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IMPACT OF RAINFALL VARIABILITY ON FLOODING OF RIVERS IN CROSS RIVER BASIN, NIGERIA

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ABSTRACT

Study was carried out to examine the impact of rainfall variability on flooding of rivers in Cross River Basin, Nigeria. It analysed time and space variability in rainfall and stage height of rivers between 1971 - 2000 and 2001 - 2012 climate regimes in the study area. Daily rainfall data were obtained from Nigerian Meteorological Agency (NIMET) from 1971 – 2012 in Eket, Uyo, Calabar, Ikom while monthly stage height data for the same period were collated from Cross River Basin Development Authority, Calabar for six rivers namely Abak Stream, Ikpa River, Cross River (Itu), Cross River (Ikom), Qua Iboe River and Abeb River. Collated data were analysed using descriptive statistics, t-test, one-way analysis of variance and Pearson Product Moment Correlation. Mean annual rainfall in Calabar, Uyo, and Ogoja were 2851.84, 2139.78 and 1946.45 mm in the past climate but increased by 7.90, 9.09 and 17.20 % (above normal) in the recent climate while the past average in Eket and Ikom were 4310.54 and 2279.20 mm with 1.60 and 1.30 % decrease (below normal) in recent period. However, significant ($p<0.05$) difference was obtained in Uyo and Ogoja only. Spatial distribution of rainfall within the basin area showed that annual rainfall amount differed significantly ($p<0.05$) among the five locations in the following order Eket > Calabar > Ikom > Uyo > Ogoja with mean rainfall of 4269.80 mm, 2894.10 mm, 2258 mm, 2243.80 mm and 1983.02 mm respectively. Also, water level at Abak stream, Ikpa River and Cross River (Itu) in recent climate deviated at 33.29, 65.49 and 9.09 % below the past average of 68.78, 186.24 and 194.12 cm while Cross River (Ikom), Abeb River and Qua Iboe River deviated at 7.12, 61.74 and 3.93 % above the past average of 320.46, 232.56 and 169.49 cm. Water level correlated differently with respective rainfall parameter at respective stream. The study revealed that rainfall intensity has increased in the study area and these have affected flows of rivers thereby increasing risk of flooding. It was therefore recommended that reservoirs like dams within the basin should be operated such that their levels are low in May and June to accommodate flood water that would arrive between July and September.

Keywords: Impact, Rainfall, Variability and Flooding

INTRODUCTION

Flooding is one of the hazards associated with rainfall event and it is defined as overflow of excess water in area which is normally not submerged (Umoh, 2008). It is a common feature in coastal areas. Nwafor (2006) defined flood as a natural hazard like drought and desertification which occurs as an extreme hydrological (runoff) event. On the other hand, Abam (2006) defined flood as large volume of water which arrives at and occupy the stream channel and its flood plain in a time too short to prevent damage to economic activities including homes. Flooding is the most common environmental hazard worldwide accounted for over 30% of all natural disasters occurring between 2000 and 2006 (IUCN cited in Adefolalu, 2010). Flood disaster is not a recent phenomenon in Nigeria, and its destructive tendencies are sometimes enormous.

Flooding affects sustainable development in many countries. It affects many hundreds of thousands of households annually causing recurrent losses of material goods and endangered lives, thereby affecting progress towards sustainable human development. The extent of damage done by flood to agriculture is enormous, it contributes to yield reduction, crop and animal diseases and death, food shortage (food insecurity), high level of hunger, and collapse of industries and farm structures, reduction of agricultural lands, competition on land for space due to displacement of people from their habitat as witnessed in migration of people from place to place as a way of coping with flood risk. It also causes serious health hazard on farmers which eventually leads to death thereby reducing the farming population (Stige, Stave and Chair, 2006). Other related problems include high crime rate due to hunger and unemployment as well as social unrest. Flooding is already one of the most widespread of hydro-meteorological hazards in present climate regime, and the Intergovernmental Panel on Climate Change (IPCC, 2012) predicts that climate change is likely to cause an increase in flood hazards in many areas of the world. In Nigeria, NIMET (2013) stated that impact of climate change is threatening almost every sector of the economy and this has already been revealed as NEMA reported 2.6trillion Naira loss to 2012 flood disaster alone.

Several submits have been held globally and nationally in attempt to combat climate hazards especially in a changing climate regime witnessed in recent time, nevertheless, climate risks like flood still abound. It is obvious that occurrence of natural disasters associated with severe climate events are now increasing in number and intensity taking terrible toll on human lives and socio-economic development. For instance, flood is the highest occurring natural disasters worldwide with 12 cases recorded between 1930 –1949. The number increased to 81 between 1950 and 1959, 156 cases between 1960 and 1969, 265 cases in 1970 – 1979, and 537 cases between 1980 and 1989. The figure increased to 800 cases from 1990 – 1999 and 984 cases between 2000 and 2006 (IUCN, 2006). From the statistics of natural disasters published by Ecosystem Livelihood natural Disasters cited in IUCN (2006), flood accounted for over 30% of all natural disasters (2860) in the world between 2000 and 2006 while drought occupied only 6.5%. Regional distribution of flood revealed that Asia had the highest (35.8 %) followed by Americas and Africa with 22.3 and 22.2 %; 17.4% in Europe with the least (2.4%) occurring in Oceania (CRED cited by IFRC, 2006). In Nigeria, serious flood disasters have occurred in Ibadan (1985, 1987 and 1990), Osogbo (1992, 1996, 2002), Yobe (2000) and Akure (1996, 2000, 2002, 2004 and 2006) and Akwa Ibom State (2012).

World flood damage estimates are in billions of U.S. dollars annually, with 1000s of lives lost; while drought costs are of similar magnitude and often lead to devastating wildfires and heat waves (Trenberth, 2011). Floods of all magnitude have the potential to impact on human health. Flooding can increase exposure to toxins and pathogens, and this may have implications for mental health. It can also disrupt the capacity of health care systems to respond to health crises (McMichael *et al.,* 2001; WHO, 2002). According to Few, Ahern, Matthies and Kovats (2004), data available shows that by far the greatest burden on mortality is in Asia, and suggests that incidence of death due to inland and coastal flooding is especially high in parts of Central and South America, the Caribbean and South Asia. Infectious disease is a major flood-related health concern in the South, especially in settings where infectious disease transmission is an endemic public health problem in most flood areas (Few *et al*., 2004). Infectious disease outbreaks have been reported following major flood events in developing countries, and these outbreaks vary in magnitude and rates of mortality.

Nigeria is already being plagued by flood as NEMA (2013) reported over 2.6 trillion Naira losses to 2012 flood disaster along with loss of lives and properties. In addition, NEMA also reported that flood disasters caused by internal waters and rains, and waters from Lagdo Dam in Cameroon have killed about 20 Nigerians in two months. Again, 16,470 Nigerians have also been displaced from homes in 2012 due to flood risk with 434 houses destroyed due to heavy rains in Kano (NEMA, 2013). The risks is likely to be worst in coastal areas like the Cross River basin due to abundance of water bodies (Umoh, 2008) and high pollution index due to small land area (which increases human activities on wetlands thereby altering hydrological processes). For instance, 2012 flood was historic in Akwa Ibom State: it claimed a community, destroyed lives and properties and disrupted people's livelihood in Ibeno Local Government Area leading to serious unemployment and poverty threats. In Uruan Local Government Area, a major road leading to Oron Local Government Area (a major economic town in the state) was over flown with flood water resulting in high transportation cost and increase poverty. In Ibesikpo Asutan, part of a community in a village called Ediam was swallowed by flood leaving the people homeless, destroying their farmlands and disrupting agricultural activities (which is the major livelihood activity in the area) leading to increase unemployment, household and community shocks.

Evidence suggests however that structural approaches can still increase vulnerability, particularly when storm events exceed the levels for which the structure was designed. Also, non structural adaptation strategies to climate hazards are seriously affected by wrong land use planning particular for agricultural purpose and urban development. knowledge about the changed pattern of rainfall has not only influenced peoples' perception to climate change, but has also influenced their responses to adaptation practices to climate related risks such as flood (Umoh, 2008; Deressa *et al*., 2008). Hence, the need for rainfall – flood study in the study area. The study therefore seeks to analyse changes in various rainfall characteristics and associated influence of such changes on flooding of rivers in Cross River Basin of Nigeria.

Objectives of the study

The aim of this study was to examine the impact of rainfall variability on flooding of rivers in Cross River basin of Nigeria. Specifically, the study:

1. compared changes in selected rainfall characteristics between the

past and present climate periods in the study area
2. compared changes in stage height of selected rivers between the two climate periods in the study area
3. determined the relationship between rainfall parameters and stage height of rivers in the area

METHODOLOGY

The study was conducted in Cross Basin, located in a coastal area of the Niger Delta region of Nigeria. The Cross River Basin lies between latitude 04°30' and 06°45' N and Longitude 07°30' and 09°15' E. It has a total land area of 58.8 km^2 covering Akwa Ibom and Cross River states. The climate of area depends on the movement of the Inter-tropical discontinuity, which is the zone separating the warm humid maritime air mass with its associated South Westerly winds from dry continental air mass (North Westerly winds). Generally, the basin is situated within the tropical monsoon climate with bimodal rainfall pattern, which begins in March and ends in mid October with a little dry spell in August traditionally referred to as "August break". The little dry spell gives rise to the two rainfall regimes with the heaviest rainfall occurring in July for first peak and September for the second peak. The mean annual rainfall in the wet season is usually heavy ranging from 1500 mm in Ogoja area to over 3500 mm along the coast at Eket (Udosen, 2008). The dry season starts from November and last till February with the mean annual temperature between 26 ^{0}C and 28 ^{0}C. The highest temperatures are experienced between January and February, the period which coincides with overhead of the sun and high relative humidity of 65 – 95 % is common.

Daily rainfall data were collected from Nigerian Meteorological Agency (NIMET) in Eket, Uyo, Calabar, Ikom and Ogoja from 1971 – 2012 while monthly stage height data for the same period were collated from Cross River Basin Development Authority, Calabar for six rivers namely Abak Stream, Ikpa River, Cross River (Itu), Cross River (Ikom), Qua Iboe River and Abeb River. The GPS locations of the stations were also collected (Figure 1). Collated data were analysed using descriptive statistics, t-test and Pearson Product Moment Correlation. The data set was grouped into two climate periods: the past climate regime represented by the long period data (1971 - 2000) and the present climate regime represented by the short period data (2001 - 2012). Percent deviation of sample mean for 2001-2012 climate period from the long term mean (1971-2000) was computed to determine degree of departure in each of the elements. The percent deviation is given as:

$$\varphi = \frac{x_r - x_l}{x_l} \times 100 \qquad (1.1)$$

where φ represents the departure, x_r is the sample mean for recent climate period (2001-2012) and x_l is the long term mean (1971-2000). Thus, φ of +1% within a cell (location) indicates that the observed mean for recent period in that location is 1 % greater than the long term mean (Above normal), a φ of -1 % indicates that the observed mean for recent period is 1 % less than the long term mean (Below normal), while a percentage deviation of 0 % indicate no difference (normal).

RESULTS

Rainfall Variability in the study area

Table 1 showed the onset, cessation and duration pattern. On the whole, the result showed that onset of rain in the Cross River Basin occurred between the 69th and 87th day of the year and t-test result showed that there was no significant difference (p>0.05) in onset date of the two climate periods except in Calabar. Cessation of rain was between the 305th and 326th day of the year in the past climate regime but between 310th and 324th day in recent period. However, there was no significant difference in cessation period of the two climate periods in any of the locations. Similarly, length of rainy season was between 228 and 246 days in the past regime and 222 – 243 days in recent time but there was no significant difference (p<0.05) between the two climate periods except in Calabar. Rainy days (RD) occupied 58.68 % of total number of days in 1971 – 2000 climate period and 63.055 % in 2001 – 2012 climate period in Eket (Table 2). It accounted for 47.57 and 47.52 % of total number of days in 1971-2000 and 2001 - 2012 in Uyo whereas it occupied 59.29 and 55.41 % of the total number of days in the two climate regimes respective. Dry days (DD) increased slightly in Uyo, Calabar and Ikom while it decreased slightly in Eket. Proportion of Wet - Dry (PWD) days occupied the greatest number of days in both climate periods followed by Proportion of Dry- Dry (PDD) days followed by Proportion of Wet - Wet (PWW) days while Dry-Wet (PDW) days had the least proportion. Little Dry Season (August break) anomalies in Table 3 showed that mean LDS for 2001-2012 climate period was lower than the long term average in the four locations but the difference was not significant (p>0.05) in Uyo and Calabar.

Analysis of frequency of rainfall of various sizes in the study area presented in Table 4 showed that out of the total number of rainfall received in 1971 - 2000 period, 23.40 % were trace rainfall which was lower than 21.30 % in 2001 – 2012 climate period in Ikom. The trace rainfall was 22.1 % in the long term period lower than 17 % in recent period for Calabar, it was 18 % lower than 15 % in Eket and 13.46 % higher than 16.21 % in Ogoja for the long term and recent climate periods respectively. However, the difference was not statistically significant (P<0.05).

Table 1: Rainfall onset and cessation pattern in the study area

Station	Climate Period	Onset period	Cessation	Duration
Eket	1971 – 2000	80±11	326±12	246±9
	2001-2012	78±16	322±20	243±28
Uyo	1971 – 2000	76 ± 18	305 ± 30	229 ± 27
	2001-2012	69 ± 29	312 ± 116	243 ± 88

Calabar	1971 – 2000	86 ± 26[a]	324 ± 20	238 ± 34[b]
	2001-2012	76 ± 23[b]	322 ± 12	246 ± 17[a]
Ikom	1971 – 2000	79 ± 14	307 ±10	228 ± 21
	2001-2012	87 ± 18	310 ± 9	222 ± 19

Means with different superscripts along the same column are significantly different (p<0.05)

Table 2: Wet and Dry Episodes in the study area

Station	Climate Period	RD	DD	PWW	PWD	PDW	PDD
		←		%		→	
Eket	1971 – 2000	58.68[b]	41.32[a]	12.51	56.06	8.52	22.91
	2001-2012	63.05[a]	36.95[b]	12.93	54.33	11.70	21.03
Uyo	1971 – 2000	47.57	52.43	15.13	30.83	15.13	38.93
	2001-2012	47.52	52.48	17.15	30.82	17.15	34.87
Calabar	1971 – 2000	59.39[a]	40.61[b]	13.45	46.90	13.03	26.62
	2001-2012	55.41[b]	44.59[a]	14.42	41.28	14.90	29.40
Ikom	1971 – 2000	51.74	48.30	12.43	39.79	12.03	35.75
	2001-2012	50.20	49.86	13.09	37.41	13.21	36.29

Means with different superscripts along the same column are significantly different (p<0.05)

RD: Rain Day, DD; Dry day, PWW: Proportion of wet followed by wet day, PWD: Proportion of wet followed by dry, PDW: Proportion of dry followed by wet day, PDD: Proportion of dry followed by dry day

Table 3: August Rainfall Anomalies in the study area

Station	Climate Period	Maximum	Mean	Cv(%)
Eket	1971 – 2000	17	7.0 ± 6.60[a]	94.29
	2001-2012	13	4.25 ± 4.39[b]	103.29
Uyo	1971 – 2000	21	12.25 ± 5.91	48.28
	2001-2012	20	11.63 ± 4.85	63.20
Calabar	1971 – 2000	18	11.34 ± 4.85	42.80
	2001-2012	13	8.73 ± 3.84	43.96
Ikom	1971 – 2000	17	10.89 ± 6.25[a]	57.42
	2001-2012	9	6.0 ± 3.43[b]	57.20

Means with different superscripts along the same column are significantly different ($p<0.05$)

Table 4: Rainfall intensity in the study area

Station	Climate Period	Trace	≤25 mm	26-50 mm	51-99 mm	100 – 150 mm	>150 mm
		←			%		→
Ikom	1971 - 2000	23.40	61.20	10.80	4.30	0.30	0.0[b]
	2001-2012	21.30	61.90	11.60	4.90	0.20	0.10[a]
Calabar	1971 - 2000	22.10	59.70	11.70	5.40	0.80	0.30[b]
	2001-2012	17.0	60.90	14.20	6.30	1.0	0.60[a]

Uyo	1971 - 2000	18.0	63.40	13.40	5.0	0.20[b]	0.0
	2001-2012	15.20	65.20	13.60	5.50	0.50[a]	0.0
Eket	1971 - 2000	13.46	60.23	14.66	9.19	1.93	0.53[a]
	2001-2012	16.21	59.04	14.69	8.07	1.66	0.33[b]

Means with different superscripts along the same column are significantly different (p<0.05)

Average annual rainfall of 2248.83 ± 222.27 mm, 3077.98 ± 485.22 mm, 2331.38 ± 203.94 mm, 4242.60 ± 357.59 mm and 2281.75 mm ± 503.30 mm were recorded in Ikom, Calabar, Uyo, Eket and Ogoja respectively in recent climate period while 2279.20 ± 222.77 mm, 2851.84 ± 355.98 mm, 2139.78 ± 394.09 mm, 4310.54 ± 429.74 mm and 1946.45± 886.33 mm were obtained in the past regime (1971 – 2000) for Ikom, Calabar, Uyo, Eket and Ogoja respectively. Time variability of rainfall (Figure 1) showed that 68.4 % of the rainfall parameters considered had means above normal while 31.6 % had means below normal in Uyo; 31.6 % had means above average while 68.4 % had means below average in Eket. In Calabar, 63.2% of the parameters had means above the long term average while means of the remaining 36.8 % were below the long term average. The pattern in Ikom was similar to Calabar and Uyo with 52.6 % parameters having their means above the long term average while the remaining 47.4% were below average. Generally, most rainfall parameters considered in the study had above normal departure. However, moderate high (5 – 20 %) departure was observed in parameters like probability of dry followed by wet (PWD), dry followed by dry (PDD), little dry season (LDS), trace rainfall, 26-50 mm, and 51 – 99 mm rainfall while very high (>50 %) departure was observed in 100 – 150 mm and >150 mm rainfall. The departure suggests that there is increase in rainfall intensity within the basin especially in Uyo and Calabar which agrees with wetter than normal condition reported by NIMET (2012) in southern coast of the country.

Spatial variability of rainfall was given in Tables 6. Analysis of variance showed significant difference (p<0.05) in all rainfall characteristics considered among the five locations except date of onset of rain. The distribution showed that onset dates in the four locations were in the order Ikom > Calabar > Eket > Uyo. Similarly, mean cessation of rain in the area were in the order Eket > Calabar > Ikom > Uyo. There was a significant (p<0.05) difference in mean cessation of rain among the four locations. On the mean, Eket had the longest rainy season (244.50 days) followed by Calabar (237.37 days) to Uyo with 230.47 days while Ikom had the least (223.48 days). The study also revealed that the duration of rainfall in Ikom was significantly (p<0.05) lower than that of Eket, Uyo and Calabar. The highest mean annual rainfall was received in Eket (4269.80mm) followed by Calabar with 2894.10 mm to Ikom (2258 mm) and Uyo (2243.80mm) while Ogoja had the least (1983 mm). Decadal variability (Table 7) revealed that annual rainfall amount had been increasing in Uyo, Calabar and Ogoja from 90s while it decreased in Eket and Ikom.

Table 5: Annual Rainfall Amount

Station	Climate Period	Mean Annual	Wet season Average
		← mm	→
Ikom	1971 – 2000	2279.20±222.27	2035.95±232.91
	2001-2012	2248.83±196.33	2065.70±196.33
Calabar	1971 – 2000	2851.84±355.98	2447.49±341.73
	2001-2012	3077.98±485.22	2632.07±438.34
Uyo	1971 – 2000	2139.78±394.09[b]	2109.30± 61.44[b]
	2001-2012	2331.38±203.94[a]	2233.05±403.83[a]
Eket	1971 – 2000	4310.54±429.74	3652.36±471.81
	2001-2012	4242.60±357.59	3599.53±318.25
Ogoja	1971 – 2000	1946.45±886.33[a]	1850.91±893.01[b]
	2001-2012	2281.75±503.30[a]	2169.0±470.78[a]

Means with different superscripts along the same column are significantly different ($p<0.05$)

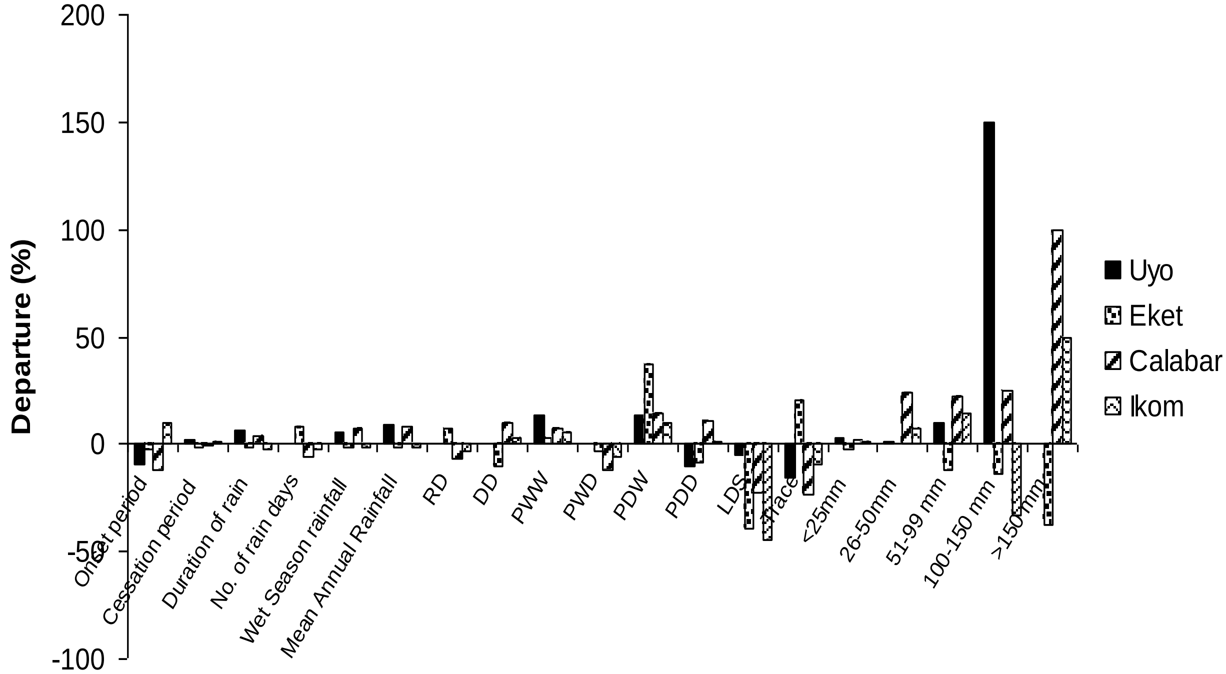

Figure 1: Time Variability of Rainfall paramters in Cross River Basin

Table 6: Spatial variability of rainfall parameters within the study area

Location	Variable	Onset	Cessation	Duration	Mean Annual (mm)	Rd	Pww	<25 Mm	26-50 mm	51-99 mm	100-150 mm	>150 mm	LDS
Uyo	Range	54-104	225-342	166-274	1208.30 - 2715.70	150-191	93-181	92-131	15-33	1 – 14	1 - 3	-	6-21
	$\overline{X}$	75.91	306.38^{b}	230.47^{bc}	2243.80^{c}	173.72^{c}	112.60^{c}	111.41^{c}	23.34^{bc}	9.03^{c}	0.59^{c}	-	12.13^{a}
	Sd	13.56	22.79	21.34	361.28	10.94	18.06	9.03	4.94	3.14	0.80	-	5.0
	Cv	17.87	7.49	9.26	16.20	6.30	16.04	8.11	21.17	34.73	134.31	-	41.24
Eket	Range	56-97	283 – 347	190-289	3488.40-4808.0	202-252	115-190	118-150	23-44	14-25	2 - 7	0 – 3	5-14
	$\overline{X}$	79.06	323.56^{a}	244.50^{a}	4269.80^{a}	223.80^{a}	155.85^{b}	133.47^{a}	32.95^{a}	19.0^{a}	3.95^{a}	0.53^{a}	7.61^{b}
	Sd	13.23	16.93	21.40	378.47	14.87	18.13	9.08	5.44	2.87	1.39	0.65	4.33
	Cv	16.74	5.23	8.75	8.86	6.65	11.63	6-80	16.52	15.09	35.30	146.75	56.90
Calabar	Range	53-117	283-338	200-274	2109.0-3770.80	186-250	126-200	99-149	14-39	3-19	2 - 6	1- 3	7-17
	$\overline{X}$	80.65	318.02^{a}	237.37^{ab}	2894.10^{b}	212.76	165.45	127.47^{b}	25.88^{b}	12.12^{b}	1.84^{b}	0.35^{b}	9.14^{b}

						b	a						
	Sd	15.68	13.13	19.06	381.38	13.61	16.93	10.33	5.19	4.08	1.43	0.65	4.24
	Cv	19.44	4.15	8.03	13.18	6.40	10.23	8.10	20.06	33.06	77.82	186.47	46.38
Ikom	Range	57-105	289-326	186-257	1760.30-2683.80	155-195	31-59	92.138	12-30	1-13	1 – 2	-	7 – 18
	$\bar{X}$	83.41	308.14^{b}	223.48^{c}	2258.0^{c}	180.05^{c}	95.68^{d}	114.73^{c}	20.73^{c}	8.41^{c}	0.50^{c}	-	10.61^{a}
	Sd	14.08	9.36	18.37	226.07	10.92	6.64	11.0	5.11	2.89	0.67	-	3.93
	Cv	16.88	3.04	8.17	10.01	6.06	14.53	9.59	24.65	34.36	134.52	-	37.09
Ogoja	Range				1251.40-3347.80	-	-	-	-	-	-	-	-
	$\bar{X}$				1983.02^{d}	-	-	-	-	-	-	-	-
	Sd				482.48	-	-	-	-	-	-	-	-
	Cv				24.33	-	-	-	-	-	-	-	-

Mean with different superscript along the same column are significantly different ($p<0.05$)

Table 7: Decadal Rainfall Variability in the study area

	Decadal Rainfall (mm)				Variability Index (%)		
Station	1971-1980	1981-1990	1991-2000	2001-2010	2nd – 1st	3rd-1st	4th-1st
Uyo	-	2038.08	2247.79	2363.05	-	10.29	15.94
Eket	-	-	4310.54	4190.48	-	-	-2.79
Calabar	2814.06	2742.5	2998.952	2964.35	-2.54	6.57	5.34
Ikom	2396.45	2182.25	2282.35	2157.6	-8.94	-4.76	-9.97
Ogoja	-	1651.53	1823.40	2136.52	-	10.41	29.37

Water stage level of rivers in past and recent climate periods in the area

Table 8 showed change in water levels between the past and present climate periods for the six rivers considered within the study area. Seasonal trend and Inter-annual variability in stage height of these rivers are also presented in Figures 1 – 6. Comparatively, Peak height of all the rivers were higher in the past climate regime than the recent period except in Cross River (Ikom). However, mean height showed significant ($p<0.05$) difference between the two periods in Abak Stream, Ikpa River and Abeb River but no significant ($p>0.05$) difference in Cross River (Ikom and Itu) as well as Qua Iboe River in Eket. Figures 2 – 7 showed that water level in the rivers were generally higher in rainy season than dry season though the change was not significant ($p>0.05$) in Qua Iboe River. This suggested that rainfall is the major cause of flooding of rivers in the study area. In other word, Cross River Basin of Nigeria is mostly affected by coastal flooding.

Apart from Seasonal changes, figures 2 revealed that water level of Cross River (Itu) was above normal in the past climate regime but slightly below normal in recent climate regime. The trend in Cross River in Ikom (Figure 3) was opposite to that of Cross River in Ikom. For Ikpa River in Uyo (Figure 4), mean water level was above normal in the past climate but below normal in recent climate while stage height of Abak Stream (Figure 5) at both periods was above normal with past climate witnessing the highest stage level. In Qua Iboe River in Eket (Figure 6), which is a major tributary of Atlantic Ocean in Akwa Ibom State, water level in the past climate period was above normal while its height at recent climate was below normal. The sharp rise in recent climate between July and October was attributed to 2012 deadly flood in the area. Similarly, changes in water level of Abeb River (Figure 7) were below normal in the past climate but above normal in recent climate. Worthy of note in this river is a sharp rise in recent period between July and October. This reflected the influence of human activity (dam operation) on flooding experiencing in recent time in the country. Generally, when the river was not dammed, the monthly mean level was below 80 cm but since it was dammed in 2003, the stage level rose to over 100 cm and sometimes exceeding 120 cm at peak rainy season suggesting high probability of flooding in recent time than in the past climate. Seasonal flow of these rivers portrays high probability of flood at the peak rainy season (between July and October) and this is attributed to increased rainfall coupled with unwise opening of dams at the peak rainfall season too.

Coefficient of variability (CV) is useful in predicting pattern of flood. Values of CV obtained were 57.86, 68.16, 16.52, 21.29, 37.97 and 10.69 % for Cross River Itu, Cross River Ikom, Ikpa River, Abak Stream, Abed River and Qua Iboe River respectively.

The result of the relationship between rainfall parameters and water level of the six rivers considered in the study was presented in Table 9. The result revealed that the relationship varied from one river to another. For instance, stage height of Ikpa River significantly ($p<0.05$) correlated with number of rainy and dry days (r = 0.665 and 0.884 respectively). It had significant ($p<0.05$) correlation with annual rainfall amount, number of rainy days, number of dry days and 26 – 50mm rain with correlation coefficient of 0.556, 0.558, - 0.559 and 0.591 respectively in Abak stream. In Cross River (Ikom), annual rainfall amount, 51 – 99mm rain and >100 mm rain correlated significantly ($p<0.05$) with stage height (r = 0.614, 0.864, and 0.660 respectively). No significant ($p>0.05$) correlation was obtained between stage height of Cross River (Itu) and Qua Iboe River (Eket) with rainfall parameters.

Table 8: Water Level of Rivers in the study area

Name of River	Mean Level (cm)		Peak Level (cm)		t-value	Sig.
	1971 – 2000	2001 – 2012	1971-2000	2001-2012		
Abak Stream (Uyo)	68.78 ± 4.95[a]	45.88 ± 17.67[b]	84.0	64.67	-2.140	0.054*
Ikpa River (Uyo)	186.24 ± 78.38[a]	64.27 ± 16.07[b]	623.0	108.0	-2.614	0.022*
Cross River (Ikom)	320.46 ± 43.19	343.29 ± 82.36	747.0	621.0	0.650	0.528
Cross River (Itu)	194.12 ± 47.29	176.47 ± 15.29	426.0	440.0	-0.999	0.339
Abeb River (Obudu)	232.56 ± 77.01[b]	376.15 ± 51.78[a]	139.48	117.60	3.992	0.001**
Qua Iboe River (Eket)	169.49 ± 46.22	176.15 ± 11.04	611.0	556.0	0.431	0.673

Mean with different superscript along the same row are significantly different ($p<0.05$)

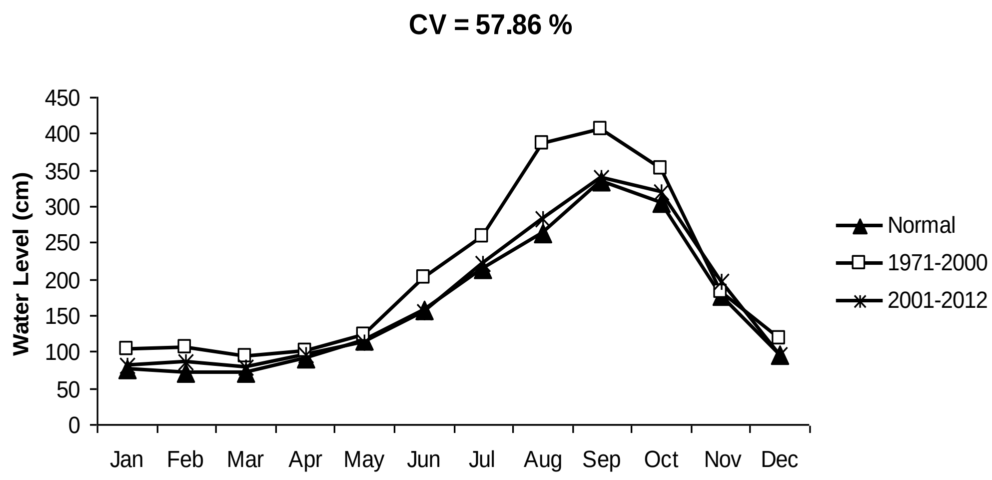

Figure 2: Seasonal changes in water level of Cross River (Itu)

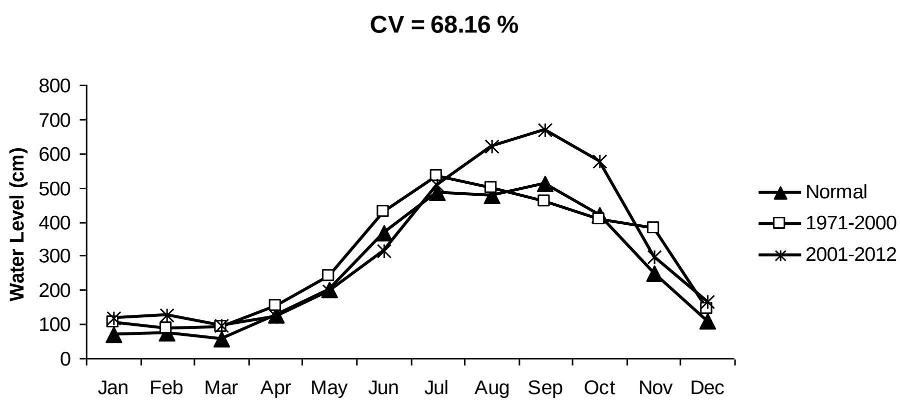

Figure 3: Seasonal changes in water level of Cross River (Ikom)

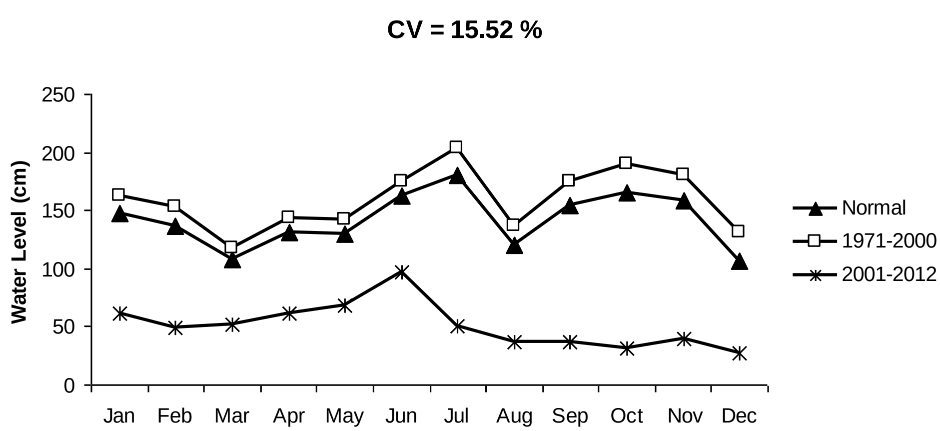

Figure 4: Seasonal changes in water level of Ikpa River

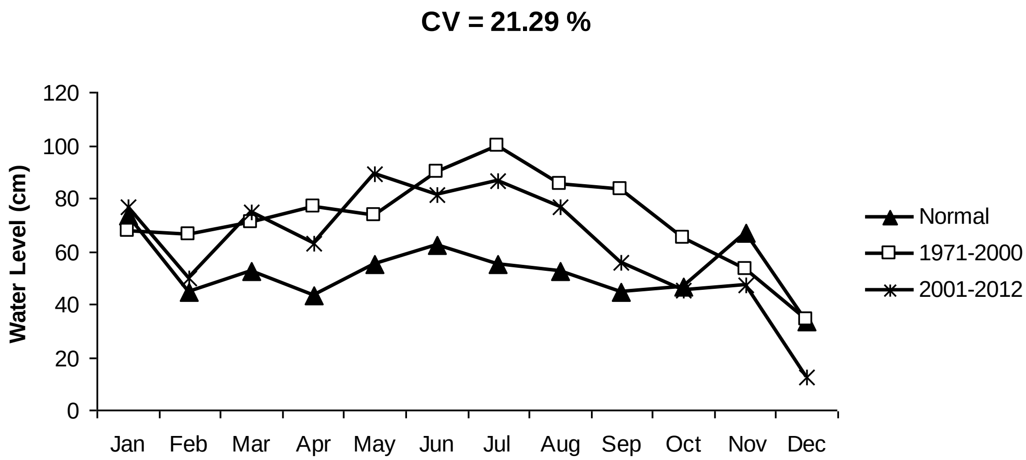

Figure 5: Seasonal changes in water level of Abak stream

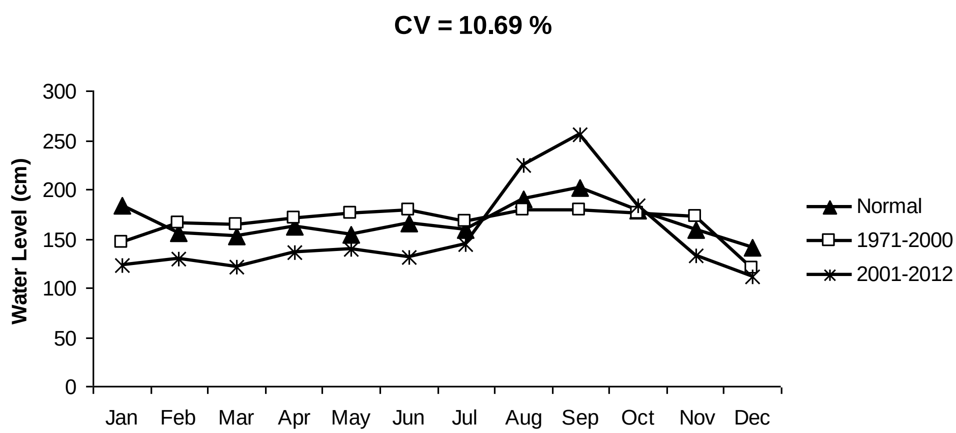

Figure 6: Seasonal changes in water level of Qua Iboe River

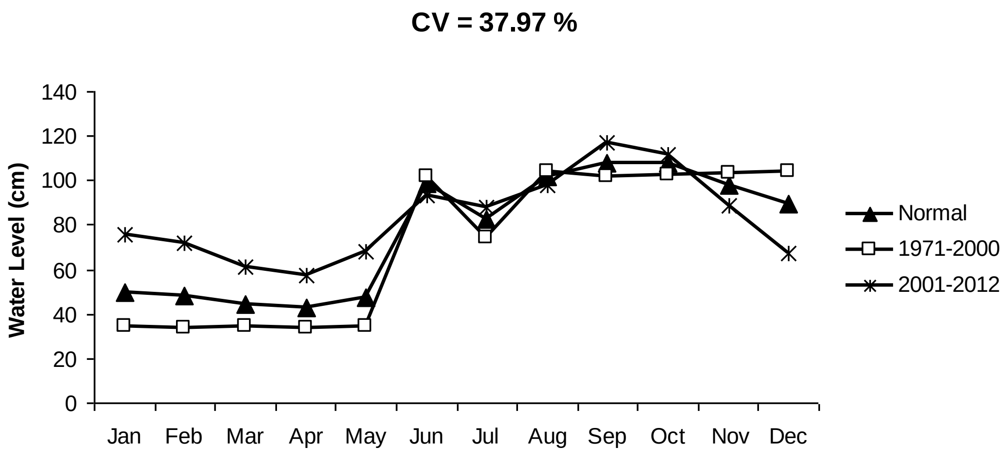

Figure 7: Seasonal changes in water level of Abeb River

Table 9: Correlation coefficient (r) between rainfall parameters and river stage level

Rainfall Parameters	Cross R. (Itu)	Ikpa R.	Abak Stream	Cross R. (Ikom)	Qua Iboe R.
Annual Rainfall amount	0.108	0.123	0.556*	0.614*	0.006
Number of rainy days	0.262	0.665*	0.558*	0.313	0.129
Number of dry days	-0.242	-0.884**	-0.559*	-0.298	-0.122
< 25 mm rain	0.091	0.335	0.185	0.059	0.237
26 – 50 mm rain	0.084	0.242	0.591*	0.384	0.021
51-99 mm rain	0.211	-0.218	0.129	0.864**	0.260
>100 mm rain	-0.213	-0.199	-0.346	0.660*	-0.397
Rainfall Duration	-0.206	0.114	0.165	0.179	-0.316

*Significant at $p<0.05$, ** Significant at $p<0.01$

Discussion of finding

The rainfall scenarios suggested a marked contrast between past and present climate in the study area. The Third Assessment Report of IPCC (2007) summarizes that there is a strong gradient of change in rainfall (increasing rainfall of as much as 2% per decade) due to climate change. Hence, it is likely that intense rainfall events has increased in frequency in some locations, especially in the wet season leading to flooding of rivers in the low lying areas. This flood destroys farmland and crop yield thereby increasing hunger, food insecurity and other household and community shocks. Findings have shown that some part of the basin are drier (Eket and Ikom) in the recent climate regime than what was obtained in past climate while most locations such as Uyo, Calabar and Ogoja experience increased rainfall in recent time than what was obtained in the immediate past climate. This results collaborates with NIMET (2012) who reported wetter than normal rainfall pattern in most parts of southern Nigeria and that of Umoh (2008) who attributed increased flooding in wetland areas of Akwa Ibom State to increased rainfall event in the area due to climate change. Also, study by Oguntunde *et al*. (2006) on characteristics of rainfall variation between 1901 and 1985 in West Africa found no observable regular patterns in trends or cycles (i.e. regularly re-occurrence pattern) but annual rainfall amount was completely different from what is obtainable in the 21st century. This has also been confirmed in Cross River Basin between the two climate periods of 1971 – 2000 and 2001 - 2012. Most rainfall characteristics within the basin area did not show significant ($p>0.05$) difference between the two periods accept rainfall intensity. However, spatial distribution of annual rainfall amount confirmed that Nigerian rainfall exhibit great variability both in time and space even within a local scale. Values obtained among the five locations reflected their proximity to the seas suggesting that Nigerian rainfall could be latitude dependent. Result of increased dry spell in almost all the locations perfectly agreed with Yusuf and Atteh (2009) and Yusuf and Mohammed (2011) who analysed rainfall data between 1911 and 1980 from twenty-eight synoptic weather stations and reported a general increase in dry spell in the coastal region which suggests decreasing rainfall events. This implies that why some locations in the coastal areas will witness more flooding others may experience drought. However, both drought and flood are detrimental to agriculture, food security and general livelihood of man. On a global scale, variation in rainfall amount may be due to dissimilarity in the distance from major source of moisture supply like oceans, sea, rivers, etc. Hence, higher total annual rainfall is expected in Eket and Calabar than Uyo, Ikom and Ogoja as also observed by Udosen (2008) in the case of Uyo and Eket in Akwa Ibom State. On a local scale however, the relative effects of individual factors like topographic position of the weather station results in variability in rainfall received among local weather stations within the same region, hence, existence of variability in rainfall of closely related locations.

