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Correlation of Meteorological Parameters to Study the Climatic Conditions of Gombe State, Nigeria.

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Abstract: This paper investigated the climatic change of Gombe State metropolis from 2004 to 2014. Data were collected from Gombe State meteoroligical center, Gombe State News Bulletin, and Meteorological unit of Gombe State International Airport. Correlaion was carried out between the meteorological parameters and the years. The data was organized and analysed using Spearson correlation coefficient and ANOVA ananlysis. The paper hereby suggests that the effect of climate change to humanity can be controlled or alleviated if concrete steps that are environmentally friendly are taken.

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1.0 INTRODUCTION

Global warming:is the increase in the average measured temperature of the earth's near-surface air and oceans since the mid-20th century, and its projected continuation (Wekipedia, 2012). Increasing global temperature is expected to cause sea levels to rise, an increase in the intensity of extreme weather events, and significant changes to the amount and pattern of precipitation, likely including an expanse of the subtropical desert regions, (Smith, 1987). Other expected effects of global warming include changes in agricultural yields, modifications of trade routes, glacier retreat, mass species extinctions and increases in the ranges of disease vectors (Botkin and Keller, 1997).

Energy development is the ongoing effort to provide sufficient primary energy sources and secondary energy forms to fulfill civilization's needs. It involves both installation of established technologies and research and development to create new energy-related technologies. Major considerations in energy planning include resource depletion, supply production peaks, security of supply, cost, impact on air pollution and water pollution, and whether or not the source is renewable (Wikipedia, 2011).

The atmospheric science is the umbralla term for the study of the earth's atmosphere, its processes, the effects other systems have on the atmosphere. These other systems includes atmospheric chemistry and atmospheric physics with a major focus on weather forecasting. Amospheric physics have a close link to meteorology and climatology, it also covers the design and consruction of instrument for studying the atmosphere and interpretation of the data they provide including remote sensing instrument (Wikipedia, 2015).

Atmospheric physicist attempt to model the earth's atmosphere and the atmosphere's % after planets using fluid flow equations, chemical models, radiation balancing and energy transfer processesin the atmosphere and the underlying oceans.In order to model weather systems, atmospheric physicist employ elements of the scatering theory, wave propagation models, cloud physics, statistical mechanics,and spatial statistics each of which incorporate high level of mathematics and physics.

1.1 Theoretical Basis of Study

The global climate is the result of numerical interaction occurring amongst hydrosphere and the atmosphere. These interactions in a particular meteorological conditions and spatial average fields of these conditions to produce climatic regimes. The purpose of the climate theory is to:

i. Identify the average distribution of meteorological elements in space and time,
ii. Respond to external factors.

Numerical models of climate are devised for the purpose which makes it possible to calculate fields of meteorological elements and calculate such fields for prolonged time intervals thus allowing calculations of average field describing climatic conditions.

Several theoretical models have been developed in the field of meteorology for the past half a century. Thses allows the description on the study of the present climate as well as change in

climatic conditions produced by natural activities. For Instance, numerical model of climate given by Manabe and Bray (1969), shows the influence of the circulation of the ocean waters on climates conditions. However, the models used to study climate change have to meet more rigorous requirements than the models used to study current climatic regime, hence the significance of this paper.

1.2 Review of Nigerian Climate

Climate change is real and its consequences will be with us for the greater part of this century of appropriate measures are taken now to stem the increase in the emission of green house cases (GHG) into the atmosphere that is responsible for the global warming, then there will be a reversal of the consequences. The Intergovernmental Parel on Climate Change (IPCC) has established through its science based research that the effect of global warming will linger for longer period if the present trend of (GHG) emission is not curtailed.

