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STATISTICAL ANALYSIS OF THUNDERSTORM ACTIVITY OVER YOLA NORTH EAST NIGERIA

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ABSTRACT: *The study examines in detail thunderstorm pattern over Yola, North East Nigeria. These include annual fluctuations, seasonal diurnal and trend. Data for this work were extracted from Nigerian Meteorological Agency, Oshodi Lagos record from 1970 - 1999 for analysis. The result on annual occurrence shows a decrease in thunderstorm activity over time during the study period. More thunderstorms tend to occur during wet season than during dry season. Thunderstorm activity within Yola exhibits a mono peak or a single maximum in August. Further analysis reveals that the diurnal pattern of thunderstorm occurrence shows a late evening peak. Finally the study reveals that there is statistical difference in diurnal, seasonal and annual variation of thunderstorm at 95% level of confidence in the study area. The study shows that there are months in the study area without a peal of thunderstorm. Full understanding of thunderstorm occurrence will be of great help to policy makers. Death resulting from thunderstorm strike will be avoided if children are prevented from playing during the peak hours.*

KEYWORDS: Annual Fluctuation, Diurnal variation, seasonal occurrence, Thunderstorm Pattern, Yola.

INTRODUCTION

Thunderstorm is a thermodynamic machine whose potential energy of latent of condensation in moist, unstable air is converted into kinetic energy of violent vertical air current, characterized by thunder, lightning, gusty wind, and sometimes hails (Trewatha and Ham, 1980). Thunderstorm occurs when the atmosphere is unstable and moist, warm air near the ground becomes buoyant. The air rises, producing much fair weather cumulus cloud that at first form and dissipate without producing rain or electric discharge. As the day proceeds, the cloud increase in size and vapour until finally several of them combine. They surge upward to form a large cloud that in few months yields rain and lightning. (Encyclopedia Americana, 1970).

A thunderstorm is a process which takes heat and moisture near earth's surface and transports it to the upper level of the atmosphere. The by-product of this process is cloud, precipitation, lightning, and wind. The birth of thunderstorm occurs when warm, humid air rises in conditionally unstable environment. The trigger needed to start air moving upward may be the unequal heating of the surface, the effect of terrain, or the lifting of warm air along zones. Diverging upper level wind coupled with converging surface winds and rising air, also provides a favourable condition for thunderstorm development (Ahrens, 1998). The roaring and rumbling of the cloud and lightening associated with it, had over the year invoke fear on millions. Many associated it to gods, others to eventuality (Alexander, 2005). The challenge thunderstorm posed on aviation industry, air force and naval personal during the Second World War cannot be underestimated. This spurred scholars to study all aspect of thunderstorm.

In the tropical regions, climate and its variables dictate the people ways of life. Thunderstorm is one of the micro variables that exert great influence on tropical activities. Adelekan (1998) examined the spatio-temporal variations in thunderstorm rainfall over Nigeria. The work pointed out that thunderstorm rainfall

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increases from the south to north up to latitude 11°N Others who had carried out research on thunderstorm activity in Nigeria include, Mulero (1973) on seasonal distribution of thunderstorm days in Nigeria for the period (1962 — 1971); Balogun (1981) on season and spatial variation of thunderstorm activity in Nigeria; Oladipo and Mornu(1984) discussed the characteristics of thunderstorm in Zaria, Nigeria; Omotosho (1984) was concerned with the individual contribution of thunderstorm line squall and Monsoon, to the total rainfall in Nigeria over five years. Salau (1986) discussed the influence of Jos Plateau on the occurrence of thunderstorm activity in Jos, Zaria, and Kaduna in her work on temporal and comparative analysis of thunderstorms and related phenomena (hail, squall and Lightening). Ologunorisa, 1991; Ologunirisa and Alexander, 2004; 2007. Alexander (2015) compared thunderstorm occurrence and rainfall in his work comparative analysis of thunderstorm and rainfall occurrence over Nigeria.

Outside Nigeria, scholars have also worked on thunderstorm activity (Sivaramkrishnam, 1990; Moide, 1995; Kolendowicz, 1998; Singh and Sontakke, 1999; Monohar et al, 1999; Moid, 2001; Bielec, 2001; Kandalgaonkar et al, 2005).