Comparison of water stage level between the recent and past climate in the study area revealed that water level increased steadily in Cross Rivers (Ikom), Abeb River (Obudu) and Qua Iboe River (Eket) but slightly reduced in Abak stream and Ikpa River as well as Cross River (Itu) in recent climate period compare to the past climate regime. Seasonal flow of the six rivers showed that steady flow occurred during the dry season (December - April) but a significant ($p<0.05$) rise occurred in the rainy season (April - October). Steady flow of these rivers in the dry season proved that flooding is not common in the basin area in the dry season. Also, a rise in river levels in the rainy season indicated that flooding could usually occur in the area during the rainy as a result of increasing rainfall. This confirmed that flooding in the Cross River Basin is seasonal. However, it has been revealed from the study that rainfall alone might not be so devastating in relation to flood occurrence in the area if not unwise management of dams. This is clear from the fact that peak height of these rivers in the past climate were higher than what is obtained in recent time suggesting that these rivers are drying up yet flood is on the increase. With a rise in water stage level of these rivers in the rainy season, unwise opening of nearby dams in the rainy season could lead to these rivers out-flowing their banks resulting in flooding. For instance, the sudden rise in Abak stream and Qua Iboe River in recent period was attributed to opening of Lagdo dams along the Benue basin as noted by NEMA (2013). Again, abnormal rise in water level of Abeb River in Obudu area in Ogoja in June/July (2003) was also attributed to rainstorm combined with release of excess water from the Lagdo Dam in Cameroon which damaged the spillway and caused flooding that destroyed over 200 houses in Odudu area (*Etiosa, 2006*). These were evidences that though rainfall contributes in building rivers in the study area, the high occurrence of flood in the area in recent time was significantly influenced by man through its numerous activities like unwise operation of dams. This is where the study disagree with most researchers that increased rainfall due to climate change is the sole cause of increased flooding in the study area in recent time. However, the study had proved that there is a connection between rainfall and flood. This was in line with findings of NIMET (2012) concerning 2012 deadly flood in Nigeria. NIMET (2012) reported that excessive rainfall from July to October and the release of water from several dams such as the Kainji and Jebba hydroelectric power dams in Nigeria and Lagdo dam in Cameroon resulted in higher water levels in rivers, streams and ponds, thereby causing a widespread flooding in 33 states of the country.

Variability of flow measures the stream flow fluctuation in a hydrological year. Study has shown that low C.V values depict rivers with relatively even flow throughout the year while high C.V values depict streams that have high discharge and flow during the rainy season but dry up during dry season (Aper, 2006) cited by Ezemonye and Emeribe (2011). The highest CV value observed in this study was obtained in Cross River Ikom followed by Cross River Itu and Abed River respectively while Qua Iboe River had the least followed by Ikpa River and Abak Stream. This implied that Cross River Ikom and Itu as well as Abed River could easily flow their banks causing flooding in the rainy season whereas Qua Iboe River, Ikpa River and Abak Stream may not easily cause flood in the rainy season except they are influenced by human activities like opening of Lagdo dam from Cameroon or other dams that can influence discharge and stage height of these rivers. Hence, communities around Cross River Ikom, Cross River Itu and Abed River Obudu should be conscious of flooding in the peak rainy season (July - October) and should evacuate the flood pathway of these rivers within this period if possible.

Investigation of the relationship between rainfall characteristics and stage height of the six rivers showed that the relationship varied from river to river. For instance, in Cross River (Itu), all the correlation coefficients were positive except number of dry days, < 100 mm rain and rainfall duration. The positive coefficients indicated that there was increase in water level of the river as rainfall increased while negative coefficient implies that the water level of the river decreased as rainfall decreased. The study revealed that rainfall parameters that build rivers (in relation to their water level) included annual rainfall amount, number of rainy days, number of dry days and rainfall intensity. Some of these parameters (rainfall amount, number of rainy days and intensity) agreed with result obtained by NIMET (2012) and NIHSA (2013).

It was also observed that rainfall parameters had significant ($p<0.05$) correlation with water level of small river but no significant ($p>0.05$) correlation with water level of large rivers. The result is expected because effect of the same volume of runoff from a given rain storm on water level is higher in small rivers due to its small volume than large river due to its large volume too. Also, most dam activities are carried out in large rivers which results in diversion of large volume of water from the large river unnoticed thereby influencing water level of the large river per given rain storm. Again, the result was attributed to the fact that large rivers are fed by many small rivers while small rivers are fed directly by rainfall. It was therefore deduced from this finding that true relationship between rainfall parameters and water level of rivers can significantly ($p<0.05$) be explained in small rivers. The high correlation of rainfall parameters with water level in small rivers indicated that rainfall do contributes to flooding of rivers in Cross River Basin of Nigeria.

Conclusion and Recommendations

Rainfall is a major source of water resource on the earth ecosystem. Changes in rainfall pattern have direct effect on changes in stage level of rivers in the Cross River Basin area. There is increased rainfall intensity in most locations within the basin in recent climate regime and these are likely to increase with further warming, thus affecting flows of rivers and increasing risk of flooding. Therefore, many areas within this low lying basin are likely to experience increased levels of flooding due to high rainfall intensity and increased atmospheric concentration of CO_2 as a result of climate change.

Based on the findings of the study, the following recommendations are made:

i. Number of rainy days is decreasing but cloud burst rain storm is increasing especially in Eket and Calabar indicating high probability of flood now than before especially in Eket and Calabar due to high rainfall intensity in the area in recent climate period. As such, yearly and timely clearing of drainage channels especially between May and June, expansion of canals as well as removal of structures on river courses are recommended.

ii. Operation of dams should be properly legalized, strictly monitored and effectively controlled. Reservoirs like dams within the basin area should be operated such that their level is low in May and June to accommodate flood waters that would arrive between July and September. However, opening of such dams at peak rainfall period (July - October) should be discouraged as this will increase water levels in nearby rivers leading to flood.

iii. Opening of Lagdo dam in Cameroon has been a major cause of flood within the Cross River Basin area, therefore, the Government of Nigeria should liaise with their Cameroon counterpart on how to manage this dam without causing any problem to Nigerians. Also, alternative dam(s) should be constructed in Nigeria by Nigerian Government that will absorb excess water released from the Lagdo dam.

iv. Also, dredging of rivers within the basin area including the River Benue is highly recommended to accommodate large volume of water that will be released from the Lagdo dam in Cameroon and other dams in Nigeria to check the intending flood in the Cross River Basin area and other nearby parts of the country.

v. Road construction should not be done in any part of the basin without a good drainage system. Engineers who intend to construct drainage channel within this study area should consider flooding potential of nearby rivers in the area as well as rainfall characteristics of the area in their system design. For instance, large and deep channels are needed in Eket and Calabar area than Uyo and Ikom area.

vi. Above all, there is scanty data in Cross River Basin area. Government at the centre should come to the aid of this basin as most of the gauge stations have been destroyed by flood with no attempt to build them. For instance, there is no discharge data in any of the stations due to lack of equipment. This has placed serious limitation on stream hydrological research which may not augur well in flood prone area like this.

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REFERENCES

Abam, T. S. 2006. Development Policy Framework for Erosion and Flood Control in Nigeria. *EARTHWATCH - Magazine for Environment and Development Experts in Nigeria* 5(1), 25-32.

Adefolalu, D. O. 2010. Climate Change, Impact and Adaptation: Role of Seasonal Climate Prediction. In: *Climate Change Impacts and Adaptation: Developmental* Issues. Nigerian Meteorological Society (2010) pp 53 – 87.

Deressa, T., Hassan, R., Alemu, T., Yesuf, M. and Ringler, C. 2008. Analyzing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia. IFPRI Discussion Paper No.798. International Food Policy Research Institute, Washington DC pp 15 – 22.

Etiosa, U. 2006. DAMS ARE UNRENEWABLE. A Discussion Paper Community Research and Development Centre pp 6 -18.

Ezemonye, M. N. and Emeribe, C. N. 2011. Flood Characteristics and Management Adaptations In parts of the Imo River System. *Ethiopian Journal of Environmental Studies and Management 4 (3): 56-64.*

Few, R., Ahern, M., Matthies, F. and Kovats, S. 2004. Floods, health and climate change: a strategic review. Tyndall Centre for Climate Change Research pp 1 – 124.

IFRC 2003. *World disasters report 2003: focus on ethics in aid* International Federation of Red Cross and Red Crescent Societies, Geneva pp 1 – 11.

Intergovernmental Panel on Climate Change (IPCC) 2012. *Managing the risks of extreme events and disasters to advance climate change adaptation: summary for policy makers.* Cambridge: Cambridge University Press pp 4 – 15.

IPCC 2007. Regional climate projections. In *Climate Change 2007*. The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, New York, US: Cambridge University Press pp 8 – 19.

IUCN 2006. Ecosystem Livelihood natural Disaster, IUCN Pub.57. In: *Climate Impacts and Adaptation*: *Developmental Issues*, NmetS, 2010 pp 53 – 61.

McMichael, A., Githeko, A., Akhtar, R., Carcavallo, R., Gubler, D., Haines, A., Kovats, R., Martens, P., Patz, J. and Sasaki, A. 2001. Human health. In *Climate change 2001: impacts, adaptation, and vulnerability* (eds, McCarthy, J., Canziani, O., Leary, N., Dokken, D. and White, K.). Cambridge University Press, Cambridge pp 22 – 39.

National Emergency Management Agency 2013. 2012 flood disaster cost Nigeria N2.6tn. *The Punch*, 20th July, 2014. Available at www.punchng.com.

Nigeria Hydrological Services Agency (NIHSA) 2013. 2013 Flood outlook pp 6 – 20.

NIMET 2013. *2013 Seasonal Rainfall Prediction*. Available at *nimet.gov.ng/seasonal-rainfall-prediction.* pp 1 – 20.

Nwafor, J. C. 2006. *Environmental Impact Assessment for Sustainable Development: The Nigerian perspective*. Enugu: EL 'DEMAK pubs pp 359-394.

Oguntunde, P.G., Friesen, J., van de Giesen, N. and Savenije, H. H. 2006. Hydro-climatology of the Volta River Basin in West Africa: Trends and variability from 1901 to 2002. *Physics and Chemistry of the Earth* 31: 1180 - 1188.

Stige, L. C., Stave, J. and Chan, K. 2006. The effect of climate variation on agro-pastoral production in Africa. *Proceedings of the National Academy of Sciences* 103: 3049–3053.

Trenberth, K. E. 2011. Changes in precipitation with climate change. *Climate Research* 47: 123–138

Umoh, G. S. 2008. Programming Risks in Wetlands Farming: Evidence from Nigerian Floodplains. *Journal Human Ecology* 24(2): 85-92

WHO 2002. *Floods: Climate Change and Adaptation Strategies for Human Health. Report on a WHO meeting*. 30 June - 2 July 2002, London, United Kingdom, World Health Organisation Regional Office for Europe, Denmark 9pp.

Yusuf, Y. O. and Atteh, B. T. 2009. Normality of daily, pentad and decadal rainfall series in Palladan, Zaria, Kaduna State. Conference Proceedings on Climate Change and the Nigerian Environment, Department of Geography, University of Nigeria, Nsukka pp 271-288.

Yusuf, Y. O. and Mohammed, N. A. 2011. An Assessment of Spatial Distribution of Rainfall Amount in Zaria, Kaduna State. A Paper Presented at the 52nd Annual Conference of the Association of Nigerian Geographers Held at the Department of Geography, Usman Danfodio University, Sokoto, Nigeria from 14th -17th February, 2011 pp 3-9.

PATTERN OF CLIMATE CHANGE IN CROSS RIVER BASIN OF NIGERIA: IMPLICATION TO AGRICULTURE AND FOOD SECURITY

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ABSTRACT

The study investigated pattern of climate change and its implication to Agriculture and food security in Cross River Basin of Nigeria. It analyzed the pattern of change in selected climatic elements between the past (1971 - 2000) and recent (2001 - 2012) climate regime in the study area. Daily rainfall data and monthly temperature, relative humidity, evaporation and wind speed were obtained from Nigerian Meteorological Agency (NIMET) from 1971 – 2012 in Eket, Uyo, Calabar, Ikom and Ogoja and analysed using descriptive statistics, t-test and one-way analysis of variance. Climate of the area was classified based on moisture index (MI) according to Thornthwaite's climate classification procedures. Mean annual rainfall in Calabar, Uyo, and Ogoja were 2851.84, 2139.78 and 1946.45 mm in the past climate but increased by 7.90, 9.09 and 17.20 % (above normal) in the recent climate while the past average in Eket and Ikom were 4310.54 and 2279.20 mm with 1.60 and 1.30 % decrease (below normal) in recent period. However, significant ($p<0.05$) difference was obtained in Uyo and Ogoja only. Temperature was generally higher in the short climate period than the long period but significant ($p<0.05$) difference was obtained in Uyo and Ogoja for maximum values only. Classification of climate of the basin showed that Eket and Calabar with MI of +265.90 and 134.19 % belonged to Per Humid climate, Uyo and Ikom with MI of +64.01 and +60.61 % belonged to Moist Humid climate while Ogoja with MI of +20 % belonged to Moist Sub-Humid climate. Spatial distribution of rainfall within the basin area showed that annual rainfall amount differed significantly ($p<0.05$) among the five locations in the following order Eket > Calabar > Ikom > Uyo > Ogoja with mean rainfall of 4269.80 mm, 2894.10 mm, 2258 mm, 2243.80 mm and 1983.02 mm respectively. The study revealed that climate change has caused increased warming condition and also changed the climatology of the study area and thus affecting agricultural activities and increasing risk of food insecurity in the area. It was therefore recommended that effective extension education by climate experts be introduced to farmers at local community to improve their skill towards adapting to climate change.

Keywords: Pattern, Climate change, Agriculture and Food Security

INTRODUCTION

It has been observed from records and simulation of atmospheric conditions that the earth's climate for the past 100 years has changed in response to various natural and anthropogenic activities (IPCC, 2007). During the last few decades, many parts of the world have witnessed abnormal heating which results in major heat waves, flood, droughts, an increase in extreme weather events leading to significant economic losses and loss of life (Adefolalu, 2010). Change in climate, either negative or positive has direct influence on the environment and human activities globally or locally. Poor agricultural yields, food insecurity (famine), flooding, and even death are some of the catastrophic impacts of drastic climate change (IPCC 2007, 2012). Experts agree that climate change threat is a serious set-back to development efforts, placing least developed countries and sub-Sahara African countries in particular already vulnerable even in more precarious position (Wolfe, Schwartz, Lakso, Otsuki, Pool and Shaulis, 2005 and NEMA, 2013). It has thus, become the most important topical development policy and global governance issue in the 21st century.

Evidence is building that climate change has changed the rainfall pattern and the hydrological cycle of many communities and regions subjected them to either flood or drought. Both drought and flood are detrimental to agriculture, food security and general livelihood of man. For instance, agriculture suffers great set back under water stress condition especially among the poor rural farmers who cannot fund irrigation system in their farm while farm lands, crops and farm produce worth billions of Naira have been flushed out by flood water leading to hunger and food insecurity in most coastal communities. The problem of food insecurity and hunger is likely to be more severe under wrong management of the earth ecosystems, such as wetlands, forests and coastal systems like high level of soil pollution caused by crude oil exploration activities in the study area. The question is no more whether climate has changed or will continue to change in response to human activities but rather by how much (magnitude), where (regional/local patterns), and when (the rate of change). It is also clear that climate change will affect weather extreme events in different communities of the world differently. Therefore regions, countries, communities must identify and quantify the changing climatic parameters to improve knowledge of influence as well as reducing vulnerability thereby lending support to sustainable development of households, communities, states, nations, regions and the world at large. This calls for a review of climate pattern in a changing climate regime especially in the coastal communities like the Cross River Basin of Nigeria.

Aim and objective of the study

The aim of this study was to analyse pattern of climate change and its implication on Agriculture and food security in Cross River basin of Nigeria. Specifically, the study:

1. examined pattern of change in selected climatic elements in the study area,
2. classified the climate of the study area based on moisture index, and
3. analysed spatial and temporal variability of selected climatic elements within the area.

METHODOLOGY

The study was conducted in Cross Basin, located in a coastal area of the Niger Delta region of Nigeria. The Cross River Basin lies between latitude 04°30' and 06°45' N and Longitude 07°30' and 09°15' E. It has a total land area of 58.8 km^2 covering Akwa Ibom and Cross River states. The climate of area depends on the movement of the Inter-tropical discontinuity, which is the zone separating the warm humid maritime air mass with its associated South Westerly winds from dry continental air mass (North Westerly winds). Generally, the basin is situated within the tropical monsoon climate with bimodal rainfall pattern, which begins in March and ends in mid October with a little dry spell in August traditionally referred to as "August break". The little dry spell gives rise to the two rainfall maxima with the heaviest rainfall occurring in July for first peak and September for the second peak.

Climate Analysis

Long term daily rainfall and monthly temperature (minimum and maximum), relative humidity, evaporation and wind speed data were collected from Nigeria Meteorological stations in Uyo, Eket, Calabar, Ikom and Ogoja for a period of 42 years (1971 - 2012). The GPS locations of the stations were also collected. Collated data were analysed statistically based on the specific objectives of the study. The stations selected have less than 10% of the daily rainfall values missing except Ogoja which did not have any daily rainfall data as at the time this study was conducted.

Each climatic element was grouped into two climate periods: the past (1971-2000) and present (2001-2012) climate periods. Percent deviation of sample mean for 2001-2012 climate period from the past climate mean (1971-2000) was computed to determine degree of departure in each of the elements. The percent deviation is given as:

$$\varphi = \frac{x_r - x_l}{x_l} \times 100$$

(1.1)

where φ represents the departure, x_r is the sample mean for recent climate period (2001-2012) and x_l is the past climate mean (1971-2000). Thus, φ of +1% within a cell (location) indicates that the observed mean for recent period in that location is 1% greater than the past climate mean (Above normal), φ of -1% indicates that the observed mean for recent period is 1% less than the past climate mean (Below normal), while φ of 0 % or near 0 % indicates no difference (normal). The change pattern in the area was rated either normal, above Normal or below normal (NIMET 2010, 2012).

Climate classification

Climate classification was carried out using Thornthwaite's (1948) procedures cited in Bello *et al.* (2004). The procedure is based on moisture index which is a measure of precipitation effectiveness to support plant growth. Thornthwaite's moisture index is computed based on the relationship between precipitation (P) and potential evapotranspiration (ET). The moisture index (MI) is given as:

$$MI = \frac{Precipitation - Potential\ ET}{Potential\ ET}\ X\ 100$$

(1.2)

where precipitation exceeds potential ET, the index is positive; where potential ET exceeds precipitation, the index is negative.

Penman equation (Penman, 1948) is one of the well known model widely used to determine evaporation from open water, bare soil, and grass (technically referred to as evapotranspiration) based on a combination of an energy balance and an aerodynamic formula. The original model is as follows:

$$\lambda E = \frac{[\Delta(R_n - G)] + (\gamma\lambda E_a)}{(\Delta + \lambda)}$$

(1.3)

Where,

λE = Evaporative latent heat flux (MJ $m^{-2}d^{-1}$),

Δ = Slope of the saturated vapor pressure curve ($\delta e_o / \delta T$), where e_o = saturated vapor Pressure (kPa) and T_{mean} = daily mean temperature (°C)];

Rn = Net radiation flux (MJ $m^{-2}d^{-1}$),

G = Sensible heat flux into the soil (MJ $m^{-2}d^{-1}$),

³ = Psychrometric constant (kPa $°C^{-1}$), and

Ea = Vapor transport of flux (mm d^{-1}).

An updated equation was recommended by FAO (Smith *et al*. 1996) with the FAO-56 Penman-Monteith Equation, simplifying equation (1.3) by utilizing some assumed constant parameters for a clipped grass reference crop. It was assumed that the definition for the reference crop was a hypothetical reference crop with crop height of 0.12 m, a fixed surface resistance of 70 s m^{-1} and an albedo value (i.e., portion of light reflected by the leaf surface) of 0.23 (Smith *et al*. 1996). The new equation was described by Zotarelli, Dukes, Consuelo, Romero, Kati, Migliaccio, and Kelly (2010) as follows:

$$ET_o = \frac{0.408\Delta\,(R_n - G) + \gamma\frac{900}{T + 273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34\,u_2)} \qquad (1.4)$$

where *ETo* = reference evapotranspiration rate (mmd^{-1}), *T* = mean air temperature (°C), and u_2 = wind speed (ms^{-1}) at 2 m above the ground. Equation (1.4) can be applied using hourly data if the constant value "900" is divided by 24 for the hours in a day and the *R*n and *G* terms are expressed as MJ m^{-2} h^{-1}.

Where,

ET_o = reference evapotranspiration, mm day^{-1};

R_n = net radiation at the crop surface, MJ m^{-2} d^{-1};

G = soil heat flux density, MJ m^{-2} d^{-1};

T = mean daily air temperature at 2 m height, °C;

u_2 = wind speed at 2 m height, m s^{-1};

e_s = saturation vapor pressure, kPa;

e_a = actual vapor pressure, kPa;

$e_s - e_a$ = saturation vapor pressure deficit, kPa;

Δ = slope of the vapor pressure curve, kPa $°C^{-1}$;

γ = psychrometric constant, kPa $°C^{-1}$.

Data Analysis

Data collected were subjected to statistical analysis using descriptive and inferential statistics. Descriptive statistics adopted include percentage, range, mean, standard deviation and coefficient of variability while inferential statistics employed include independent t-test, Analysis of variance (ANOVA) and simple regression analysis. Descriptive statistics and independent t-test were used to analyse objective one, objective two was analysed using Descriptive statistics while Descriptive statistics and one-way analysis of variance were employed in analyzing objective three.

RESULTS

Pattern of change in selected climatic elements in Cross River Basin of Nigeria

Rainfall

Table 1 showed the onset, cessation and duration pattern of rainfall in the study area. There was no significant difference ($p>0.05$) in onset dates within the basin in the two climate periods except in Calabar. Cessation of rain for the two climate periods did not differ significantly ($p>0.05$) too in all the locations whereas duration of rainfall for the two periods showed significant ($p<0.05$) in Calabar only. Rainy days (RD) occupied greater proportion of total number of days in the past and recent climate periods in most the entire locations (Table 2). Number of Dry Days (DD) increased slightly in Uyo, Calabar and Ikom while it decreased slightly in Eket. The result also showed that Proportion of Wet - Dry (PWD) days occupied the greatest number of days in both climate periods in all the locations. Little Dry Season (August break) anomalies in Table 3 showed that mean in recent climate was lower than what was obtained in the past climate but the difference was not significant ($p>0.05$) in Uyo and Calabar.

Analysis of frequency of rainfall of various sizes in the study area (Table 4) showed that out of the total number of rainfall received in 1971 - 2000 period, lower proportion were trace rainfall in both periods in most locations. However, differences in trace rainfall were not statistically significant ($P<0.05$) in all the locations. Significant ($p<0.05$) difference in means annual rainfall amount were obtained in Uyo and Ogoja (Table 5) only.

Table 1: Rainfall onset and cessation pattern in the study area

Station	Climate Period	Onset period	Cessation	Duration
Eket	1971 – 2000	80±11	326±12	246±9
	2001 – 2012	78±16	322±20	243±28
Uyo	1971 – 2000	76 ± 18	305 ± 30	229 ± 27
	2001 – 2012	69 ± 29	312 ± 116	243 ± 88

Calabar	1971 – 2000	86 ± 26[a]	324 ± 20	238 ± 34[b]
	2001 – 2012	76 ± 23[b]	322 ± 12	246 ± 17[a]
Ikom	1971 – 2000	79 ± 14	307 ±10	228 ± 21
	2001 – 2012	87 ± 18	310 ± 9	222 ± 19

Means with different superscripts along the same column are significantly different ($p<0.05$)

Table 2: Wet and Dry Episodes in the study area

Station	Climate Period	RD	DD	PWW	PWD	PDW	PDD
		←		%			→
Eket	1971 – 2000	58.68[b]	41.32[a]	12.51	56.06	8.52	22.91
	2001 – 2012	63.05[a]	36.95[b]	12.93	54.33	11.70	21.03
Uyo	1971 – 2000	47.57	52.43	15.13	30.83	15.13	38.93
	2001 – 2012	47.52	52.48	17.15	30.82	17.15	34.87
Calabar	1971 – 2000	59.39[a]	40.61[b]	13.45	46.90	13.03	26.62
	2001 – 2012	55.41[b]	44.59[a]	14.42	41.28	14.90	29.40
Ikom	1971 – 2000	51.74	48.30	12.43	39.79	12.03	35.75
	2001 – 2012	50.20	49.86	13.09	37.41	13.21	36.29

Means with different superscripts along the same column are significantly different ($p<0.05$)

RD: Rain Day, DD; Dry day, PWW: Proportion of wet followed by wet day, PWD: Proportion of wet followed by dry, PDW: Proportion of dry followed by wet day, PDD: Proportion of dry followed by dry day

Table 3: August Rainfall Anomalies in the study area

Station	Climate Period	Maximum	Mean	Cv(%)
Eket	1971 – 2000	17	7.0 ± 6.60[a]	94.29
	2001 – 2012	13	4.25 ± 4.39[b]	103.29
Uyo	1971 – 2000	21	12.25 ± 5.91	48.28
	2001 – 2012	20	11.63 ± 4.85	63.20
Calabar	1971 – 2000	18	11.34 ± 4.85	42.80
	2001 – 2012	13	8.73 ± 3.84	43.96
Ikom	1971 – 2000	17	10.89 ± 6.25[a]	57.42
	2001 – 2012	9	6.0 ± 3.43[b]	57.20

Means with different superscripts along the same column are significantly different ($p<0.05$)

Table 4: Rainfall intensity in the study area

Station	Climate Period	Trace	≤25 mm	26-50 mm	51-99 mm	100 – 150 mm	>150 mm
		←			%		→
Ikom	1971 – 2000	23.40	61.20	10.80	4.30	0.30	0.0[b]
	2001 – 2012	21.30	61.90	11.60	4.90	0.20	0.10[a]
Calabar	1971 – 2000	22.10	59.70	11.70	5.40	0.80	0.30[b]
	2001 – 2012	17.0	60.90	14.20	6.30	1.0	0.60[a]
Uyo	1971 – 2000	18.0	63.40	13.40	5.0	0.20[b]	0.0

	2001 – 2012	15.20	65.20	13.60	5.50	0.50[a]	0.0
Eket	1971 – 2000	13.46	60.23	14.66	9.19	1.93	0.53[a]
	2001 – 2012	16.21	59.04	14.69	8.07	1.66	0.33[b]

Means with different superscripts along the same column are significantly different ($p<0.05$)

Table 5: Annual Rainfall Amount

Station	Climate Period	Mean Annual	Wet season Average
		← mm	→
Ikom	1971 – 2000	2279.20±222.27	2035.95±232.91
	2001 – 2012	2248.83±196.33	2065.70±196.33
Calabar	1971 – 2000	2851.84±355.98	2447.49±341.73
	2001 – 2012	3077.98±485.22	2632.07±438.34
Uyo	1971 – 2000	2139.78±394.09[b]	2109.30± 61.44[b]
	2001 – 2012	2331.38±203.94[a]	2233.05±403.83[a]
Eket	1971 – 2000	4310.54±429.74	3652.36±471.81
	2001 – 2012	4242.60±357.59	3599.53±318.25
Ogoja	1971 – 2000	1946.45±886.33[a]	1850.91±893.01[b]
	1971 – 2000	2281.75±503.30[a]	2169.0±470.78[a]

Means with different superscripts along the same column are significantly different ($p<0.05$)

Temperature

Temperature anomalies in the study area were shown in Tables 6. Mean minimum temperature for Eket, Uyo, Calabar, Ikom and Ogoja were 24.21, 23.32, 23.53, 22.56 and 22.96 °C respectively during 2001 – 2012 climate period which were higher than 23.81, 22.55, 22.95, 22.05 and 22.21°C obtained in 1971 – 2000 climate period for Eket, Uyo, Calabar, Ikom and Ogoja respectively. Similarly, mean maximum temperature obtained for Eket, Uyo, Calabar, Ikom and Ogoja in recent climate period were 30.98, 31.93, 31.95, 31.89 and 33.75 °C higher than 30.60, 30.99, 30.41, 31.75 and 32.66 °C recorded in 1971 – 2000 regime for respective locations. The differences were significant ($p<0.05$) in Eket, Uyo and Calabar but not significant ($p>0.05$) in Ikom and Ogoja for minimum temperature while maximum temperature of the two climate periods differed significantly ($p<0.05$) in Uyo and Ogoja only.

Relative Humidity

Table 7 showed relative humidity of the study area for the two climate periods. Comparatively, average daily relative humidity for 2001 – 2012 climate period in Eket and Uyo were 85.92 and 81.01 % higher than 82.87 and 78.76 % obtained in 1971 - 2000 climate period. But in Calabar, Ikom and Ogoja, average relative humidity for 2001 - 2012 were 84.99, 81.71 and 72.14 % relatively lower than 85.13, 82.71 and 72.53 % in 1971 - 2000 climate regime. The t-test result clearly showed that there was a significant ($p<0.05$) difference in relative humidity of Eket, Uyo and Ikom but no significant difference ($p>0.05$) in Calabar and Ogoja between the two climate periods.

Evaporation and Wind Speed

Average daily evaporation rates (Table 8) for recent climate were 3.04, 2.99, 2.62, 2.24 and 3.61 mmday^{-1} in Eket, Uyo, Calabar, Ikom and Ogoja respectively while 2.98, 2.28, 2.36, 2.27 and 3.48 mmday^{-1} were recorded in the past climate in the five locations respectively. However, t-test analysis in revealed that there was a significant ($p<0.05$) difference in Uyo and Calabar but not significant ($p>0.05$) in Eket, Ikom and Ogoja. Furthermore, mean daily wind speed (Table 9) for recent climate were 3.50, 2.76, 5.52 and 2.08 ms^{-1} but 3.57, 3.06, 5.44 and 2.99 ms^{-1} for the past climate in Eket, Uyo, Calabar and Ikom respectively. Wind speed of the recent climate was lower than the past climate indicating decrease in wind speed over the basin area except in Calabar. However, from t-test result significant difference ($p<0.05$) was obtained in Uyo and Ikom only.

Table 6: Mean minimum, maximum and mean temperature of the area

Station	Climate Period	Temperature (°C)		
		Minimum	Maximum	Mean
Eket	1971 – 2000	23.81±0.41^{b}	30.60±0.71	27.20 ± 0.40
	2001 – 2012	24.21±0.23^{a}	30.98±0.38	27.25 ± 0.23

Uyo	1971 – 2000	22.55±0.84^{b}	30.99±1.19^{b}	27.01 ± 0.45^{b}
	2001 – 2012	23.32±0.44^{a}	31.93±0.44^{a}	28.24 ± 0.42^{a}
Calabar	1971 – 2000	22.95± 0.46^{b}	30.41± 4.46	27.18 ± 2.17
	2001 – 2012	23.53± 0.48^{a}	31.95± 0.33	27.23 ± 0.29
Ikom	1971 – 2000	22.05±0.64	31.75±0.63	26.40 ± 0.43
	2001 – 2012	22.56±0.55	31.89±0.35	26.96 ± 0.31
Ogoja	1971 – 2000	22.21±1.06	32.66±0.39^{b}	27.50 ± 0.45
	2001 – 2012	22.96±0.89	33.75±1.26^{a}	27.85 ± 0.24

Means with different superscripts along the same column are significantly different ($p<0.05$)

Table 7: Mean Annual Relative Humidity in the study area

Station	Relative Humidity (%)	
	1971 – 2000	2001 – 2012
Eket	82.87±3.74^{b}	85.92±2.31^{a}
Uyo	78.76±1.47^{b}	81.01±1.69^{a}
Calabar	85.13±0.27	84.99±0.24
Ikom	82.71±1.47^{a}	81.71±0.91^{b}
Ogoja	72.532±2.71	72.14±2.13

Mean with different superscript along the same row are significantly different ($p<0.05$)

Table 8: Mean Daily Evaporation rate in the study area

Station	Evaporation Rate(mm/day)	
	1971 – 2000	2001 – 2012
Eket	2.98±0.73	3.04±0.57
Uyo	2.28±0.40[b]	2.99±0.19[a]
Calabar	2.36±0.40[b]	2.62±0.24[a]
Ikom	2.27±0.29	2.24±0.19
Ogoja	3.48±0.59	3.61±0.43

Mean with different superscript along the same row are significantly different (p<0.05)

Table 9: Mean Daily Wind Velocity in the study area

Station	Wind Speed (ms^{-1})	
	1971 – 2000	2001 – 2012
Eket	3.57±0.32	3.50 ± 0.32
Uyo	3.06 ± 1.18[a]	2.76 ± 1.66[b]
Calabar	5.44 ±1.85	5.52±1.57
Ikom	2.99 ±0.49[a]	2.08± 0.40[b]
Ogoja	-	-

Mean with different same superscript along the same row are significantly different (p<0.05)

Pattern of climate change in the study area

Figure 1 showed percent departure of rainfall characteristics of the study area while Table 10 showed pattern of change of temperature, relative humidity, evaporation and wind speed in the study area. Most of the rainfall parameters considered in the study showed above normal departure from the past climate. However, onset, cessation, duration, mean annual rainfall and wet and dry episodes showed < 20 % departure from past climate means in all the locations, little dry season (LDS) had > 20 % departure from the past climate means with most locations exhibiting below normal departure except Eket whereas >100 mm rainfall had >50 % departure (above normal) in Uyo, Calabar and Ikom but below normal in Eket.

Temperature anomalies showed a linear increase of 0.4, 0.77, 0.58, 0.51 and 0.75 °C above the past climate average for minimum temperature in Eket, Uyo, Calabar, Ikom and Ogoja while 0.38, 0.44, 1.54, 0.14 and 1.09 °C increase were recorded for maximum temperature in

Eket, Uyo, Calabar, Ikom and Ogoja respectively. These gave percent departure of 1.68, 3.41, 6.71, 2.71 and 2.31 % above normal for minimum temperature in Eket, Uyo, Calabar, Ikom and Ogoja and 1.24, 3.03, 5.06, 0.44 and 3.34 % departure above normal in maximum temperature in Eket, Uyo, Calabar, Ikom and Ogoja respectively. For relative humidity, result showed a linear increase of 3.45 % and 3.48 % above normal in Eket and Uyo while 0.16, 1.22 and 0.52 % departure below normal were recorded in Calabar, Ikom and Ogoja. Similarly, it was clear from the result that evaporation series in 2001 – 2012 climate period was slightly above normal in Eket, Calabar and Ogoja but below normal in Uyo and Ikom. The result further showed -1.96, -9.80, +1.47 and -30.43 % departure in 2001 – 2012 wind speed from the past climate means in Eket, Uyo, Calabar and Ikom respectively. From the result, the highest departure in wind speed within the study period occurred in Ikom followed by Uyo while the least departure was obtained in Eket.

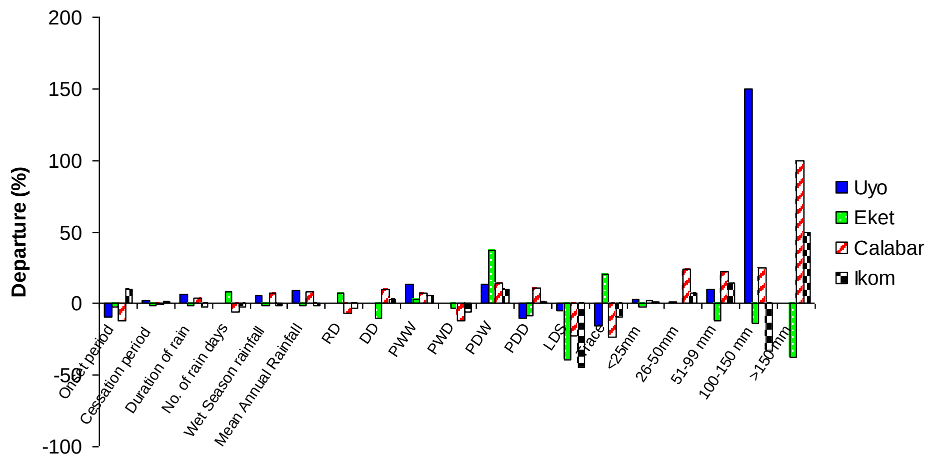

Figure 1: Rainfall Anomalies in the study area

Table 10: Temperature, relative humidity, evaporation and wind anomalies in the study area

Climatic Element	Uyo	Eket	Calabar	Ikom	Ogoja
Minimum Temperature	+3.41	+1.68	+6.71*	+2.31	+3.34
Maximum Temperature	+3.03	+1.24	+5.06*	+0.44	+3.31
Mean Temperature	+1.27	+0.18	+2.12	+4.55	+0.18
Relative Humidity	+3.48	+3.45	-0.16	-1.22	-0.52
Evaporation	-12.72*	+2.01	+11.02*	-1.32	+3.74
Wind speed	-9.80*	-1.96	+1.47	-30.43**	-

* Moderate ** High

Classification of climate of the study area

Monthly moisture index in Table 11 showed that wet months in Eket starts from March to November while Uyo had its wet months from April to October and March to October in Calabar. Similarly, Ikom and Ogoja had similar number of wet months which occurred between April and September. From Table 12, Eket had the highest moisture index (+265.90 %) followed by Calabar (+134.19 %), Uyo (64.01 %) and Ikom (60.61 %) while Ogoja had the least (20.0 %). From Thornwaite's climate classification model, Eket and Calabar belonged to Per Humid climate type, Uyo and Ikom were within moist humid climate type while Ogoja belonged to a moist sub-humid climate type as presented in Figure 2.