The 2012 Nigeria climate change review has shown very interesting features in the variability of the atmospheric elements compared to their long term averages. Notable among the observed features are positive rainfall anomaly recorded in most part of the country. Indeed the northeast zone recorded positive anomaly for the first time in the last five (5) years and the highest anomaly in the last 10 years. The above normal rainfall resulted in unprecedented flooding which caused loss of lives and properties. The magnitude of the losses recorded could be attributed to non-adherence of relevant agencies to the early warming provided by NIMET with very good leadtime. The little dry (harmattan) season was very pronounced in the southwest. Its severity and the duration was the highest recorded in the last 5 years. Most states in the North also recorded above normal day time temperature at early part of the year which increase the discomfort level.

Nigeria climate review bulletin is one of the many Science based publications of NIMET geared towards informing all stakeholders and the general public of the variations in climatic elements for better decision making and policy formations. It is produced yearly and provides wealth of information on the climate of the year under review. The climate of Nigeria has shown considerable temporal and spatial shifts in its variability and change. Extreme climate and weather events (draught, flood, heat waves, ocean Surges etc) have become more regular. The impacts of extreme weather and climate may be gradual but they are destructive to live and property, negative impact on economy. Floods have become a perennial challenge with increasing intensity each year leaving dossal losses and trauma. The low-lying coast of the country experience perennial inundation due to ocean surges and strong tidal waves.

The 2012 Nigerian climate review bulletin added new climate indicators such as "rainfall months" addition to standard statistically examined climatic elements (maximum and minimum temperature, rainfall amount and pattern of onset and cessation of rainfall). This innovation is to provide scientist and experts in the socio-economic sectors more useful information on variability and trends with a view of addressing the many multi-hazard challenges facing the country.

The synoptic features indicated dominance of the subtropical high pressure systems at the beginning of the year, leading to the rising of dust particles of at the surface in the sahara desert and subsequently transportation and reduction of horizontal visibility across the country. The southwesterly winds gained momentum at the coast and this brought about enhanced rainfall and thunderstorms, flash flooding and the associated impacts. The seasonal and meridunal oscillation of the inter-tropical discounting (ITD) attained a peak position of about latitude 18.8^{o}N in August. In addition, the dynamics of the atmosphere showed unusual surging and pulsation of the (ITD), such that severe storms were experienced over the coast as early as February in 2012, particularly over Lagos. Further scientific studies are presently being undertaken to understand the causative factors.

Rainfall amount were normal to above normal with high intensity during the month of July, August and September. It is important to note that for that first time since 2008, the northeast had rainfall more than normal values in more than ten consecutive years. Widespread flooding peaked between September and mid-October across the country and was particularly severe in the North-central and coastal states. Nigeria experienced the most flooding in 2012 for more than a century.

The hot season in 2012 led to significant socio-economic impacts. Strong rounds in the magnitude of 60 – 70 knots were experienced in the south and the North for the month of February and June respectively. Daily maximum temperature of 40.0^{o}C and higher were experienced in the northern part of the country and in some places for sixty days, although the days were not consecutive. High impact daily rainfalls of 100.0mm and higher values were recorded in the year between may and August.

Primary analysis in the agricultural sector suggest that out of the major food crops (yam, cassava, maize, Sorghum and rice) being produced in the country, yam would be the most affected, followed by rice and cassava. There were outbreaks of cholera in some states due to food and water contamination from floods. Mostly affected states by the flooding were Gombe, Kogi, Adamawa, Delta and Bayelsa state. Storms destroyed

infrastructures leading to disruptions of socio-economic activities.

Recent research has also noted the impact of climate change, agriculture and natural resources management in countries of Africa, Asia and latin America (Sparanza, 2010) because of how adaptive capacities and the projected impacts of climate change is a consensus has emerged that developing countries are more vulnerable to climate change than developed countries because of the pre-dominance of rainfed agriculture in their economics, the scarcity of capital for adaptation measures, their warmer baseline climates and their heightened exposure to extreme events (Fisher, *et al.*, 2015; Nnamachi and Ozor, 2009).

1.3 Evidence of Climate Change

The climate of Nigeria has shown considerable signals of a changing climate through the careful study of meteorological data. Analysis of long term trends of meteorological parameters such as rainfall, in terms of onset and cessation of the rain season, hail frequency and average maximum temperature during the hot season (February – April) lend support to this deduction.