Though attempt has been made to study thunderstorm in all its aspect — diurnal, seasonal, annual, and trend in a single study. The station investigated was a coastal station. Therefore it is imperative to study thunderstorm away from coastal station to ascertain the effect of river on thunderstorm pattern and to also observe the effect of altitude on thunderstorm. Therefore Yola was chosen. This study seeks to carry out a detailed analysis of thunderstorm over Yola.

STUDY AREA

Yola was established in 1841, it is a municipality that sprawls across the hillside of North-Eastern region of Nigeria. It was the capital of a state of Fulani community until it was taken over in 1901 by the British. Today, it is the capital of Adamawa State, which was formed in 1991 from part of Gongola State. It is the capital city and administrative center of Adamawa State, Nigeria. It is located on the Benue River, it has a population of 336,648 (2010). Yola is split into two parts. The old town of Yola where the Lamido resides is the traditional city but the new city of Jimeta (about 5 km NW) is the administrative and commercial center. Generally the term Yola is now used to mean both. To the north are the Mandara Mountains and the south are the Shebshi Mountain with Dimlang (Vogel) Peak the second highest point (2,042 m) in Nigeria after Chappal Waddi (mountain of death). Yola is an access point to the Gashaka Gumpti Nature Reserve, which is the largest national park in Nigeria, the Ngel Nyaki Montane forest reserve, the Mambilla Plateau, The Surkur UNESCO World heritage site, which is Africa's first cultural landscape to receive World Heritage List inscription. The Yadin Waterfalls, The Kiri Dam on the Gongola River, the Benue National park in nearby Cameroon, The Waza National Park and Cameroonian town of Garoua, which lies across the Border, on the Benue River.

The nearby town of Jimeta or new Yola has a market, zoo, an airport with direct flights to Saudi Arabia, NiPost and NiTel offices as well as the main mosque and cathedral. Being a state capital, it is a major transport hub with buses and taxis heading north to Mubi and Maiduguri, west to Numan, Gombe, Jalingo, Bauchi and south to Makurdi and Katsina Ala. Taxis are available to Garoua in Cameroun. There is an airport with regular flights to Abuja and Lagos. The town is home to various institutions of learning, such as the: America University of Nigeria- AUN, Adamawa State Polytechnic, The Modibbo Adama University of Technology, Yola (MAUTECH) previously known as Federal University of Technology, Yola, located about 10 km north of the city on the road to Mubi, The Federal Government Girls College, Yola, ABTI Academy, Chiroma Ahmad Academy, Ahmadu Ribadu College, MAUTECH university secondary school, Concordia College (which was nominated as the best post primary school of the year 2007 by the National Association of Nigerian Students), and many other educational institutions. Adamawa has one of the best

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depots in Nigeria, located about 5 km west on the road to Numan. Tourist sites include: the *Three sister hills*, which are three scenic rock formations standing side by side at the same height, The Njuwa lake fishing festival, The Lamido's Palace and the Annual horse-riding durbar. Although originally a Fulbe settlement, the town is now home to virtually all of Nigeria's ethnic groups, as well as people from the neighboring republic of Cameroon (Wikipedia .org). This and more information abound in the net.