Table 11: Monthly mean Moisture Index (%) of the study area

Month	Eket	Uyo	Calabar	Ikom	Ogoja
January	-23.50	-86.23	-86.50	-95.58	-93.73
February	-22.81	-71.76	-66.09	-87.42	-94.11
March	55.88	-8.18	51.35	-16.27	-77.38
April	175.30	33.59	138.75	103.02	120.41
May	264.11	118.29	227.34	204.18	70.55
June	653.81	200.65	389.44	165.42	69.81
July	688.10	298.33	566.85	315.77	135.82
August	714.46	209.43	487.31	226.91	245.51
Sept	593.85	218.80	301.33	292.02	205.33
October	408.95	122.59	92.04	-64.28	-61.88
Nov	145.44	-8.37	-75.91	-92.37	-94.49
Dec	-40.35	-88.44	-36.97	-30.58	-49.41

Table 12: Climate types in the study area

Station	Rainfall Amount (mm)	PE (mm)	MI (%)	Climate Type
Eket	341.02	93.20	+265.90	A (Per Humid)
Uyo	182.11	111.03	+64.01	B (Moist Humid)
Calabar	237.87	101.57	+134.19	A (Per Humid)
Ikom	175.86	109.49	+60.61	B (Moist Humid)

Ogoja	164.13	136.78	+20.00	C_1 (Moist Sub Humid)

PE: Potential Evaporation, MI: Moisture Index

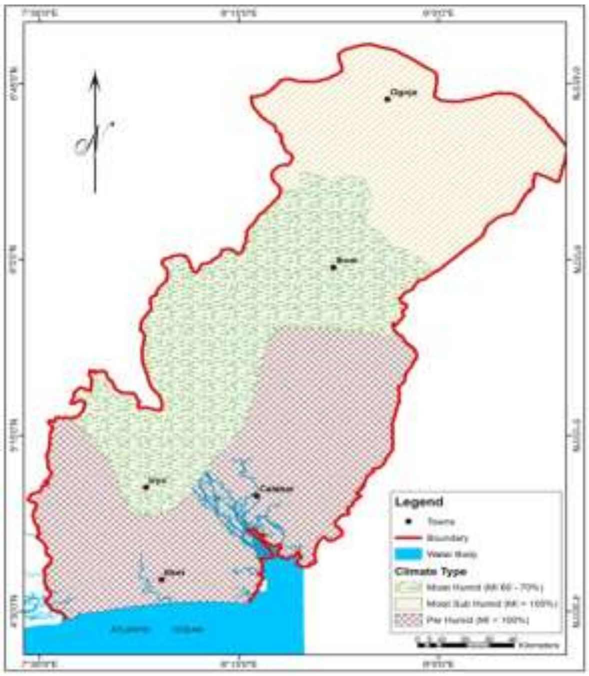

Figure 2: Climate types in Cross River Basin of Nigeria

Spatial and temporal variability of climate elements in the study area

Spatial variability in rainfall characteristics were given in Tables 13 and while Table 14 showed decadal variability in rainfall amount. Mean onset dates in the four locations were in the order Ikom > Calabar > Eket > Uyo. However, analysis of variance showed that there was no significant ($p>0.05$) difference in onset periods among the four locations. Similarly, mean cessation of rain in the area were in the order Eket > Calabar > Ikom > Uyo. There was a significant ($p<0.05$) difference in mean cessation of rain among the four locations. On the mean, Eket had the longest rainy season (244.50 days) followed by Calabar (237.37 days) to Uyo with 230.47 days while Ikom had the least (223.48 days) but duration of rainy season in Ikom was significantly ($p<0.05$) lower than that of Eket, Uyo and Calabar. The highest mean annual rainfall was received in Eket (4269.80mm) followed by Calabar with 2894.10 mm to Ikom (2258 mm) and Uyo (2243.80mm) while Ogoja had the least (1983 mm). Decadal variability of rainfall (Table 14) showed that there increased rainfall occurred in Uyo, Calabar and Ogoja but decreased rainfall in Eket and Ikom.

Spatial variability in minimum and maximum temperature were given in Tables 15 while temporal variability was given in terms of decadal variability in Table 17 (a and b). Spatial variability of minimum temperature showed that Eket had the highest (24.04 ± 0.37 °C) followed by Calabar (23.10 ± 0.53 °C) to Uyo with 22.61 ± 2.24 °C and Ogoja (22.30 ± 0.58°C) while Ikom had the least (22.21 ± 0.66°C) whereas mean maximum temperature were in the order Ogoja > Ikom > Uyo > Calabar > Eket. Decadal variability revealed increased trend in both minimum and maximum temperature in all the five locations (Table 16a-b). Annual trend of minimum temperature showed increased trend at annual rate of 0.04, 0.06, 0.02, 0.01 and 0.03 °C in Eket, Uyo, Calabar, Ikom and Ogoja while maximum temperature (Figures 45 - 49) increased at annual rate of 0.01, 0.03 and 0.03, 0.023, and 0,026 °C in Eket, Uyo, Calabar, Ikom and Ogoja respectively.

Table 17 showed spatial variability of relative humidity (RH) in the study area while temporal variability is shown in terms of decadal variability in Table 18. Means values of RH obtained were in the order Calabar > Eket > Ikom > Uyo > Ogoja. Decadal variability of RH (Table 19) showed that in the 1st, 2nd, 3rd and 4th decades of the study, mean RH was decreasing in Calabar, Ikom and Ogoja but increased in Uyo and Eket.

Table 19 showed spatial variability in daily evaporation rate among the five locations while decadal variability was shown in Table 20. The highest evaporation rate was obtained in Ogoja followed by Eket to Calabar and Ikom with while Uyo had the least evaporation rate and the difference was statistically significant ($P<0.05$). Decadal variability of evaporation showed that it was decreasing in Uyo, increased in Eket, Calabar and Ogoja in the 2nd , 3rd and 4th decades while Ikom experienced decrease in evaporation rate in the 3rd decade but increase in the 4th decade.

The highest wind speed was recorded in Calabar followed by Eket, Uyo while Ikom had the least (Table 21) and the difference was significant ($p<0.05$). Decadal variability of wind velocity (Table 22) showed decreasing trend in Eket, Uyo, Ikom but increasing trend in Calabar. Inter-annual variability (rate of change) of various climatic elements was presented in Table 23 (a and b). Minimum temperature showed significant ($p<0.05$) annual changes in Eket and Uyo while wind speed showed significant ($p<0.05$) annual changes in Ikom whereas others were not significant ($p>0.05$).

Table 13: Spatial Distribution of rainfall parameters within the study area

Location	Variable	Onset	Cessation	Duration	Mean Annual (mm)	Rd	Pww	<25 Mm	26-50 mm	51-99 mm	100-150 mm	>150 mm	LDS
Uyo	Range	54-104	225-342	166-274	1208.30 - 2715.70	150-191	93-181	92-131	15-33	1 – 14	1 - 3	-	6-21
	$\bar{X}$	75.91	306.38^{b}	230.47^{bc}	2243.80^{c}	173.72^{c}	112.60^{c}	111.41^{c}	23.34^{bc}	9.03^{c}	0.59^{c}	-	12.13^{a}
	Sd	13.56	22.79	21.34	361.28	10.94	18.06	9.03	4.94	3.14	0.80	-	5.0
	Cv	17.87	7.49	9.26	16.20	6.30	16.04	8.11	21.17	34.73	134.31	-	41.24
Eket	Range	56-97	283 – 347	190-289	3488.40-4808.0	202-252	115-190	118-150	23-44	14-25	2 - 7	0 – 3	5-14
	$\bar{X}$	79.06	323.56^{a}	244.50^{a}	4269.80^{a}	223.80^{a}	155.85^{b}	133.47^{a}	32.95^{a}	19.0^{a}	3.95^{a}	0.53^{a}	7.61^{b}
	Sd	13.23	16.93	21.40	378.47	14.87	18.13	9.08	5.44	2.87	1.39	0.65	4.33
	Cv	16.74	5.23	8.75	8.86	6.65	11.63	6-80	16.52	15.09	35.30	146.75	56.90
Calabar	Range	53-117	283-338	200-274	2109.0-3770.80	186-250	126-200	99-149	14-39	3-19	2 - 6	1- 3	7-17
	$\bar{X}$	80.65	318.02^{a}	237.37^{ab}	2894.10^{b}	212.76	165.45	127.47^{b}	25.88^{b}	12.12^{b}	1.84^{b}	0.35^{b}	9.14^{b}

						b	a						
	Sd	15.68	13.13	19.06	381.38	13.61	16.93	10.33	5.19	4.08	1.43	0.65	4.24
	Cv	19.44	4.15	8.03	13.18	6.40	10.23	8.10	20.06	33.06	77.82	186.47	46.38
Ikom	Range	57-105	289-326	186-257	1760.30-2683.80	155-195	31-59	92.138	12-30	1-13	1 – 2	-	7 – 18
	$\overline{X}$	83.41	308.14^{b}	223.48^{c}	2258.0^{c}	180.05^{c}	95.68^{d}	114.73^{c}	20.73^{c}	8.41^{c}	0.50^{c}	-	10.61^{a}
	Sd	14.08	9.36	18.37	226.07	10.92	6.64	11.0	5.11	2.89	0.67	-	3.93
	Cv	16.88	3.04	8.17	10.01	6.06	14.53	9.59	24.65	34.36	134.52	-	37.09
Ogoja	Range				1251.40-3347.80	-	-	-	-	-	-	-	-
	$\overline{X}$				1983.02^{d}	-	-	-	-	-	-	-	-
	Sd				482.48	-	-	-	-	-	-	-	-
	Cv				24.33	-	-	-	-	-	-	-	-

Mean with different superscript along the same column are significantly different ($p<0.05$)

Table 14: Decadal Rainfall Variability in the study area

	Decadal Rainfall (mm)				Variability Index (%)		
Station	1971-1980	1981-1990	1991-2000	2001-2010	2nd – 1st	3rd-1st	4th-1st
Uyo	-	2038.08	2247.79	2363.05	-	10.29	15.94
Eket	-	-	4310.54	4190.48	-	-	-2.79
Calabar	2814.06	2742.5	2998.952	2964.35	-2.54	6.57	5.34
Ikom	2396.45	2182.25	2282.35	2157.6	-8.94	-4.76	-9.97
Ogoja	-	1651.53	1823.40	2136.52	-	10.41	29.37

Table 15: Spatial distribution of temperature in the study area

Location	Variable	Maximum	Minimum	Mean
Uyo	Range	30.39-32.74	21.43-23.87	26.36 – 29.06
	X	31.59[ab]	22.61[bc]	27.47
	Sd	0.49	2.24	0.74
	Cv	1.56	9.91	2.70
Eket	Range	30.0 - 32.10	23.25 - 24.71	26.76 – 27.98
	X	30.59[b]	24.04[a]	27.31
	Sd	1.04	0.37	0.32
	Cv	1.74	1.54	1.17
Calabar	Range	29.61 - 54.89	22.06 – 24.48	26.24 – 28.53
	X	31.29[ab]	23.10[b]	27.20
	Sd	3.81	0.53	1.85
	Cv	12.17	2.28	6.80
Ikom	Range	30.46-32.90	19.92 – 23.20	25.79 – 27.92
	X	31.79[a]	22.21[c]	26.99
	Sd	0.56	0.66	0.43
	Cv	1.78	2.97	1.59
Ogoja	Range	31.94-35.42	21.05 – 22.98	26.34 – 29.17
	X	33.16[a]	22.30[bc]	27.66
	Sd	1.04	0.58	0.62
	Cv	3.13	2.61	2.23

Mean with different superscript along the same column are significantly different (p<0.05

Table 16a: Changes in decadal minimum temperature in the study area

	Decadal Minimum Temperature (°C)				Variability Index (%)		
Station	1971-1980	1981-1990	1991-2000	2001-2010	2^{nd} - 1^{st}	3rd-1^{st}	4th-1^{st}
Uyo	-	21.19	22.54	23.71	-	6.36	11.89
Eket	-	-	23.81	24.19	-	-	1.60
Calabar	23.03	23.06	23.16	23.66	0.12	1.48	2.27
Ikom	22.02	22.06	22.34	22.69	0.18	1.43	3.06
Ogoja	-	21.94	22.33	22.50	-	1.77	2.58

Table 16b: Changes in decadal maximum temperature in the study area

	Decadal Maximum Temperature (°C)				Variability Index (%)		
Station	1971-1980	1981-1990	1991-2000	2001-2010	2^{nd} - 1st	3rd-1^{st}	4th-1^{st}
Uyo	-	31.27	31.50	31.88	-	0.74	1.95
Eket	-	-	30.60	30.98	-	-	1.24
Calabar	30.35	30.68	30.80	31.04	1.09	1.48	2.27
Ikom	31.03	31.93	32.13	32.24	0.04	3.55	3.90
Ogoja	-	32.46	32.81	33.41	-	1.08	2.98

Table 17: Spatial Distribution of Relative Humidity (%) within the study area

Location	Uyo	Eket	Calabar	Ikom	Ogoja
Range	77.30 – 4.60	77.67 –87.83	80.75 – 7.92	79.67 – 5.42	65.75 – 6.75
X	79.81^{c}	84.51^{a}	84.89^{a}	82.45^{b}	72.28^{d}
Sd	1.81	3.26	1.42	1.30	2.44
Cv	2.27	3.86	1.68	1.59	3.38

Mean with different superscript along the same row are significantly different ($p<0.05$)

Table 18: Decadal Variability of Relative Humidity within the study area

	Decadal Relative Humidity (%)				Variability Index (%)		
Station	1971-1980	1981-1990	1991-2000	2001-2010	2nd - 1st	3rd-1st	4th-1st
Uyo	-	78.46	79.36	81.17	-	1.14	3.45
Eket	-	-	82.88	85.40	-	-	3.06
Calabar	86.26	83.90	84.83	85.06	-2.73	-1.66	-1.39
Ikom	83.78	82.37	82.20	81.82	-1.69	-1.89	-2.35
Ogoja	-	73.67	71.77	71.80	-	-2.58	-2.54

Table 19: Spatial Distribution of Evaporation (mm) within the study area

Location	Uyo	Eket	Calabar	Ikom	Ogoja
Range	1.36 – 3.10	1.86 -3.52	0.90 – 3.0	1.80 – 2.80	2.90 – 5.0
X	2.17^{d}	2.91^{b}	2.44^{c}	2.25^{cd}	3.54^{a}
Sd	0.38	0.39	0.38	0.25	0.50
Cv	17.34	13.32	15.86	11.25	14.24

Mean with different superscript along the same row are significantly different ($p<0.05$)

Table 20: Decadal Variability of Evaporation

	Decadal Evaporation (mm)				Variability Index (%)		
Station	1971-1980	1981-1990	1991-2000	2001-2010	2nd - 1st	3rd-1st	4th-1st
Uyo	-	2.28	2.28	1.99	-	- 0.30	-12.75
Eket	-	-	2.86	3.01	-	-	5.25
Calabar	2.26	2.39	2.45	2.69	5.58	8.23	18.84
Ikom	2.15	2.47	2.12	2.29	14.88	-1.40	6.51
Ogoja	-	3.35	3.57	3.89	-	6.47	15.99

Table 21: Spatial Distribution of Wind Speed (ms^{-1}) within the study area

Location	Uyo	Eket	Calabar	Ikom	Ogoja
Range	0.76 – 5.81	2.86 – 3.95	2.04 – 10.64	0.36 – 3.16	-
X	2.65^c	3.56^b	5.51^a	1.89^d	-
Sd	1.59	0.32	1.69	0.71	-
Cv	59.77	9.13	30.50	37.41	-

Mean with the same superscript along the same row are not significantly different ($P>0.05$)

Table 22: Decadal Variability of Wind Speed in the study area

	Decadal Wind Speed (ms^{-1})				Variability Index (%)		
Station	1971-1980	1981-1990	1991-2000	2001-2010	2nd - 1st	3rd-1st	4th-1st
Uyo	-	3.31	1.98	2.77	-	-40.20	-16.44
Eket	-	-	3.57	3.54	-	-	-0.96
Calabar	3.80	6.56	5.96	5.99	72;46	56.61	57.43
Ikom	2.47	2.41	1.85	1.12	-2.51	-25.07	-54.59
Ogoja	-	-	-	-	-	-	-

Table 23a: Trend of different climatic elements in the study area

Location	Rainfall Amount (mm)	Minimum Temperature (°C)	Maximum Temperature (°C)
Eket	Y= -0.84x + 4278.6	Y= 0.04x + 23.59	Y= 0.01x + 30.50
	R^2 = 0.002	R^2 = 0.46*	R^2 = 0.01
Uyo	Y= 17.48x + 1955.4	Y= 0.06x + 23.06	Y= 0.03x + 31.03
	R^2 = 0.21	R^2 = 0.72**	R^2 = 0.42
Calabar	Y= 11.66x + 2665.9	Y= 0.02x + 22.81	Y= 0.03x + 30.23
	R^2 = 0.13	R^2 = 0.19	R^2 = 0.32
Ikom	Y= -3.42x + 2326.3	Y= 0.01x + 22.07	Y= 0.03x + 31.25
	R^2 = 0.03	R^2 = 0.02	R^2 = 0.30
Ogoja	Y= 24.96x + 1728.3	Y= 0.03x + 21.97	Y= 0.09x + 31.92
	R^2 = 0.07	R^2 = 0.12	R^2 = 0.46

*Significant at $p<0.05$, ** Significant at $p<0.01$

Table 23b: Trend of different climatic elements in the study area

Location	Relative Humidity (%)	Evaporation (mm)	Wind Speed (ms^{-1})
Eket	Y= 0.16x + 82.77	Y= 0.03x + 2.95	Y= 0.003x + 3.49
	R^2 = 0.09	R^2 = 0.08	R^2 = 0.004
Uyo	Y= 0.14x + 77.79	Y= -0.01x + 2.37	Y= -0.06x + 3.71
	R^2 = 0.32	R^2 = 0.09	R^2 = 0.10
Calabar	Y= -0.02x + 85.36	Y= 0.01x + 2.24	Y= 0.05x + 4.52
	R^2 = 0.02	R^2 = 0.09	R^2 = 0.09
Ikom	Y= -0.06x + 83.66	Y= -0.003x + 2.33	Y= -0.05x + 2.80
	R^2 = 0.29	R^2 = 0.02	R^2 = 0.66*
Ogoja	Y= -0.03x + 72.83	Y= 0.04x + 3.28	-
	R^2 = 0.01	R^2 = 0.11	-

*Significant at $p<0.05$, ** Significant at $p<0.01$

Discussion of Finding

Effect of climate change on climatic elements varied among climate elements and among locations. Onset of rain was a little beat late in the past climate but somehow early in the recent climate regime in the entire locations except in Ikom where the reverse occurred. The result collaborated with the finding of NIMET (2012) who reported that onset of rain is earlier than normal in most locations in the southern Nigeria. There was no significant ($p>0.05$) difference in retreat of rain in the entire locations compared to the past average. This suggested normal cessation of rain in the study area. Considering duration of rain, the findings have shown that duration of rainy season in recent climate was not significantly ($p>0.05$) different from what was obtained in the past climate except in Calabar. Though the difference was not significant, agricultural activities are likely to suffer set back in areas of decreasing rainfall duration (Eket and Ikom) as a result of deficit in water supply associated with climate change. This was in agreement with NIMET (2012) who reported that agricultural sector is likely to suffer the greatest effect of climate change and called for effective adaptation from all stakeholders. .

The climatology of August rainfall in the study area exhibited rainfall maxima in most locations and this could be due to the northern influence of moisture from the South Atlantic Ocean. The study had shown that there was a shift in double rainfall maxima between July and September to June and September in recent climate while the short dry season (August break) was being experienced more in July as against its normal occurrence in the month of August in the past climate. This may be attributed to a shift in savanna belt southward due to alteration in climatic belt caused by climate change. This observation is in line with Akpodiogaga-a and Odjugo (2010) who stated that while areas experiencing double maxima shifted southward due to climate change, the short dry season (August break) was being experienced more in July as against its normal occurrence in the month of August prior to the 1970s.

Apart from annual rainfall total and monthly rainfall distribution, engineers and hydrologists require information on the frequency and magnitude of extreme precipitation, the distribution of rainfall storm of different sizes as well as the characteristics of rainfall for system design and analysis. Analysis of frequency of rainfall of various sizes in the study area showed that proportion of trace, < 25 mm, 26 – 50 mm and 51 – 99 mm rains were slightly higher in recent climate regime than the past climate indicating increase in rainfall intensity across the basin which might have contributed to high incidence of flooding in the study area in recent time. The result also showed that there was increase in the proportion of cloud burst rains in the basin in the recent climate compared to the past climate and this was attributed to climate change (NEMA, 2013). Analysis of temporal pattern of the concentration of rainstorms of varying sizes in the basin area is useful in planning for flood control, soil moisture management/farming activities as well as erosion control.

There was abrupt increase in maximum and minimum temperature in the study area in the entire locations confirming incidence of global warming even in a local scale. Hence, global warming is real as confirmed at local levels. This linear increase in annual warming in recent period occurs as a result of increase in global atmospheric concentration of carbon dioxide (CO_2) levels plus the effect of other anthropogenic greenhouse gases. This is in line with observation made by Adelalu (2012) and Bello (2013). Also, the study confirmed that warmer than normal temperature prevailed over the basin in recent climate period which agreed with IPCC (2007), Ogunjobi *et al.* (2012), NIMET (2012), Bello (2013) among other climate experts who stated in their separate studies that global temperature has been on the increase in the past 100 years. The result also suggested more warming condition in the future.

Higher evaporation rate in recent climate period may be attributed to warmer than normal condition of the area associated with increased rainfall amount as supported by NIMET (2012). However, seasonal evaporation exhibited great similarity across the basin with high rates occurring in dry season (between December and March) and lowest rates obtained at peak wet seasons (between June and September). Higher evaporation rate in Eket and Ogoja reflected drier than normal condition in Eket and Ogoja which also suggested that most rivers were drying up in those locations. This is because evaporation is an important component of the hydrological cycle which has great influence on the water balance of the earth surface. Also, the low wind speed in most locations in recent climate period could be attributed to shift in the air front (International convergence zone, ITCZ) southward as supported by NIMET (2012). This might have influenced the increase occurrence of cloud burst storm in Calabar and Eket than other three locations. The increased wind speed in Calabar could also be attributed to its proximity to the sea which exerts its wave influence in form of wind storm.

There was significant ($p<0.05$) variation in prevailing climate sub types in the area. This variation was attributed to differences in the climatology of the study area. Basically, the study confirmed that rainfall increased towards the coast and decreased away from the coast. In other words, rainfall decreases with increasing latitude. This agreed with Olaniran (2002) who reported that Nigerian rainfall is latitude dependent. Eket which is in the vicinity of the Atlantic ocean major tributary (The Qua Iboe River) had the least amount of evapotranspiration which ranged from 2.40 mm in August to 3.93 mm in February. However, the values were all within the range of 2 mm and 6 mm reported by Chineke, Idionoba and Ajay (2011) for South Eastern cities in Nigeria namely Benin, Asaba, Yenegoa, Porthharcourt, Uyo and Calabar. The study showed that Eket had 9 wet months per year, 7 for Uyo, 6 for Ikom and Ogoja respectively while Calabar had 8 wet months per year. The wet and dry months identified in Uyo disagreed slightly with findings of Udosen (2008) who stated that rainfall in Uyo is seasonal with three to four months (November - February) being relatively dry. However, number of wet months in Eket agreed perfectly with his findings. Hence, wet months in recent climate begin in March and lasts till November in Eket, April to October in Uyo, March to October in Calabar, April to September in Ikom and Ogoja. This scenario has a lot of implications for farming activities, flood hazard, erosion menace, and other human activities in the study area.

Analysis of spatial variation of climatic elements within the basin area showed that the five locations did not differ significantly ($p>0.05$) in onset date but varied significantly ($p<0.05$) in other rainfall characteristics received. The coefficient of variability of rainfall parameters obtained in the study area were very high confirming that variability is eminent in seasonal rainfall characteristics of the basin in particular and Nigeria's rainfall pattern in general as earlier noted by Ysuf and Atteh (2009). Considering rainfall amount, the highest mean annual rainfall was received in Eket followed by Calabar to Ikom and Uyo while Ogoja had the least. This agreed with the range obtained by Udosen (2008) in Uyo and Eket and means reported by NIMET (2012) for Eket, Uyo and Calabar. The spatial spread of rainfall in the five locations showed that rainfall amount decreased with increasing latitude and the proximity of an area to the sea. On a global scale, variation in rainfall amount may be due to dissimilarity in the distance from major source of moisture supply like oceans, sea, rivers, etc. Hence, higher total annual rainfall is expected in Eket and Calabar than Uyo, Ikom and Ogoja as also observed by Udosen (2008) in the case of Uyo and Eket in Akwa Ibom State. On a local scale however, the relative effects of individual factors like topographic position of the weather station results in variability in rainfall received among local weather stations within the same region, hence, existence of variability in rainfall of closely related locations.

Spatial variability in mean annual temperature for the study period showed that Ogoja had the highest maximum temperature, significantly ($p<0.05$) higher than Eket, but not significantly ($p>0.05$) different from Uyo, Calabar and Ikom.

Similarly, the highest minimum temperature was obtained in Eket followed by Calabar and Ogoja while Ikom had the least. The study further showed that Uyo, Calabar and Ikom had almost similar temperature while Eket and Ogoja had different temperature range compare to the other three locations within the basin. Decadal variability did not only show continuous increase in temperature but had also revealed that 2001 - 2010 was the warmest decade in the last four decades in the area. The finding indicated a stronger warming condition in the study area with the highest warming in the last decade occurring in Ikom followed by Calabar to Ogoja while Eket was the least. This is a proof that global warming is real and evident even at the local scales.

In terms of the rate of temperature rise, there was no evidence from the data that warming in the study area was faster than the global average as many scientists have predicted for Africa. According to IPCC (2012), the global average surface temperature has increased by 0.6 ± 0.2 °C over the 20th century. The overall global trend for the maximum temperature is put at +0.88 °C per 100 years, while the trend for minimum temperature is +1.86 °C per 100 years (Easterling *et al*., 2007). Considering the maximum temperature rise obtained in this study, rates of temperature rise obtained in Calabar and Ikom agreed perfectly with rate of 2.5 % increase reported by NIMET (2012) from 1941 - 2010, rates in Uyo and Ogoga were slightly higher while rate of rise in Eket was significantly ($p<0.05$) lower than the long term average reported by NIMET (2012). The observed increase in linear warming from 1971 – 2012 time periods might have occurred as the global atmospheric concentration of equivalent carbon dioxide (CO_2) levels and the effects of other anthropogenic greenhouse gases have increased.

Implication to Agriculture and Food Security in the study area

There is a close connection between ecological type and Agricultural land use system on the one hand and between ecological change and climate pattern on the other hand. As noted by Bello *et al*. (2004), there is no need for farmers to stick to the traditional method of using vegetation type alone as indicator of the type of crop cultivar that can be grown in an area, instead climate production potential based on critical climatic requirements of the crops should be considered. As the cropping patterns of an area basically depend on moisture availability index of the soil as the prime factor especially in the tropics, and for the fact that water stress condition varies both in time and space; availability of water in the soil as well as the water stress condition of the soil has great influence on cropping pattern in an area.

Climate change has altered the climatology of many communities within the basin area, collapsed double maxima in some locations and created it in other locations. This means that length of farming season will be affected seriously in most locations like Eket, Ikom and Ogoja as a result of climate change. Not only in Cross River Basin area will this challenge exist, but the entire ecological zones in the country whose climatology is altered by climate change. For instance, the second season farming otherwise called 'Late planting' in Akwa Ibom State is no more in existence resulting in reduction in crop yield and food supply and this has raised food insecurity threat in the area.

The study has revealed that agriculture is at great risk in this low lying area suggesting high probability of food insecurity in locations like Uyo, Eket and Calabar. For instance, the thermal and moisture requirements of different crops showed that Ikom and ogoja area of the basin have higher climatic production potential and their soils are less polluted for production of most arable crops like swamp rice, upland rice, maize and yams. Crops like bananas, soyabeans, maize, oil palm have optimum cropping potential in both the humid and moist sub humid climates which comprised Uyo, Ikom and Ogoja. In the order hands, Eket and Calabar have higher climatic production potential for tree crops implying that they are most suitable for agro-forestry yet the soil is highly polluted. This has revealed why arable crop production in locations like Ikom and Ogoja are and will still be more significantly better even with little inputs than locations like Uyo, Eket and Calabar areas of the basin despite the level of soil amendment added. Indeed, agricultural activities and food security situation in Uyo, Eket and Calabar are further worsened by high level of soil pollution caused by oil exploration activity, which on its own, has sent many farming households to bed hungry.

Conclusion and Recommendations

It has been shown that pattern of climate change varies with climatic elements and among locations except temperature which is on the increase across locations. Analysis of pattern of change in rainfall, temperature, relative humidity, evaporation and wind speed within the basin area has also shown that annual rainfall in Calabar, Uyo, and Ogoja is above normal, while that of Eket and Ikom is below normal. Minimum and maximum temperatures are above normal in the entire basin area. Similarly, relative humidity is above normal in Eket and Uyo but below normal in Calabar, Ikom and Ogoja. Evaporation in Eket, Calabar, and Ogoja is above normal while that of Uyo and Ikom is below normal. Wind speed in the entire basin area is below normal except in Calabar where it is above normal. There is increased warming condition and rainfall intensity within the basin in recent climate regime and these are likely to increase with further warming, thus affecting agricultural activities and increasing risk of food insecurity in the area. Therefore, many communities within this low lying basin are likely to experience poor agricultural output and high level of food insecurity due to abnormal rainfall event and increased atmospheric concentration of CO_2 as a result of climate change.

The study therefore recommended the following:

i. Onset date and length of growing season have been altered in some location like Calabar due to climate change; therefore, yearly farming calendar should be prepared by agro-climatologists to guide the farmers in such location.

ii. There is evidence of increase warming in the basin area confirming the reality of global warming even at local level. Therefore, government at all levels should step up modalities to reduce warming in their environment. For instance, gas flaring in the Niger Delta region should be diverted to other economic uses instead of allowing it to waste and also cause a problem to the environment. Tree planting should be budgeted for yearly to check excess concentration of CO_2 in the atmosphere.

iii. As a matter of fact, there is need for farmers' education now than before as climate change is going to affect agricultural sector seriously.

iv. Apart from farmers, other sectors like transportation, clothing, aviation, water resource management, engineering, name them are not left out from the influence of climate change. This calls for high level of climate consciously by every individual. As such, climate information and climate related research should be supported by all stake holders in order to win the climate war confronting the world in the 21st century.

v. With high level of anomalies experienced in our climate system in recent time, government at the state and Federal levels should pay serious attention to weather stations. Sophisticated weather measuring equipments should be provided not only in Lagos stations of NIMET but also in every other stations to be able to provide warning signals on where and when the next climate related risk is expected. This will not only improve forecasting, effective and prior warning signals released from our local stations can save lives of many Nigerians and also increase availability of weather data which is one of the greatest challenges in climate research in Nigeria as encountered in the study area.

vi. Climate classification of the study area has shown that climate differs even within the same ecological zone. Therefore, crop should be planted where they have higher climate production potential. To achieve this, Government at State and Local levels should extend climate classification to other ecological zones within their areas for better land use planning, agricultural and irrigation practices.

vii. Irrigation facilities are highly recommended in Ogoja area to supplement the low rainfall for agricultural activities to thrive not only because of its low rainfall but because this area has higher climate production potential for almost all the arable crops in the region. This will increase food security in the country.

viii. Government at Federal, State and Local levels should rise up for poor agricultural activity and food insecurity challenges which are already evident in Uyo, Eket and Calabar by investing more in processing agriculture to make food accessible and affordable in these areas.

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REFERENCES

Adefolalu, D. O. 2006. Weather events, Climate variability and change in relation to NEEDs and MDGs problems and prospects of the Nigerian economy p 73.

Adefolalu, D. O. 2010. Climate Change, Impact and Adaptation: Role of Seasonal Climate Prediction. In: *Climate Change Impacts and Adaptation: Developmental* Issues. Nigerian Meteorological Society (2010) pp 53 – 87.

Adelalu, T. G. 2012. Climate Variability and River Benue Discharge in Jimeta, Yola Area, Nigeria. Special Publication of the Nigerian Association of Hydrological Sciences , Hydrology for Disaster Management pp 23 – 30.

Akinsanola, A. A. and Ogunjobi, K.O. 2014. Analysis of Rainfall and Temperature Variability Over Nigeria. *Global Journal of Human-Social Science*: *B Geography, Geo-Sciences, Environmental Disaster Management* 14 (3):1- 19.

Akpodiogaga-a, P. and Odjugo, O. 2010. General Overview of Climate Change Impacts in Nigeria, *J Hum Ecol.* 29(1): 47-55).

Ayoade, J. O. 2003. *Climate Change: A synthesis of its nature, causes, effects and management*. Ibadan Vantage Publishers Ltd. pp 18 – 26.

Bello, N. J., Akanni, C.O. and Ufoegbune, G. C. 2004. Climatic classification approach to agricultural land Use Planning in Ogun-Oshun River Basin area Nigeria. *Journal of Nigerian Meteorological Society* 4(2):50 – 62.

Chineke, T. C., Idinoba, M. E. and Ajayi, O. C. 2011. Seasonal evapotranspiration signatures under a changing landscape and ecosystem management in Nigeria: Implications for agriculture and food security. *American Journal of Scientific And Industrial Research* 2 (2):191-204.

Easterling, D. R., Horton, B., Jones, P. D., Peterson, T. C., Karl, T. R., Parver, D. E., Salinger, M. J., Razuvaer, V., Plummer, P., Jamason, R. and Folland, C. K. 2007. Maximum and Minimum Temperature Trends for the Globe. *Science*, 277 (5324): 364-367

Howell, T. A. and Evett, S. R. 2006. The Penman-Monteith Method. Available online: http://www.cprl.ars.usda.gov/

Intergovernmental Panel on Climate Change (IPCC) 2012. *Managing the risks of extreme events and disasters to advance climate change adaptation: summary for policy makers.* Cambridge:

Cambridge University Press pp 4 – 15.

IPCC 2007. Regional climate projections. In *Climate Change 2007*. The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK, New York, US: Cambridge University Press pp 8 – 19.

National Emergency Management Agency 2013. 2012 flood disaster cost Nigeria N2.6tn. *The Punch*, 20th July, 2014. Available at www.punchng.com.

Nigerian Meteorological Agency (NIMET) 2010. Nigeria climate review bulletin 2010 pp 8 - 19

NIMET 2012. *2012 Seasonal Rainfall Prediction* pp 6 – 15.

NIMET 2013. *2013 Seasonal Rainfall Prediction*. Available at *nimet.gov.ng/seasonal-rainfall-prediction.* pp 1 – 20.

Ogundebi, A.O. 2004. Socio-economic impacts of Flooding in Lagos State, *Environmental Impact Analysis* 12 (1): 16-30.

Olaniran, O. J. 2002. Rainfall anomalies in Nigeria: The contemporary understanding. *An Inaugural Lecture is an academic obligation which all persons appointed/promoted professors in the University of Ilorin would be required to fulfill in the course of their career in the University* 23pp.

Smith, B. W. 1996. Coping as a predictor of outcomes following the 1993 Mid-West flood. *Journal of Social Behavior and Personality* 11: 225-239.

Stern, N 2008. The Economics of Climate Change*, American Economic Review* 98 (2): 1-37.

Udo-Inyang, U. C and Edem, I. D. 2012. Analysis of Rainfall Trends in Akwa Ibom State, *Nigeria Journal of Environment and Earth Science* 2(8): 2-12.

Udosen, C. E. 2008. Rainfall Analysis and Forecasting in Akwa Ibom State. Uwana Graphics Press, Uyo, Nigeria pp 21-33.

Wolfe, D. W., Schwartz, M. D., Lakso, A. N., Otsuki, Y., Pool, R. M. and Shaulis, N.J. 2005. Climate change and shifts in spring phenology of three horticultural woody perennials in northeastern USA. *Internat J Biometeorol*, Meteorological Organization 49:303-309.

Yusuf, Y. O. and Atteh, B. T. 2009. Normality of daily, pentad and decadal rainfall series in Palladan, Zaria, Kaduna State. Conference Proceedings on Climate Change and the Nigerian Environment, Department of Geography, University of Nigeria, Nsukka pp 271-288.

Yusuf, Y. O. and Mohammed, N. A. 2011. An Assessment of Spatial Distribution of Rainfall Amount in Zaria, Kaduna State. A Paper Presented at the 52nd Annual Conference of the Association of Nigerian Geographers Held at the Department of Geography, Usman Danfodio University, Sokoto, Nigeria from 14th -17th February, 2011 pp 3-9.

Zotarelli, L., Dukes, M. D., Consuelo, C., Romero, K., Kati, W., Migliaccio, E. and Kelly, T. M. 2010. Step by Step Calculation of the Penman-Monteith Evapotranspiration (FAO-56 Method). Available at http://edis.ifas.ufl.edu. Pp 3- 10.

AN ANALYSIS OF SOME WATER BALANCE INDICES IN NIGERIA OVER TWO YEARS WITH CONTRASTING MOISTURE CONDITION

ABSTRACT

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A routine study of water balance indices is a veritable tool in monitoring the amount of water that will be available in the soil of any particular place at a particular time for optimal crop production and other uses. The semi-arid region of Africa and Nigeria in particular, is constantly bedeviled with the problem of inadequate water for efficient crop production. Hence, the needs for adequate information on soil water balance for efficient water management to boost crop production. However, this study makes analysis of some water balance indices in Nigeria over two years with contrasting moisture condition. The year 1983 has been described as a dry year while the year 2003 on the other hand as a wet year. This study used mean monthly air temperature and monthly rainfall data. The data were sourced from the archives of the Nigerian Meteorological Agency NIMET with respect to twenty-seven synoptic weather stations across Nigeria. The entire mean monthly air temperature and monthly rainfall data for 1983 and 2003 were subjected to Thornwaite's method to estimate water balance indices such as potential evapotranpiration, actual evapotranspiration, and water deficit. Paired sample test revealed that there is a significance difference between the water balance indices of a dry year and a wet year and across the weather stations in Nigeria [p=.000]. This study concluded that there is no uniformity in the pattern of water balance indices across Nigeria and over the two years. The study thus suggests that government should provide alternative sources of water inform of irrigation to those locations where water deficit is higher in order to boost their crop production. On the other hand, places with high moisture surplus and runoff should be properly managed to forestall greater danger of soil erosion and flood.

Keywords: water balance, indices, actual evapotranpiration, potential evapotranspitraion, water deficit, water surplus and runoff.

INTRODUCTION

There are reports of an increasing trend in aridity in the arid and semi-arid region of Nigeria [1]. As a result, Irrigation agriculture can be 2 to 3 times more productive than rain-fed agriculture in Sudao-Sahelian zone of Africa. The development of irrigation potential in this region is based on the availability of reliable information on the water resources.

Long term and routine records of scientifically documented facts about the water balance are a necessary pre-requisite to sustainable developments of water resources. It is against this backdrop that this study focuses on the analysis of some water balance indices in Nigeria over two years with contrasting moisture condition. The year 1983 and 2003 has been described as a dry and a wet year [2]. The objectives of this study are: to estimate the potential evapotranspiration for each of the weather stations selected in Nigeria for the year 1983 and 2003, to compute water balance sheet for each of the weather stations in Nigeria for 1983 and 2003, to determine the spatial, temporal and latitudinal variations of the water balance indices in Nigeria and to find out whether there is any significance difference between the water balance indices of a dry year and a wet year in Nigeria.

Water balance is an accounting of the inputs and outputs of water on the earth's surface. The water balance of any place, whether it is an agricultural field, watershed, or continent, can be determine by calculating the input, output and storage changes of water at the earth's surface. The major input is from precipitation and output is evapotranspiration [3]. [4] Stresses that inadequate water supply is the most important factor affecting agricultural production in Sudano-Sahelian region of Africa and a better understanding of the magnitude and dynamics of the different components of the soil water balance is very crucial to development of technological options for sustainable management of soil and water resources.

Materials and methods

The study area is Nigeria. It is located between latitude 4°N and 14°N of the equator and longitude 3°E and 15°E of the Greenwich Meridian. The materials used for this study include the Excel template used to estimate the PE, the Thornwaite,s Monograph containing the soil water holding capacity used for computing the water balance indices, Journals and other publications used as literature. The data used for this study are the mean monthly air temperature and monthly precipitation for only two years with contrasting moisture condition. The data were sourced from the archives of the Nigerian Meteorological Agency [NIMET] with respect to twenty seven [27] selected weather stations well spread across Nigeria. The air temperature data collected were subjected to Thornwaite's method to estimate the monthly potential evapotranspiration [PE] for each of the stations for the selected wet and dry year. The estimated monthly PE values in conjunction with the monthly rainfall data and Thornwaite's soil water holding capacity of 250mm serve as the input data to compute other water balance indices. The water balance indices analyzed in this study are: Potential evapotranspiration, precipitation, actual evapotranspiration and soil water deficit. The results of the annual water balance indices for the two years were presented in a table. Spatial maps were produced using Arc GIS to show the spatial pattern of the annual water balance indices in Nigeria. The monthly and latitudinal variations of the water balance indices were presented on charts for better understanding.

Figure1 Map of Nigeria showing the distribution of selected synoptic meteorological stations Source: [2].