1.4 Onset and Cessation of the Wet Season

The onset of the rainy (wet) season between 1941 and 1970 was monthly from early to normal isolated places around Sokoto, Maiduguri, Owerri, Port-Harcourt and Calabar had late onset of the rainy season. However, increasingly late onset of the rainy season characterized later years such that by 1971 – 2000 a vast portion of the country now experienced late onset of the rains.

2.0 MATERIALS AND METHODS

Data, Samples and Sampling Techniques

Data for the study covers the six meteorological parameters to study the climatic condition of Gombe State from the year 2004 to 2014. The parameters include:

i. Cloud amount
ii. Temperature
iii. Rainfall
iv. Humidity
v. Wind speed
vi. Pressure.

Samples for the research work were collected from the meteorological centre, in Federal Lowcost, opposite Fadama II Gombe, Gombe State and Gombe State International Airport, Lawanti along Bauchi road.

2.1 Techniques for Data Analysis

The technique used in this study is the statistical tool called correlation.This technique is used to determine the strength of relationship that exist between variables. Correlation value is denoted by "r". There are two types of correlation:

i. Pearson Product Moment correlation coeefficient
ii. Spearman Rank Correlation coefficient (Refs)

Pearson Product Moment Correlation Coefficient can be obtained by using the relation:

$$r = \frac{nE_{XY} - (E_X)(E_{XY})}{\sqrt{(nE_X^2 - (E_X)^2}(nE_Y^2 - E_Y^2)} \quad (1)$$

Spearman Rank Correlation Coefficient can be obtained by using the equation:

$$r = \frac{1 - 6ED^2}{n(n^2 - 1)} \quad (2)$$

where D is the difference in the pair of ranking.

2.2 Wind speed

$$D = \frac{d}{t} \quad (3)$$

where d = distance

t = time and r = speed or rate head and distance = (plan ground speed – and speed multiply by time ($t \times r$)

Time of flight is the actual time an aircraft is in the air flying from its departure point to its destination point.

$$Time = \frac{Disance}{Speed} \quad (4)$$

Speed can be measured in m/s

Cloud Base

$$Cloudbase = \frac{(Temperature - dewpo\,\text{int}) \times 100}{4.4} \quad \textbf{(5)}$$

$$Temperature = \frac{4.4 \times cloudbase \times dewpo\,\text{int}}{1000} \quad (6)$$

$$Dewpo\,\text{int} = \frac{Temerature - 4.4 \times cloudbase}{1000} \quad \textbf{(7)}$$

Humidity

Heat index

Heat index (HI) or apparent temperature (AI)

HI = 42.379 + 2.04901523 (IF) + 10.14 33127 (RH)

Summer Simmer Index (SSI)

SSI = 1. 98 (IF – 0. 55 – 0. 0055 (RH)) (TF – 58) – 56. 83

T(F) = air temperature in degrees Fahrenheit

RH = Relative humidity expressed as a whole number.

Results and Discussion

This chapter presents results of the study and the analysis as indicated on Tabes 1- 3, with discussions on each table.

Table 1**:** Average yearly climatic data in Gombe metropolis from 2004 to 2014

Year	Cloud amount (Oktas)	Temperature (^{o}C)	Humidity (%)	Rainfall (mm)	Pressure (hpg)	Wind speed (Knots)
2004	6.75	32.90	51.75	83.80	18.77	120.98
2005	6.55	32.19	48.67	81.29	17.82	89.09
2006	6.13	33.26	46.42	80.62	15.76	106.56
2007	6.48	32.82	49.08	73.44	18.03	120.76
2008	6.88	32.68	46.33	78.87	16.84	124.09
2009	6.75	32.94	49.17	76.93	18.88	87.96
2010	6.92	32.66	47.25	54.83	18.19	87.12
2011	6.73	32.29	46.94	65.40	17.92	96.78
2012	6.65	32.08	44.33	60.83	16.87	97.26
2013	6.82	33.13	49.08	90.78	18.98	122.57
2014	8.57	33.40	49.75	47.35	18.56	91.86