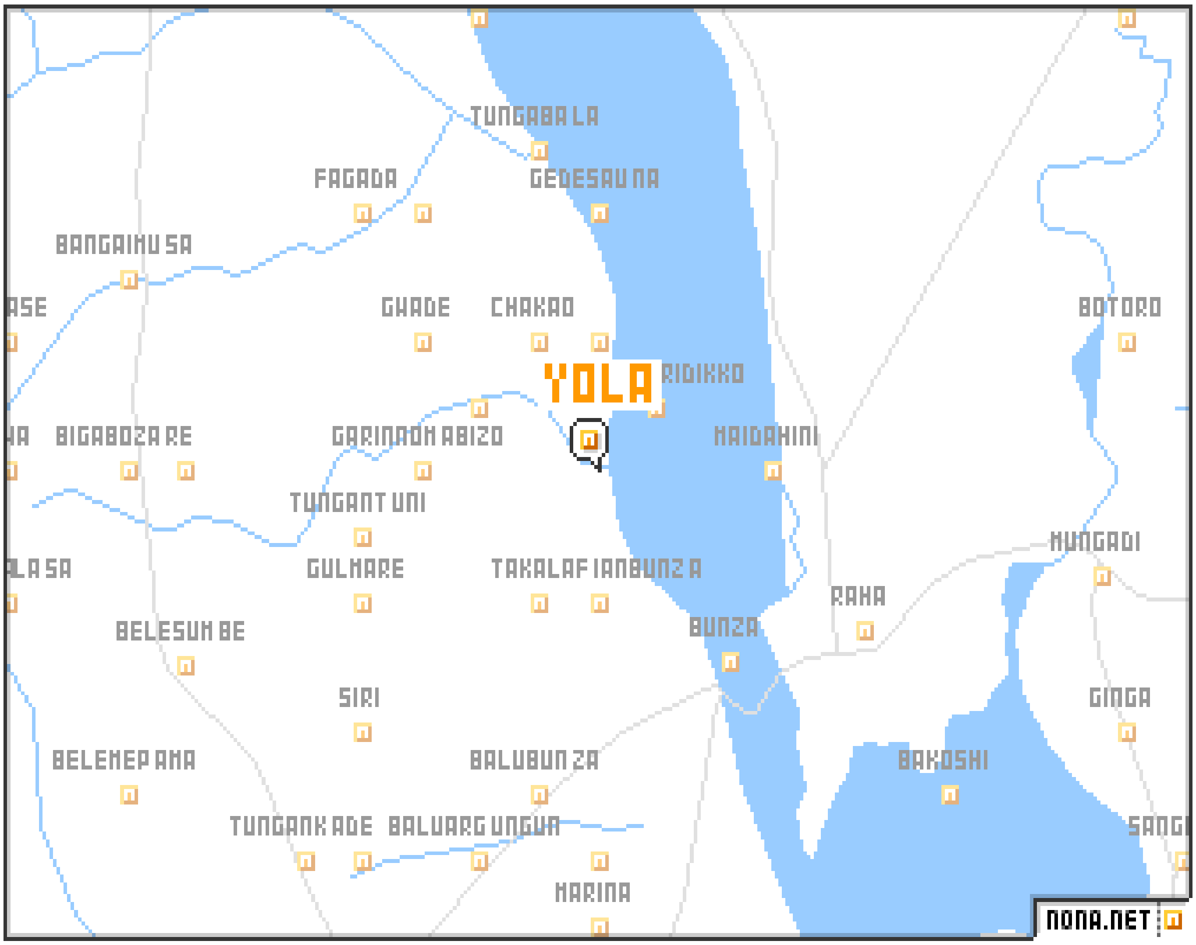

Figure 1: Map of Yola Capital of Adamawa State.

METHODOLOGY

The data used in this work were extracted from form 100/5 of daily weather register of Nigerian methodological Agency Oshodi, Lagos. The study covered 30 years (1970 — 1990). The method of data analysis includes descriptive and inferential statistics. Descriptive statistics such as means, percentage and co-efficient of variation (C.V) were used. The C.V was used in determining the variation in diurnal and seasonal occurrence of thunderstorm. Ologunorisa (1999) and Alexander (2015) used it in their work.

$CV = STD/\square *100$ …………………………………………………………………………. (1)

Inferential statistics used include Spearman rank correlation use for annual distribution and regression analysis for trend in thunderstorm activity over Yola r´ is given as

$r' = 1 - 6\Sigma d^2/N(n^2 - 1)$ ………………………………………………………………………… (2)

Where Σd^2 is the summation of the squared differences of the ranked data. N is the sample size, and n^2 is the square of sample size.

$$y = a + bx \quad \ldots\ldots (3)$$

y is the regression line examination, where a and a are constants, while x is the dependent variable.
To test for the significance of the seasonal and annual occurrence of the thunderstorm, student t" test was used.

$$t = r\sqrt{(n-2)}/\sqrt{(1-r^{2})} \quad \ldots\ldots (4)$$

The results are presented in table and graphs

DISCUSSION AND RESULT

1a. Diurnal Distribution of Thunderstorm

The diurnal distribution of thunderstorm in Yola is shown in table 1 and figure 2. The least occurrence was recorded between 0900 – 1200 GMT hours with 355 peals, while the highest occurred in the late afternoon hours of 1500- 18000MT with 885 peals.