Result and discussion

Spatial, latitudinal and monthly variations of Potential evapotranspiration in Nigeria

Result from table1 indicates that the rate of PE varies across Nigeria in both dry year [1983] and wet year [2003]. It could be observed from figure 3 that most of the stations located north of latitude 7°N experiences higher rate of potential evapotranspiration of above 2000mm in both the year 1983 and 2003 when compare to those stations south of latitude 7°N. Gusau recorded the highest PE of 2205mm in 2003 while Yelwa recorded the highest PE of 2199mm in 1983. On the contrary, Jos recorded the least amount of PE in both years. Critical examination of table 1 show that the amount of PE recorded in 2003 is significantly higher than that of 1983. See figure 2a & 2b for the spatial pattern of PE in Nigeria. The spatial variation of PE is being influenced by factors such as the amount of available water, energy from solar radiation, topography, vegetation cover, and time [season] of the year etc. The manifestations of these factors give Jos a distinct record of low PE among her counterpart in the north.

Result from figure 4 revealed that the rate of PE is higher during the month of February, March, April, May, June, October and November both in 1983 and 2003. The highest PE was recorded during the month of April and March in 1983 and 2003 respectively. The lowest PE on the other hand was recorded in January in 1983 and August in 2003.

Spatial, Latitudinal and Monthly variations of Rainfall in Nigeria

Result from table 1 shows that the amount of rainfall varies across Nigeria both in the year 1983 and 2003. It could be inferred from table 1 that rainfall is significantly higher in most of the stations located south of latitude 6°N where, most of the stations recorded annual rainfall above 2000mm compare to those located north of latitude 6°N of the equator. Warri recorded the highest annual rainfall of 2523mm in 1983 while Calabar recorded the highest rainfall of 2440mm in 2003. On the contrary, Nguru in the extreme north east recorded the least rainfall in both years. See detail in table 1. See figure 5a &5b for spatial pattern of rainfall in Nigeria and figure 6 for the latitudinal variation as well. Result shows that the amount of rainfall varies from January to December across Nigeria in both 1983 and 2003. A visual observation of figure 7 unfolds that the amount of rainfall is low from January to around May in both years. The months with the higher records of rainfall are June, July, August, and September

Spatial, Latitudinal and Monthly variation of Actual evapotranspiration in Nigeria

Actual evapotranspiration is the actual "amount of water use" that is, water that is actually evaporating into the atmosphere based on the environmental condition of that particular location [3]. However, result from table 1 shows that the rate of AE varies across Nigeria and over the dry and the wet years. It is also evidence from figure 8a &8b that the rate of annual AE increases from the north towards the south where there are higher amount of rainfall in both years. Most of the stations located south of latitude 6°N record higher AE of above 2000mm both 1983 and 2003. The highest AE of 1521mm was recorded in Ikom in 1983 while Calabar recorded the highest AE of 1771mm in 2003. Nguru recorded the least AE in both 1983 and 2003. A critical observation of table 1 shows that the rate of AE is significantly higher in the wet year compare to the dry year. See detail of latitudinal variation of Actual evapotranspiration in Nigeria over the two years in figure 9.

Result from figure 10 shows that the rate of AE varies from the month of January to December in 1983 and 2003. While the monthly AE is significantly low during the months of January, February, March, November and December, it is on the other hand higher during the months of May, June, July, August September and October across Nigeria in 1983 and 2003. The month with the highest AE in 1983 is June while the highest AE was recorded in the month of October in 2003. See figure 10.

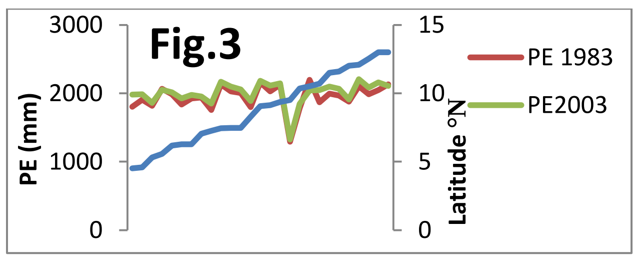
Spatial, Latitudinal and Monthly variation of Water Deficit in Nigeria

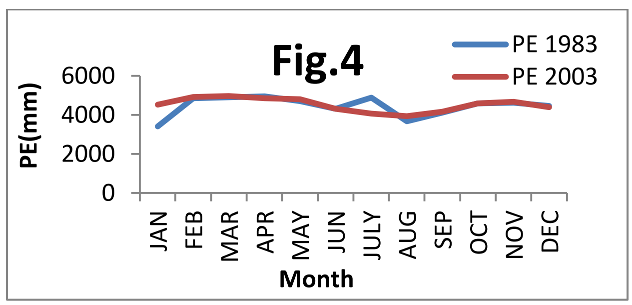
Moisture deficit occurs when the demand for water on the earth's surface exceeds what is actually available. In order words, deficit occurs when PE exceeds AE i.e. [PE>AE]. However, it could be observed from table 1 and figure11a &11b that the occurrence of moisture deficit is higher northwards in both years when compare to what is obtained in the southern stations. It could also be observed that stations located south of 6°N such as Calabar, Portharcourt, Warri, Benin, Enugu, Jos and Lagos recorded lower annual moisture deficit in both 1983 and 2003. See figure 12 for latitudinal variation. The spatial pattern of soil moisture deficit across Nigeria could also be related to the findings of [5].

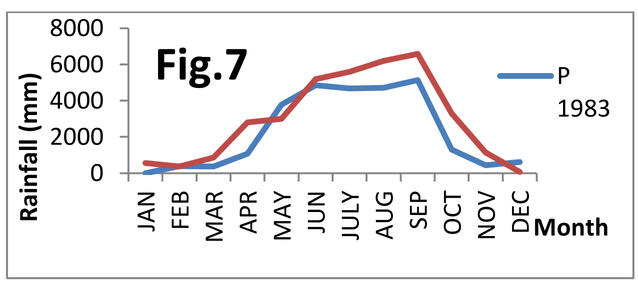
Result from figure13 reveals that stations such as Nguru, Katsina, Minna, Yelwa, Kano, Maiduguri, Sokoto, Bida, except Jos, Yola and Kaduna, experiences moisture deficit throughout the year while virtually all the stations in the south only experiences deficit for between four to five months in the years. Detail observation of figure13 shows that the amount of water deficit decreases from January across the stations during the years to around September in the north and to October in the south. It could also be observed that the amount of water deficit increases from the month of November to December in both the dry and the wet years. It is very clear from figure 14 that January recorded the highest water deficit while lowest water deficit on the other hand was recorded during the month of August in both 1983 and 2003.

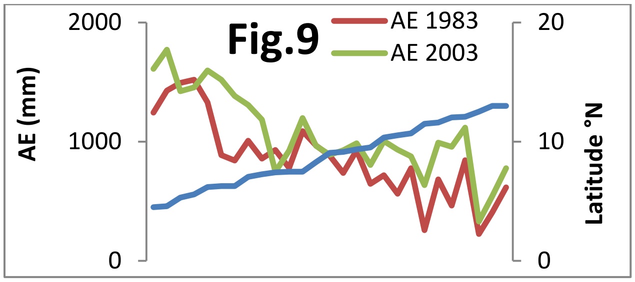
Conclusion and Recommendations

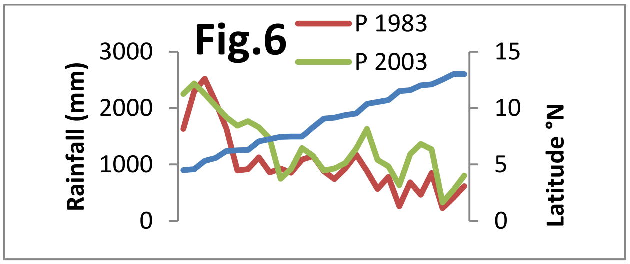
This study concludes that there is no uniformity in the spatial, latitudinal and temporal pattern of water balance indices in Nigeria. This study therefore recommends that Government should provide alternative source of water inform of irrigation scheme in those part of Nigeria where there are very low rainfall, high potential evapotranspitation and high water deficit to boost crop production. Places with high rainfall, water surpluses and runoff should be properly managed to forestall severe soil erosion and flooding.











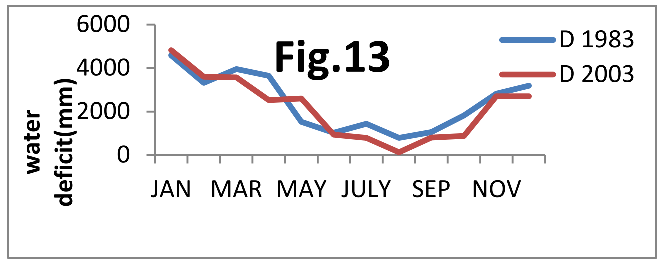
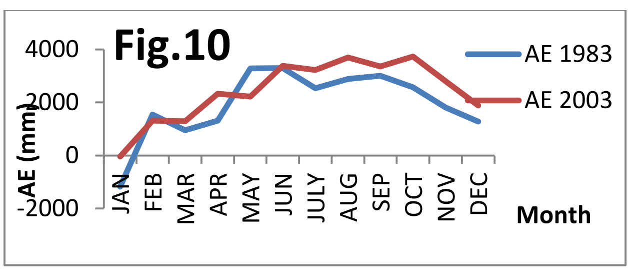


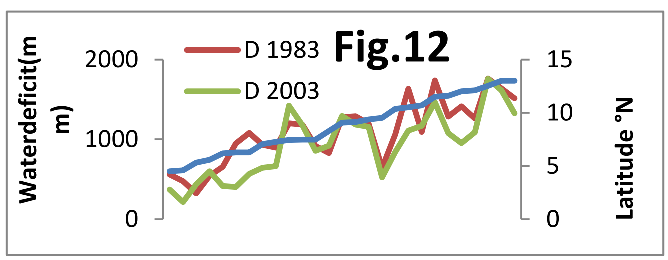
Table 2 summary of some annual water balance indices across twenty seven weather stations in Nigeria for the year 1983 and 2003 values [mm]

station	latit°N	long°E	PE1983	P1983	AE193	D1983	PE2003	P2003	AE2003	D203
Port/H	4.51	7.01	1805	1633	1244	561	1982	2248	1610	372
Calabar	4.58	8.21	1906	2298	1428	478	1987	2440	1771	216
Warri	5.31	5.44	1818	2523	1494	324	1861	2252	1424	437
Ikom	5.58	8.58	2065	2110	1521	544	2054	2041	1455	599
Benin	6.19	5.06	1989	1630	1331	658	2013	1833	1598	415
Lagos	6.27	3.24	1838	893	887	951	1925	1691	1521	404
Enugu	6.28	7.33	1924	918	843	1081	1977	1769	1382	568
Ondo	7.06	4.5	1941	1126	1008	933	1953	1660	1309	644
Ibadan	7.26	3.54	1755	858	858	897	1849	1460	1184	665
Makurdi	7.44	8.32	2132	930	930	1202	2170	749	749	1421
Lokoja	7.47	6.44	2029	854	780	1187	2101	924	924	1177
Oshogbo	7.47	4.29	2007	1089	1089	918	2056	1293	1198	858
Ilorin	8.29	4.29	1798	1152	969	829	1887	1157	965	922
Bida	9.06	6.01	2161	882	882	1279	2184	891	891	1293

Yola	9.14	12.28	2029	738	738	1291	2112	927	927	1185
Minna	9.37	6.32	2125	928	928	1197	2145	1024	986	1159
Jos	9.52	8.45	1293	1176	647	646	1328	1280	805	523
Kaduna	10.36	7.27	1780	885	720	1060	1848	1633	1005	843
Yelwa	10.53	4.45	2199	563	563	1636	2044	1080	933	1111
Bauchi	10.7	9.49	1871	779	779	1092	2046	967	878	1168
Maidug.	11.51	13.05	1996	257	257	1739	2101	635	635	1466
Zaria	11.6	7.41	1970	683	683	1287	2068	1183	991	1077
Kano	12.3	8.12	1880	464	464	1416	1911	1366	957	954
Gusau	12.1	6.42	2106	846	846	1260	2205	1266	1117	1088
Nguru	12.53	10.28	1989	227	227	1762	2087	329	330	1757
Katsina	13.01	7.41	2046	409	409	1637	2162	546	546	1616
Sokoto	13.01	5.15	2131	618	618	1513	2107	801	779	1328

Source: author's computation, 2016





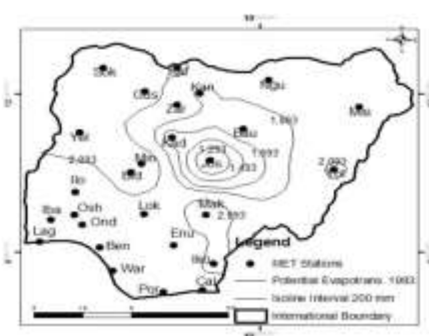


Fig.2 a

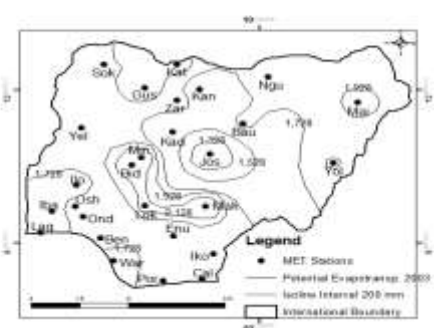


fig.2b

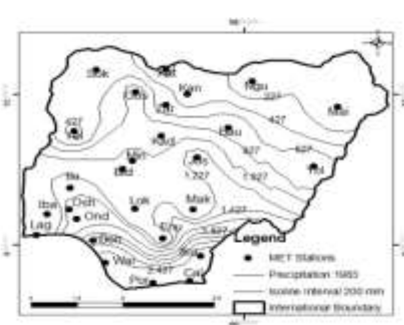
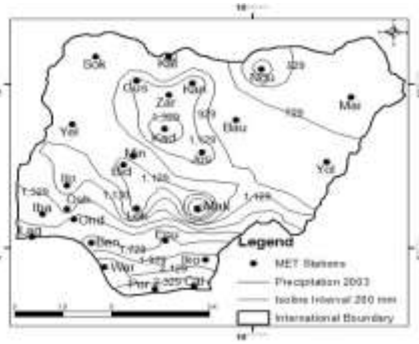
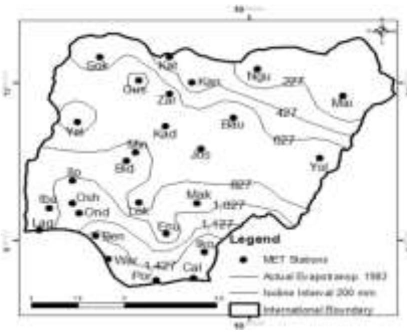


fig.5a





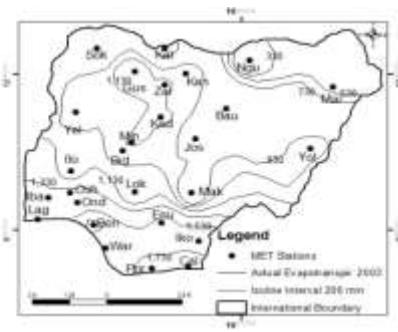


Fig.5b Fig.8a Fig.8b

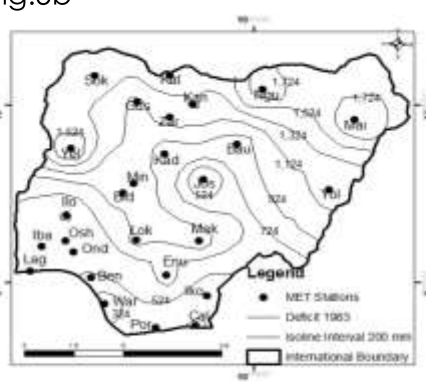


Fig.11a

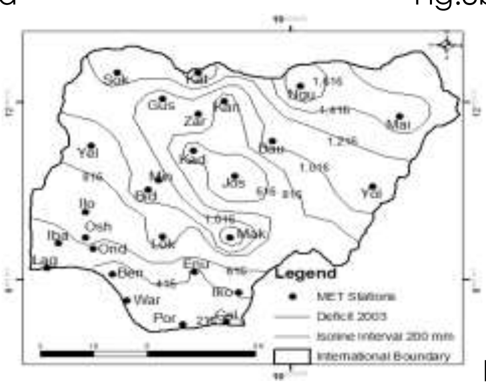


Fig.11b

References

1 Sawa, B. A, Ati, O. F, Jayeoba, I. A, Oladipo, E. O (2015) Trends in Aridity of the Arid and Semi-Arid Regions of Northern Nigeria: *Journal of Environment and Earth Sci.* 5 (10): 61-68.

2 Ritter, M. E. (2012) The Physical Environment: *An Introduction to Physical Geography.* Retrievedfromhttp//www.earthonlinemedia.com/ebooks/tpe-3e/tittle-page.html.2012.

3 Umar, A.T (2013) Frequency and Spatial Pattern of Droughts in Nigeria, *J. of Meteorolo. And Climate Science*, J. Met & Clim. Sci. 11(1):58-74.

4 Lal, R (1991) *Current Research on Crop Water Balance and Implication for the future*. Soil Water Balance in the Sudano-Sahelian Zone (Proceedings of the Niamey Workshop, February 1991). LAHS Publi. No 199, 1991. Page:31-32.

5 Nigerian Meterologica Agency (NIMET) (2013), *Quarterly Weather Review*, January, February, March and April. Pp 1-25.

FLOOD FREQUENCY ANALYSIS OF RIVER DONGA, AT DONGA, TARABA STATE, NIGERIA

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ABSTRACT

The aim of the study was to analyze the flood flows regimes of River Donga by modeling stream flow using Gumbel's probability distribution. Annual maximum discharge of the river for a period of 35 years (1955 to 1989) was modeled to predict floods for return periods (T) of 10, 25, 50 and 100 years. The predicted water level and flood flow magnitude obtained for respective return periods are as follows: 5.39 meter and 2,385.0 Cumecs, 5.72 meter and 2,631.2 Cumecs, 5.97 meter and 2,812.0 Cumecs, 6.2 meter and 2,980.4 Cumecs. The result revealed a gradual rise in both water level and magnitude with increase in return period (10, 25, 50 and 100 year flood). It was hypothesized that there is no significant difference between observed and predicted flood flow for river Donga. A goodness of fit test was conducted using regression analysis and non-parametric Chi square to find out if Donga flood flow fits the Gumbel distribution. From the trend line equation, R2 gives a value of 0.0105. This indicates that the flow data fits Gumbel distribution and hence, can be used to predict the frequency and magnitude of flood flow of river Donga catchment area. The plot also gives the relationship between the observed flow and corresponding year as: 2.9697 xs + 3916.9. The regression curve shows that there is no significant difference in the observed frequency of discharge (m^3/S) within the period 1955-1989 in the study area at a co-efficient of 1.05%. The outcome of the Gumbel's flood frequency analysis from this study provides relevant information that is useful for flood mitigation and management through engineering design of hydraulic structure (bridges, dams, culverts) for storm water, extreme river discharges and flood disaster early warning systems. This will minimize damages to lives, properties and even the environment associated to recent river Donga episodic floods.

Key words: Flood, flood-frequency, return-period, Gumbel's distribution, peak discharge.

INTRODUCTION

Flooding is one of the most common and widely distributed natural risks to life and property worldwide. Flood has been identified worldwide as highly destructive. It has a special place in natural hazards and accounts for approximately one third of all natural disasters in both developed and developing world (UNISDR 2012 cited in: Oyatayo, et al., 2016).

Floods are the leading cause of natural disaster worldwide and were responsible for 6.8million deaths in the 20th century. Asia is most flood-affected region, accounting for nearly 50% of flood related disaster leading to death, change in landform, and creation of flood plain in the 20th century. Flooding is the most common environmental hazard in Nigeria (Etuonovbe, 2011). Flood disaster is not a recent phenomenon in the country, and its destructive tendencies are sometimes enormous. Reports have it that serious flood disasters have occurred in Ibadan (1985, 1987 and 1990), Osogbo (1992, 1996, 2002), Yobe (2000) and Akure (1996, 2000, 2002, 2004 and 2006). The coastal cities of Lagos, Port Harcourt, Calabar, Uyo, and Warri among others have severally experienced incidences that have claimed many lives and properties worth millions of dollar.

Nwafor (2006) defined flood as a natural hazard like drought and desertification which occurs as an extreme hydrological (run off) event. Flood is a large volume of water which arrives at and occupies the stream channel and its flood plain in a time too short to prevent damage to economic activities including homes. Flood is a large amount of water covering an area that is usually dry. It is an overflowing of a great body of water over land not usually submerged (Abam, 2006).

Okereke (2007) observes the following as consequences of flooding: loss of human lives, flooding of houses, streets, inflow to soak away, municipal pollution, damage to properties, health hazards, cleanup costs, disruption of services, traffic problems, adverse effects on aesthetics, disturbances on wildlife habitats, economic loses and infrastructural damage.

Decision makers, planners and stakeholders need to know the frequency and magnitude of flooding. Utilization of flood stage or river gage levels in the land is essential for hazard zoning.

It is therefore necessary to use scientific methodology such as flood frequency analysis to provide a basis for concerted action-plan to be carried out in flood plain planning, flood structures or hazard mitigation, warning systems and rescue operations by either government or non-governmental agencies as applicable.

Flood frequency analysis is a viable method of flood flow estimation and provides reliable prediction in regions of relatively uniform climatic conditions from year to year and it is now an established method of determining critical design discharge for small to moderately sized hydraulic structures (Haktan, 1992). Flood frequency analysis is the universal method used for the estimation of recurrent interval of any hydrological event (Izinyon, 2011). Karmakar (2008) observes that flood estimation via flood frequency analysis provides a basic standard for flood risk evaluation especially in areas that are close to floodplains. More precisely, Izinyon (2011) affirms that return periods associated with annual maximum flood peaks are modeled using flood frequency analysis. This gives room for prediction of such extreme events (especially river runoff) since they are unpredictable and difficult to estimate spatiotemporally. Scientists and researchers find flood frequency analysis a useful tool for the estimation of the contribution of precipitation to stream flow and river runoff to flood occurrence. Hence, the need for this research. This is pivotally essential for the management of flood in Donga Town with respect to mitigation, design, planning and operations through the use of fundamental knowledge of flood characteristics in modeling.

2.0 Study Area

2.1 Location

The Donga River at Donga Town is located between latitude 7°43′00″N and longitude 10°03′00″E. The river arises from theMambilla Plateau in northeastern Nigeria. It forms part of the international border between Nigeria and Cameroon, and flows northwest to eventually merge with the Benue River in Nigeria. The Donga watershed is 20,000km^2 (7,700 sq mi) in area. At its peak near the Benue, it the river delivers 1,800 m^3 (64,000 cu ft) of water per second.

2.2 Climate

The mean annual rainfall of the study area is 1200mm. The area has two marked seasons, the dry and the rainy season. November to March, and April to October for dry and the rainy season respectively. The temperature is generally high with mean annual temperature at 32^{0}C recorded in April and minimum temperature as low as 10^{0}C experienced in December January, with the mean annual temperature at 22^{0}C (Enoch, 2014).

2.3 Geology and soil

Donga is underlain by sedimentary rock of post Cambrian land era, and consist mainly of gentle undulating land with plains. It's river and the basin constitutes one of the fertile arable lands of the region. The hilly undulating land stand at an altitude of 120-130 meters above sea level (Enoch, 2014). The soils by the river bank are not far from alluvial type according to the Food and Agriculture Organization (F.A.O) genetic classification. They are highly susceptible to annual flooding which takes place around the months of August and September with locally developed lithosols. Also the notable quality soil doesn't retain much water and is not highly forested. This makes it more manageable than soils found in the flood plains of the southern parts of the country.

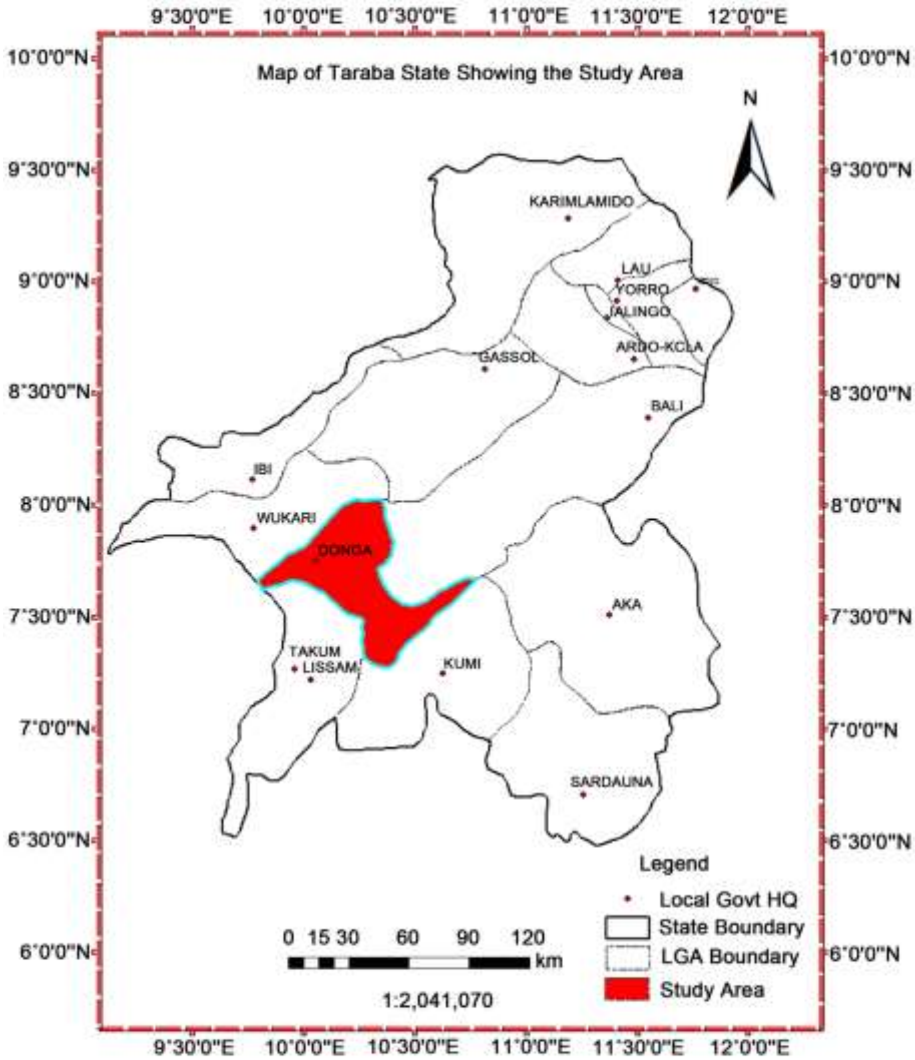

Figure 1: Location of Donga Local Government Area on Map of Taraba
Source: Ministry of Land and survey, Jalingo, Taraba State.

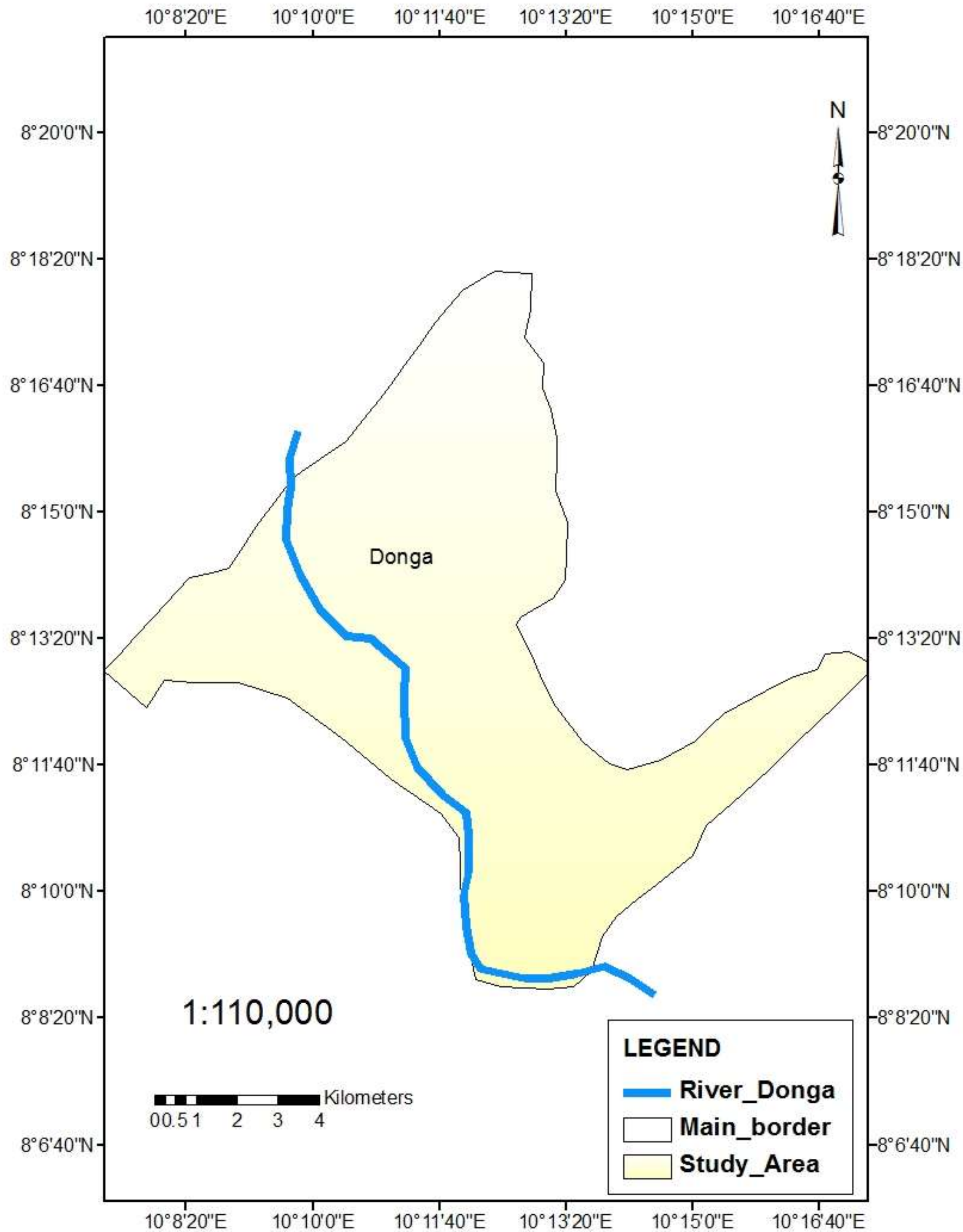

Figure 2: Map of Donga Local Government Area Showing River Donga
Source: Ministry of Land and Survey Jalingo, Taraba State.

2.4 Vegetation

Donga local government falls within the woodlands savannah zone a distinct type of vegetation, which is a transition between forest and savannah vegetation type. Thus there are both varieties of forest and savannah vegetation in which natural plant cover consist of trees, shrubs, and grasses, some of them loose there leaves for only short period in the year. A forest variety such as oil palm is formed scattered all over the area, (Enoch, 2014)

3.0 MATERIALS AND METHOD

3.1 Materials and Data:

The materials and data used for this study are as follows:

Hardware:

Computer, Printer, Scanner

Software:

MS Excel, SPSS.

Sources of Data

The following are the primary and secondary sources of data used:

Primary source

The primary data is the annual maximum gage height data of River Donga at Donga from 1955 to 1989 obtained from the measurements carried out by the National Inland Water Authority (NIWA), Lokoja, Kogi State, Nigeria.

Secondary source of data

The secondary source of data includes official and unofficial statistics from both national and international publication including newspapers, articles, journals, thesis, dissertations and websites.

3.2 METHOD OF DATA ANALYSIS

Flood Flow Modeling

The Gumbel statistical distribution methodology as defined by Sharma and Sharma (2003) was adopted in this research. According to Gumbel, the annual maximum flow data are the extreme values in observed data of various years and hence should follow the extreme value distribution law. In this study, Gumbel distribution has been applied for flood frequency analysis because:

(a) Peak flow data are homogeneous and independent hence lack long-term trends;

(b) The river is lessregulated, hence is not significantly affected by reservoir operations, diversions or urbanization; and

(c) Flowdata cover a relatively long record (more than 10 years) and is of good quality.

Based on this, annual maximum gage height data for thirty five (35) years was used for the analysis. The Gumbel's Extreme Value Statistical Distribution equation is given by:

$T = \bar{X} + k * SDV$

Where

T = Value of variate with a return period 'T'

$\bar{X}$= Mean of the variate

SDV = Standard deviation of the sample

k = Frequency factor expressed as:

$K=\sqrt{\frac{6}{n}}[\ 0.57721 + Ln^* \ (Ln_{T-1}^{T})]$

3.3 Goodness of fit test

To determine whether Donga flood flow fits Gumbel distribution, the following hypothesis was postulated:

H0: There is significant difference between recorded and predicted flood flow of River Donga at Donga.
H1: There is no significant difference between observed and predicted flood flow of River Donga a Donga
Chi square and regression analysis with the aid of the statistical package for social science (SPSS) was used to test the stated hypothesis.

4 RESULTS AND DISCUSSION

4.1 Introduction

This section presents the result of the flood frequency analysis conducted using the Gumbel extreme value distribution for different flood return periods. Also presented, are the results of the Chi-square ($\chi 2$) and regression analysis conducted to test the stated hypothesis.

4.2 Annual maximum discharge of River Donga from 1955 to 1989

Annual maximum discharge values for River Donga at Donga were derived from annual maximum gage height data of the river obtained for a period of 35 years. The maximum instantaneous flow and water level of 2,172 Cumecs and 5.69 meter were recorded in 1985, while the lowest values of 548 Cumecs and 2.99 meter were recorded in 1976. The 35-year mean instantaneous flood flow and water level is 1,939 Cumecs and 479.1 meter respectively.

4.3 Water level and flood flow prediction (magnitude)

Table 2: Modeled water level and magnitude

Return Period (year)	Water level (Meters)	Magnitude (Cumecs)
100	6.20	2980.4
50	5.97	2812.0
25	5.72	2631.2
10	5.39	2385.0

Table 1 shows the results of modeled water level and magnitude values of 100, 50, 25 and 10 year flood of river Donga at Donga town. The water level and magnitude for 100 year flood is 6.2 meter and 2,980.4 Cumecs, 50 year flood is 5.97 meter and 2,812.0 Cumecs, 25 year flood is 5.72 meter and 2,631.2 Cumecs and 10 year flood is 5.39 meter and 2,385.0 Cumecs respectively. The result shows a gradual rise in water level and magnitude with increase in return period (10, 25, 50 and 100 year flood). This confirms the works of Mujere (2011), Shakirudeen and Saheed (2014) and Okoroafor et al.,(2015). Flood frequency of this nature is a multi-dimensional tool used in the assessment of water resource potential as well as a measure of both hydrologic and hydraulic measure that must be integrated in the engineering construction of structures that concern a defined water body. In addition, this measure is a tool of necessity to ascertain the extent of inundation based on available hydrologic data. It provides the data frame for inundation area mapping as well as for the assessment of flood hazard and risk within an area (Shakirudeen and Saheed, 2014).

4.4 Test of Goodness of fit

Table 2: Statistical analysis

Return period (year)	**Magnitude (Cumecs) (O)**	**Expected (E)**	**(O-E)**	**(O-E)2**	**(O-E)2/E**
100	2980.4	2702.2	278.3	77423.1	28.7
50	2812	2702.2	109.9	12067.0	4.5
25	2631.2	2702.2	-70.9	5033.9	1.9
10	2385	2702.2	-317.2	100584.1	37.2
Total	**10808.6**	**10808.6**		**Chis. Value Cal.**	**72.2**
Expected	**2702.15**	**2702.15**			

Chi-squares calculated value= 72.2

Chi squares Tabulated value:

Chi-square (3) at degree of freedom (df) =4-1=3

Right-tail probability = 0.05

Complementary probability = 0.95

Critical value = 7.81473

Decision Rule

- If the $\chi^2_{cal} < \chi^2_{tab}$, accept Ho Otherwise,
- $\chi^2_{cal} > \chi^2_{tab}$, accept H1.

From the empirical result of $\chi^2_{cal}(72.2) > \chi^2_{tab}(7.81)$, this indicates that there is enough evidence to reject H0 in favour of H1 and therefore there is no significant difference between observed and expected flow data in the study area. The χ2 test revealed a satisfactory fit between observed and estimated flood flow values. This indicates that the flow data fit Gumbel distribution and hence, can be used to predict frequency of floods of river Donga at Donga. This confirms the findings of Mujere (2011) who conducted a research on flood frequency analysis using Gumbel distribution and presented a result of measured and predicted flood flows showing no significant (p=1.000) differences hence, a goodness of fit of the Gumbel distribution.

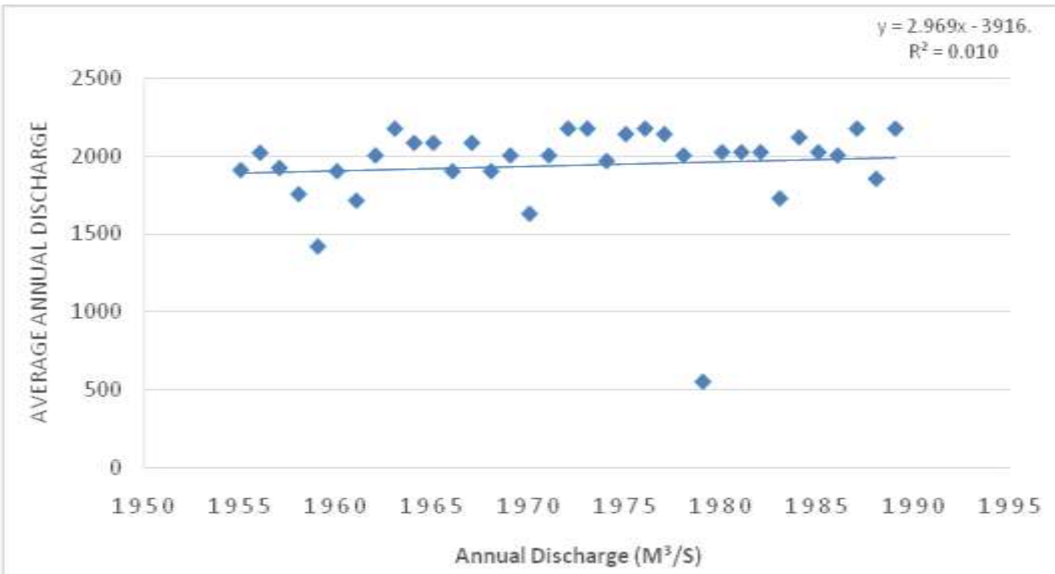

Figure1: Plot of River Donga at Donga Discharge

Figure 1 shows a plot of the flow of the river using the observed data. From the trend line equation, R2 gives a value of 0.0105. This shows that the pattern of the scatter is narrow and that Gumbel's distribution is suitable for predicting expected flow in the river. The plot also gives the relationship between the observed flow and corresponding year as: 2.9697xs + 3916.9. The regression curve shows that there is no significant difference in the observe frequency of discharge (m^3/S) within the peroid 1955-1989 in the study area with the co-efficient of 1.05%.From here, other values not shown in chart can be extrapolated. These and other values obtained will be useful in the area of flood mitigation and management and also in the engineering design of hydraulic structure such as storm water drains, culverts with a view to protecting lives and properties at the downstream of the river. This corroborate the findings of Okonofua and Ogbeifun (2013) whose trend line equation (R2) gives a value of 0.954which shows that Gumbel's distribution is suitable for predicting expected flow in riverOsse.

5 CONCLUSION AND RECOMMENDATION.

5.1 CONCLUSION

The conclusion from the research is that river Donga flow data fit Gumbel distribution and hence, can be used to predict flood flow in the study area.

The conclusion also from the study is that modeled water level and magnitude values of 100, 50, 25 and 10 year flood of river Donga at Donga include: 6.2 meter and 2,980.4 Cumecs, 5.97 meter and 2,812.0 Cumecs, 5.72 meter and 2,631.2 Cumecs and 5.39 meter and 2,385.0 Cumecs respectively. The result shows a gradual rise in water level and magnitude with increase in return period (10, 25, 50 and 100 year flood). These values will be useful in the area of flood protection and management, in engineering design of hydraulic structure such as storm water drains, culverts and with a view to protecting lives and properties at the downstream of the river.

5.2 RECOMMENDATIONS

Probability of flooding can be reduced but never eliminated. Flood flow studies can be used as a guide in determining the capacity of a structure. Reliable flood frequency estimate are vital for floodplain management: to protect the public, minimize flood related cost to government and private enterprises and assessing hazard related to the development of floodplain. Flood risk can be reduced by reducing the flood hazard or flood mitigation. The finding provides the following recommendation:

- Flood control structures should be constructed and early warning system put in place.
- Due to high discharge flood flow the land use/ land cover system in the study area needs to be checked, as more research on land use and land cover will help in harnessing the potential of the study area.