Table 2**:** Correlation on Yearly Climatic data 2004 to 2014

Years	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
2004	1.00										
2005	0.98	1.00									
2006	1.00	0.99	1.00								
2007	1.00	0.96	0.99	1.00							
2008	1.00	0.96	0.99	1.00	1.00						
2009	0.98	1.00	0.99	0.96	0.97	1.00					
2010	0.98	0.95	0.98	0.99	0.98	0.97	1.00				
2011	1.00	0.97	0.99	1.00	0.99	0.98	0.99	1.00			
2012	0.99	0.96	0.99	1.00	1.00	0.97	1.00	1.00	1.00		
2013	1.00	0.98	1.00	0.99	0.99	0.99	0.97	0.99	0.99	1.00	
2014	0.96	0.90	0.94	0.98	0.96	0.92	0.99	0.97	0.98	0.94	1.00

Table 1 presents the average yearly climatic data in Gombe metropolis from the year 2004 – 2014. The highest amount of cloud was observed in 2014 with the average of 8.57 (oktas) and the lowest amount of cloud was in 2006 having an average of 6.13 oktas.

The highest temperature also recorded in 2014 with an average of 33.40 ^{O}C. the lowest temperature variation was in 2012 with the average of 32.08 the highest humidity variation in Gombe from the data above was recorded in 2014 with the average of 51.75 ^{O}C and the lowest humidity was 44.33 ^{O}C.

The highest average rainfall drops from table Table1 was in 2013 with an average of 90.78 Mm whereas the lowest average of rainfall drops was in 2014 with the area of 47.35 Mm.

The highest pressure from Table 1 was in 2013 with an average of 18.98 Hpg. whereas, the lowest pressure was in 2006 with an average of 15.76 Hpg. The highest wind speed recorded was in the year 2008 with an average of 124.09 knots and the lowest was in 2010 with the average of 87.12 knots.

From the data on Table 2 the parameters are thus;

1. The parameter in 2004 are correlated with the parameters in 2007, 2008, 2011, 2013
2. The parameters in 2005 are correlated with the one in 2009
3. The parameters in 2006 are correlated with the one in 2013
4. The parameter in 2007 are correlated with the one in 2012
5. The parameter in 2008 are also correlated with the one in 2012
6. The parameter in 2009 are not correlated with any other year
7. The parameters in 2010 are correlated with the parameters in the year 2012
8. The parameter in 2011 are correlated with the parameters in the year 2012
9. The parameter in the year 2012 are not correlated with any of the year
10. The parameter in 2013 are not correlated with any of the year
11. The parameters in 2014 are not correlated with any of the year.

From the Table 3 data, when amount of cloud is high and the temperature is low which also affects the wind speed, pressure and also lowers the amount of rainfall drops. When the temperature is also high H increases the humidity, rainfall and wind speed but lowers the pressure.

When the humidity is high the pressures will be very low with high wind speed. And when there is high pressure the wind speed will be very low, vice-visa.

Table 3: Correlation matrix on the Climatic data from 2004 to 2014

Parameters	Cloud amount (Oktas)	Temperature. (oC)	Humidity (%)	Rainfall (mm)	Pressure (hpg)	Wind speed (Knots)
Cloud amount (Oktas)	1.00					
Temperature (oC)	0.39	1.00				
Humidity (oC)	0.30	0.49	1.00			
Rainfall (mm)	0.63	0.80	0.67	1.00		
Pressure (hpg)	0.42	0.19	0.75	-0.01	1.00	
Wind speed (Knots)	-0.25	0.26	0.19	0.60	-0.07	1.00