Obviously the explanation of afternoon - evening types of diurnal thunderstorm over Yola is complex. Different researchers have proposed divergent mechanisms (Balogun, 1981; Oladipo and Mornu 1984). (1) Those based on thermo-dynamic process e.g. solar radiation that affects the static stability. (2) Those based on dynamic processes that influence the mass convergence within planetary boundary layers (3) Those based on semi- diurnal pressure wave (Wallace, 1975), and (4) those based on the role of radiation difference between organized Meso-Scale Cloud regions (Gray and Jacobson, 1975). So there is no single hypothesis that can be used to explain the afternoon - evening regime in Port Harcourt. Therefore, the afternoon-evening regime is as a result of multi-dynamic and circumstantial processes.

Table 1: Diurnal Thunderstorm Activity

Time	Total TS	Mean	T Mean	STD	CV	%
0000-0300	492	16.4	2.05	38.04	92.79	10.7
0300-0600	460	15.33	1.92	38.41	100.21	10
0600-0900	375	12.5	1.56	32.11	100.74	8.2
0900-1200	355	11.83	1.48	32.91	111.26	7.8
1200-1500	582	19.4	2.43	50.17	103.44	12.8
1500-1800	885	29.5	3.69	65.61	88.96	19.3
1800-2100	857	28.56	3.57	61.12	85.58	18.7
2100-0000	572	19.06	2.53	43.56	91.39	12.5
Total	4578	152.58	**19.08**	361.93	774.37	100
Mean	572.25	**19.08**	2.39	45.24	97.04	12.5
T-Mean	**19.08**	0.64	0.08	1.05	3.23	0.41

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The diurnal co-efficient of variation of thunderstorm (C.V), percentage and mean were calculated. The result shows that diurnal C.V is generally moderate. The range in C.V is 25.68%. The 1800-2100GMT hours has the least variability of 85.58%, while 0900-1200 GMT hours has the highest variation of 111.26%.

The period (hours) with lesser than (<) 100 peal C.V are considered low diurnal hours. These include 1800-2100, 1500-1800, 2100- 0000, and 0000- 0300 hours, with85.58%, 88.96%, 91.39%, and 92.79% respectively. The high diurnal hours are those that records above 100%, these includes 0300-0600, 0600-0900,1200-1500, and 0900-1200 GGMT, with record value of 100.21%, 102.74%, 103.44%, and 111.26% respectively. The hours between 1200-0000 GMT accounted for over 63% of the total thunderstorm occurrence over Yola, while the hours between 0000-1200GMT contributed lesser than 37% of Yola's thunderstorm during the period of study. The concept of true mean is used to address statistical illusion. It is used in two forms. The first is in diurnal variation, as shown in table 1, and the second in seasonal distribution of thunderstorm.

Note - true mean = total thunderstorm occurrence/duration of study * the hourly interval.
The thunderstorm for Yola for the 30 years is 4578 peals. The hourly interval for diurnal occurrences is 8 (i.e. 24hrs / 3). The true mean = 4578/ (30*8) = 19.08 peals. The true mean explain the ideal daily thunderstorm occurrence over a station and any particular parameter of interest.
True mean = mean of mean.