APPENDIX

Table of DISCHARGE (Q)

YEAR	ANNUAL MAXIMUM Gage height	DISCHARGE (Q) in M^3	$Q - \bar{Q}$	$(Q - \bar{Q})^2$
1955	471	1906	-33.4	1115.6
1956	483	2017	77.4	5990.8
1957	472	1920	-19.4	376.4
1958	454	1752	-187.4	35118.8
1959	418	1416	-523.4	273947.6
1960	475	1899	-40.4	1632.6
1961	456	1710	-229.4	52624.4
1962	483	2000	60.6	3672.4
1963	500	2172	232.6	54102.8
1964	497	2081	141.6	20050.6
1965	498	2081	141.6	20050.6
1966	474	1899	-40.4	1632.6
1967	494	2081	141.6	20050.6
1968	475	1899	-40.4	1632.6
1969	488	2000	60.6	3672.4
1970	440	1626	-313.4	98219.6
1971	482	2000	60.6	3672.4
1972	514	2172	232.6	54102.8
1973	514	2172	232.6	54102.8
1974	479	1964	24.6	605.2
1975	499	2137	197.6	39045.8
1976	569	2172	232.6	54102.8
1977	495	2137	197.6	39045.8
1978	482	2000	60.6	3672.4
1979	299	548	-1391.4	1935994.0
1980	484	2021	81.6	6658.6
1981	486	2021	81.6	6658.6
1982	489	2021	81.6	6658.6
1983	450	1724	-215.4	46397.2
1984	494	2116	176.6	31187.6
1985	487	2021	81.6	6658.6
1986	481	2000	60.6	3672.4
1987	519	2172	232.6	54102.8
1988	467	1850	-89.4	7992.4
1989	500	2172	232.6	54102.8
		$\sum Q$=67879/35 Q=1939.4cumecs		$\sum(Q - \bar{Q})^2$ =3002324

Source: Research calculation 2016

Standard deviation= $\frac{\sqrt{\sum(Q-\bar{Q})2}}{N}$

= $\frac{\sqrt{\sum 3002324}}{35}$ =$\sqrt{85780.7}$

SD= 292.9

X = RETURN PERIOD 100, 50 ,25 and 10 years

$(\bar{Q})$= 1939.4 cumecs

K= Frequency Factor

SD= 292.9

X=$\bar{X}$+KS

X 100= 1939.4 + (3.554 x 292.9)

=1939.4+1040.96

=2980.4 cumecs

X 50= 1939.4 + (2.979 x 292.9)

=1939.4 + 872.5

=2812.0 cumecs

X 25= 1939.4 + (2.354 x 293.9)

=1939.4 + 691.8

=2631.2 cumecs

X 10= 1939.4 + (1.516 x 293.9)

=1939.4 + 445.6

=2385 cumecs

TABLE OF ANNUAL GAUGE HEIGHT (cm) (X)

×	$\times - \bar{X}$	$(\times - \bar{X})^2$
471	-8.1	65.6
483	3.9	15.2
472	-7.1	50.4
454	-25.1	630.0
418	-61.1	3733.2
475	-4.1	16.8
456	-23.1	533.6
483	3.9	15.2
500	20.9	436.8
497	17.9	320.4
498	18.9	357.2
474	-5.1	26.0
494	14.9	222.0
475	-4.1	16.8
488	8.9	79.2
440	-39.1	1528.8
482	2.9	8.4
514	34.9	1218.8
514	34.9	1218.8
479	-0.1	0.01
499	19.9	396.0
569	89.9	8082.0
495	15.9	252.8
482	2.9	8.4
299	-180.1	32436.0
484	4.9	24.0
486	6.9	47.6
489	9.9	98.0
450	-29.1	846.8
494	14.9	222.0
487	7.9	62.4
481	1.9	3.6
519	39.9	1592.0
467	-12.1	146.4
500	20.9	436.8
$\sum X$= 16768 $\frac{\sum X}{n}$= 16768/35 $\bar{X}$= 479.1		$\sum(\times - \bar{X})^2$= 55148

Standard deviation$\frac{\sqrt{\sum(\times-\bar{X})2}}{N}$

$=\frac{\sqrt{55148}}{35}=\sqrt{1575.7}$= 39.69

SD= 39.7

X=$\bar{X}$+KS

X=Return Period

$\bar{X}$= Mean

K= Frequency Factor

S= Standard Deviation

X 100= 479.1 + (3.554 x 39.7)

=479.1 + 141.09

=620.19

Cm to M= 620.19/100

X_{100} =6.20M

X 50= 479.1 + (2.979 x 39.7)

=479.1 + 118.26

=597.36

Cm to M= 597.36/100

X_{50} =5.97m

X 25= 479.1 + (2.354 x 39.7)

=479.1 + 93.45

=572.55

Cm to M=572.55/100

X_{25} =5.72m

X 10= 479.1 + (1.516 x 39.7)

=479.1 + 60.18

=539.28

Cm to M= 539.28/100

X_{10} =5.39m

REFERENCES

Abam T.K.S. (2006): The Application of Kruskal-Wallis technique for flood prediction in the Niger Delta, Nigeria, Management of Environmental Quality; An International Journal, Vol17 Iss: 3, pp 275-288.

Enoch, B. (2001) History of Donga Local Government. Donga Educational Books, Donga, 1- End.

Etuonovbe, A K (2011),"The devastating effect of flooding in Nigeria", FIG Working Week 2011, Bridging the Gap between Cultures, Marrakech, Morocco, available at http://www.fig.net/pub/fig2011/papers/ts06j/ts06j_etuonovbe_5002.pdf, accessed November 11, 2013.

Haktan Y.T (1992): Comparison of Various flood frequency distribution using annual flood Peaks data of rivers in Anatolis. 136; 1-31

Mujere, N. (201). Flood Frequency Analysis Using theGumbel Distribution. *International Journal on Computer Science and Engineering.* Vol.3 (7)

Nwafor A. N, (2004): Flood Extent Mapping in Bayelsa State, Nigeria. *Journal of Geography,* Vol 8 (33),pp 18-22

Izinyon, O.C., Ihimekpen, N. andIgbinoba, G.E. (2011). Flood

Frequency Analysis of Ikpoba River Catchment at Benin City Using Log Pearson Type III Distribution. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS), 2 (1): pp. 50 – 55.

Okereke, C. (2007): The politics of the environmental: A Survey: Europe politics of Series. Taylor & Francis, London, pp 136-157. ISBN9781857433418

Okonofua and Ogbeifun (2013). Flood Frequency Analysis of Osse River Using Gumbel's Distribution .*Civil and Environmental Research*, Vol.3, No.10.

Okoroafor, O.O., Egwuonu, C.C., Chikwue M.I., Okafor, V.C. and Nzediegwu. C. (2015). Flood Frequency Analysis of Otamiri River Catchment Area Using Gumbels Distribution Method. *International Journal of Emerging Technology and Advanced Engineering*. Volume 5, Issue 10.

Oyatayo,K.T., Songu, G.A., Adi, T., Jidauna, G.G., Ndabula, C. (2016). Assessment of People's Awareness andPerception of Flooding in Donga Town,Taraba State, Nigeria. *Journal of Geoscience and Environment Protection,*2016, 4, 54-62

Karmakar, S. and Simonovic, S.P. (2008). Bivariate flood frequency analysis using copula with parametric and non-parametric marginal. Paper Presented at the Fourth ISFD Conference Toronto Canada, 22

Shakirudeen, O. andSaheed, A. R. (2014). Flood Frequency Analysis and Inundation Mapping. *Journal of Water Resource and Hydraulic Engineering*. Vol. 3 Iss. 3, PP. 48-59

Sharma, R. K and Sharma, T. K. (2000). A Textbook of Hydrology and Water resources Engineering. DhanpatRai Publications (P) Ltd, New Delhi. Fifth Edition

UNISDR (2012): United Nations International Strategy for Disaster reduction, available at: http://www.unisdr.org (last access: 31 March 2012), 2012.

CLİMATE CHANGE MİTİGATİON IN SUB-SAHARAN AFRİCA: THE GREEN CİTY CONCEPT

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Abstract.

This paper reports the current mitigation challenges faced in Sub-Saharan Africa as climate change continues to be a state of concern to many developing and underdeveloped countries. While taking a look at the climate change scenarios, there is a need to assess the critical role of cities in advancing green growth and combating climate change effects. This can be lead to debates and formulation of eco-friendly policies that will enhance a clean environment.

This paper therefore looks at the socio-economic challenges involved in advancing an urban green city concept. It also considers how the government and its citizens can play key roles in advancing this cause, which is basically by proper measurements and monitoring, thereby providing the enabling environment and finance to make this a reality.

It therefore concludes by suggesting suggestions for future research based on various scenarios, to achieve better results and make our environment a better place.

Keywords: Climate change, Urbanization, Green Cities, Urban Sustainability, Mitigation

Introduction

The term mitigation refers to efforts to cut or prevent the emission of greenhouse gases - limiting the magnitude of future warming. It may also encompass attempts to remove greenhouse gases from the atmosphere. It differs from climate change adaptation, which refers to the actions taken to manage the unavoidable impacts of climate change. Mitigation may require the use of new technologies, clean energy sources, change people's behavior, or make older technology more energy efficient.

Switching to low-carbon energy sources such as wind power, solar, geothermal, hydroelectric or nuclear represents one of the major strategies for lowering the emissions of greenhouse gases in the atmosphere. Also greening urban areas can also make a difference. Cities are home to half the planet's population, and are responsible for three-quarters of energy consumption and 80% of carbon emissions. Retro-fitting buildings to make them more energy efficient and cutting the impact of transport emissions represent some of the strategies for doing this (*BBC*, 2014)

Clımate Change and Urbanızatıon

Climate change is defined as the change in the distribution of weather patterns when that changes lasts for an extended period of time (*Wikipedia*, 2016). Scientific evidence indicates that the Earth’s climate is changing and, without taking appropriate and early action, climate change will have potentially disastrous effects for many areas of the planet. Some factors that tend to climate change are, variations in solar radiation, variations in the Earth's orbit, variations in the albedo or reflectivity of the continents and oceans, mountain building and continental drift and changes in green house gas concentrations. These factors can either be "internal" or "external". The internal factors are natural processes within the climate system itself e.g. thermohaline circulation while the external factors can either be natural e.g. changes in solar output or anthropogenic e.g. increased emissions of greenhouse gases. Climate related risks are created by a range of hazards. Some are slow in their onset (such as changes in temperature and precipitation leading to droughts, or agricultural losses), while others happen more suddenly (such as tropical storms and floods).

Urbanization is the process in which the number of people living in cities increases compared with the number of people living in the rural areas. A country is said to be urbanized when over 50% of its population lives in urban places. For any city, the scale of the risk from these extreme weather events is much influenced by the quality of housing and infrastructure in that city, the extent to which urban planning and land-use management have successfully ensured risk reduction within urban construction and expansion, and the level of preparedness among the city's population and key emergency services. For small and large coastal settlements, the integrity of coastal ecosystems and in particular protective mangrove and salt marsh systems will also influence risk.

Urbanization and Climate Challenges in Africa

Though Africa has the lowest proportion of its population living in cities compared to other regions, this trend is quickly changing: According to a report by McKinsey, in 2010, Africa was nearly as urbanized as China and had as many cities with over one million people as Europe. Forecasts from the World Urbanization Prospects 2014 suggest that by 2050, Africa's urban population is projected to triple, making the continent the host of the world's second-largest urban population behind Asia. At the moment, according to a recent KPMG Africa report in 2012, three African cities—Lagos, Cairo, and Kinshasa—fall within the true definition of "megacities" (10 million people or more).This rapid growth of African cities will push at least another six cities—Johannesburg, Luanda, Nairobi, Addis Ababa, Casablanca, and Khartoum—into the "megacity" class within the next couple of decades.

Africa In Focus puts it that Increasing urban populations have been driving up energy demands and pollution levels—as anyone who has been stuck in traffic congestion in Lagos already knows. Thus, this trend not only raises global warming concerns, but also, if these rising demands and greenhouse gas emissions are left unmonitored, they could potentially pose further challenges for urban planning needs. This outcome results from the fact that urbanization on the continent is not just driven by standard models of structural transformation that have been explored in economic literature. Many have argued that urbanization in Africa is also driven by factors such as climate change: In some areas the lengthened dry seasons and environmental shocks are forcing Africa's rural workforce to seek employment in the city. As they move into cities, a large proportion of rural migrants get stuck in low-productivity employment in the non-tradable sector—increasing demand for better urban planning for basic services, infrastructure, housing, waste management, human livelihoods, and health.

Some of the climatic challenges experienced are categorized as follows:

Emissions from the following subsectors:

1. Energy industries – combustion emissions from electricity generation, petroleum refining and the production and processing of briquettes and natural gas
2. Manufacturing industries and construction – emissions from on-site combustion of fossil fuels by the manufacturing and construction industries (not including emissions from industrial processes, which are accounted for separately)
3. Transportation – combustion emissions from motor vehicles, rail, civil aviation, shipping and recreational vehicles
4. Fugitive emissions – the unintended release of emissions (such as carbon dioxide and methane) that may result from exploration, extraction, processing and distribution of oil, natural gas and coal. Emissions result from leakage, evaporation and storage losses, and venting and flaring activities

The Concept of Green Cities

Green cities are seen as cities that are environmentally friendly. A green city designed with consideration of environmental impact, inhabited by people dedicated to minimization of required inputs of energy, water and food, and waste output of heat, air pollution - CO_2, methane, and water pollution (*Wikipedia,* 2016). The term "Greening" refers to gardening. The purpose of "Greening" is to improve the phenomenon of cement-filling, and change it into an environment which relaxes people. "Greening" could be conducted at the roof, on the streets, on the slopes or on the ground. The benefits of "Greening" include: improving the appearance of the city, offering a space of resting, reducing the urban heat island effect, improving the quality of air, blocking some graceless scenery as well as messy or destroyed environment, reducing noises, reducing the influence of dazzling sunshine, resisting desertification and reducing the death rate between poverty gaps.

Green Buıdıng and Envıroment

"Sustainable Development" is a necessary condition for continuation of the earth; "Healthy and Comfortable"is a necessary condition for the continuation of life. Additionally, we are facing serious energy and naturalresource shortage, where global climate change is the problem cannot be ignored (Hsieh et al., 2011).

Green buildings afford a high level of environmental, economic, and engineering performance. These include energy efficiency and conservation, improved indoor air quality, resource and material efficiency, and occupant'shealth and productivity. The impact of climate change on buildings is deeply intertwined with consequences for the building occupants and key processes that take place in those buildings. As buildings have different functions, climate change impactassessment studies must be tailored towards the specific needs and requirements at hand. Complex interactionsexist for instance between the comfort as experienced byoccupants, control settings in the building, and energyconsumption of heating and cooling systems (Nicol and Humphreys, 2002). . The economic analysis showed that both zero carbon plants are feasible, and that the air-to-air heat pumps yield a shorter payback time. The exergy analysis confirmed the feasibility of both plants, and showed that the ground coupled heat pumps yield a higher energy saving.

Green Transportation

Transport-related pollution, noise and vibration can pose serious threats to human health and wellbeing. Local air pollution is caused by exhaust emissions produced by traffic, mostly in the form of Sulphur Oxides (SOx), Nitrogen Oxides (NOx), Carbon Monoxide (CO), Hydro Carbon (HC), Volatile Organic Compounds (VOC), Toxic Metals (TM), Lead Particles7 and Particulate Matter (PM) – including Black Carbon. These emissions represent a large proportion of pollutants, especially in developing cities.

Congestion is caused when the volume of traffic reaches the capacity of infrastructure. It is particularly common in urban areas. To achieve a green transportation, provision for Infrastructure such as tracks for buses and rail, pavements and bicycles, routes for public transport vehicles, low emission vehicles, park-and-ride facilities should be put in place so that not all citizen will be on the road with a personal car at the same time causing traffic congestions, noise and air pollution. Telecommunication tech - nology could also be used to substitute conventional transport, e.g. telework/ teleconferencing and technologies to enact green transport, GPS systems, Intelligent Transport Systems, green logistics etc. As a result of these investments, carbon emissions are reduced radically, by 8.4 Gt of CO_2, or 68 per cent relative to BAU_2 in 2050.

Generating Green Energy

Over decades, fossil fuels were and are still being used as the major energysource for households, industries and service providers. However, due to the limited amount offossil fuels, energy is becoming more and more expensive, and the consequence of their consumption is having an impact on our environment and climate.

Solar Energy

This is a method of using the sun to generate electricity using a solar panel. A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assemblyof solar cells. The solar panel can be used as a component of a larger photovoltaic system togenerate and supply electricity in commercial and residential applications. A photovoltaicsystem typically includes a panel or an array of solar modules, an inverter, and sometimes abattery and/or solar tracker and interconnection wiring. Depending on construction,photovoltaic modules can produce electricity from a range of frequencies of light, but usuallycannot cover the entire solar range (specifically, ultraviolet, infrared and low or diffused light).Hence much of the incident sunlight energy is wasted by solar modules, and they can give farhigher efficiencies of illuminated with monochromatic light. Therefore, another design conceptis to split the lightinto different wavelength ranges and direct the beams onto different cellstuned to those ranges. This has been projected to be capable of raising efficiency by 50%.

Solar panels can be installed on roofs or on the ground. Additional trackers sense the directionof the sun and tilt the modules as needed for maximum exposure to the light. There are twomain types of catching solar energy easily, one which absorbs the direct sunlight andtransforms it into energy, and the other method is by using the sun's heat as an energy source. The invention of affordable solar stoves has been used since few years in Madagascar. Households use the sunlight for cooking and are even able to store energy in a battery for later use.

Wind Energy

Countries rich on wind often refer back to the installation of windmills on wide and open fields. Around 90 countries are supporting the consumption of electricity through windmills since a few years, and more and more countries are following this new boom of eco-friendly technology. Windmills can be also installed off shore, in areas using the sea and ocean wind for generating electricity. However, whether on-or-off shore, the windmills cannot be working properly when the amount of wind is either too low or too strong. Windmills are always installed in certain fields and areas, mostly far from cities and villages due to the noise pollution and the need for open fields with wind. Municipalities therefore obtain regional planning on fields away from farms and even protected areas, since windmills can become a threat to wild birds. While fans use electricity to generate wind, the windmill does exactly the opposite. The blades of a windmill rotate once wind is present, which have a shaft connected to the generator to create electricity.

Hydro Energy

Water energy can come in different forms and variations. One type of renewable energy source is the building of dams. This relies on the potential energy difference in the levels of water reservoirs, dams and lakes and their discharge tail water levels downstream. The hydro power potential of Nigeria, for example, is very high and currently accounts for about 29% of the total electrical power supply. The first hydro power supply station in Nigeria is the Kainji dam on the River Niger where the installed capacity is 836mw with provisions for expansion to 1156mw. The second hydro power station on the Niger at Jebba has an installed capacity of 540mw.

Even though the majority of dams are immense in size, their process to generate electricity is however simple. "The water in the reservoir is considered stored energy. When the gates open, the water flowing through the penstock becomes kinetic energy because it's in motion". Thefaster and stronger the flow of the water, the more energy is generated.

Greenıng the Envıronment

A lot of damage is being through deforestation, which is contributing immensely to desertification. This occurs in the form of tree felling for energy, bush burning and overgrazing by herdsmen. It is very amazing that even though there exist wide range of disparity between human and trees, they still cannot survive independently. Man needs oxygen which tend to be produced as the waste product of trees, on the other hand, trees also needs carbon dioxide which is also a waste from humans, in order to survive. The importance of trees and its usefulness according to scientific proven illustration has it that trees could be very resourceful as the first defensive measure against global warming because they absorb the carbon-dioxide in the atmosphere, and replenish the air with oxygen and also contribute immensely to aesthetic of the environment. Trees also prevent erosion and stem the tide of windstorm by serving as wind breakers. They are also brilliant cleansers; they remove other pollutants through the stomates on the leaf surface. Trees acts as what some call a carbon sink, storing the gas in the branches, trunk, leaves, etc, instead of leaving the gas to become free floating and further polluting the atmosphere. Trees directly reduces the growth of the green house effect and counteract global warming. It provides natural habitat for small and large creatures , and reduce the temperature by providing shades. In times of heavy rain, trees roots help solidify the soil. Trees are not just beautiful creatures standing amongst the many phenomenal picturesque setting of this world, it is a powerful and vital tool that directly ensures our survival.

Park ecosystems often offer significant amounts of open space that allow for relatively high densities of trees, shrubs, grasses, and other vegetated surfaces. Other vegetation types such as shrubs and grasses will have similar effects to trees, but often to a lesser degree due to their smaller stature.For example, healthy shrubs and grass will remove air pollution to a lesser degree than trees.However, their effects are not always similar. For example, shrubs and grass will not have the same effect as trees in reducing ultraviolet radiation loads on humans because they often do not reach the height necessary to block solar radiation reaching humans.

Some Examples of Governments Adopting Green Growth Strategies

1. Chile launched the National Green Growth Strategy in December 2013 outlining a set of actions over the short, medium, and long term (2014-2022). Actions include implementing environmental management instruments, promoting the market for environmental goods and services, and monitoring and measuring progress (Government of Chile, 2013).
2. China has committed to green growth in its 12th Five Year Plan. Actions include investing in natural resource management, with the aim of creating one million new forestry jobs and reducing rural poverty (OECD, 2013).

3. Mozambique launched the Green Economy Roadmap at the Rio+20 Conference on Sustainable Development, setting out its vision to become an inclusive, middle income county by 2030. In October 2013 the government approved the Plan of Action for 2013/2014 laying out the actions over the period of one year on the road to a green economy and is in process of linking the Roadmap to the long-term National Development Strategy 2015-2035 (WWF, 2013).
4. Rwanda released the Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development in October 2011. It aims to be a developed climate-resilient, low carbon economy by 2050, through the achievement of three key strategic objectives: energy security and a low carbon energy supply; sustainable land use and water resource management; and social protection and disaster risk reduction (Republic of Rwanda, 2011).

Summary

Human and societal well-being depends on nature. According to Lehrer (2001), to work towards creation of sustainable development, one must understand theenvironmental impacts of buildings and their relative importance. The most and best understood impact is causedby energy used in building operations. The primary energy loads in buildings are created by lighting, space heating, cooling equipments and domestic hot water. The production and consumption of this energy contributes to air pollution, acid rain and global climate change. Conventional buildings have a significant impact on the environment including wetland depletion and deforestation (Otegbulu 2006). However, estimates indicate that climate – sensitive design with the use of appropriate and available technologies could cut heating and cooling energy consumption by 60 percent. Heating is however not important in tropical climate regions like that of Africa where cooling is mostly required. The design of the building must reflect consideration directed towards reduction in energy cost. Microclimatic temperature is affected byradiation, convection and evaporative cooling. Trees affect microclimate through their effect on these processes.

Trees abound in Sub-Saharan Africa but most often, building sites are cleared of all vegetation (trees) and covered with asphalt orconcrete which often have adverse environmental consequences. Energy could also be saved through provisionof natural ventilation and lighting in building design.

Recommendations

The following are the recommendations associated with increasing green concept in our environment which will result into a friendly and comfortable environment:

- Increase the number of healthy trees (increases pollution removal).
- Maximize use of traditional practices that have been proved to be environmentally beneficial for housing in various African cities, given the fact that urban

population is rapidly increasing in growth.

- Designing buildings taking into account climatic conditions on the continent and by so doing making use of naturally available energies that can be harnessed profitably.
- Reduce fossil fuel use in maintaining vegetation (reduces pollutant emissions).
- Plant trees in energy conserving locations (reduces pollutant emissions from power plants).
- Plant trees to shade parked cars (reduces vehicular VOC emissions).
- Utilize evergreen trees for particulate matter reduction (year-round removal of particles).

In general, in terms of vegetation designs for trees, the more tree cover the better, as the trees can reduce air temperatures and directly remove pollution. Tree cover that is aggregated together in forest stands can reduce pollutant concentrations toward the center of the stands. However, species composition can also affect pollution effects.

Actions at all governance levels, involving the participation of all relevant stakeholders, are needed for a successful transition to a green economy.

Green growth can improve quality of life and, if designed and implemented well, can address social equity issues. By reducing environmental degradation and conserving vital natural resources, governments can enhance the quality of life for citizens, especially the poor who are particularly vulnerable to natural resource limits and environmental damage. It also an established truth that green buildings have many benefits for our environment, not only can they save energy, but also they reduce the damage to the environment. It is believed that, with the continuing development of Green Buildings, people may have a greater chance to live in a natural and healthful environment in the near future.

References

Africa in Focus (2015). Mobilizing Africa's Rapid Urbanization For Sustainable Climate change.

BBC (2014). *What is climate change mitigation?* http://www.bbc.com/news/science-environment-26980837

Hsieh, T.-T., C.M. Chiang, M.C. Ho, and L.P. Lai. (2011). *The application of green building materials to sustainable building for environmental protection in Taiwan*. Proceedings of the International Conference on Materials for Environmental Protection and Energy Application, 27-28 September, Kuala Lumpur, Malaysia.

KPMG (2012). *The role of cities in Africa's rise*. www.kpmgafrica.com

Nicol, J.F., and M.A. Humphreys. 2002. Adaptive thermal comfort and sustainable thermal standards for buildings. Energy and Buildings, 34(6):563–72.

Otegbulu A.C. (2006). An Assessment of User Demand Preferences of Urban Infrastructure in Lagos Metropolis Using Contingent Valuation Model: PhD Thesis Submitted to The Faculty of Environmental Science, Enugu State University of Science and technology Enugu, Nigeria

Republic of Rwanda. (2011). Green Growth and Climate Resilience: National Strategy for Climate Change and Low Carbon Development. Kigali: Republic of Rwanda.

WWF. (2013). Mozambique Government approves 2013-2014 action plan for Green Economy. 21 October 2013. WWF News

The Ministry of Environment and the Ministry of Finance. Government of Chile. (2013). *National Green Growth Strategy*.

Wikipedia (2016). *Climate change*. https://en.wikipedia.org/wiki/Climate_change

Analysis of Precipitation Concentration Index (PCI) for Awka Urban Area, Nigeria

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Abstract

Causes and consequences of climate variability of which the fluctuation in rainfall amounts over time represent an important indicator is indeed an area that has continued to generate research attention. The aim of this paper is, therefore, to evaluate the concentration and variability of rainfall in time using PCI based on monthly precipitation over 38 years period (1976 – 2013) and its implications for flooding and water supply in the town. Data for the study were collected from NIMET, Lagos. The PCI was calculated for annual and seasonal and decadal scales (wet and dry seasons) using annual, wet and dry season equations. Result shows that annual PCI value range from the lowest of 12% in 1976 to the highest in 1987 of 20. About 78% of the years were characterized by PCI values that fall within moderate range, an indication of moderate precipitation distribution within the 38 years, while 24% of the years recorded annual value within the irregular range indicating an irregular rainfall distribution and concentration across the months. Again the fact that many months have PCI values within ≥ 16.7 is a further manifestation that almost 90% of the rainfall occurred in 6 months. These results show that the area is having reasonable floods with consequent pollution of the surface water bodies as well as soil erosion as observed in the town. It is, therefore, recommended that the Awka Capital Territory Development Authority (ACTDA) should take cognizance of this result in the planning of the new layouts and redevelopment of the old areas of the town.

Keywords: annual, concentration, decadal, precipitation and seasonal.

1. INTRODUCTION

Prospects of climate change due to global warming have moved from the realm of speculation to general acceptance (Stefouli et al., 2011). It has become a dominant global environment in the last three decades (Scholz and Hasse, 2008). This realization has led to questions about the relative effects of shifts in climate conditions on natural ecosystems and processes. Odjugo (2010) reported that global warming and decreasing rainfall together with erratic pattern of rainfall will produce a minimal recharge of ground water resources, wells, lakes and rivers in most parts of the world especially Africa, thereby creating water stress. This change in the nature of precipitation over an area that accompany climate change has the potential to alter some aspects of the hydrological cycle (McGuire et al, 2002) and to cause shifts in a number of natural process such as ground water recharge, water availability, modification of fluvial regimes, the likelihood and serenity of erosion, increased flood risk and variations in sizes of surface water systems (De – Luiz et al, 2011; Adegun et al, 2012; Ezemonye and Elemenbe, 2011; Nzoiwu, 2015)

With recent flood devastation of some parts of Europe with France recording an all- time high precipitation value of 192mm for the month of May above the 92mm normal. With global warning, Le Trent et al (2007) in Jiang et al (2011) noted that precipitation intensity, amounts and patterns are expected to change while extreme weather events such as drought and flood are expected to occur more frequently. Precipitation extremes such as rainstorms and particularly heavy precipitation events occurring over a few days that accounts for high percentages of the annual total, are directly responsible for flood occurrences and will bring more frequent disasters for human society (Jiang et al, 2011).

This was the case of France with its Seine River rising to about 6 meters due to a few days rainfall. Therefore, precipitation total on annual, seasonal or monthly scales are key elements affecting water availability, but precipitation concentration in Time also plays a decisive role (de – Luis et al, 2011). The incidence of erratic rainfall has been a major climatic event in most parts of the world with Nigeria inclusive with some sporadic events. For example, the 2012 flood problem in Nigeria which left a lot of destruction in its trail has continued to be remembered. The study of precipitation concentration for major urban areas in Nigeria including Awka has now become of concern to government and researchers.

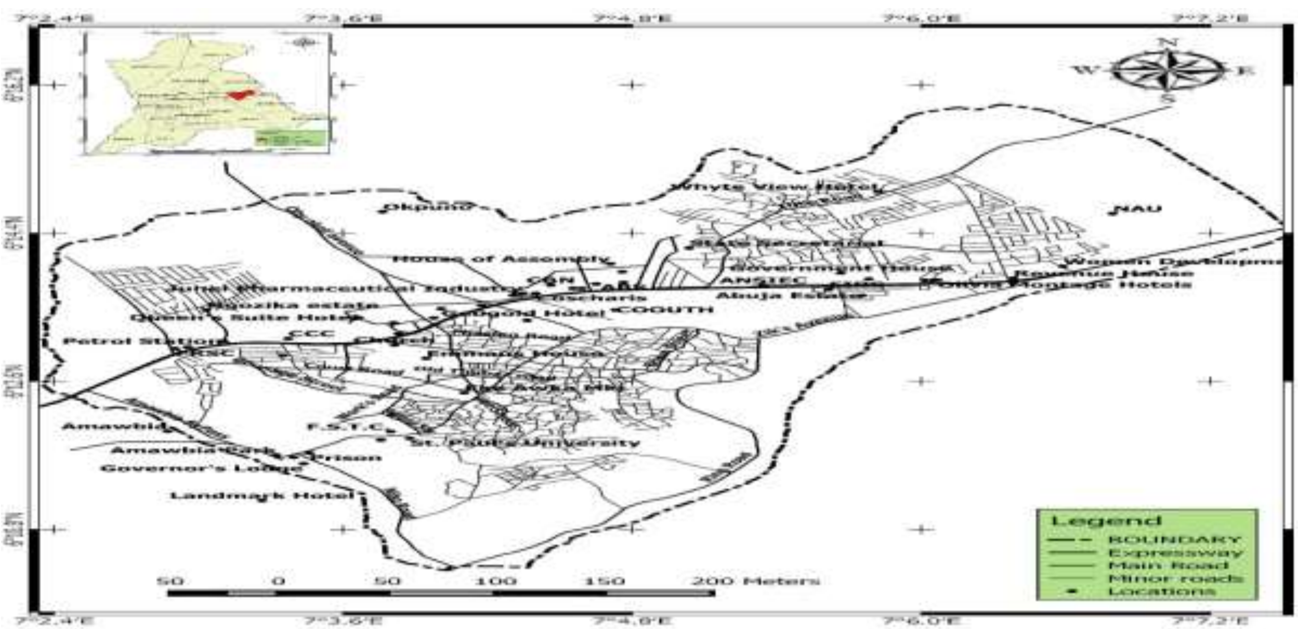
Awka, located in the eastern part of Anambra State, South east of Nigeria is characterized by a typical tropical wet and dry climate. There is considerable variation in the total annual rainfall from year based on some studies carried out in the study area. Attempts have also been made to study the cycles and periodicities of rainfall in the area (Ezenwaji et al, 2014). Until now, there has been no detailed study on concentration and variation of rainfall in Awka despite the yearly flood events ranging parts of the town with each rainy season. In this respect, the only attempts made in addition to the study by Ezenwaji et al (2014) were studies to evaluate causes of flooding in the town (Okoro and Basil, 2012; Ezenwaji et al 2013) and study examining the precipitation and water balance characteristics of the town (study in progress)

However, understanding precipitation variations on various time scales and their correlation is important for assessment of flood risks and for water resource Management. Precipitation extremes can, therefore be quantified by the frequency analysis of rainfall series and precipitation heterogeneity indexes (Shi et al, 2014). Some straight forward indicators have been employed to evaluate precipitation concentration used to provide information on its variability (Apayoden et al, 2006; De- Luis et al, 2011). This indices include Precipitation Concentration Index (PCI) (Oliver, 1980; De-Luis et al, 1997, 2011), Simple Daily Intensity Index (Vincent et al, 2011), Precipitation Concentration Degree (PCD) and Precipitation Concentration Period (PCP) (Jiang et al, 2011), modified Fourier Index (Hemando and Romana, 2015; Liyan and Gabriels, 2005), Seasonality Index (Kumbuyo et al, 2014) etc. A higher precipitation concentration represented by greater percentages of the yearly total precipitation in a few rainy days, has the potential to cause flood and also drought phenomena (Hy et al, 2008). In the face of recurring flood events within the Awka urban area, almost on annual basis, it is very important to investigate precipitation variation and concentration. As a result, the aim of this paper is two – fold: first, is to evaluate the concentration and variability of rainfall in time using PCI based on monthly precipitation over 38 year period (1976-2013) and secondly, to explore possible relationship between PCI and annual rainfall total and rainy days. The use of PCI is based on recommendations by numerous studies that it provides information on long term total variability in the amount of rainfall received (Michiels et al, 1992; Apaydin et al, 2016, De - luis et al 2010b, 2016).

2. MATERIALS AND METHODS

2.1 Study Area

Awka town is located in the South – Eastern part of Nigeria and in the eastern part of Anambra State. It covers the whole of Awka South Local Government and some parts of Awka North. It is bounded by Latitudes 60 111N and 60 171N and longitude 70 021E and 70 081E, Fig. 1.



The topography is characterized by rugged relief and it lies completely on the Awka - Orlu upland (Ezenwaji et al, 2013). The climate of Awka falls within the tropic wet and dry type on koppen's classification. The rainfall is patterned in such a manner that the long wet season occurs normally from April – October while the dry season occurs normally from April – October while the dry season occurs from November – March. The mean annual rainfall is about 1805mm while the maximum and minimum temperatures are 32.1oC respectively. In recent times, the onset and cessation period of the rainfall in the study area has been observed to vary over time.

2.2.1 Data Collection

Monthly rainfall dataset was obtained from the Nigerian Meteorological Agency (NIMET) Lagos State. The data was for a period of 38 years (1976-2013). The rainfall data is quite homogenous as there are no gaps to necessitate interpolations.

2.2.2 Data Analysis

PCI of Oliver (1980) further developed by De-Lius et al (1997), has equally been expressed as an indicator of rainfall concentration for annual and seasonal scales (wet and dry seasons). We are using the technique to examine 38 year rainfall data for Awka Urban Area. The equations employed for the purpose (see Oliver 1980 and De-Luis et al, 1997) are written as follows:

$$PCI_{annual} = \frac{\sum_{i=1}^{12} P_i^2}{(\sum_{i=1}^{12} P_i)^2} \times 100 \quad (1)$$

$$PCI_{dry} = \frac{\sum_{i=1}^{12} P_i^2}{(\sum_{i=1}^{5} P_i)^2} \times 42 \quad (2)$$

$$PCI_{wet} = \frac{\sum_{i=1}^{12} P_i^2}{(\sum_{i=1}^{7} P_i)^2} \times 58 \quad (3)$$

Where Pi is monthly precipitation of any month i

Equation 1 is for annual PCI while equations 2 and 3 are utilized for the analysis of seasonal scales (rainy and dry seasons). The classification of PCI values according to Oliver (1980) is presented in Table 1.

Table 1: PCI range and classification (Oliver, 1980)

PCI RANGE	CLASSIFICATION
≤10	Uniform Precipitation Range
11 - 15	Moderate Precipitation Range
16 - 20	Irregular Distribution
>20	Strong Irregularity

Furthermore, statistics employed in the analysis include Pearson Product Moment Correlation to establish the relationship between PCI and annual rainfall and further between PCI and number of rainy days. The calculation was performed using the Statistical Package for Social Sciences (SPSS) version 20.

3. RESULTS

On annual basis, the result of the PCI was calculated for Awka (Fig 1). The PCI value range from the lowest value of 12 in 1976 to the highest of 20 recorded in 1987. The result showed that 76% of the years were characterized by a PCI value within the moderate range, an indication of moderate precipitation distribution within these years while 24% of the years recorded annual PCI value within the irregular range indicating an irregular rainfall distribution/concentration across months of three years.

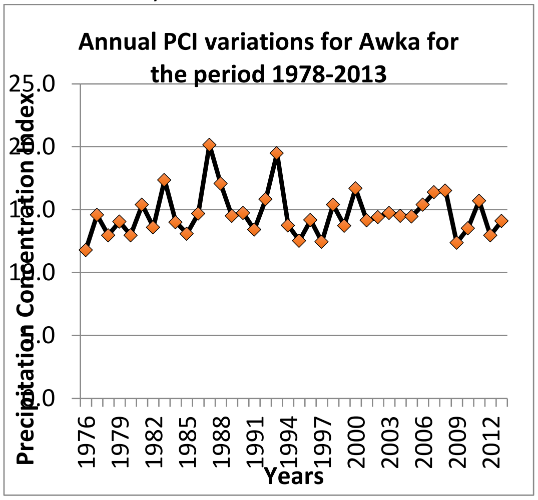


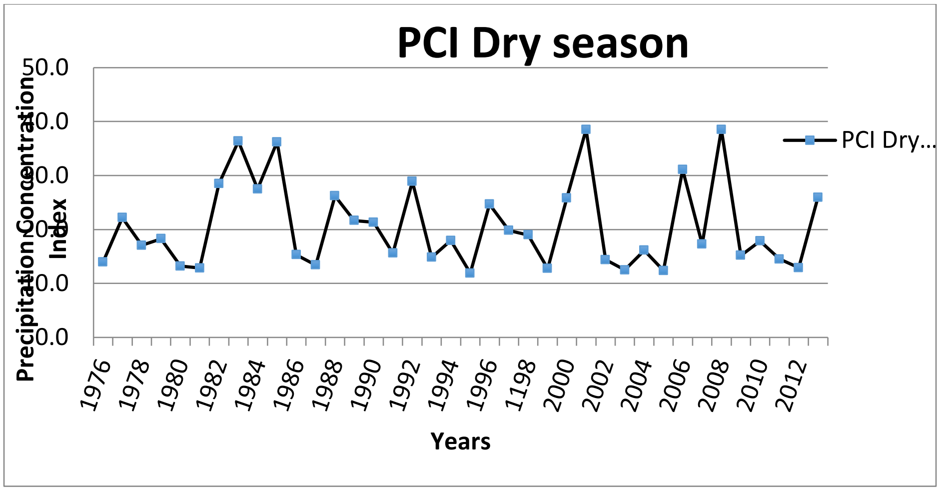
Fig. 2: Annual Precipitation Concentration Index for Awka

This also indicates that in each of the years for which the PCI value falls within the irregular range, with a PCI value of □ 16.7, precipitation will be concentrated in half of the period (De-Luis et al, 2011) i.e. almost 90% of total annual rainfall occurred in 6 months. The mean annual PCI value for Awka was calculated to be 15; while of the 38 years under study, only 12 of those years recorded values above the mean while 26 years were predominantly below the mean.

On seasonal scale, the mean annual PCI for the dry season was calculated and found to be 21 (strong irregularity). For the 38 years period, 40% of the years yielded a PCI value greater than 21, indexing strong irregularity in rainfall distribution, 37% of the years showed PCI value within 11-15 range (moderate rainfall concentration/distribution) while the remaining 23% yielded PCI value of the irregularity range.