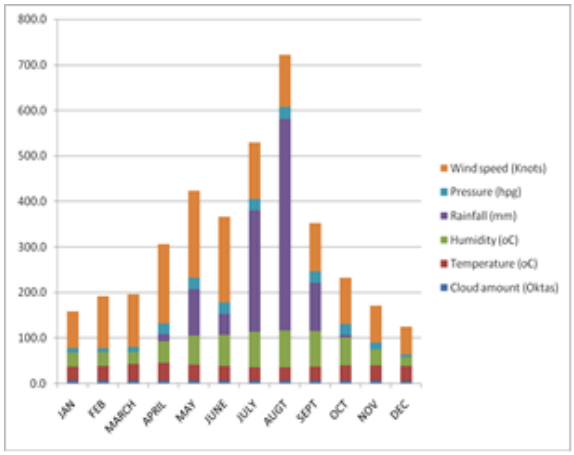

Figure 4.1: Climatic data from January to December 2004

Fig 4.1 revealed that the meteorological activities in the year 2004 is more pronounced in the month of August followed by July, May then September as well.

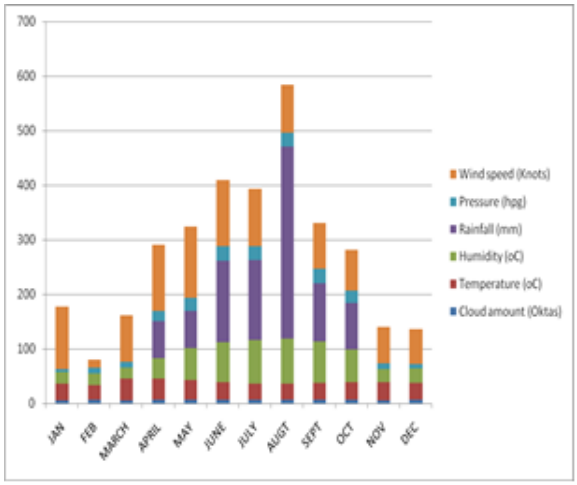

Figure 2: Climatic data from January to December 2005

Fig 2 indicated that the highest meteorological activities lies in the month of August followed by the month of June then July and September subsequently.

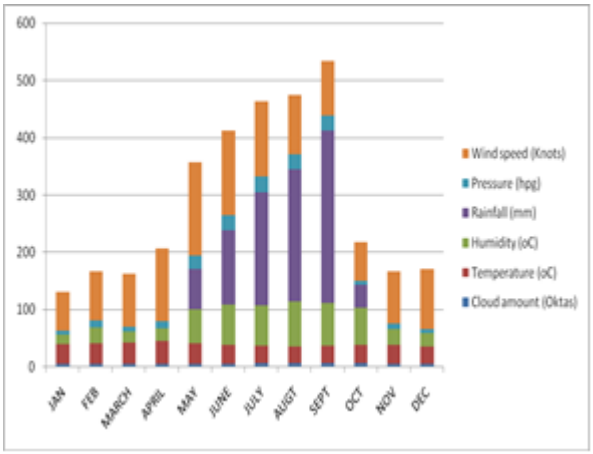

Figure 3: Climatic data from January to December 2006

Fig 3 shows that the highest meteorological activities were more pronounced in the month of September followed by the month of August and July subsequently.

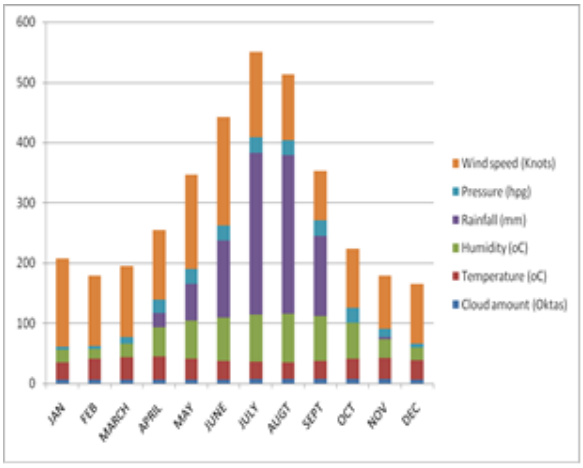

Figure 4: Climatic data from January to December 2007

Fig 4 indicates that the highest meteorological activities for 2007 were more pronounced in the month of July followed by the months of August than June subsequently.