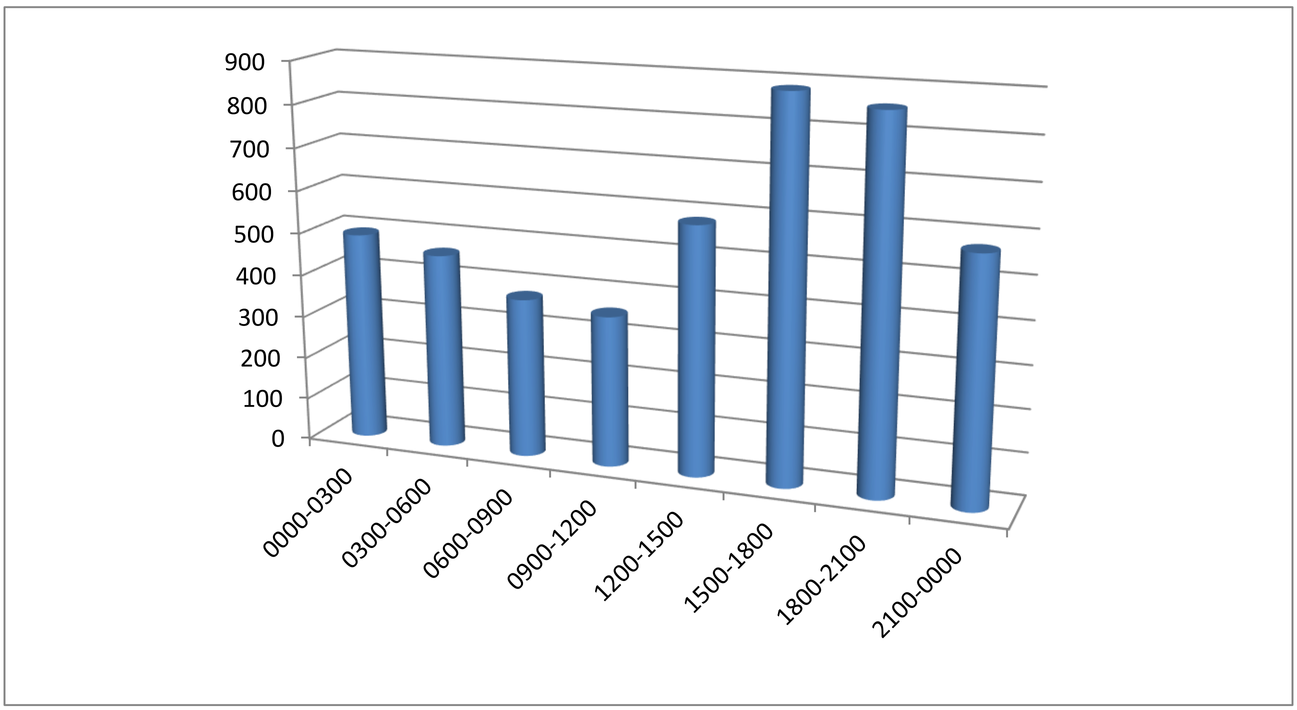

Figure 2: Diurnal Distribution of Thunderstorm over Yola.

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SEASONAL OCCURRENCE OF THUNDERSTORM

Figure 3 explained the seasonal occurrence of thunderstorm over Yola (1970 — 1999) from the graph it was observed that February had no trace of thunderstorm occurrence, while January and December recorded 1 and peals respectively. The month of August had the highest thunderstorm occurrence of 849 peals; September was second with 771 peals of thunderstorm. The dry season months of November, December, January, February, March and April accounted for 416 peals of TS representing 9.08% of the total TS occurrence. The wet season in the other hand accounted for 4162 peals representing about 90.92% of the station thunderstorm during the study period. This implies mathematically that for every wet season at least about 138.73 peals of thunderstorm occur, meaning that about 11.56 peals occurs every wet season months.

Table 2: Seasonal Variation of Thunderstorm.

Month	**Total**	Mean	T-Mean	STD	CV	%
Jan	1	0.03	0	0.35	282.84	0.02
Feb	0	0	0	0	0	0
Mar	48	1.6	0.13	5.68	94.7	1.5
Apr	350	11.67	0.97	27.25	62.28	7.6
sMay	680	22.67	1.89	36.43	42.86	14.9
Jun	702	23.4	1.95	26.66	30.38	15.3
Jul	754	25.13	2.09	26.07	27.66	16.5
Aug	849	28.3	2.36	32.84	30.95	18.6
Sep	771	25.7	2.14	25	25.94	16.7
Oct	406	13.53	1.13	31.37	61.83	8.8
Nov	15	0.5	0.04	1.46	104.5	0.3
Dec	2	0.07	0	0.46	185.1	0
Total	4578	152.6	**12.72**	213.57	949.04	100
Mean	381.5	**12.72**	1.58	17.7	79.1	8.3
T-Mean	**12.72**	0.42	0.04	0.55	0.09	0.3