Table 2: Mean decadal values of Seasonal and Annual PCI for Awka

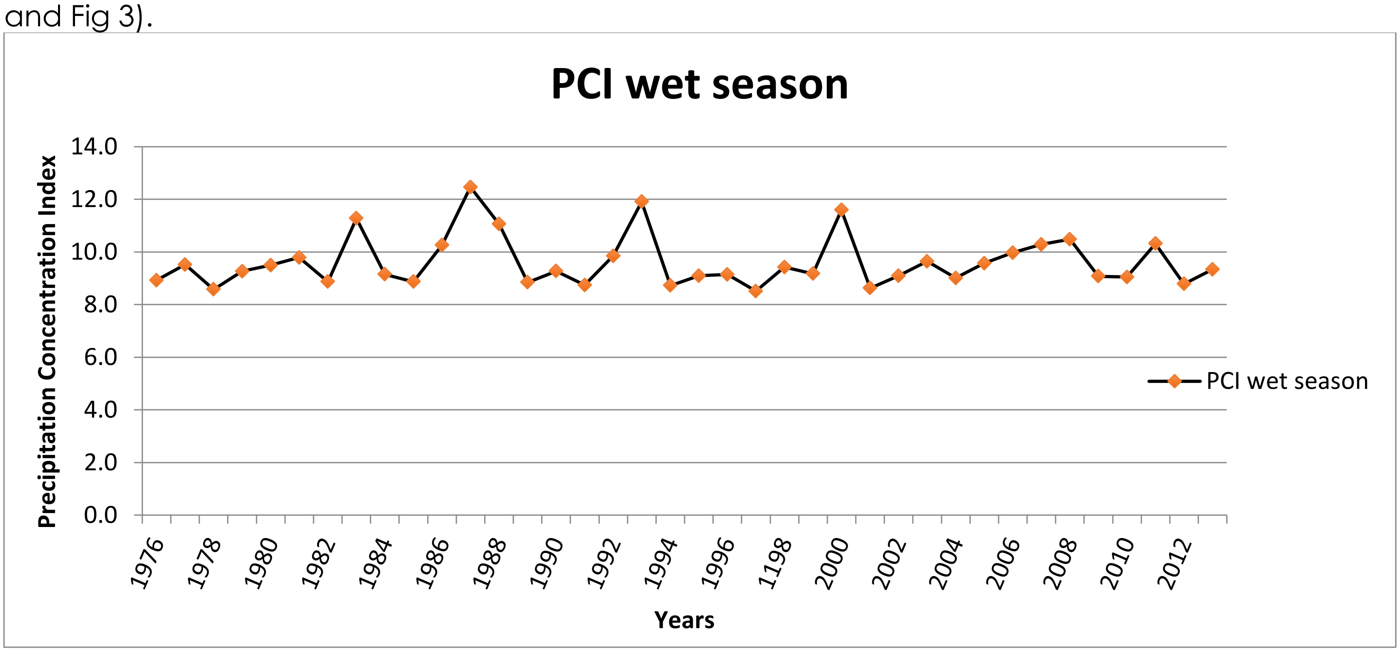
Decade	Wet Season	Dry Season	Annual
1976 - 1985	9	15	13
1986 - 1995	9	16	14
1996 - 2005	10	15	15



The irregularity in rainfall concentration during the dry season as strongly indicated by the values of PCI in Table 2 depicted in figure (2).

Fig 3: Precipitation Concentration Index for dry season in Awka

For the wet season, rainfall was generally uniformly distributed with 13% of the 38 years period having moderate precipitation concentration while 87% of these years are characterized by estimated PCI value within the uniform category. In De Luis et al (2011), it was stated that the lowest theoretical value of PCI is 8.3 indicating perfect uniformity in precipitation distribution. The implication is that nearly the same amount of rainfall occurs in each month of the wet season for the 87% of these years given that the PCI values calculated are □10 though none of these years has a perfect uniform precipitation distribution (see Table 2 and Fig 3).



In addition, the mean annual PCI value calculated for the wet season was found to be within the uniform category (= 9)

DECADAL VARIATIONS IN PCI VALUE

To further investigate the characteristics of PCI in Awka, decadal values were calculated. On the decadal scale, the annual PCI for 1976 – 1985 and 1999-2005 falls within the moderate precipitation concentration category giving average value of 14 respectively while the period 1986-1995, with a PCI value of 16, is characterized by highly precipitation distribution for the wet season, the PCI value for the 3 decades showed that rainfall was generally uniformly distributed for all the decades for the dry season, while rainfall concentration was observed to be uniformly distributed for the periods 1976 -1985 and 1996 – 2005 for the last period, 2006 – 2013, PCI for annual, dry season and wet season are 15, 13 and 9 respectively.

To further characterize the behavior of PCI in Awka, a correlation analysis was performed to evaluate its relationship with annual precipitation and number of rain days using PPMC. A negative but not statically significant correlation was observed between annual precipitation and annual PCI values at 0.05 confidence level, while with rainy days, a negative and statistically significant correlation was observed. This implies that PCI is expected to increase with decrease in number of rainy days and decrease in annual rainfall total for Awka.

4. DISCUSSION

A good knowledge of critical values of the series of various climatic elements such as rainfall and some of their derived indices is of great importance in detecting variability which has implications for water resource planning and management, disaster preparedness etc. This study underscores the usefulness of PCI in detecting precipitation concentration and variability. It was observed based on the plot for rainfall and PCI that this climatic variable and the associated index are changing. On annul scales, PCI was found to range from the lowest value of 12 in 1976 to the highest, for the 38years period under study, of 20 in 1987. This implies that rainfall pattern in the study area is not uniformly distributed but had fluctuated between moderate irregularity and irregular distribution range; 76% of the years were characterized by PCI value within the moderate range (11-15) while 24% annual PCI values ranged from 16 to 20 (demonstrating irregular distribution). The implication of such irregular precipitation recorded for the 24% of the year is that this can have high erosion-potential (Iskander et al, 2024).

In addition, similar observation was not obtained at seasonal scales Awka is characterized by 5 months of dry season and 7 months of rainy season. For the dry seasons, Average annual PCI was found to be 21 (strong irregularity of precipitation distribution) for the 38years period, 60% of the years yielded a PCI value above the average of 21; 37% are within the irregular range. The implication of this outcome is wide and varied given the susceptibility of this region to flooding and erosion due to the frail nature of the soil, its profile and underlying geology once exposed (as a result of high human contact with the environment e.g. Urbanization and deforestation) to the vagaries of weather. For the wet season, rainfall is more uniformly distributed, with 87% the year having PCI of less than 10 while 13% falls in the moderate category.

However, attempt was made to examine the possible relationship between PCI and number of rain days, and between PCI and annual precipitation using Pearson Product Moment Correlation. PCI was negatively correlated with both variables but, while it is statistically significant with the number of rainy days at P=0.05, it was not significant with annual precipitation. Though the correlation of PCI and annual rainfall is not statistically significant, the negative correlation still indicates that PCI is expected to be large when annual precipitation is low and vice versa. The same applies to the number of rain days which shows a correlation that is statistically significant.

More so, atmospheric precipitation is a key component of water cycle and a main source of all water resources on land; thus analysis of precipitation characteristics of a place have scientific and practical value (Li et al, 2011). On this note, studies (De-Lius et al, 2011, Adegun et al, 2012; Michiels et al, 1992 etc.) index of rainfall variability, water variability and its peri-urban communities have been experiencing, on annual basis, the biting effects of flooding and erosion.

Even when basin and rivers exist to carry flood, heavy rainfall often causes their carrying capacities to be exceeded. Efforts were made in this regard by Ezenwaji et al (2013a,b) to evaluate the contributing factors to flood occurrence in this region and concluded that climatic elements contributed highly in flood occurrence in Awka and the proportion of observed variation in flood occurrence in the Northern parts of Anambra state. This, however, supported the assertion by Agrail (2009) that the climatic factors especially rainfall is the most important factor responsible for flooding in the urban area of most tropical countries.

Consequently, despite the persistent case of flooding and erosion within Awka urban area and the surrounding peri-urban communities, no single attempt have been made to evaluate precipitation variability notwithstanding the wide range of problems rainfall variability would cause. Based on the result above, rainfall in Awka is not uniformly distributed but can be characterized as being moderately irregular in some years and regular in others. This implies that the tendency is high for rainfall in this region to be heavy and intensive but within a short instance of time. Precipitation of such nature is capable of generating flash flood which could lead to erosion and other water related problems incident in the area. Similarly, given that precipitation variability is capable of modifying fluvial regimes; Nzoiwu (2015) remarked that Agulu Lake, a fresh water lake located in Agulu town, a peri-urban community of Awka, lost approximately 17% of its surface area due to such variability between 1983 and 1988. It was also found that the lowest number of rainy days and annual rainfall for the 38years period occurred between 1983 and 1988 while highest PCI value occurred in the same period. This shows a strong agreement with the correlating of PCI and number of rainy days, and annual rainfall. Also, there is need to further investigate the spatial variability in PCI value on all scales for Awka and its region given that precipitation is spatially highly variable.

5. CONCLUSION

Therefore, the results presented in this study are valuable for water resource planning and management, disaster preparedness, and provides information on water variability for the relevant government agencies and should be taken into account, since the implication of such observed change might have a strong influence on natural process of soil erosion, flooding, fluvial require and groundwater recharge. PCI can, therefore, serve as a warning tool for flooding and erosion within Awka and environs.

6. References

1. Adegun, O, Balogun, I and Adeaga, O (2012). "Precipitation Concentration Changes in Owerri and Enugu". Hydrology for Disaster Management.special publication of NAHS
2. Agrail, F. D. (2009). Rainfall and its Effects in Urban Environment. J. Atmos. Sci. 13(2).
3. Apaydin, H., Erpul, G., Bayramin, I. and Gabriels, D. (2006). Evaluation of Indices fo characterizing the distribution and concentration of precipitation: A case for the region of south eastern Anatolia Project, Turkey, J. Hydrol., 328, 726-732.
4. De-Luis, M., Gonzales-Hudalgo, J.C., Brunette, M and Longares, L.A. (2011). Precipitation Concentration Changes In Spain 1946-2005. Natural Hazards And Earth Systems Sciences, 11, 1259-1265
5. Ezemonye, M. N. and Emeribe, C.N. (2011) "Correlogram Analysis Of Trends And Cycles In Rainfall Over Southeastern Nigeria". Pakistan Journal of Social Sciences. 8(6), 325-333
6. Ezenwaji, E.E., Phil-Eze, P.O., Enete, I.C. and Osuiwu, B.O. (2014). "An Analysis of the Cycles and Periodicities of Annual Rainfall over Awka Region, Nigeria". Atmospheric
7. and Climate Sciences, 4, 665-671.http://dx.doi.org/10.4236/acs.2014.44059
8. Ezenwaji, E.E., Phil-Eze, P.O., Otti, V. I. and Eduputa B. M. (2013). "Household Water Demand in the Peri-Urban Communities of Awka, Capital of Anambra State, Nigeria". Journal of Geography and Regional Planning.Vol.6(6), pp. 237-243. DOI: 10.5897/JGRP2013.0385
9. Hernando, D. and Romana, M.G. (2015) "Estimating The Rainfall Erosivity Factor From Monthly Precipitation Data in the Madrid Region (Spain)" J. Hydrol. Hydromech., 63, , 1, 55–62
10. Iskander, S.M., Rajib, M.A. and Rahman, M.M. (2014). "Trending Regional Precipitation Distribution And Intensity: Use Of Climatic Indices". Atmospheric and Climate Sciences 4, 385-393.

11. Kumbuyo, C.P., Yasuda, H., Kitamura, Y and Shimizu K. (2014) "Fluctuation Of Rainfall Time Series in Malawi: An Analysis of Selected Areas" GEOFIZIKA VOL. 31
12. McGuire B, Macon I, and Kilburn C. (2002).Natural Hazards and Environmental Change, Arnold, London, 13 – 61.
13. Michiels, P., Gabriels, D. and Hartman, R. (1992). "Using the Seasonal and Temporal Precipitation Concentration Index for Characterizing Monthly Rainfall Distribution in Spain". CATENA, 19, 43-58.
14. Nzoiwu, P. C. (2015). An assessment of the Effects of Climate Variability and Climate change on Agulu Lake, Anambra State. Unpublished Msc. Thesis. The University of Ibadan, Oyo State.
15. Odjugo P. A. O. (2010b). "Regional evidence of climate change in Nigeria". Journal of Geography and Regional Planning. Vol. 3(6), pp. 142-150.
16. Odjugo P.A. (2010a). "General Overview of Climate Change Impacts in Nigeria". J Hum Ecol, 29(1): 47-55
17. Oliver, J. E (1980) Monthly Precipitation Distribution: A Comparative Index. Professional Geographer. 32, 300-309
18. Stefouli M., Charou E. and Katsimpra E. (2011)."Monitoring Lake Ecosystems Using Integrated Remote Sensing / Gis Techniques: An Assessment in the Region of West Macedonia, Greece". Environmental Monitoring, EmaEkundayo (Ed.), ISBN: 978-953-307-724-6, InTech, Available from: http://www.intechopen.com/books/environmental-monitoring/monitoring-lake-ecosystems-using-integratedremote-sensing-gis-techniques-an-assessment-in-the-regio.
19. Valli, M., Sree, K. S. and Krishna, I. V. (2013). Analysis of Precipitation Concentration Index and Rainfall Prediction in various Agro Climate Zones of Andhra Pradesh, India. Inter. Research Journal of Env. Sci. 2(5), 53 – 61.

ASSESSMENT OF THE IMPACT OF CLIMATE CHANGE ON IRISH POTATO YIELD IN NIGERIA.

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Abstract

Potato yields are predicted to decrease in some areas most especially the Sub-Saharan Africa while increasing in others like northern Russia, mostly due to changes in water and temperature regimes. This study examined some of the climatic factors affecting Irish potato yield in Nigeria. Time series data for the period of 1981-2013 (on yield and climatic variables) were sourced from Food and Agriculture Organization (FAO) of the United Nations, Nigerian Meteorological Agency (NiMet) and World Bank. In order to validate and make useable the sourced data, various tests like unit root test (check for stationarity), Johansen co-integration (to check long-run association), Vector error correction model (to check long and short-run causality), serial autocorrelation test and test of residual normality distribution were first carried out and to achieve the objective of the study, an ordinary least square regression was adopted to analyze the data. The regression results showed that the significant variables account for 52.3% of changes in Irish Potato yield. The climatic factors found to be affecting yield were total rainfall, maximum temperature and sunshine hours. Rainfall was negatively significant at 5% implying that increase in rainfall will lead to a decrease in potato yield. This is probable since Late blight *disease that afflicts most Irish potato farms benefits from higher temperatures and wetter conditions. Poorly drained soil also causes poor stand and poor tuber formation***.** *Maximum temperature was also negatively significant at 5% implying that a unit increase in atmospheric temperature will lead to a decrease in yield of Irish potato. Increase in temperature above requirement can* slow tuber growth and initiation, less partitioning of starch to the tubers, Physiological damage to tubers (e.g. brown spots), shortened/non-existent tuber dormancy, making tubers sprout too early, increased incidence of pest and diseases. *Finally, sunshine hours was positively significant at 10% meaning that increase in sunshine hours will lead to increase in potato yield (increased photosynthetic rate that leads to fast growth) and vice-versa. Disease, drought, fast growing and heat-stress resistance varieties are highly recommended.*

Keywords: *Irish potato, maximum temperature, sunshine hours, Total rainfall, yield*

INTRODUCTION

Solanum tuberosum (family solanaceae) also known as Irish Potato originated from Latin America. It was of a great importance as a staple food to the Incas who live in the Andes mountain of Peru and Bolivia. The crop ranks fourth after rice, maize and wheat in terms of world production volume. Potato does best in areas of cool climate and therefore requires a cool growing season with a moderate and well distributed rainfall of about 800mm during growing seasons with no prolonged dry weather. Cultivation could be under rain-fed condition or irrigated, but waterlogged areas are The importance of Potatoes cannot be underestimated most especially in the developing world as it has become an important source of food, employment as well as income (FAO, 2008). Furthermore, the potato's high energy content, short shelf life (3-4 months) and ease of production have also made it an important component of both urban and rural agriculture. Potato produces considerably more energy and protein than cereals Haverkort et al., (2012) and nutritionally, the crop is considered to be a well-balanced major plant food with a good ratio between protein and calories, and has substantial amounts of vitamins, minerals, and trace elements. Presently in Nigeria, Irish potato has become a staple that is increasingly wanted but not needed due to the availability of other cheap substitutes. Unlike Nigeria where this staple is only of marginal relevance for overall food safety in the country, it is esteemed in other African countries like Kenya as an important contributor to national food security and a means of national and individual wealth. Its consumption in Nigeria has been on the increase and presently above 1 Million tons as at 2012. Urban population growth, rising incomes and dietary diversification has increased demand from the fresh market, fast food, snack and convenience food industries. This increasing demand for Irish potato must therefore be met with sustainable supply so as to close the increasing food demand-supply chasm and insecurity. And since there is a constraint in production due to its environmental and climatic unsuitable. Potato yields best in the regions with maximum temperature of 300°C and minimum of about 150°C and falls with temperature increase (Akoroda & Ngere, 1998; Ahmed 1980). requirement, intensification (yield increase) is the obvious way by which supply can be increased. But currently in Nigeria, among the major staple crops such as cassava, yam and sweet potato, harvest volumes of Irish potatoes hardly represent 1% of the total annual output of all staple crops in Nigeria (Sylvanus et al, 2014). Moreover Nigerians pay more for potatoes than for any other staple crops. Because efficiency of potato production is very low, it costs up to 30-40 % more than cassava or yam. The Nigerian potato sub-sector is still underdeveloped marking one of the lowest yields in the world and with added value processing activities almost absent when compared to the potential 35-45 tons per hectare in countries like Ireland, India and China (OECD, 2015). According to FAO, (2008) an annual production of 1.1 million tons was recorded on an area of roughly 260,600 ha resulting in an average yield of 4.2 tons. Then within 4 years' time this modest yield increased slightly to reach 5 tons per hectare in 2012. Among the factors contributing to this low supply is the effect of the Increasing temperatures, erratic rainfall and the frequency and intensity of extreme weather events which exacerbates the already existing pressure on the global agricultural system – which is already struggling to respond to rising demands for food and renewable energy. Hence, a need for a study as this so as to unveil the prevailing situation in Nigeria's Irish potato sub-sector.

METHODOLOGY

This study was carried out in Nigeria. The main producing state in Nigeria is plateau state where about 90% of nation's production is domiciled. Data used were sourced from Food and Agricultural Organization (FAO), Nigerian Meteorological Agency (NiMet), World Bank. Data were collected on Irish potato yield and climatic conditions i.e. for the major Irish potato producing state (Plateau State) between 1980-2013. The following tests were first carried out to validate the usefulness of the data. Unit-root test, co-integration test, vector-error correction model and serial autocorrelation Then Descriptive statistics and Ordinary Least Square Regression was used to determine the climatic factors that are critical to the yield of Irish Potato. The general form of the regression equation is presented as follow:

$$\mathbf{Y = a + b_1x_1 + b_2x_2 + b_3x_3 + b_4x_4 + b_5x_5 + b_6x_6 + e}$$

where, **Y** = Irish potato yield;
a = constants;
b = coefficients;
$\mathbf{X_1}$ = Total rainfall (mm);
$\mathbf{X_2}$ = Maximum temperature ^{O}C;
$\mathbf{X_3}$ = Minimum temperature ^{O}C;
$\mathbf{X_4}$ = Relative humidity;
$\mathbf{X_5}$ = Sunlight (Hours);
$\mathbf{X_6}$ = Soil Temperature;
e = Error term.

RESULTS AND DICUSSION

a) Characteristics of agro-climatic parameters

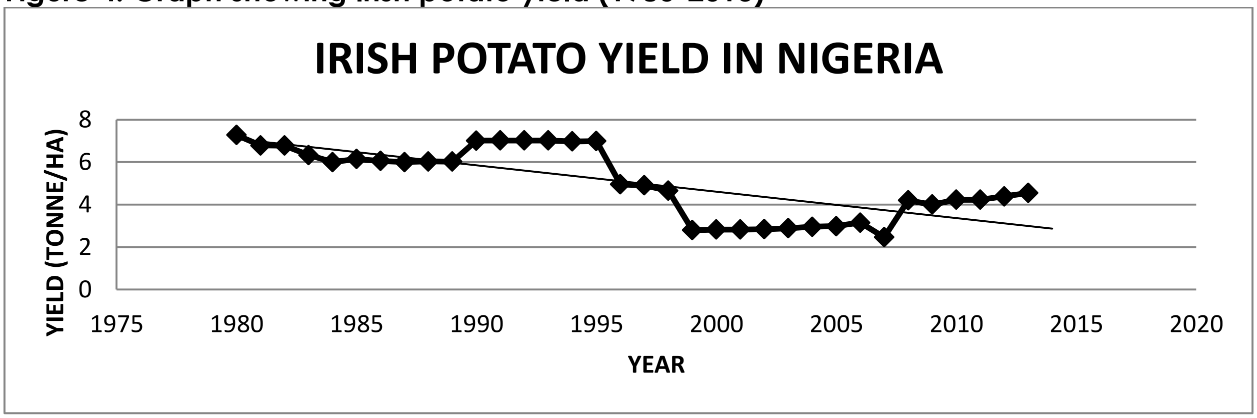
Table 2: Descriptive Statistics of Climatic Variables and Yield of Irish Potato (1980 – 2013)

Variables	Obs.	Mean	Std. Dev.	Minimum	Maximum	Variance
Rainfall	34	1237.4	156.5527	814.7	1686.2	24508.75
Max. Temp	34	27.725	0.5429	25.508	28.425	0.294787
Rel. Humidity	34	51.453	3.407	43.25	57.5	11.60946
Sunlight (Hr)	34	5.655	2.886	-	7.7917	-
Min.Temp	34	15.534	0.558	13.708	16.267	0.310851
Soil Temperature	34	23.78	0.5494	22.23	24.63	

Source: Data Analysis Output, 2016

The mean of total rainfall (1237.4mm) not only met up with the requirement for Irish potato production which is about 800mm (Ahmed,1980; Ambrose et al, 2013), it also exceeds it which might indicate some events of excessive rainfall that can give rise to waterlog and increase in pest and diseases which is detrimental to yield. This can also be observed in the high variation (24508.75) between the annual data. Poorly drained soil often causes poor stand, diseases such as late blight (Forbes 2012). There has been an increase above the optimal yield temperature which is about 26^{O}C. Maximum Temperature has even gotten as high as 28^{o}C. Increasing temperature has been associated with pest and diseases which also affects yield greatly (Stephen, 2013). The mean of sunlight hours is also small (5.655) which imply less time for photosynthesis (food production by green plants) thus delaying growth. This calls for further probe into these factors so as to determine the degree of contributions of each of these factors. It is on the basis of this that the use of regression analysis was employed to determine the contribution of these factors to growth and yield of Irish potato.

Figure 4: Graph showing Irish potato yield (1980-2013)



Source: Data Analysis Output, 2016

b) Climatic factors affecting Irish potato yield in Nigeria.

Table 7: Climatic factors affecting Irish Potato yield.

VARIABLES	COEFFICIENTS	t-statistics	STANDARD ER
Constant	30.66442	2.50**	12.284
Max temp	0.2245	-2.29**	0.4918
Total rainfall	0.3645	2.13**	0.7768
Minimum temp	0.3231	0.68	0.4775
Relative humidity	0.4105	0.51	0.07978
Sunshine hours	-0.2828	3.21***	0.08801
Soil Temperature	-0.1202	-0.27	0.44017

Source: Data Analysis Output, 2016

The regression results showed that the significant variables account for 52.3% of the variation in Irish Potato yield. According to the result, the significant variables were Total Rainfall, Maximum temperature and Sunshine hours. Rainfall was negatively significant at 5% implying that a unit increase in rainfall will lead to 0.3645 decrease in potato yield and vice-versa. The works of Zaag et, al (1981) and Ambrose et al, (2013) correlates with this result that excess soil moisture at tuber bulking/ripening stage causes poor soil aeration and root damage which affects crop development and yield. Nwakocha

(1987) also reported that blight causes between 40-80% reductions in yield. The peak incidence of this disease is between July and August incited by pathogen phythopthora. The disease is accompanied by high relative humidity, temperature, dew and frequent rainfall (Hienfling 1987). Maximum temperature was also negatively significant at 5% implying that a unit increase in temperature will lead to 0.2245 decrease in yield of Irish potato. This correlates with the works of *Haverkort and Verhagen, (2008); Hijmans and Robert, (2003*) who reported that hot weather will reduce the number of tubers per plant i.e. yield. Tuber growth and yield can be severely reduced by temperature fluctuations outside 5-30 °C. Finally, sunshine hours was positively significant at 10% meaning that a unit increase in sunshine hours will lead to 0.2828 increase in potato yield and vice-versa. Irish potato requires at least 6-8 hours of sun each day.

CONCLUSION AND RECOMMENDATION

Irish potato yield is affected by rainfall, maximum temperature and sunshine hours. Rainfall and maximum temperature has a negative relationship with Irish potato yield while sunshine hours have a positive relationship with yield. Meaning an increase in this particular variable will lead to an increase in Irish potato yield. In line with the result of this study, the following are therefore recommended that there should be a prompt development and effective distribution of Irish species that are resistant to local pests and diseases(E.g.Solanum verrucosum which is resistance to late blight); heat stress tolerance (which have the ability to maintain tuber growth and initiation under high temperatures) and Fast growing/early maturation specie which adjusts to shorter growing season and reach maturation before the completion of pests lifecycle.

REFERENCES

1. Ahmed, S.A. (1980). Irish potato, production in Bangladesh in proceeding of third International symposium on potato production for south-East Asia and pacific region held at Badung Indonesia pp 50.
2. Ambrose A. Zemba, Solomon Z. Wuyep, Abel A. Adebayo & Clement J.Jahknwa., (2013). Growth and Yield Response of Irish Potato to Climate in Jos-South, Plateau State, Nigeria. Federal University of Technology, Nigeria. Global Journal of HUMAN SOCIAL SCIENCE Geography, Geo-Sciences, Environmental Disaster Management. Volume 13 Issue 5. Online ISSN: 2249-460x & Print ISSN: 0975-587X
3. *Haverkort, A. J.; Verhagen, A. (October 2008). "Climate Change and Its Repercussions for the Potato Supply Chain". Potato Research 51: 223–237.* doi:10.1007/s11540-008-9107-0
4. *Hijmans, Robert J. (2003). "The Effect of Climate Change on Global Potato Production". American Journal of Potato Research 80: 271–280.* doi:10.1007/bf02855363
5. Climate change - can potato stand the heat?" *WRENmedia. Retrieved 7 November 2012.*

6. Stephen, (2013). Projected Economic Impacts of Climate Change on Irish Agriculture. Commissioned report on behalf of Stop Climate Chaos. Stop Climate Chaos, 9 Upper Mount Street, Dublin 2, Ireland. +353 1 6394653 info@stopclimatechaos.ie www.stopclimatechaos.ie.
7. *Forbes, G. A., (2012)* "Implications for a warmer, wetter world on the late blight pathogen: How CIP efforts can reduce risk for low-input potato farmers" *(PDF). CIP.*
8. Food and Agricultural Organization of the United Nation FAO (2008), International Year of the Potato. Potato diffusion (Hidden treasure) Retrieved 17th July 2008 from http: www.potato 2008.or on potato.
9. Akoroda, M.O. & J.M. Ngere (1998). Root crop in the 21 century Benin: International Society for Tropical Root Crop Anthony, Y & O.C. Fred (1986). Introduction to Tropical Agriculture. Longman group ltd, China.
10. Hienfling, J. W. (1987) Late blight of potato. Technical Bulletin, International potato Centre (CIP) p12.
11. Nwakocha, H.N. (1987). Weed interference studies in Irish potato. Annual Report, National Root Crops Research Institute, Imudeke, pp. 88-93.
12. Zaag, D.E. (1981). Water supply to potato crops Nivaa. Pub. Ministry of Agric. and Fishery. The Hague the Netherlands pp20.

PASTORALISTS' COPING STRATEGIES TO THE EFFECT OF CLIMATE VARIATION ON ANIMAL PRODUCTION IN TALATA-MAFARA LOCAL GOVERNMENT AREA OF ZAMFARA STATE, NIGERIA.

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ABSTRACT

The study examined pastoralists' coping strategies to the effect of climate variation on animal production in T/Mafara Local Government Area of Zamfara State. Specifically, the study investigated the socio-economic characteristics of livestock farmers, livestock farmers' climate related constraints, the coping strategies employed by pastoralists and barriers to coping practices. Random sampling technique was used to select 250 respondents for the study. Data collected through questionnaire were analyzed using frequency counts, percentages, mean distribution, chi-square and Pearson Product Moment Correlation Coefficient. Results obtained revealed that majority (87%) of livestock farmers in the study area were males with a mean age of 32.8 years. Predominant coping strategies adopted by pastoralists were moving long distances to find pasture ($\bar{\chi}$ =2.8), water harvesting ($\bar{\chi}$ =2.7) and herd splitting ($\bar{\chi}$ =2.7). Pearson product moment correlation indicated that there were significant and positive relationships between perceptions of climate change indicators (increasing drought, increasing hot temperature and irregular rainfall) and animal performance. Consequently, efforts should be geared towards developing and making available, animal species that are tolerant to change in climate elements and weather extremes like excessive warmth, intense coldness and drought. This study as well recommends prompt weather information, increased research and development of innovation for sustainable livestock production in the face of climate variation.

Key Words: Animal Production, Coping Strategies, Climate Variation, Pastoralist, Zamfara State.

1. INTRODUCTION

A number of studies have revealed significant and unpleasant adverse impacts of climate change and adaptation of livestock farmers in various regions of the world (Dineshsingh & Nilotpal, 2014; (Kimaro & Chibinga, 2013). Several researches on climate change impact submits that the negative effects of rising temperature and variable rainfall will be more in sub-Saharan Africa owing to low adaptive capacity and heavy dependence on rain fed agriculture (IPCC, 2001). In developing countries of Africa, including Nigeria, agricultural production and the livelihoods of smallholder farmers are inhibited by various challenges that worsen food security, such as disease and pest invasions, post-harvest losses, market shocks and lack of capital/credit, among others (Andrew, Bruce, Bismark, & Bern, 2016). Previous studies on climate change and adaptation of livestock farmers have shown that climate change affects livestock farming directly and indirectly (Kabubo-Mariara, 2008)). Direct effects have been observed to include retardation of animal growth, low quality animal products including hides and skins, and animal production in general. Indirect effects have included general decline in quantity and quality of feedstuffs for example, pasture, forage, grain severity and distribution of different species of livestock, and other effects such as increase in livestock diseases and pests Hence, adaptation to climate change effects on agriculture has emerged as a key concern to numerous stakeholders in sub-Saharan Africa (SSA), with special emphasis on how to assist farmers in improving their adaptive capacity (Temidayo,2011).

However, effective adaptation policy must recognize farmers' knowledge and perception of climate change, their prospective adaptation measures, and conceivable obstacles and limitation to adaptation (Gbetibouo,2009;Fosu-Mensah & Vlek, 2012).

Contemporary knowledge on the link between climate change effects and livestock production is deficient particularly in Nigeria regardless of the economic significance of livestock agriculture in the country. Several related studies in the country have reported on the impacts of climate change on crop farmers as compared to livestock farmers. This deficiency has created a knowledge gap which affects livestock management authorities and several development projects.

In addition, Zamfara state is among the states with the highest incidence of theft of animals in northern part of Nigeria (Mohammed, Muazu, Yahaya, & Midat, 2014). Undoubtedly, in most African countries including Nigeria, a basic causal relationship links climate change with violence. Hence, poor responses to climatic shifts create shortages of resources such as land and water. Moreover, inappropriate adaptive responses resulting in damage to crops and blocking of transhumant corridors have caused violent conflicts between crop farmers and pastoralists (Muhammed, Belel, & Muhammed, 2015)

In view of the foregoing, this present study attempts to examine pastoralists' coping strategies to the effect of climate variation on animal production in Talata-Mafara Local Government Area of Zamfara state, Nigeria.

In order to empirically study the phenomenon of this research, the following research questions provided a guide:

1. What has been the climate condition (in terms of the pattern of rainfall and temperature variability) in the study area in the past nineteen (19) years?
2. What do nomadic pastoralists know and perceive of climate variability in the study area?
3. What are the effects of climate variability on the livelihoods of nomadic pastoralists?
4. What are the coping strategies adopted by nomadic pastoralists to mitigate the effects of climate change on their activities?
5. What are the barriers to coping strategies adopted?

2. HYPOTHESIS OF THE STUDY

This research is guided by the following hypotheses:

I. There are no significant differences between pastoralists' perception of climate variability and impact on animal production in the study area.
II. There are no significant relationships between the socio-economic and demographic characteristics of pastoralists and coping strategies to climate variability in the study area.

3. Conceptual Framework

The conceptual framework presented in Figure 1 was adopted and modified from Smit and Olga (2001) and O'Brien, Nyaard and Schjolden (2007) to elucidate the associations between climatic variables, animal performance, crop production, forestry, fishery, adaptation strategies and policy framework and institutions. The framework avows that exposure to climate variability and change affects livelihood patterns and autonomous adaptation strategies. This is because competition for space leads to conflicts. It further illustrates how policies and institutions directly influence planned adaptation to impacts and vulnerabilities. Planned adaptation reduces vulnerability of households and builds resilience to climate extremes through the adoption of climate-smart agricultural technologies.

Climate-smart agriculture (CSA), therefore, is an integrative approach to address the interlinked challenges of food security and climate change. It is a practice that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. CSA has three main objectives:

I. sustainably increasing agricultural productivity, to support equitable increases in farm incomes, food security and development;
II. adapting and building resilience of agricultural and food security systems to climate change at multiple levels; and
III. reducing greenhouse gas emissions from agriculture (including crops, livestock and fisheries).

CSA is an approach for developing agricultural strategies to secure sustainable food security under climate change. CSA offers the means to help stakeholders from local to national and international levels identify agricultural strategies suitable to their local conditions. (www.climatesmartagriculture.org)

4. LITERATURE REVIEW

4.1 Definition and Concepts of Climate Change

The term Climate speaks of the average (general) weather conditions that a region or country experiences. Climate is averaged over a number of years. Whereas Weather talks about the current state of the atmosphere in regards to temperature, cloud cover, wind speed and direction, precipitation, humidity etc. FAO (2008) noted that when these weather phenomena are measured systematically at a specific location over several years, a record of observations is accumulated from which averages, ranges, maximums and minimums for each variable can be computed, along with the frequency and duration of more extreme events.

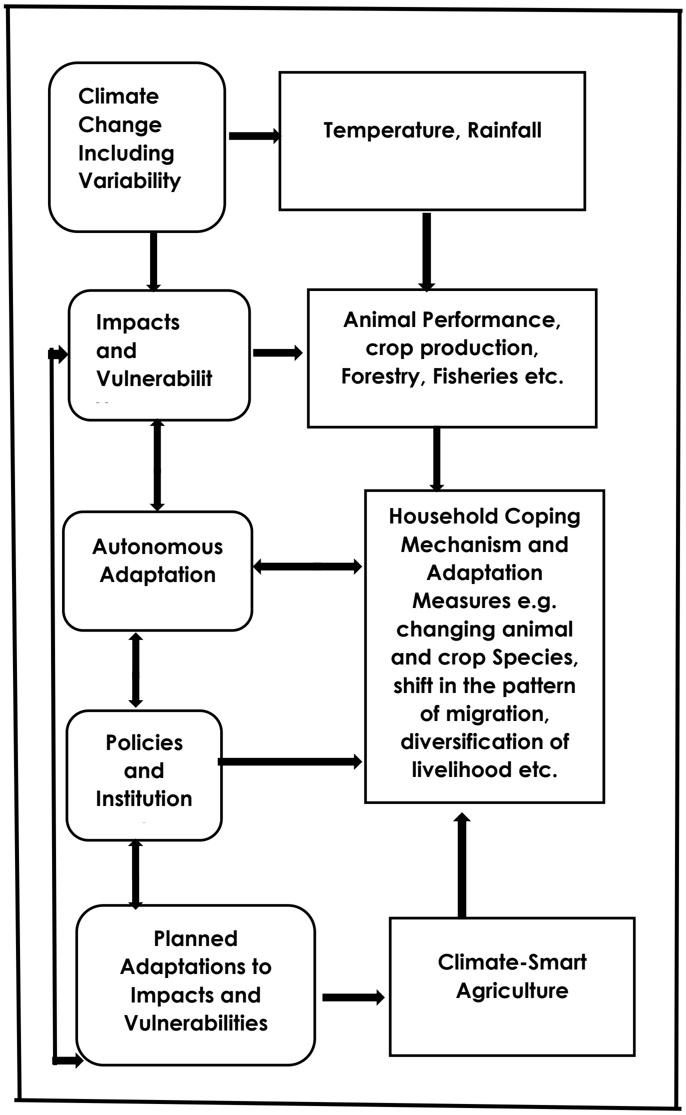

Figure1: Conceptual framework showing steps involved in planned agricultural adaptation to climate change and variability

Source: Modified from Smit and Olga 2001; O'Brien, Eriksen Nyaard and Schjolden 2007.

According to a definition provided by UNFCCC (2012), climate change is a change of climate which is attributed directly or indirectly to any human activity that alters the composition of the global atmosphere and which is in addition to natural variability observed over comparable time periods. In addition, IPCC (2007) expressed climate change as deviations from a regional climatology determined by analysis of long-term measurements, usually over a period of at least 30 years.

Hence, the most universal meaning of climate change is a change in the statistical properties of the climate system when considered over long periods of time, regardless of cause (Osman, 2015). Moreover, The Intergovernmental Panel on Climate Change (IPCC) forecasts that during the next decades, billions of people, principally those in developing countries, will face variations in rainfall patterns that will contribute to severe water shortages or flooding, and rising temperatures that will cause shifts in crop growing seasons. This will increase food shortages and distribution of disease vectors, putting populations at greater health and life risks.

Osman(2015) opined that natural causes only cannot explain all of these changes; and that human activities (both crop and livestock farming) are contributing to climate change, basically by releasing billions of tons of carbon dioxide (CO2) and other heat-trapping gases, known as greenhouse gases, into the atmosphere every year. According to FAO (2006), animal agriculture is responsible for 18% of greenhouse gas (GHG) emissions (9% CO_2, 37% methane and 65% N_2O). It is instructive to know that the more greenhouse gases we emit; the larger future climate changes will be. EPA (2011) stated that
changes in the climate system has adverse effect on our health, environment, and economy. Therefore. There is need to prepare for some of the impacts of climate change in order to reduce their effects on our wellbeing.

4.2 Famers' Perception and Adaptation to Climate Change

Adaptation to climate involves two processes or stages. Firstly, it requires that farmers first notice that the climate has changed, and secondly identify suitable adaptations and implement them. A substantial amount of literature examined farmers' perception of and adaptation to climate change in Africa. For instance, Maddison (2006) notes that perception of climate change seems to center on the experience of farmers and the accessibility of open extension services in terms of climate change. In addition, Gbetibouo (2009) contends that farmers with access to extension services are expected to perceive changes in the climate since extension services provide information about climate and weather. Therefore, awareness and perceptions of a problem causes action or inaction on the problem of climate change. Furthermore, Maddison (2007) noted that farm-level Adaptation encompasses dual steps, one, is to perceive the change in climate, and second, is deciding whether to adapt or not, or which adaptation approach to take. Besides, there are salient questions on perception that need to be answered. They include: Are farmers capable of perceiving the change in climate in the long run, if they do what changes are they able to perceive, what factors (economic, social and institutional) inspire their level and speed of perception (Deressa, Hassan, Ringler, Alemu, and Yesuf, *2009*). Basically, farmers who have observed the change in climate may perhaps not adjust or the kind of their adjustment might differ owing to a multifaceted interaction between social, economic and institutional factors (Maharjan , Sigdel , Sthapit, Regmi, 2011).Hence, adaptation to climate change according to Osman (2015), embraces all modifications in behaviour or economic structure that lessen the vulnerability of society to changes in the climate system, whereas, adaptability talks about the extent to which adjustments are possible in practices, processes or structures of systems to projected or actual changes of climate. Essentially, Smith, Vogel and Cromwell (2009) submit that adaptation can be spontaneous or planned, and can be carried out in response or in anticipation of change in conditions. Consequently, adaptation options to climate change can be grouped into autonomous or private and planned or public sector adaptation strategies. Private adaptation strategies involve action taken by non-state agencies such as farmers, communities or organizations and or firms in response to climate change. Accordingly, Bruin (2011) itemized some adaptation strategies of farmers such as switching crops, shifting crop calendar, engaging new management practices for a specific climate regime, changing irrigation system and selecting different cropping technologies. However, in livestock production, adaptation involves, shift in migration pattern, herd splitting, use of crop residue to supplement pasture etc. Public adaptation on the other hand, consists of actions taken by local, regional and or national government to provide infrastructure and institutions to reduce the negative impact of climate change. Public adaptation strategies according to World Bank, (2010) involves development of new irrigation infrastructure, transport or storage infrastructure, land use arrangements and property rights, water shed management institutions. As stated by Sathaye and Christensen (1998) and Bruin (2011) adaptation options can be either proactive or anticipatory depending whether it takes place before or after climate change. Therefore, reactive adaptation options addresses effects of climate change after they have been experienced, but proactive adaptation options are engaged in anticipation of climate change. In crop production, reactive adaptation options include control of soil erosion, construction of irrigation dams, improving soil fertility, development of new varieties, shifting planting and harvesting time. Whereas, in animal husbandry, reactive adaption could involve migration, water harvesting, herd destocking etc. Anticipatory adaptation options on the other hand involve the development of tolerant cultivars and improved animal breed, research improvement, enhanced policy measures on taxation and incentives.