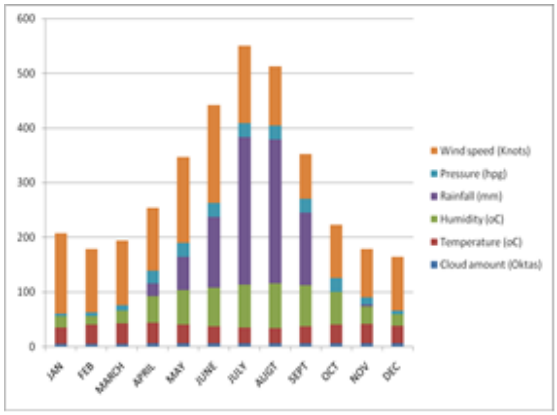

Figure 5: Climatic data from January to December 2008

Fig 5 indicates that the meteorological activities in the year 2008 noticeably in the month of July then August subsequently.

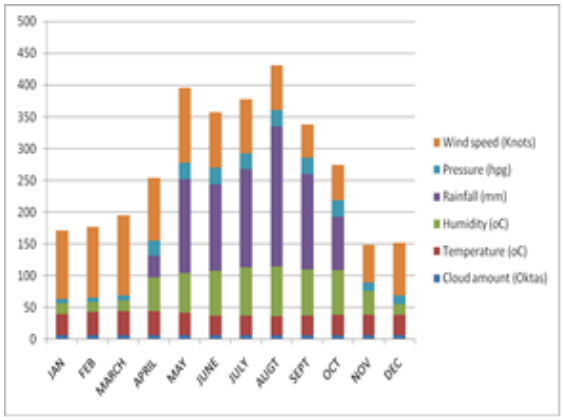

Figure 6: Climatic data from January to December 2009

Fig 6 indicates that the highest meteorological activities is more noticeably in the month of August followed by the month of May then July subsequently.

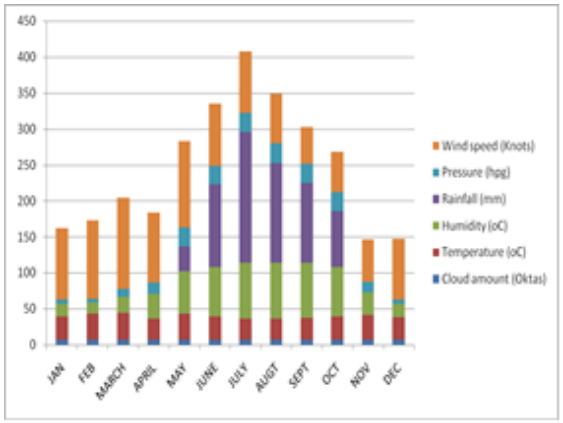

Figure 7: Climatic data from January to December 2010

Fig 7 revealed that the highest meteorological activities is more obvious in the month of July followed by the month of August then June subsequently.

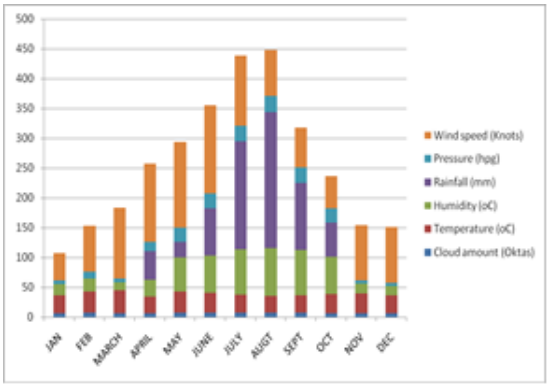

Figure 8: Climatic data from January to December 2011

Fig 8 shows that the highest metrological activities is more distinctive in the month of August followed by the month of June subsequently.