The reason for high thunderstorm during wet season can be explained by the effect of altitude, availability of moisture, sporadic wind, and differential temperature. The seasonal variations of thunderstorm, mean, true mean and coefficient of variation (C.V) over the period of study were calculated as shown in table 2. The seasonal C.V during the study period over Yola is large. The result shows a range of 282.84%. January has the highest CV of 282.84, while February has zero variation. Thunderstorm tends to be reliable during wet season than during wet season. The result also shows that dry season months has higher CV. Thunderstorm occurrence varies with and within seasons.

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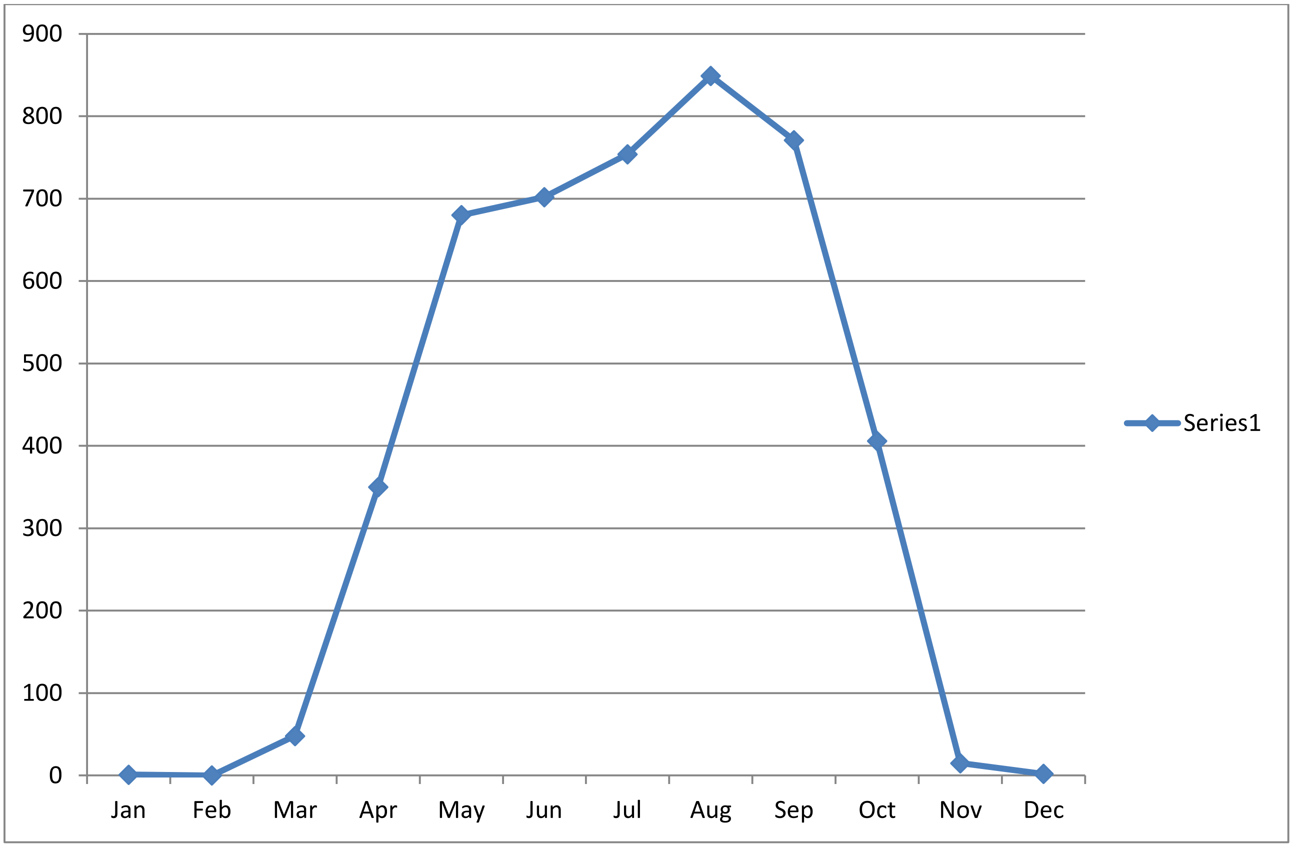

Figure 3: Seasonal Distribution of Thunderstorm over Yola.