4.3 Impact of Climate Variability On Livestock Production in Nigeria.

Ozor (2009) stated that livestock production systems in Nigeria would be vulnerable to climate change in respect of anticipated decrease in rainfall in the Sudan-sahelian zone and consequent reduction in the available pastureland. This he explained further by listing the various ways the anticipated decrease in rainfall will affect livestock as declining availability of surface water resources for animals, possible increase in salinity at water resources for animals, possible increase in salinity at watering points due to increase in temperature and evaporation in the face of reduced rainfall. This is to say that further changes in rainfall and temperature will affect livestock production as well as availability of animal species. Some species might be unable to adapt quickly enough and habitants might not be available for them to move into. If global temperatures rise by 2 degrees Celsius, 30 percent of all land-living species may be threatened by an increased risk of extinction. Though increase in temperature is generally seen to be destructive to the production of crops and human lives, FAO (2009) noted that livestock production could be boosted by temperature increase. Similarly, Nze et-al. (2010) maintained that the proliferation of pests and crop diseases (again originating with climate change) can attack crops and animals. The current warming trend hinders livestock production and reproduction by reducing animal weight gain and dairy production. As well, livestock are usually subjected to long treks to find water and grass in the more southerly areas of the country during the dry seasons. Warming trends also affect the growth of/farming systems of grain crops such as maize, guinea corn, and rice, and makes storage of root crops and vegetables difficult. This in turn affects the availability of crop residues used as animal feeds. Supporting the aforementioned, Kim, Ikpe and Sawa (2015) stated that in the sub humid zone of Nigeria, infectious diseases continue to be the most common cattle health hazard. The principal ones are rinderpest, foot-and-mouth disease, and contagious bovine pleuropneumonia. These have led to the deaths of many livestock. Conversely, Deressa and Hassan (2009) found increasing temperature damaging to the Ethiopian agriculture; a situation that is not uniformly distributed across agro-ecological zones. Issa (2009) in agreement with the findings of Deressa and Hassan (2009) reported that commercial Livestock producers are negatively affected by rising temperature. This to say that varying climate has varying effects on crops and livestock depending on the agro-ecological location.

5.MATERIALS AND METHODS

5.1 Description of the Study Area

Talata Mafara is a Local Government Area in Zamfara State. Its precise location is 12^0 21′ 00′ ′N 6^0 04′ 00′ ′E (Fig.2). It has an area of 1,430km^2 and a population of 215,178 at the 2006 census (Wikipedia, 2013)

Talata - Mafara records 798mm of rainfall. The onset of the rains, on the average is between mid-March and May, lasting for about six months till the end of October. The temperature of the place ranges between 31^{0}C to 35^{0}C (Ibrahim and Mohammed)

Vegetation of the study area consists largely of Sudan savanna. It is structurally characterized by woodlands, where grasses occur either totally or mixed with other herbaceous or shrubby plants. They are green in the rainy season with fresh leaves, but become dry during the dry season.

5.2. Study Design and Sampling

The study employed a cross sectional survey design. Using this design, a sample of the population of nomads was selected, and from these nomads, data was collected to help answer the research questions. Data collection tools included secondary data review, Focused Group Discussions (FGDs), Questionnaire, Key Informant Interviews and Personal Observation. Ten research assistants (each representing a locality) were adequately trained to carry out the interview. The questionnaires were purposively administered to household who keep livestock and have been residing in the area for at least 30 years. The essence was to collect data from respondents who have had long time experiences in animal husbandry and climate variability and change over the years and are more concerned and conscious about the looming danger of these changes on their environment.

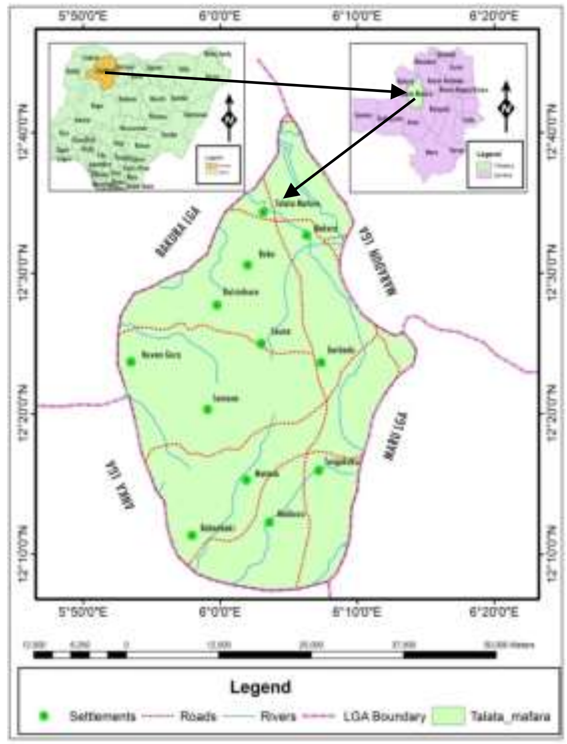

Figure:2. Map of Study Area.
Source: GIS Lab. Dept. of Geography, ABU, Zaria.

The respondents were selected from each category of people depending on who is the head of a given household. In addition, a Focus Group Discussion (FGD) of ten people (one representative from each of the 10 localities of the LGA) was also held in September, 2015 at T/Mafara in order to obtain profound and up-to-date data on climate change, variations in animal performance, disaster preparedness and adaptation strategies of the communities. Furthermore, key interview session was conducted once on nomad leaders (Miyyeti-Allah) and opinion leaders. The interview session was held with five persons among whom was the secretary of Miyyeti-Allah.

A total of ten villages were covered in the study. These included T/Mafara, Matusgi,Ruwan Bore, Makera, Garbadu, Kagara,Morai,Ruwan Gora, and Tungar Miya. The selection of these villages was premised on the population of nomads and prior knowledge of the prevalence of cattle rustling and crop farmers and herders' conflicts. Purposive sampling was used to select the villages for the study, while 250 farmers were randomly selected i.e. 25 from each village to give equal representation. However, the selection of farmers considered gender sensitivity where a balance of males and females' interviewee was observed (Table 1).

TABLE1: COMPOSTION OF INTERVIEWED PASTORALISTS BY GENDER (250)

Name of Locality	Male	Female	Total
T/MAFARA	18	7	25
Matusgi,	20	5	25
Ruwan Bore	16	9	25
Garbadu	19	6	25
Makera	15	10	25
Kagara	14	11	25
Ruwan Gora,	18	7	25
Tungar Miya	15	10	25
MORAI	13	12	25
Mabangala	16	9	25
Total	**164**	**86**	**250**

Source: Field survey, 2015

5.3 Measurement of Variables and Data Analysis

Objective 1: Analysis of the trend of climate variability- The temporal changes in rainfall and temperature over the 19 years in the study area were examined by employing the time series analysis. The trend analysis of climate records (1996- 2015) obtained from Nigerian Metrological Station, Gusau was used to assess the level of concurrence of pastoralists' perception of climate variability with the report and data collected from the Nigerian Metrological Agency.

Objective2: Investigation of nomadic pastoralists' perception of climate variability-The primary qualitative data on farmers' perception of temperature and rainfall variations was categorized into increase, decrease and no change and was analyzed using descriptive statistics - percentage and charts.

Objective 3: Assessment of the effects of climate variability on nomadic pastoralists' livelihood- Respondents were required to select from the list of variables (DAP-Decreased animal productivity, IAM- Increased animal productivity, RIL-Reduction in income from livestock etc.) that provided the effects of climate change on animal production. To achieve this objective, a three-point likert rating scale was used. Each respondent was required to indicate opinion by checking any of the three options i.e. agree. disagree and undecided. Values that were assigned to these options were 3. 2 and 1 respectively. The contribution of each of the factors to the perceived impacts of climate variability in the study area was examined and the ranking of the attributes in terms of their criticality as perceived by the respondents was done by use of Relative Importance Index (RII); depicted by RII=$\sum W$/A∗N ($0 \leq RII \leq 1$) Where: W – is the weight given to each factor by the respondents, A – is the highest weight and; N - is the total number of respondents. The guide for RII rating is given as: very significant=0.76 above, Significant=0.67-0.75, fairly significant=0.45-0.66, not significant=0.44

Objective 4: Examination of nomadic pastoralists' coping strategies to climate variability -Respondents were asked to select from the list of variables (MLD-Move long distance to find pasture, UCR- Use of crop residue as animal feeds, DLA-Diversification of livelihood etc.) that provided the coping strategies to climate change employed by pastoralists. A 3-point Likert Rating Scale (LRS) 'agree', 'disagree' and 'neutral' was employed to judge pastoralists' response to questions on coping strategies to climate variability. The mean score of respondents was computed as follows: 3 + 2 + 1 =2.0. Using an interval scale of 0.5, the upper limit is 2.5 while the lower limit is 1.5. Response options with scores equal to or above 2.5 are accepted as predominant coping strategies while those equal to or below 1.5 are regarded as rarely practiced strategies.

6. RESULTS AND DISCUSSION

6.1Socio-Economic and Demographic Characteristics of the Respondents

The result of the study (Table 2) shows that the mean age of the respondents is on the active age category which is 32.00 years with standard deviation of 6.16.

Table 2: Demographic and socio economic characteristics of respondents

Variable	Mean	Mini	Maxi	Std
Age	32.80	20	50	6.160
Income	25000 0	50,00 0	40000 0	57076.0 0
Herd size	1500	50	3500	0.679
Herding Experience	19	10	40	0.632
Household size	14.80	5	25	0.641

Source: Fieldwork, 2015.

Objective 5: Examination of barriers to pastoralists' coping strategies-Respondents were requested to select from the list of variables (COS-Conflict over scarce resources, LMA-Limited Market Access, IPC- Inappropriate policy etc.) that provided barriers to coping strategies employed by pastoralists. A three point LRS was also used (agree=3, disagree =2 and neutral=1). Using an interval scale of 0.5, the upper limit is 2.5 while the lower limit is 1.5. Any response option with mean score less than 1.5 was regarded as not a strong impediment to adaptation while options with mean score equal or above 2.5 were regarded as solid impediments to adaptation strategies adopted by nomadic pastoralists.

At this age bracket, Falola, Segun, Akangbe and Ibrahim (2012) reported that pastoralists are capable of handling tedious herding activities such as covering long distances to graze animals, fetching of water from well for the animals to drink, collection of fodder or hay for the animals during scarcity etc.

The results of the study (Table 2) shows that the average family size of the total pastoralists' sample households is 14.80 with standard deviation of 0.64. It is apparent from Table 2 that the study area has abundant family labour supply that could be used to carry out herding operations as this would save cost. This investigation is in harmony with Gbetibouo (2009) who noted that large households are more willing to choose labour-intensive adaptation measures.

The average annual income of the pastoralists' sampled households is N250,000.00 with standard deviation of 57076.00 (Table 2). This investigation discloses that in general, pastoralist in

T/Mafara are in the medium economic level and hence bouyant enough to adopt improved adaptation practices. Onubuogu, Chidebelu and Eboh (2013) corroborated this findings by noting that farmers' incomes (whether on-farm or off-farm income) have a positive relationship with the adoption of agricultural technologies since the latter requires sufficient financial wellbeing to be undertaken.

Table 2, further expresses that the average year of herding experience in the study area is 19 with a minimum of 10 and maximum of 40 years. This suggests that pastoralists in T/Mafara have had ample herding experience and are likely to understand the effect of climate change and take up some measures to adapt to it. Gbetibou (2009) in a similar study of farmers' perception of climate change in South Africa confirmed that experienced farmers have diverse skills in farming techniques and management, and are able to spread risk when faced with climate variability.

Table 2 discloses that the average herd size of pastrotalsts in the study area is 1500 with a minimum of 50 and a maximum of 3500. This indicates that pastoralists in T/Mafara have fairly large cattle size. Livestock is an asset/wealth for Pastoralists; this means pastoralists who have large livestock number, have more probability to adapt to climate change. This result agrees with the findings of Osotimehin, Tijani, and Olukomogbon, (2006) that the size of herd is traditionally considered a measure of wealth and social status among the nomads; the larger the size of the herd of a nomad, the greater the security such an individual enjoys.

Table 3: Demographic and socio economic characteristics of respondents

Variable	Frequency	Percentage
Sex : Male	218	87
	32	13
Female		
Total	**250**	**100**
Education		
Tertiary	12	4.8
	31	12.4
Secondary		
Primary	57	22.8
Informal	150	60
Total	**250**	**100**

Source: Fieldwork, 2015.

Table 3 shows that, more than half (60%) of the pastoralists had no formal education and this makes it is difficult for pastoralists in the study area to understand new adaptation options. This is because education enhances the capacity to obtain, process, and utilize information disseminated by different sources. Kehinde (2014) validated the foregoing investigation that low level in education could prevent farmers from keying into the Agricultural Transformation Agenda of the Federal Government of Nigeria and the Nomadic Education Programme which may thus affect their socio-economic status.

Table 3 illustrates further that herding activities in the study area is male dominated as almost all the pastoralists (87%) were males. In actual fact, the tending of cattle requires long distance travelling on daily basis. This is probably beyond the scope of the female (Ayanda, Oyeyinka, Salau, and Ojo, 2013). Moreover, Montle and Teweldemedhin (2014) observed that female-headed households might be slow to respond to changing climate conditions through the adaptation of diversified strategies due to the challenge posed by their customary household duties (e.g. childcare)

6.2 Trends in Rainfall and Temperature Attributes

The trend analysis of the temporal changes in rainfall and temperature over 19 years show a consistent rising trend in annual mean surface temperature and inter-annual variability in precipitation in the study area. The trend of annual rainfall for 40 years and the trend of annual temperature for 19 years in Zamfara state are depicted graphically in Figure 3 and Figure 4 respectively.

Figure 3 shows a steady increase with much fluctuations-rising and falling trend in annual mean rainfall in the study area with the average maximum rainfall (314.9mm) between 2006 -2007. The speed of increase is higher for 1990 to 2000 and 2003 to 2012. Figure 4 reveals the trend analysis of record of the level of temperature between 1996-2015 in the study area which shows an increasing trend with the average minimum (20.2°C) and average maximum (34.5°C) temperature recorded in 2005 and 2008 respectively.

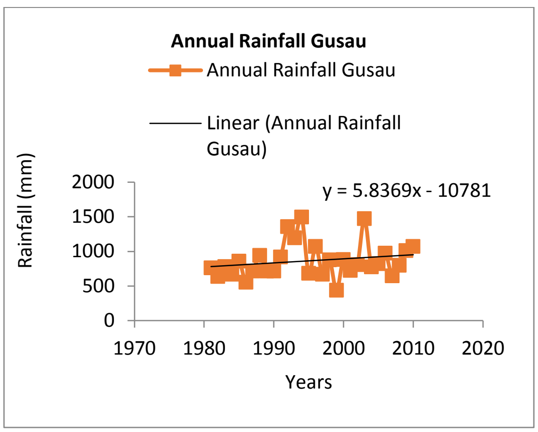

Figure 3: Annual mean rainfall (1975-2015) Zamfara state.
Source: NMetS. Gusau

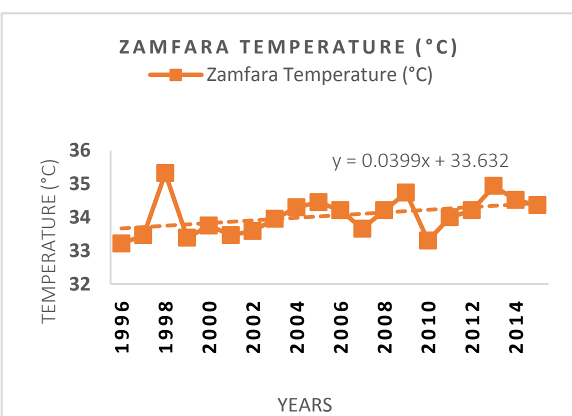

Figure 4: Annual mean temperature (1996-2015) Zamfara State
Source: NMetS. Gusau.

The preceding analysis is validated by Odjugo (2010) indicating that the temperature trend in Nigerian since 1901 shows increasing pattern. The increase was gradual until the late 1960s and this gave way to a sharp rise in air temperatures from the early 1970s, which continued till date. Odjugo (2010) furher stressed that the mean air temperature between 1938 and 2007 in the semi-arid region of Nigeria was 28.96°C while the rainfall amount was 847 mm. Between 1938 and 1972 climatic period, the temperature was 28.24°C and the rainfall amounted to 937 mm while it was 29. 67°C and 758 mm respectively for the period of 1973-2007. This indicates an increase of 1.43°C for temperature and reduction of 178 mm of rainfall for the two climatic periods.

6.3 Nomadic Pastoralists' Perception of Climate Variability

The surveyed pastoralist household heads were asked about their perceptions of changes in various climate variables over the past 19 years. The most important components were yearly temperature, rainfall, drought, and the incidence of pests and diseases. Perceptions on climatic components were categorized into three: increased, decreased and remaining same. Figure 5 shows Pastoralist perception of changes in Rainfall, Temperature, Drought, Pests and Diseases incidences in T/ Mafara from 1996-2015.

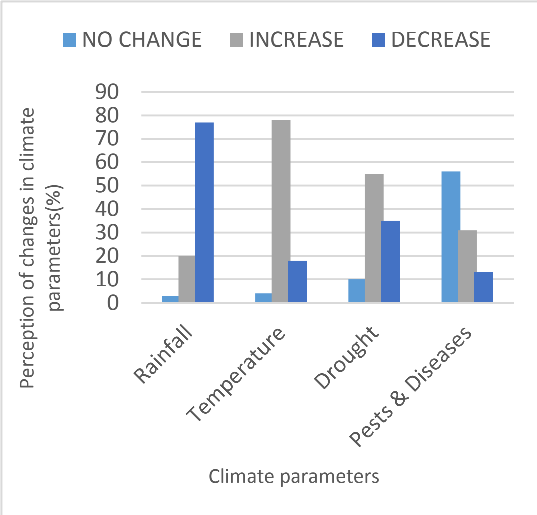

Figure 5: Pastoralists perception of changes in Rainfall, Temperature, Drought, Pests and Disease.

From the graph (Figure 5) we can see that majority (77%) of the pastoralists perceived decrease in rainfall, while 78% perceived increase in temperature, above half (55%) observed increase in drought, whereas 31% perceived increase in pests and diseases.

The accuracy of farmers' perceptions of climate change was assessed by comparing their perceptions of long-term changes in temperature and precipitation with climate trends recorded at nearby meteorological stations. This perception was confirmed by the statistical record for Zamfara State between 1986 and 2015, which showed the increase in temperature occurring mostly in the summer months (October to March) and varying trend in rainfall. An analysis of climate data at the regional level shows the same general trend of increasing temperature with some minor variations in terms of the severity of the increase and its timing.

Thus, farmers' perceptions are supported by the statistical record. Additionally, the forgoing analysis of pastoralists' observation of climate variability is in harmony with the work of Ishaya and Abaje, (2008) in which 73% of the respondents were of the opinion that temperature has been increasing over the past few decades. This is also in agreement with the study of Oladipo (2011) that the country has been experiencing temperature increase of about 0.2°C – 0.3°C per decade in all its ecological zones. However, decrease in rainfall as perceived by the pastoralists is in sharp contrast with similar studies in the region. For instance, Ati, Iguisi, and Afolayan (2007); Odekunle, Andrew and Aremu, (2008) and Abaje, Ati, Iguisi, and Jidauna, (2013) using recorded rainfall data observed that the sudano-sahelian zone of Nigeria is now experiencing wetter conditions in recent years. Hence, Odjugo (2009) opined that while rainfall duration and amount is decreasing, the intensity is increasing.

6.4 Effects of Climate Variability on Nomadic Pastoralists' Demographic and Socio- Economic Activities

Table 4 displays the ranking of the effects of climate variability as perceived by pastoralists based on their level of severity. The results show that all the perceived effects were very severe because they all ranked 0.76 and above on the relative importance index (RII). However, decreased animal productivity (0.88), decrease in forage availability and quality (0.87) and exacerbated conflicts over scarce resources (0.85) ranked higher on the relative importance index (RII).

Table 4: Pastoralists perceived impacts of climate variability.

	1	2	3	∑f	∑fx	$\bar{\chi}$	RII	R
DAP	10	70	170	250	660	2.6	0.88	1
IAM	40	50	160	250	620	2.5	0.83	4
DFAQ	30	40	180	250	650	2.6	0.87	2
RIL	40	70	140	250	600	2.4	0.80	6
RWQA	50	70	130	250	580	2.3	0.77	7
ECSR	30	50	170	250	640	2.6	0.85	3
IIPD	50	70	130	250	580	2.3	0.77	7
SRVS	40	60	150	250	610	2.44	0.81	5

Legend: 1=Neutral, 2= Disagree, 3= Agree

Source: Field work, 2015

DAP=Decreased Animal Productivity, **IAM**=Increase in Animal mortality, **DFAQ**=Decrease Forage availability and quality, **RIL**=Reduction in Income from Livestock, **RWQA**=Reduction in water quality and availability, **ECSR**=Exacerbated conflicts over scarce resources, **IIPD**=Increase incidence of pests and diseases, **SRVS**= Shift in rangeland vegetation structure or boundaries.

The high impacts of climate variability and change on pastoralists' socio-economic activities cannot be unconnected with the increase in temperature, high rainfall variability, and high incidence of drought occurrences in the area as revealed in Figure 5. This could impair animal performance and hence results to increase in the cost of meat, milk and other animal products as well as high incidence of crop farmers-headers conflict in the study area.

The results of the pastoralists perceived effect of climate variability agreed with BNRCC (2008) that the impact of climate change can be vast in Nigeria. Hence, Ayanda, Oyeyinka, Salau, and Ojo, (2013) remarked that some stable ecosystems such as the Sahel Savanna may become vulnerable because warming will reinforce existing patterns of water scarcity and increase the risk of drought in Nigeria and indeed most countries in West Africa. Similarly, NRC (2002) confirmed that climate change could impact the economic viability of livestock production systems worldwide.

6.5 Pastoralists Coping Strategies

Table 5 presents information on various coping strategies adopted by pastoralists in the study area. From Table 5, the following inferences can be easily drawn. The predominant coping strategies adopted by pastoralists in the study area include; moving long distances to find pasture ($\bar{\chi}$=2.8), herd splitting ($\bar{\chi}$=2.7), praying to God ($\bar{\chi}$=2.6) and water harvesting($\bar{\chi}$=2.7)and concentrate feeding ($\bar{\chi}$=2.6). These strategies had a mean score above the standard reference mean of 2.5, hence considered the most significant coping strategies implemented in the study area. The submission of Ayanda, Oyeyinka, Salau, and Ojo (2013) is in line with this finding that more than half of the pastoralists engaged in the use of crop residue as feed supplements and herd size reduction as measures to ameliorate adverse effect of climate variability on their activities.

Table 5: Pastoralists' coping

Coping Strategies						
	1	2	3	$\sum f$	$\sum fx$	$\bar{\chi}$
MLD	12	18	220	250	708	2.8
UCR	40	40	170	250	630	2.5
DLA	20	100	130	250	610	2.4
HDS	10	60	180	250	670	2.7
HDK	20	90	140	250	620	2.5
HDF	40	100	110	250	570	2.3
CTF	10	80	160	250	650	2.6
WHT	20	30	200	250	680	2.7
PTG	20	50	180	250	660	2.6

Standard Reference Mean: 2.5
Sources: Fieldwork, 2015
Legend: 1=Neutral, 2= Disagree, 3= Agree

Note: MLD=Move Long Distances to find Pasture, **UCR**=Use of crop residue as animal feeds, **DLA**=Diversification of livelihood activities, **HDS**= Herd splitting, **HDK**=Herd destocking, **HDF**=Herd Diversification, **CTF**= Concentrate Feeding, **WHT**=Water Harvesting, **PTG**=Praying to God

Similarly, Kirimi, John and Nalunkuuma (2013) opined that migrating to other areas was highly practiced by pastoralists in Kenya during shortage of grasses. Discussion with key informants confirmed this, as one of the opinion leaders aptly stated:

We don't stay in one place, any where we notice there is enough grass for cattle we move there, especially during the dry season we used to go far to the southern and middle belt region of the country, where there are enough grasses and water for our animals. Nowadays our movements have been very restricted due to conflicts with crop farmers (Ibrahim, 06/06/ 2015)

6.6 Barriers to Adaptation Options

Table 6 shows data on barriers to coping strategies in the area of study. The analysis of barriers to adaptation to climate change presented in Table 6 indicates that there are three major constraints to adaptation in the study area. These are conflict over scarce resources-pasture and water ($\bar{\chi}$ =2.8), agricultural expansion limiting livestock movement ($\bar{\chi}$ =2.8) and minimal extension services ($\bar{\chi}$=2.7).

Table 6: Barriers to coping strategies

Coping Strategies						
	1	2	3	∑f	∑fx	$\bar{\chi}$
COS	10	40	200	250	690	2.8
LMA	30	96	124	250	594	2.4
IKC	23	85	142	250	619	2.5
IPC	48	66	136	250	588	2.4
MES	11	42	197	250	686	2.7
URB	21	96	133	250	612	2.4
POV	45	80	125	250	580	2.3
AEM	9	30	211	250	702	2.8
LSI	44	64	142	250	598	2.4

Source: Field Survey, 2015
Standard Mean Reference: 2.5
Legend: **COS**=Conflict over scarce resources-pasture and water, **LMA**=Limited Market Access, **IKC**=Inadequate Knowledge and Information on Climate Variability, **IPC**= Inappropriate policy, **MES**= Minimal Extension Services, **URB**= Undefined Regional Boundaries, **POV**= Poverty, **AEM**= Agricultural Expansion Limiting Livestock Movement, **LSI**=Limited Skill to engage in new income

Other impediments include; limited access to market ($\bar{\chi}$ =2.4), inappropriate policy ($\bar{\chi}$ =2.4) in adequate knowledge and information on climate variability ($\bar{\chi}$ =2.5) and limited skill to engage in new income ($\bar{\chi}$ =2.4). Further probing with FGDs participants revealed that some of these desired strategies, such as development of water sources, concentrate feeding and grain and fodder storage facilities require an initial investment capital that is beyond the reach of many households. Access to improved livestock breeds and suitable veterinary services are also problematic, because of financial constraints. Insecurity and conflicts associated with livestock raids are also major constraints to some of the coping responses in the study area. A discussant succinctly declared:

We are aware of some of the new and better ways of taking care of cattle but not all of us have the money to purchase the materials. Please help us tell government to assist us in the area of bore holes, health facilities and conflict management (Umaru, 06/06/2015).

6.7 Relationship between Climate Variability (Rainfall, Temperature, Drought, Pests and Diseases) and Pastoralists' Perception of its impact on livestock production.

Correlational analysis was used to quantify effects of temperature, rainfall, drought and pests and diseases on livestock production. The Pearson Product Moment Correlation coefficient was used to test the significant relationship at 0.05 and 0.01. Table 7 depicts information on the relationship between climate variability and pastoralists' perception of the impact on livestock production. The variable pairs indicated in Table 7 represent the significant correlation the hypothesized perception of climate change indicators has on animal production.

Hence, in Table 7, rainfall (r = 0.301, 0.302 and 0.355, p ≤ 0.000) was found to impact significantly on the perception that animal performance is declining, forage availability and quantity are decreasing as well as reduction in income from livestock. The implication of this is that rainfall affects the availability of animal feed and water for livestock rearing. Changes in rainfall patterns will likely affect the quantity and quality of water available for livestock consumption.

Table 7: Correlation Between Pastoralists' Perception of Climate Variability and Impact on Animal Production

Variable pairs	r- value	p-value	Decision
Decrease in Rainfall and decreased animal performance	0.301	0.000	Significant
Decrease in Rainfall and decreased forage availability and quantity	0.302	0.000	Significant
Decrease in Rainfall and reduction in income from livestock	-0.355	0.000	Significant
Increase in Temperature and increase in animal mortality	-0.633	0.000	Significant
Increase in Temperature and increased incidence of pests and diseases	0.456	0.000	Significant
Increase in Drought and reduction in water quality and availability	-0.745	0.000	Significant

**Correlation is significant at 0.01 level (2-tailed). Source: Field Work, 2015

This would affect livestock health, with potential impacts on the quality of meat and milk. Studies by Solomon (2001), Kgosikoma (2006) and Abdeta (2011) influences herd dynamics in terms of herd die-off and lower birth rates, which also considerably affects milk production.

6.8 Relationship Between the Socio-Economic Characteristics of the Pastoralists and their Coping Strategies to Climate Change.

To assess the association between socio-economic characteristics of agree with the preceding findings that there are correlations between rainfall variability and livestock population dynamics-rainfall variability greatly pastoralists and their coping strategies in Zamfara and Katsina states, a chi square analysis was conducted (Table 8). The table revealed that sex has a significant and positive relationship (χ^2= 321.898, P≤ 0.05) with coping strategies for climate extremes. A

Table 8. Association Between Pastoralists' Socio-Economic Characteristics and Coping Strategies to Climate Change (n = 250)

Variable	Df	χ^2cal.	χ^2tab.	Prob.	Comment
Gender	1	321.898	3.841	000	Significant
Age	3	219.664	7.815	000	Significant
Marital Status	3	1046.730	7.815	000	Significant
Household Size	3	326.248	7.815	000	Significant
Education	4	168.150	9.488	000	Significant
Income	4	79.062	9.488	000	Significant
Occupation	4	793.807	9.488	000	Significant
Size of Cattle	4	147.639	9.488	000	Significant
Types of animal reared	5	270.168	11.070	000	Significant
Duration	3	270.168	7.815	000	Significant

Source: Field work, 2015.

possible implication of this relationship is that male headed households are likely to choose more laborious and risky strategies such as livestock migration, herd splitting and feeding on crop residue than the female headed household. This is due to the physical and natural capability difference in male and female. In addition, male headed households have a greater likelihood of acquiring information regarding different farming technologies than their female counterpart due to the traditional social barriers placed on women. In most cases, women are found to adopt less laborious strategies like selling of firewood and charcoal, petty trades, feeding on wild fruits and roots, reducing food intake etc.

The preceding investigation is in concurrence with Asfaw and Admassie (2004) who found that male headed households have a greater possibility of obtaining information regarding new farming technologies as well as undertake riskier ventures than female headed households. In a related vein, Tenge and Hella (2004) observed that female headed households are not likely to adopt soil and water conservation practices as women might have limited access to information, land, and other resources caused by traditional social barriers.
On the contrary, Nhemachena and Hassan (2007) asserted that female headed households are more likely to adopt different methods of climate change adaptation than male headed households.

Table 4.9 has also revealed that age (χ^2 =219.664, p≤0.05) of pastoralist is significantly related to the coping strategies. Effect of age on coping strategies has been varied in the literature. First and foremost, age may have a negative effect on the decision to adopt new farming technologies basically because older farmers may be more risk-averse and therefore, less likely to be flexible than younger farmers.

Gbetibouo (2009) and Ayanda, *et al.* (2013) corroborate the foregoing results that the youth are highly travelled, venturesome and can take on risky ventures more than the adults.

Second, age could have a positive effect on the decision of the farmer to adopt for the fact that older farmers may perhaps have more experience in farming and as a result, more capable of assessing the features of a new farming technology than the younger adverse effects of climate change. On the other hand, Aymone (2009) established that education level and gender did not have a significant impact on the probability of choosing any adaptation techniques.

With regards to income of respondents, Table 4.9 has demonstrated a significant connection (χ^2= 79.062, p≤ 0.05). Income of the farmers, irrespective of sources- whether farm or nonfarm, signifies the wealth of individual households. Consequently, Knowler and Bradshaw (2007) indicate that farmers' income has a positive relationship with the uptake of farming technologies as any adoption/adaptation process requires that the farmer has sufficient financial wellbeing.

Household size of respondents is also significantly related (χ^2 =326.248, p≤ 0.05) to their coping strategies. Rogers (2003) asserted that the larger the size of the household the ease with which tasks

farmers. Maddison (2006) and Nhemachena and Hassan (2007) supported the aforementioned that experience in farming increases the probability of uptake of adaptation measures to climate change.

Regarding educational attainment of respondents, Table 4.9 revealed a positive and significant relationship (χ^2 =168.150, p≤ 0.05) with coping practices. Basically, educated farmers are expected to have more knowledge and information about climate change and agronomic practices that they can use in response. Ayanda, *et al.* (2013) concurred with the forgoing view by admitting that educational attainment will enable farmers to access information on animal husbandry practices through the print or electronic media that can assist them to mitigate

can be accomplished and innovations are adopted. Similarly, Croppenstedt, Demeke and Meschi (2003) argued that larger households have a larger pool of labour and as a result, they are more likely to adopt agricultural technologies than smaller households. Furthermore, Yirga (2007) established that households with large families may be forced to divert part of the labour force from farm to off-farm activities in an attempt to earn some income that can ease the consumption pressure imposed by a large family in the face of climate change.

7. CONCLUSION AND RECOMMENDATION

It is evident from this study that pastoralists are experiencing change in climate and have been undergoing series of adaptations in response to climate variability already. However, the persistent increase in the magnitude of change is expected to present heightened risk, new combinations of risks and potentially grave consequences, which could stifle their ability to cope effectively.

Irregular rainfall pattern affects the availability of water and pasture which is crucial to animal productivity. Consequently, livestock are usually subjected to long treks to find water and pasture in the more southerly areas of the country during the dry seasons. Hence, reduction in rainfall and its inter-annual variability in the study area necessitates adaptation of pastoralists and environmentally induced conflicts especially by the cattle rustlers as well as crop farmers owing to space contestation.

The inconsistency of pastoralists' perception of climate variability with recorded climatic data in the study area indicates low knowledge of climate variability and change among the pastoralists. This could pose a threat to acceptance of new innovations in adaption strategies by pastoralists in the study area.

Excessive warming hinders livestock production and reproduction by reducing animal weight gain and dairy production as well as income. Hence, the increasing warming trend in the study area poses a threat to animal performance. In addition, the decline in animal productivity, reduction in income from livestock farming and shortage in forage availability and quantity identified in the study area have shown that pastoralists in the study area are highly constrained by unproductive agricultural practice and hence prone to out-migration to favourable environment or diversification of livelihood.

Basically, Fulani herdsmen, in the seasons when rainfall is very low and the graze lands are unable to sustain the population of livestock in the zone, geared their livestock to farmland area in the zone or down south in the country, situation which has caused brutal fight between the herdsmen and farmers. Examples include conflict in Barkin- Ladi and Shendam in Plateau State in June to July 2002 between indigenous tribes and the nomad fulani, over farm lands and grazing areas, incessant crises between Agatu people and Fulani in Benue State and rampant cases of cattle rustling in the north-western zone of the country. Hence, climate change is the bane of incessant resource use conflicts in the study area.

Based on the findings of this study, it is suggested that government and other development actors should put in place the following policy measures to mitigate the adverse effects of climate change on pastoralists.

I. **Breed Improvement:** Government and NGOs should promote the use of improved cattle breeds by introducing exotic breeds have high resistance to drought and diseases at subsidized prices to pastoralists.
II. **Improvement in livestock health care:** Government and other development partners should invest in equipping and establishment of veterinary health centres in pastoral communities as well as training educated pastoralists in the correct use and application of veterinary drugs.
III. **Improvement in the extension service:** This could be achieved by increasing extension farmers' ratio and making the extension

services more accessible to pastoralists

IV. **Improving climate information forecasting and dissemination:** Since adaptive capacity is relatively determined by knowledge (local knowledge inclusive) and the awareness of climate change threats, it will be vital to increase pastoralists' awareness of potential climate related hazards, as well as suitable mechanism to address such risks. This could be done through local awareness campaign, mainstreaming climate change issues into other trainings and conducting awareness meetings.

8. REFERENCES

Abaje, I. B., Ati, O. F., Iguisi, E. O., and Jidauna, G. G. (2013). Droughts in the Sudano-Sahelian Ecological Zoneof Nigeria: Implications for Agriculture and Water Resources Development. *Global Journal of Human Social Science (B): Geography, Geo-Sciences and Environmental*, 13(2): 1-10.

Abdeta, A. (2011). *Effects of Drought on Cattle Herd Dynamics and its Implication on Local Livelihood Systems in Borana, Ethiopia*. Food Security Centre (FSC) Brief No 1, 16.

Andrew, M., Bruce, E., Bismark, A., & Bern, L. (2016). Farmers' perception and adaptation practice to climate variability and change: a case study of the Vea catchment in Ghana. *Springerplus*, 5(1), 830.

Asfaw, A., and Admassie, A. (2004). The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia. *Agricultural Economics*, 30 (3), 215–228.

Ati, O. F., Iguisi, E. O., and Afolayan, J. O. (2007). Are we experiencing drier conditions in the sudano-sahelian zone of Nigeria? *Journal of Applied Science and Resources*, 3(12): 1746-1751.

Ayanda, I., Oyeyinka, R., Salau, S., and Ojo, F. (2013). Perceived Effects of Climate Change on Transhumance Pastoralists in Ogun State,Nigeria. *Global Journal of Human Social Science (B)*, 13(1):38-47.

Bruin, K. (2011). An Economic Analysis of Adaptation to climate Change under Uncertainty. Unpublished Doctoral Dissertation, University of the Wageningen, Netherlands.

Croppenstedt, A., Demeke, M. and Meschi, M. (2003). Technology adoption in the presence of constraints: the case of fertilizer demand in Ethiopia. *Review of Development Economics*, 7 (1), 58–70.

Deressa, T., Hassan, R. M., Alemu, T., Yesuf, M., and Ringler, C. (2008). *Analysing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia,IFPRI Discussion Paper 00798*. International Food Policy Research Institute.

Deressa, T., and Hassan, R. (2009). Economic Impact of Climate

Change on Crop Production in Ethiopia: Evidence from cross-section maesures. *African Journal of Economics*, 18:529-554.

Dineshsingh, S., & Nilotpal, G. (2014). Impact of Climate Change on Livestock Production: A Review. *Journal of Animal Research*, 4(2),223-239.

EPA (United States Environmental Protection Agency). (2011). *Climate Change Science Overview.*

Food and Agricultural Organisation(FAO). (2008). *Climate Change Adaptation and mitigation in the Food and Agriculture Sector.* pp56: High -level conference on food security:the challenges of climate change and bioenergy.

Fosu-Mensah, B., & Vlek, P. M. (2012). Farmers' perception and adaptation to climate change: a case study of Sekyedumase district in Ghana. . *Environ Dev Sustain.*, 14:495–505.

Falola, A. F., Segun, B., Akangbe, J. A., and Ibrahim,H.(2012).Climate Change Mitigation Activities and Determinants in the Rural Guinea Savannah of Nigeria.*Sustainable Agriculture Research*, 1:(2):170-177.

FAO, (2006). Steinfeld H, Gerber P, Wassenaar T, Castel V, Rosales M, de Haan C (eds.) Livestock's long shadow. Environmental issues and options. http://fao.org/docrep

Gbetibouo,G.(2009). *Understanding Farmers' Perceptions and Adaptations to Climate Change and Variability: The Case of the Limpopo Basin, South Africa.* . Washington DC: IFPRI.

Intergovernmental Panel on Climate Change (IPCC). (2001). *Climate Change: The scientific basis.* . New York: Cambridge University Press.

International Panel on Climate Change (IPCC). (2007). *Climate Change 2007: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the IPPC.* . Cambridge: Cambridge University Press.

Ishaya, S., and Abaje, I. B. (2008). Indigenous people's perception on climate change and adaptation strategies in Jema'a Local Government Area of Kaduna State, Nigeria. *Journal of Geography and Regional Planning,*, 1(8):138-143.

Kabubo-Mariara, J. (2008). Climate change adaptation and livestock activity choices in Kenya: An economic analysis. *Natural Resource Forum* , 32; 131-141.

Kehinde, E. (2014). Conflict Management Strategies to reduce consequences of livelihoods of fulani cattle herds and farmers in Kabba Bunnu,Kogi State,Nigeria. *Nigerian Journal Of Rural Sociology*, 14(2):15-21.

Kimaro, E. G., & Chibinga, O. C. (2013). Potential impact of climate change on livestock production and health in East Africa: A review. *Livestock Research for Rural Development*, 27(7): 127-145.