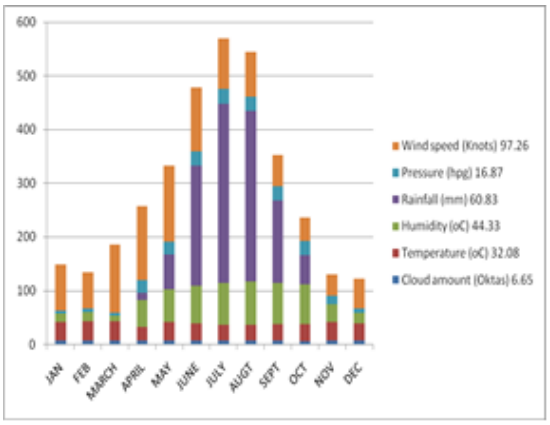

Figure 9: Climatic data from January to December 2012

Fig 9 indicates that the highest meteorological activities is more pronounced in the month of July followed by the month of August then June subsequently.

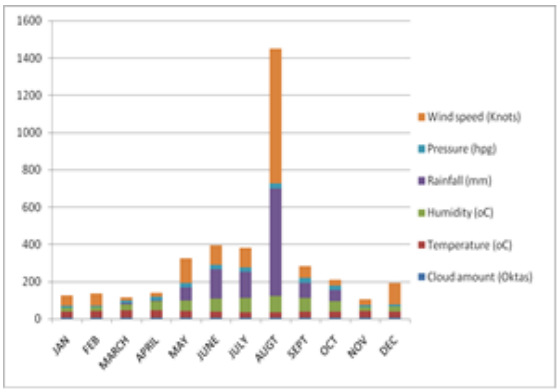

Figure 10: Climatic data from January to December 2013

Fig 10 shows that the highest meteorological activities are more notable in the month of August followed by June subsequently.

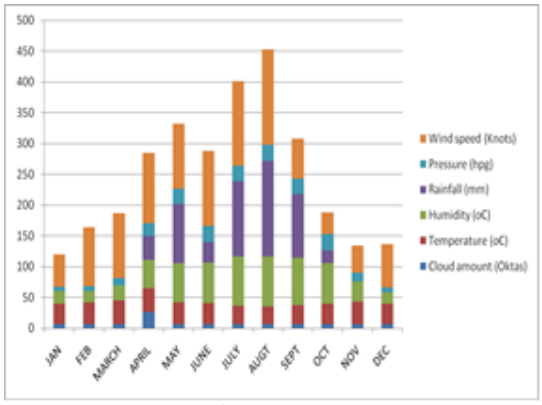

Figure 11: Climatic data from January to December 2014

Fig 11 shows that the highest meteorological activities are more notable in the month of August followed by the month July, then May subsequently.

Conclusion

Based on the data analysis, this study has revealed that:

i. When the cloud amount is high, the temperature will be low which can affect the wind speed, pressure, and also lowers the amount of rainfall drops which has a serious effect on agricultural activities. This can lead to food scarcity, outbreak of diseases, and mass level of migration.

ii. When the temperature is so high it increases the level of humidity, wind speed and high amount of rainfall which can lead to flooding, emergence of epidemic, mass level of migration and also outbreak of diseases such as cholera and bilharzias

Findings

The findings of this study, incude but not limited the the following.

i. The parameters averages in 2004 are correlated with the parameters in 2007, 2008, 2011 and 2013.

ii. The parameter's averages in 2005 are correlated with the parameters in 2009.

iii. The parameter's averages in 2006 are correlated with the parameters in 2013.

iv. The parameter's a in 2007 are correlated with the parameters in 2014.

v. The highest meteorological activities takes place in the month of august followed by July then September subsequently. While the months of January, February, November and December carries the lowest meteorological activities.

These assumptions made us to draw a conclusion that there might likely be a shortage of rainfall in Gombe metropolis in the next ten years (10). And there will be possibility of draught which may cause desertification.

Recommendations

From the findings of this study the following recommendations were drawn:

i. There is need for the government and the community to prepare for any natural hazard or extreme changes that can be predicted,

ii. They should also identify both man-made and natural causes of climate change and;

iii. Plan how to mitigate climate change impact on human and the environment at large.

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