ANNUAL DISTRIBUTION OF TS AND TREND

The annual TS distribution is explained in table 3 and figure 4. 1972recorded the highest peals of thunderstorm 322, followed by 1971 and 1973 with 274 and249 peals respectively. 1982 recorded the least thunderstorm occurrence of 49peals during the study period. This is closely followed by 1996 and 1997 with 75 and 82 peals respectively. Figure 4 shows the fluctuations over the years. It was observed that 7 years had peak thunderstorm occurrence. These include 1972, 1978, 1985, 1988,1991, 1994,and 1998; the minimum frequency during the same period are 1977, 1982, 1987, 1989, 1993, and 1996. The peak here does not mean the highest TS occurrence of, rather it mean sharp edges before a fall in distribution.

Using Spearman Rank correlation for analyses, it was observed that there is significant relationship between thunderstorm occurrences with time. Further using student‘t’ test shows that the relationship was negative at95% level of confidence.

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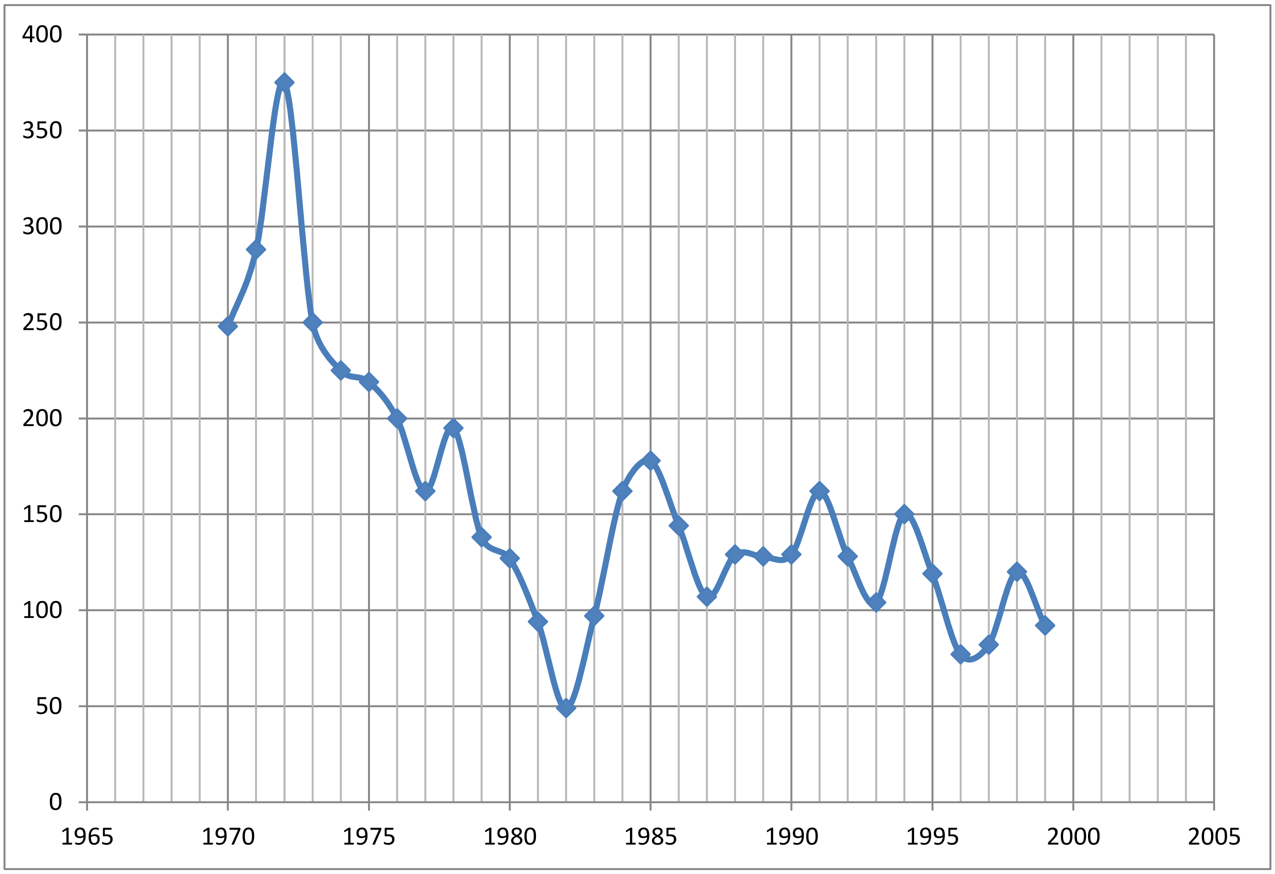

