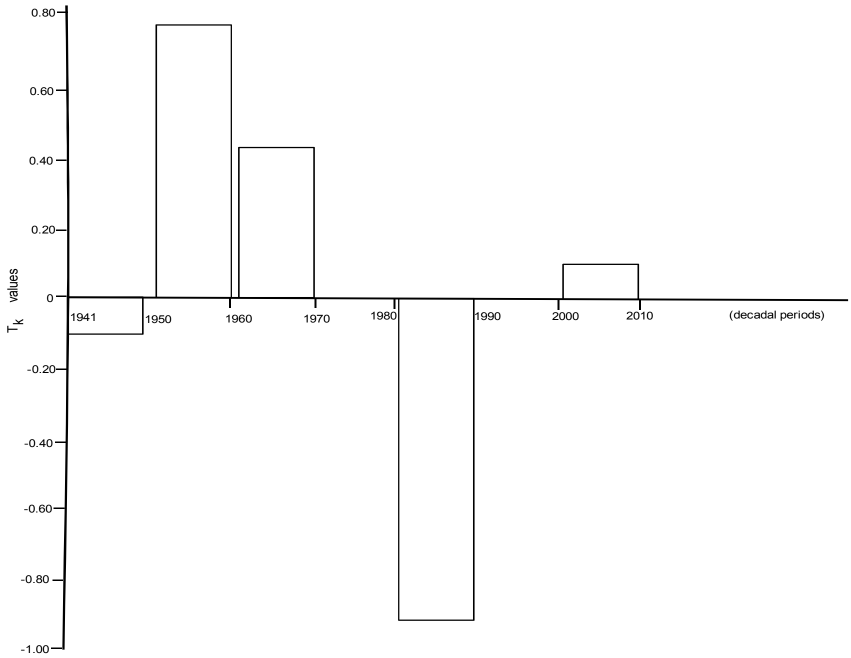


**Fig.6.: t k values indicating decadel fluctuations in rainfall(Maiduguri)**
Source:Fieldwork, 2012.

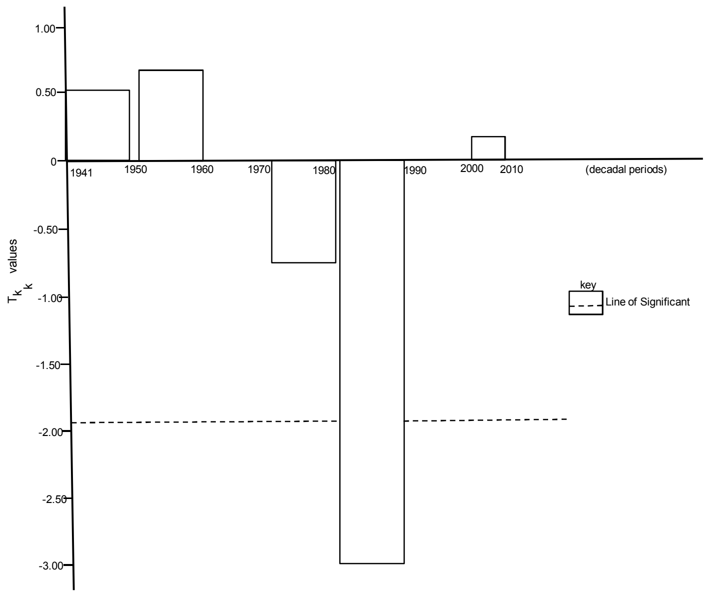


**Fig. 7 : $t_k$ values indicating decadel fluctuations in rainfall (Sokoto).**
Source:Fieldwork, 2012.

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