Figure 4: Annual Thunderstorm Fluctuation over Yola.

Trend Analysis

The result on trend analysis shows a negative or downward scope over the years. This implies that TS occurrence in Yola decreases with time. The negative correlation co-efficient showed that the relationship was not by chance. The negative scope is an indication of a linear tendency toward a general decrease in TS occurrence over the study period and thus a downward trend.

The decrease in TS could be as a result of reducing rainfall resulting from reduction in moisture contained in the atmosphere.

Table 3: The Annual Variation of Thunderstorm.

Correlation	STD X	STD Y	Critical value	Coefficient determination	Students
Coefficient “r”			Value	r^2 x l00	“t” test
-0.74	8.80	63.76	±2.05	54.76%	- 5.82

Note: 54.76% of thunderstorm occurrence in Yola is explained by time or years.

The result r = -0.74, shows a negative relationship. This agrees with the descriptive statistics above. The “t” critical is > T-calculated (-5.82). This indicates a significant relationship between TS activity and time over Yola. The (-) points to a negative trend. The regression analysis is shown in table 4 below

The regression analysis points to the fact that TS decreases over years during the period of study 1970 - 1999 in Yola.

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Figure 3: The Annual Trend of Thunderstorm.

Regression Coefficient	Regression equation	t-critical	t-calculated
- 5.5	Y =237.9-5.5x	±2.05	-5.82

RECOMMENDATION

Thunderstorm play a vital role in formation of rainfall, which dictate the farming calendar in Nigeria. The study recommend that thunderstorm data should be well analyse before cultivation is carried out. This is because the resultant rainfall from thunderstorm are always flood, storm, and torrential rainfall, which leads to soil erosion and extensive runoffs.Construction workers should consult experts on climatological and weather related issues to minimize thunder related risks. Aviation industries must take note of diurnal implication of thunderstorm activity.

I hope that in future, study on prediction and warning of thunderstorm on both micro and macro scale be carried out. Government and Non-governmental organizations should involve themselves in the study of thunderstorm, either as a source of energy or to avoid its destructive consequences.Understanding of TS occurrences will help in harvesting rainfall effectively, since TS precedes rainfall occurrence. Finally Children should be discouraged from playing out door from 1500-1800 GMT hours especially in August to avoid TS strike.

CONCLUSION

The study of thunderstorm occurrence is a complex one, especially in a developing country like Nigeria. The study shows a late afternoon- and early evening diurnal peak. It also reveals that wet season accounted for majority of the thunderstorm occurrence during the period of study. The month of August recorded the highest thunderstorm occurrence, in addition the study shows that TS occurrence decreases with time over years. There is statistical relationship between thunderstorm occurrence and time; the relationship is negative at 95% level of confidence. The study further revealed that the Month of February had no peal of thunderstorm over the 30 years of study. January and December had just 1 and two respectively. This is a serious finding. It implies that rain fall and thunderstorm cannot disrupt social activities during these months.

TS shows a late afternoon / evening diurnal peak occurrence around 1500-1800 hours. TS occur more during wet season than dry saison. It was observed that TS has a double seasonal peak (double maxima) The study of TS activity in Yola will help Administrators', Planners, and Policy Makers. Farmers yield are poor because of undermining the onset of rainfall, end and duration of rainfall, which can be predicted by studying TS activity.

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