Kgosikoma, O. (2006). *Effects of Climate Variability on Livestock Population Dynamics and Community Drought Management in Kgalagadi, Botswana.* Norway: M.sc Thesis, Norwegian University of Life Sciences.

Kirimi, N., John, G. M., and Agnes, O. N. (2013). Climate Change Challenges and Adaptation Strategies among the Pastoralits of Laikipia county Kenya.*International Journal of Agricultural Extension*, 1(1):20-30.

Knowler, D., and Bradshaw, B. (2007). Farmers' adoption of conservation agriculture: a review and synthesis of recent research. . *Food Policy* , 32 (1), 25–48.

Maddison, D. (2006). *The perception of and adaptation to climate change in Africa. CEEPA* . University of Pretoria, South Africa: CEEPA Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa.

Maddison, D. (2007). *The perception of and adaptation to climate change in Africa.* Washington D.C., USA: The World Bank.

Maharjan, S.K., Sigdel, E.R., Sthapit, B.R., Regmi, B.R. 2011. Tharu community's perception on climate changes and their adaptive initiations to withstand its impacts in Western Terai of Nepal. Int NGO J 6(2):35–42.

Mohammed, I., Muazu, E., Yahaya, S., & Midat, J. (2014, July 15). Food Insecurity Looms as Cattle Thieves Roam Free. *Leadership Newspapers*, pp.leadership.ng/news/food-insecuritylooms-cattle-thieves-roam- free.

Montle, B., and Teweldemedhin, M. (2014). Assessment of farmers' perceptions and the economic impact of climate change in Namibia:Case study on small-scale irrigation farmers (SSIFs) of Ndonga Linena Irrigation project . *Journal of Development and Agricultural Economics*, 6(11):443-454.

Muhammed, I., Belel, A., & Muhammed, U. (2015). An Assessment of Farmer-Pastoralists Conflict in Nigeria Using GIS. *International Journal of Enginnering Science Invention*, 2(7),74-83.

Nhemachena, C., & Hassan, R. (2007). *Micro-Level Analysis of Farmers Adaption to climate change in Southern Africa.* Washington DC: International Food Policy Research Institute, Washington.

NRC (2002). *Abrupt climate change inevitable surprises.* Washington, Dc.: National Academy press.

Odekunle, T., Andrew, O., and Aremu, S. (2008). Towards a wetter Sudano-Sahelian ecological zone in twenty-first century Nigeria. *Weather*, 63(3):66-70.

Odjugo, P. (2009). Quantifying the cost of climate change impact in Nigeria: Emphasis on wind and rainstorms. *Journal of Human Ecology*, 28(2):93-101.

Odjugo, P. A. (2010). Adaptation to Climate Change in the Agricultural Sectorin the Semi-arid Region of Nigeria. *2nd International Conference:*

Climate, Sustainability and Development in Semi-arid Regions, (pp. 1-14). Fortaleza - Ceará, Brazil.

Oladipo, E. (2011). The challenge of climate change for Nigeria: An overview. In E. O. Iguisi, O. F. Ati, R. O. Yusuf, and A. E. Ubogu, *Climate Change Impacts: Risks and Opportunities* (pp. 22-44). Zaria: Proceedings of the International Conference of the Nigerian Meteorological Society held held at Ahmadu Bello University,Nigeria,13th-17th November,2011.

Onubuogu,G., Chidebelu, S., and Eboh, E. (2013). Enterprise Type, Size and Allocative Efficiency of Broiler Production in Imo State, Nigeria. *International Journal of Applied Research and Technology*, 2(6): 10 – 19.

Osotimehin,K.O.,Tijani, A. and Olukomogbon, E. (2006).An economic analysis of small scale dairy milk processing in Kogi State, Nigeria *Livestock Research for Rural Development*, 18(117)Retrieved:November14,2015,fromhttp://www.lrrd.org/lrrd18/11/osot18157.htm.

Ozor, N. (2009). Understanding Climate Change. Implications for Nigerian Agriculture,Policy and Extension. *National Conference on Climate Change and the Nigeria Environment.* Nsukka: Department of Geography,University of Nigeria.

Solomon, D. (2001). *Cattle Population Dynamics in the Southern Ethiopian Rangelands.* Utah State University, Logan, Utah, USA.: Research Brief 01-02.The GL-CRSP Pastoral Risk Management Project (PARIMA).

Osman, M. (2015). *Analysis of factors influencing women's decision to adapt to climate change: The case of rural women in Haramaya District, Eastern Ethiopia.* Ethiopia: A thesis submitted to the school of natural resources management and environmental sciences, school of graduate studies, Haramaya University.

Smit, B. and Olga, P. (2001). *Adaptation to Climate Change in the Context of Sustainable Development and Equity.* In: McCarthy, J. J., O. F. Canziani, N. A. Leary, D. J. Dokken and K. S. White (eds.): Climate Change 2001: Impacts, Adaptation, and Vulnerability-Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

Smith, J.B., Vogel, J.M. & J.E. Cromwell (2009). An architecture for government the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Uncertainty. Unpublished Doctoral Dissertation, University of Wageningen, the Washington D.C., 2008. Washington, D.C., IFPRI.

Sathaye, J. A., and Christensen, J. (1998). Mitigation and Adaptation Cost Assessment: Western Terai of Nepal. *Int NGO J* ,6(2):35–42.

Temidayo, G. (2011). Factors influencing the perception and choice of adaptation measures to climate change among farmers in Nigeria. Evidence from farm households in Southwest Nigeria. *Environmental Economics*, 2(4),74–83

Tenge De Graff, J. and Hella (2004) Social and Economic Factors Affecting the Adoption Of Soil and Water Conservation in West Usambara Highlands, Tanzania. *Land Degradation And Development*, 15 (2), 99–114.

UNFCCC (2012) *United Nations Framework Convention on Climate change*. . Retrieved from Retrieved from www.unfccc.int/adaptation/items/2973.php.

World Bank, 2010. The Economics of Climate Change. A Synthesis Report. Final Constitution Draft. EACC.

Yirga, C. (2007). *The dynamics of soil degeradation and incentives for optimal management in Central Highlands of Ethiopia.* Pretoria,South Africa: Unpublished PhD. Thesis. University of Pretoria.

GLOBAL ECONOMIC CRISIS AND MARKET TREND IN LOCAL TIMBER IN OGUN STATE, NIGERIA: THE CLIMATE CHANGE ADVANTAGE

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Abstract

The study examined the effect of global economic crisis (2005 – 2009) on forest conservation and carbon sink with contribution towards climate change. Ogun State was zoned into four strata based on ethnic and geographical characteristics. The strata are Egba, Yewa, Ijebu and Remo. Empirical data from Ogun State Ministry of Forestry were subjected to statistical analysis to examine the demand trend of local timber in the market. The result shows that there was low demand and weak market between 2005 and 2009. Timber demand dropped from 58,468 in 2005 to 13,540 in 2009 representing 76.9% decrease. Consequently, sawmills decreased from 290 units in 2005 to 207 in 2009 representing 39.2% decrease. Both softwood and hardwood species were exploited The climate change advantage was identified through the amount of carbon sink estimated at 8,470mg C for 110ha of natural species based on previous estimates. This translates into reduced forest degradation and deforestation (REDD) and the resiliency of the forest allowed for recovery. It is recommended that forest policy must encourage reduced exploitation through ecocentric ideology to allow immature species to grow and improve carbon sequestration through forest resiliency and consequently protect the environment from greenhouse gas emission.

Keywords: Global economic crisis, Forest conservation, Carbon sink, REDD and REDD+

Introduction

The current economic crisis in the world has been described as economic meltdown – a word that captured the reality of the present situation at the global level. Global financial crisis have long historical background that dates back to 1929 during Wall Street crash and the ensuing depression that engulfed the entire world economy (Mailafia, 2008). The global financial crisis was expressed as depression and depreciation in terms of social amenities. Accordingly, Mailafia (2008) noted that expressing failure of scientific experiments as loss of few rats or negative results from an experiment sound mild to note, however, failure of economic experiments affect lives and entire societies if not the global communities as witnessed with the economic downturn. Therefore, economic experiments must ensure judgment and ethical responsibility to protect man and the society. Perhaps, it suffices to note that the relationship of economic failure with threat to the environment was mostly not reviewed with economic crisis. The industrial revolution of the 19th century in Britain was a pointer to the relationship between economy and the environment. The industrial revolution brought significant economic transformation but with consequences on the environment. There was deforestation and degradation with decrease in forest estate or appropriately environmental degradation. Therefore, there is a strong linkage between the economy and the environment. Nisbet (1991) reported that the earth was damaged and the damage is becoming worse. Thirgood (1981) reported that forests decreased from 6.2 billion ha to 4.3 billion ha. This period marked the beginning of carbon emissions to the atmosphere without adequate record of greenhouse gas emission.

Nature and Economic Crisis

Financial booms and busts are not new phenomena. They remained inherent features of the world capitalist economy since the industrial revolution of 19th century in England. The industrial revolution brought economic transformation and improved the welfare of the people. However, the consequences that followed the revolution remained till date and have continued to hunt man. Thirgood (1981) reported that the industrial revolution started the process of deforestation which has increased over the years to the point that the well-being of people, animals and plants are threatened. The resulting impacts of the multiplier effect are potentially irreparable. Examples include greenhouse gas effect, ozone depletion, acid rain, global climate change, marine pollution, toxic wastes, desertification and the loss of forests categorized as avalanche and natural catastrophes. Perhaps, it suffices to mention that the first major global depression occurred in 1870s, followed by 1907 Bankers panic and 1929 Wall Street crash that led to worldwide depression and world war. The totality of the effect is expressed through poor GDP and GNP and low purchasing power of consumers (Mailafia, 2008). Consequently, the forest and its resources are used to abate world economic crisis especially in developing nations where the fragile ecosystem is the source of livelihoods. Thus, the threat posed by environmental stress and environmental impacts in different parts of the globe remained as threat that affects the future of the whole globe. This therefore underscores the significance of this paper with the objectives below:

- To examine the effect of economic meltdown on forest resources exploitation.
- To identify the effect of the forest exploitation on climate change.

Methodology

The Study Area

The study covers round wood consumption in Ogun State, southwest, Nigeria. Ogun State has an estimated population of 3,728,096 people over land area of 16,762.06km^2 (Oyesiku, 1992; Awojuola, 2001; NPC, 2006). Ogun State is situated between latitude 7°15’N and 6° and longitude 3°20'E and 4°37'W. The climate of Ogun State has tropical characteristics with rainy season starting in March – October followed by dry season, November – February. The mean annual rainfall varies from 128cm in the southern part of the State to 105cm in northern areas. Average monthly temperature ranges from 23°C in July to 32°C in February. The northern part of the state has transited to derived Savanna while the southern part of the State has relics of Mangrove swamp.

Major economic activity in the state is agriculture providing income and employment to a larger percentage of the population. Cultivated crops are yam, maize, cassava, vegetables, plantain and cash crops such as cocoa, cashew, oil palm and rubber (Ogun State, 2001). About 20 percent of the state is preserved as forest reserves

(26.352ha) mainly with tree crops of Gmelina, Teak and Pine. Other conomic activities include tailoring, woodworks and carpentry, cloth weaving (tie and dye), sawmilling and metal fabrication. Over 38% of the state populations were categorized as poor or moderately poor (NBS, 2004).

Data Collection

The study looks into market trend in Ogun State, Nigeria. The study was based on the results of different studies on carbon sink; financial returns for conservation activity and the number of individual trees per hectare in natural forests. Detailed secondary information on wood consumption was available from Ministry of Forestry in Ogun State, Nigeria. Ogun State was divided into ten zones based on existing log control units of Abeokuta, Owode Egba, Ota, Ijebu-Ode, Ogbere, Iperu, Sagamu, Ayetoro, Ilaro and Ijebu Igbo.

Data Analysis

Data collected were analysed and discussed using descriptive statistical procedure. Conservation advantage from unexploited tree species in terms of carbon sink was estimated. Carbon sink estimate was projected from previous studies carried out in Sri Lanka disturbed forest (Baishya *et al,* 2009) and other areas in the base period. The number of individual trees per hectare in Ogun State was based on a recent study (Oladoye, 2012) and this was estimated at 446 individuals per hectare. The expected carbon sink was estimated as follows:

$$Cs = Ev \times Tf \qquad \text{...(1)}$$

Where:

Cs= Carbon sink

Ev= Estimated carbon sink value in a disturbed forest (Sri Lanka)

Tf= Total unexploited forest (Ogun State, Nigeria) in hectares

The projected contribution to climate change was also estimated based on the quantity of carbon sink in Ogun State as part of global green house gases GHGs. The projected economic return from conservation activities was estimated using the per hectare calculation of carbon sinks in tropical forest for developing countries (Butler *et al,* 2009) and the financial return for the conservation activities in the tropics based on REDD and its more evolved form of REDD+.

Results and Discussion

Wood consumption in Ogun State (Roundwood) in Table 1 shows the annual roundwood consumption that is annual timber cut in 2005 before economic recession.

Table 1: Annual timber exploitation in 2005

Location	Zones	Quantity exploited	Cumulative total	Cumulative % of total	No of species
Abeokuta North, Abeokuta South, Ewekoro, Odeda	Abeokuta	1,532	1,532	2.6	49
Obafemi Owode	Owode-Egba	1,648	3,180	2.82	42
Ifo, Ado-Odo Otta	Otta	1804	4984	3.09	43
Ijebu Ode, Ijebu N.E, Odogbolu	Ijebu-Ode	4,284	9268	7.33	28
Ijebu East, Ogun Water Side	Abigi and J6	1,616	10884	2.76	41
Ijebu North	Ijebu Igbo	29,450	58468	50.37	27
Remo North, Ikenne	Iperu	592	11476	1.01	32
Sagamu	Sagamu	8,163	19639	13.96	36
Yewa North, Imeko Afon	Ayetoro, Oja Odan Imeko	5,166	24805	8.84	23
Yewa South	Ilaro, Owode Yewa	4,213	29018	7.21	44
Total	**10**	**58,468**			

From table 1 above, over 58,000 units of roundwood (logs) of different tree species were exploited. These species cover both softwood and hardwood and consequently contributed to deforestation and emission in the state. The pattern of wood consumption in 2005 increased across the zones with rising population and industrialization. This is in line with ITTO (2010) that noted that annual sawn wood consumption was expected to increase from 456 million m^3 in 1990 to 245 million m^3 in 2010. In fact, there was sawn wood consumption increase but not as projected from 1990 to 2010. In 2007, the annual cut of wood consumption decreased significantly as the phenomenon of economic recession was gradually showing its ugly face (Table 2). Furthermore, by 2009, annual timber cut dropped to 13,540 in Ogun State (Table 3).

Table 2: Annual timber exploitation in 2007

Location	Zones	Quantity exploited	Cumulative total	Cumulative % of total	No of species
Abeokuta North, Abeokuta South, Ewekoro, Odeda	Abeokuta	1,411	1,411	7.3	35
Obafemi Owode	Owode-Egba	1,868	3279	16.97	42
Ifo, Ado-Odo	Otta	1,052	4331	22.42	50
Ijebu Ode, Ijebu N.E, Odogbolu	Ijebu-Ode	631	4962	25.68	43
Ijebu East, Ogun Water Side	Abigi and J6	4,616	9578	49.57	34
Ijebu North	Ijebu Igbo	3,246	12824	66.37	27
Remo North, Ikenne	Iperu	1,576	14400	74.53	41
Sagamu	Sagamu	550	14950	77.38	37
Yewa North, Imeko Afon	Ayetoro and Imeko	2,110	17060	88.30	22
Yewa South	Ilaro, Owode Yewa and Oja Odan	1,192	18252	94.47	42
Ijebu East	Ogbere	1,069	19321	5.5	39
Total	10	19,321		100.0	

Table 3: Annual timber exploitation in 2009

Location	Zones	Quantity exploited	Cumulative total	Cumulative % of total	No of species
Abeokuta North, Abeokuta South, Ewekoro, Odeda	Abeokuta	791	791	5.06	12
Obafemi Owode	Owode-Egba	307	1098	8.11	19
Ifo, Ado-Odo	Otta	127	1225	9.05	8
Ijebu Ode, Ijebu N.E, Odogbolu	Ijebu-Ode	1,362	2587	19.11	11
Ijebu East, Ogun Water Side	Ogbere	3,180	5767	42.59	18
Ijebu North	Ijebu Igbo	3,565	9332	68.92	20
Remo North, Ikenne	Iperu	878	10210	75.41	25
Sagamu	Sagamu	894	11104	82.01	14
Yewa North, Imeko Afon	Ayetoro and Imeko	1,939	13043	96.33	13
Yewa South	Ilaro, Owode Yewa and Oja Odan	497	13537	99.98	14
Total		**13540**	**13,540**		

Source: Ministry of Forestry, Ogun State, Nigeria

From table 3, cumulative quantity of species exploited decreased to 19,321 that is 67% decrease. This decrease created a multiplier effect on sawmills which decreased from 290 units in 2005 to 199 in 2007 (Table 4).

Table 4: Sawmill trend 2005 – 2007

S/N	Zone	2005	2007	% change
1	Egba	95	62	(34.7)
2	Remo	29	20	(31.0)
3	Ijebu	135	100	(35.0)
4	Yewa	31	17	(45.2)
	Total	**290**	**199**	**(31.4)**

Note: Figures in parenthesis indicate percent decrease

The values of percentage change showed that Yewa zone recorded the highest number of sawmill decrease. Sawmills reduced to almost half the number from 31 in 2005 to 17 in 2007. By year 2009, the effect of the economic recession was further felt and therefore the annual timber cut further decreased. Table 5 below indicates that the annual cut decreased to 13,540. However, there was sharp difference between 2007 and 2009. The annual cut decreased by 70% but sawmill units rose from 199 to 207 units that is 4.0% increase. This was however a pointer to recovery from recession by sawmills.

Table 5: Sawmill trend 2005 – 2009

S/N	Zone	2005	2007	% change	2009	% change
1	Egba	95	62	(34.7)	57	(8.1)
2	Remo	29	20	(31.0)	27	(35.0)
3	Ijebu	135	100	(35.0)	98	(2.0)
4	Yewa	31	17	(45.2)	25	41.2
	Total	**290**	**199**	**(31.4)**	**207**	**4.0**

Figures in parenthesis indicate percent decrease

In fact by year 2009, all the zones recorded decrease in sawmills but Yewa alone recorded 41.2% increase, a factor that contributed to 2009 partial recovery that is sawmill increase of 4%. Perhaps, majority of the sawmills that were shut down have received life line support (loan) and were able to come up in addition to new ones. Yewa zone of the state is located in low land rainforest and rich in species (FAO, 1989). This account for the increase in sawmills to exploit available forest resources in the area for processing and conversion to sawnwood.

Projected economic returns of wood consumption decrease.

The economic returns from reduced exploitation or decrease in round wood consumption could be explained in terms of REDD and REDD+ meaning reducing carbon emissions from deforestation and forest degradation developed as a financial mechanism to compensate land owners, organization or governments for the value of carbon stored in forests that would otherwise be released into the atmosphere through deforestation (Miles and Kapos, 2008). Consequently, carbon credits are used to pay for forest protection, biodiversity conservation and poverty alleviation. Therefore, based on a carbon price of $18 – 46 per ton of Co_2 and using the estimate of Butler *et al* (2009), REDD+ carbon credit of $1,600 per hectare, the financial returns expected of the decreased wood consumption in Ogun State, Nigeria will be $726,000. This value has put forest protection in economically vantage and competitive position to ensure that there is reduced exploitation of roundwood from the forest towards promoting the resiliency of the forest for proper conservation. Consequently, the unexploited forest in Ogun State as part of global forest under REDD+ will mitigate climate change (through carbon capture and storage), conserve biodiversity, protect other ecosystem goods and services, increase income for forest owners and managers and help address issues of forest governance.

Contribution to Climate Change

REDD and its more evolved form REDD+ was defined in the framework of the climate change negotiations of the United Nations Framework Convention on Climate Change (UNFCCC, 2010) as policy approaches and positive incentives on issues relating to reducing emissions from deforestation and forest degradation in developing countries. There is no doubt that forests in developing countries have major human interference as source of livelihoods. Despite the level of disturbance, Van Breugel *et al* (2011) reported that secondary forest are a major terrestrial carbon sink and reliable estimates of their carbon stocks are pivotal for understanding the carbon balance and initiatives to mitigate Co_2 emission through forest management and reforestation. The unexploited forest in Ogun State, Nigeria would fall within the submission above. However, REDD+ focuses on the capacity of forests especially in the tropics to capture and store carbon. Accordingly, 1TTO (2011) reported that forest carbon occurs in living and dead above ground biomass, litter, below ground biomass (roots) and the organic soil collectively referred to as carbon pools.

Forests sequester and store more carbon than most other terrestrial ecosystem and could therefore play important role in mitigating climate change. The unexploited forests in Ogun State, Nigeria within the period of economic crisis therefore contributed immensely towards reducing greenhouse gases (GHGs: such as methane) as part of global concern to mitigate climate change. According to Houghton (2005), tropical deforestation was estimated to release 1 – 2 billion tonnes of carbon per year over the past 20 years with estimates to the contribution to global GHG emissions ranging up to 20%. However, the largest source of GHG emissions in most tropical countries is deforestation and forest degradation. Accordingly, FAO (2005) noted that in Africa, deforestation accounts for nearly 70% of total emissions. Furthermore, clearing tropical forests destroy globally important carbon sinks that are currently sequestering Co_2 from the atmosphere that is critical to future climate stabilization. Consequently, the unexploited forest formed part of the tropical global forest contributing to mitigate climate change with impacts in Ogun State as part of the globe protecting the environment from green-house gases.

Conclusion

A study of the economic recession period in Ogun State, Nigeria (2005-2009) showed that the recession brought a reduction in the consumption of roundwood (logs) in the State with significant effect on global carbon sink. FAO (2005) reported that tropical forests spread over 13.76 million km^2 and accounted for 60% of global forests and play a key role in global carbon cycle in terms of carbon flux and the volume of carbon stored. Consequently, the reduction in wood consumption in Ogun State was reflected in reduced number of wood processing centres (sawmills) which decreased by 31.4% in 2007 and slightly increased by 4% in 2009. The wood consumption decrease indicated a 70% reduction from 58,000 units to 13,540 between 2005 and 2009. Baishya *et al* (2009) reported that tropical forests act as storage facility with large quantities of carbon in vegetation and soil and also exchange carbon with the atmosphere through photosynthesis and respiration. The contribution of the wood consumption decrease to climate change mitigation was based on Sri Lanka disturbed forest of 77mg C ha^{-1} - a value considered to be low for a developing country like Nigeria where the fragile ecosystem of the renewable natural resource is a source of livelihoods for the teaming population.

Consequently, an estimated amount of 8,470mg C was considered fixed by unexploited forests in Ogun State as part of global contribution towards mitigating the effect of greenhouse gases for sustainable environment. However, using the REDD+ financial mechanism for conservation, it is expected that the wood consumption decrease would bring an economic return of $66,000 an amount capable of encouraging further conservation activities to improve the level of carbon sinks in Ogun State as part of global tropical forests. It is hereby recommended that government should put in place policies to encourage more conservation activities to benefit more from proposed REDD+ financial incentive and allow forest resiliency to improve on carbon sinks for a better future.

REFERENCES

Awojuola, E. 2001. Ogun State Investors Guide. Published by Eni-Meg Nigeria Ltd in Collaboration with Ogun State Ministry of Industries and Social Development, Abeokuta, Ogun State.

Baishya, R. Barik, S. K. and Upadhaya, K. 2009. Distribution pattern of above ground biomass in natural and plantation forests of humid tropical in northeast India. Tropical Ecology 50 (2): 295 – 304, 2009.

Butler, R. A. and Koh, P. L. 2009. REDD in the red; palm oil could undermine carbon payment schemes. Conservation letters 2: 67 – 73, 2009.

FAO, 1989. Forestry and food security. FAO Forestry paper 90, Rome, Italy.

FAO, 2005 Global forest Resources Assessment, Progress towards sustainable forest management. FAO forestry paper 147, Rome, Italy.

Houghton, R. 2005. Above ground forest biomass and the global carbon balance; Global Change Biology 11: 945 – 958, 2005.

ITTO, 2010 Annual Review and Assessment of the World Timber Situation, International Tropical Timber Organisation (ITTO), Yokohama, Japan.

ITTO, 2011 Status of Tropical Forest Management. ITTO Technical series 38, ITTO, Yokohama, Japan.

Mailafia, O. 2008. Nigeria and the Global Financial meltdown. The Nigerian Muse: That the world may know. www.nigeriamuse.com

Miles and Kapos, V. 2008, Reducing greenhouse gas emissions from deforestation and forest degradation; Global land use implications, Science 320: 1454 – 1455, 2008.

NBS, 2009. National Bureau of Statistics. Facts and Figures about Nigeria. National Bureau of Statistics, Abuja, Nigeria.

Nisbet, E. G. 1991. Nigeria Environment. A National Profile, NEST, Ibadan, Oyo State Nigeria.

NPC 2006. National Population Commission. National Census News published in the Nation

National Newspaper, January 2007.

Ogun State, 2001. Ogun State Today. An appraisal of the Gateway State – (1976 – 2001) Ogun State Ministry of Information. Ogun State, 2001.

Oladoye, A. O. 2012. Assessment of the dynamics of forest regeneration in a tropical rainforest ecosystem in southwest, Nigeria, Ph.D thesis of the Department of Forestry and Wildlife Management, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria. 234p

Oyesiku, O. O. 1992. Ogun State in Nigeria in Ogun State in Maps (eds Onakomaiya *et al*). Rex Charles Publications. Ibadan, Oyo State, Nigeria.

Thirgood, J. V. 1981. Man's impact on the forests of Europe. *Journal of World Forest Resources Management* 4 (2): 127 – 167, 1981.

UNFCCC, 2010. Report of the conference of the parties on its sixteenth session held in Cancun, 29 November – 10 December, 2010. United Nations Framework Convention of Climate Change, Bonn, Germany.

Van Breugel, M. J., Ransijn, D, Craven, F. and Hall, J. S. 2010. Estimating carbon stock in secondary forests; Decisions and uncertainties associated with allometric biomass models. Forest Ecology and Management 262: 1648 – 1657, 2011.

World Bank 2009a. Global Monitoring Report 2009: A Development Emergency. The World Bank, Washington, D.C. USA.

Frequency Distribution of Millet Intercrop Production of Northern Nigeria

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Abstract

Twenty six years of assessed regional millet intercrop yields by the Ministry of Agriculture and rainfall data from the National Meteorological Agency were correlated and the relationship obtained was used to calculate 100 years of regional and state millet intercrop yields from annual rainfall data. The results obtained show a mean regional millet intercrop yield 910 kg.ha., 20% probability yield of 780 kg.ha., 10% probability of 710kg.ha and a 5% probability of 660kg.ha. There are considerable differences in the State yield probabilities. At Kano State the long term mean millet yield is 1120 kg.ha. There is 5% probability of 800kg.ha. At Sokoto State the long term mean yield is 970kg.ha. There is a 5% probability of 640kg.ha. At Borno State the long term mean yield is 870kg.ha. There is a 5% probability of 560kg.ha. No pattern of the distribution of drought years (440mm or less) could be established.

Key words: Frequency analyses, Millet intercrop yields, Northern Nigeria

Introduction

The area of adaptation of Pearl Millet, Pennisetum Americanum (L) is clearly defined by the mean rainfall isohyets of 200 – 800 mm (Bidinger et. al. 1982). Inter and intra seasonal variability of available soil moisture is the major hazard of pearl millet production (Huda et. al. 1984). Historically the agricultural system that has developed in the region is intercropping, a system which seems to make better use of growth resources, especially soil water. The socio-economic conditions of the farming population limits the adoption of higher input technologies (Oluwasemire et.al. 1995). Under such conditions variable rainfall, high soil and air temperatures, high evaporative demand and poor soils, make agriculture a risky undertaking. The most prolonged and widespread droughts occurred in 1973 and 1984 at almost all African countries (Sivakumar, 2005). Millet is the main source of calories and protein for the people of the region. The long term risk of millet production at the traditional farming level, is therefore of major importance.

Methods

The data analyzed came from three sources. State Millet yields from the Central Bank of Nigeria, rainfall data from the National Meteorological Agency and the soil properties from the literature (Maduakor, 1991).

The rainfall data used were from three meteorological stations with long term series. Kano, $12^{0}2'$N $8^{0}30'$E. 1905 – 2006, mean rainfall 835mm; Sokoto, $13^0$2'N 5^0 16'E. 1916 – 2006, mean rainfall 640mm; Maiduguri $12^0$0'N $13^0$20'E. 1915- 2006, mean rainfall 580mm. The rainfall season commences in April or May and terminates in October. Rainfall amounts at the beginning and end of the rainfall season are small and usually lost to evaporation.

The millet yield data was obtained from the Central Bank of Nigeria for a 26 year period (1981 – 2006) for 6 States. Kano, Sokoto, Zamfara, Yobe, Borno, and Katsina. The regional millet yield is the mean annual yield of the six states.

Regional yields of six years, 1987, 1988, 1989, 1993, 1996 and 1999 departed considerably from the calculated regression line and were therefore considered suspect. The analyses of the relationship between the millet yields and rainfall are given for the assessed series of 26 years as well as for 20 years excluding the above suspected six year yields. For the state yields of Kano there were only three suspect years (1987, 1988,1999).

The soils of the Sudan Savanna region are sandy to very fine sandy loam, with soils at depressions and bottom lands having a higher percentage of the clay fraction. The mean surface texture of the soil at the states of Kano, Sokoto and Borno are given below.

Region	Sand %	Silt %	Clay %
Kano	90	6	4
Sokoto	84	11	5
Borno	80	13	7

Surface texture of soils in the Sudano Sahilian region, mean of five locations.

Infiltration rate reported for a sandy loam texture was moderate to rapid. Runoff is reported commonly low on upland sandy soils due to their higher infiltration rates. When disturbed by cultivation the soils can be subject to runoff due to surface scaling (Maduakor,1991).

The soil water balance was calculated for Kano using monthly data during the millet intercrop growing season of July to September:

Monthly rainfall at the 80% probability; evapotranspiration using regional crop coefficients (Agnew,1982; Dancette, 1991); runoff assumed to occur when the mean monthly rainfall amount per rain day exceeded 12mm (Ibrahima and Schmitt, 1991) and drainage took place when the soil water amount exceeded 60 mm.

Results

The relationship between millet intercrop yields and annual rainfall was calculated for the state of Kano and the mean six state regional yields. The annual rainfall at Kano ranged from 479mm in 1984 to 1872mm in 1998. For the regional intercrop millet yields and the mean annual rainfall amount of Kano, Sokoto and Maiduguri, the annual rainfall amount ranged from 431mm in 1984 to 1131mm in 1998. The results obtained are presented in Table 3.1

Table 3.1 Relationship between millet yields and annual rainfall amounts for the state of Kano and the mean six state (regional) millet intercrop yields.

Annual Rainfall - mm	Kano State yields – kg.ha	Regional yields- kg.ha
400	650	750
600	820	940
800	1000	1060
1000	1180	1120
1200	1360	1120
1400	1580	
1600	1330	

The curvy linear relationship between annual rainfall amounts at Kano and the Kano state millet intercrop yields is R^2 =0.441, sign. at 2%, n=26. If three doubtful year yields (1987. 1988 and 1999) are excluded from the data base, the relationship improves to R^2=0.507, sign. at 1%,n=23. Exceedingly high annual rainfall amounts during 1998 (1.872mm) and 2001 (1791mm) decreased the state yields (1998 – 1180 kg.ha. and 2001 – 1112kg,ha.). The long term mean yield is 1120 kg.ha. with a 10% probability of 880 kg.ha. and a 5% probability of 800 kg.ha. (Table 3.2)

The regional mean six state millet intercrop yields and their relationship with the mean annual rainfall of Kano, Sokoto and Maiduguri also shows a curvy linear relationship, R^2=0.456. sign. at 2.%, n=26. If six year doubtful regional millet yields are excluded, (1987, 1988, 1989, 1993,1996 and 1999) the curvy linear regression is much improved R^2=0.633,sign. at 1%, n=20. The long term mean regional yield is 910kg.ha with a 10% probability of 710kg.ha. and 5% probability of 660kg.ha.

The cumulative probability distribution of millet intercrop yields of the state of Kano and the regional yields are presented in Table 3.2

Cumulative probability %	Kano State Yields kg.ha.	Regional Yields kg.ha.
5	800	660
10	880	710
20	980	780
50	1120	910
80	1310	1070
90	1390	1180
95	1500	1220

Table 3.2 Calculated cumulative probability (%) of the Kano State and the regional millet intercrop yields.

Calculated evapo transpiration and the soil water balance.

The calculated evapo transpirtion of the millet – cowpea intercrop sown during the last week in June and harvested during the first days of October at Kano is 317mm. Table 3.3 present the soil water balance.

Month	c/f mm	Rainfallmm	Et. mm	Ro.mm	Dr.mm	Sm. mm
July	20	132	56	12	24	60
August	60	200	138	44	18	60
Sept.	60	75	123	0	0	12
Total	20	407	317	56	42	12
%		100	74	13	10	3

Table 3.3 Calculated soil water balance at Kano during the millet inter crop growing season of July to September.

The calculated Et. of the millet inter crop agrees fairly well with the measured Et. of 330mm. at Samaru, Northern Nigeria by Kassam and Kowal (1975) and 328mm at Sadore, Niger by Garba and Renard (1991). At the 80% monthly rainfall probability there seems to be adequate rainfall during July and August. But monthly rainfall amounts are inadequate during September. On soils where the soil water holding capacity at the end of August contains at least 50 – 60mm. of available soil water there will be an adequate water supply. From the total rainfall amount of 407mm. 317mm (74%) are used by Et., 98mm (24%) is lost by runoff and drainage and some 12mm (3%) remains in the soil at the end of the growing season.

Discussion

The 90 – 100 day millet intercrop evapo transpiration during July to September is some 320mm. There is an adequate rainfall amount during July and August. Rainfall during September is however inadequate (75mm on 5-6 rain days) except on soils that will contain some 50 - 60mm of soil moisture at the beginning of September.

The calculated mean 100 year regional millet intercrop yield is 910kg.ha. with a 10% probability of 710kg.ha. and a 5% probability of 660kg.ha. At the state of Kano with higher annual rainfall amounts the mean state intercrop yield is 1120 kg.ha. with a 10% probability of 880kg.ha. and a 5% probability of 800kg.ha.

No clear pattern of the duration, in years, of drought conditions could be determined. During the 100 year period at Maiduguri (Borno State) 14 years of water stress conditions (440mm or less) there were 7 such single years, one drought case of a three year duration (1971 –

1973) and one drought case of a four year duration (1982 – 1985).

References

Agnew, C.T. 1982. Water availability and the development of rainfed agriculture in South West Africa. Trans, Inst. Br. Geogr. N.S.7, 419 – 457

Bidinger, R.F., Mahalakshmi, .Y., Talukdar, B.S. and Alagarsevamy, G. 1982. Improvement of drought resistance in Pearl Millet. Proc. D. Drought resistance in crops. Los Banos, Philippines, IRRI.

Dancette, C. 1991. Critique des recherché sur le balance hydrique en zone Sudano Sahilianne. Proceedings of the Niamey Workshop. Feb.1991. JAHS. Pub. no. 199.

Garba, N. and C, Renard. 1991. Biomass production, yield and water use efficiency in some Pearl Millet – legume cropping systems at Sadore, Niger. Pros. Of the Niamey workshop. IAHS. Pub. 1999 Wellingford U.K.

Huda, A.K.S., M.V.K. Sivakumar, G. Alagarswamy, S.M. Virmani and R.L. Vanderlip. 1984. Problems and prospects in modeling pearl millet growth and development: A suggested framework for a millet model. Proc. Intr. Symp. ICRISAT, India.

Ibrahima, A. and A. Schmitt, 1991. Bilan hydrique a la parcelle: cas d'une etude realisee sur le plateau Mossi au Burkina Faso. IAHS Pub. no. 1999.

Kassam, A. H. and J.M. Kowal, 1975. Water use, energy balance and growth of gero-millet at Samaru, Northern Nigeria. Agric. Met. 15, 333 – 342.

Maduakor, H.O. 1991. Physical and Hydrolic properties of soils of the Suddanno – Sahilian region of Nigeria. IAHS Pub. no. 199

Oluwasemire, K.O., J.J. Owonubi, E.O. Oladipo, S,S,. Jagtab and C.J. Stigter, 1995. Microclimate improvement and soil protection aspects of inter cropping with leguminous (cover) crop. The TTMI – project and the Picnic model. Wageningen Agric. University, Netherlands.

Sivakumar, M.V.K. 2005. Impacts of natural disasters in Agriculture range land and forestry : an overview. Eds. Sivakumar, Motha, Das, Natural disasters and extreme events. Springer pub.

ON THE FUNDAMENTALS OF WEATHER FORECASTING IN WEST AFRICA

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Abstract

In this paper, the critical ingredients involved in weather forecasting in West Africa are discussed. Also the associated forcing functions are examined to enhance the understanding of their individual and coupled effects on various weather phenomena. The framework for forecasting of various weather events is presented with a view to bringing into sharp focus the interactions between the dynamic and thermodynamic aspects of the West African atmosphere. Also background climatology is viewed as an indispensable factor during the forecast process.

1.0 INTRODUCTION

In West Africa, weather forecasting has come a long way, dating back to more than six decades. For a long time, forecasters relied on subjective approach in analysis of data to issue qualitative forecasts. For example, tracking of propagating convective systems as well as 'dust plumes' were done by interpretation of plots of weather events on the surface synoptic charts. This was complimented by reports from aircraft pilots flying within such zones of weather occurrence. However, with the advent of satellite technology, it became possible to track the evolution, intensity, propagation and decay of mesoscale convective systems as well as dust plume dynamics.

Up till the last decade of twentieth century, most forecasters in the West African sub-region did not have the opportunity to access Numerical Weather Prediction (NWP) Products. However, at their disposal were dense network of surface and upper air observations on real time basis. The "ground truth" nature of the three – dimensional data architecture provided forecasters with natural forecasting tools needed to diagnose the true state of the atmosphere. Thus they were able to make informed decisions on the future state of the atmosphere. Indeed, forecast accuracy was very encouraging during that era.

Modern weather forecasting in West Africa relies heavily on NWP model products that can be accessed from various model centres. They contain errors which can sometimes adversely affect forecast skill. However, significant improvement can be made if the domain climatology is thoroughly understood and incorporated into forecast process. Therefore the model products serve as a useful guide to the forecaster.

The purpose of this paper therefore, is to discuss those factors which constitute the fundamental requirements for weather forecasting in West Africa. This knowledge is expected to immensely assist the forecaster in improving forecast skill.

2.0 BASIC FORCING FUNCTIONS

These are functions that can dictate or modulate weather; and there are many of them. Their presence constitutes complexity which has led to the difficulty encountered in weather forecasting within the West African domain. We now briefly examine these forcing functions and their impacts.

2.1 **South – West Monsoons**: These are moisture - ladden southwesterly winds of oceanic origin. They are prominent during rainy season (April to October) and are responsible for moisture transport into West Africa, complimenting the occurrence of cloudiness, precipitation and thunderstorms.

2.2. **North-East Trades:** These dry winds of Saharan origin are responsible for transport of harmattan dust haze across West Africa during dry season (November to March. They have westward trajectory due to Coriolis Effect. They sometimes extend to the coastal areas thereby enveloping them with dust.

2.3 **Saharan High Pressure Cell:** Located at about latitude 30^0N, the influence of this high pressure cell is very prominent during dry season (November to March). Its strong anticyclogenesis during this period leads to generation of strong surface winds which play a crucial role in occurrence of harmattan dust haze. This high is also referred to as sub-tropical anticyclone (STA).

2.4 **St. Helena high pressure cell:** This high pressure cell is located in the Southern hemisphere with centre at about 30^0S. The south-easterlies in the southern hermisphere originate from this high pressure cell. On reaching the equator, they veer and become south-westerlies as they enter the coastal areas of West Africa in northern hermisphere. This is due to Coriolis Effect.

2.5 **The Inter-Tropical Discontinuity (ITD):** Exhibits oscillatory motion of poleward – equatorwards direction. It motion has limits of about lat. 22^0N in August and about lat. 04^0N in January/February. The position of the ITD at any point in time plays a key role in determining the expected weather conditions over a particular domain. This is so because of the established zones – Zone A,B,C and D. Zone C may be further divided into C_1 and C_2. Zone C_1 is poleward of C_2. Generally Zone A is north of ITD and is characterized be dust haze. Zone B is immediately south of the ITD and is associated with fine weather conditions as well as fair weather cumulus. Zone C is mainly characterized by convective precipitation as well as thunderstorms. Finally Zone D is associated with cloudy conditions and slight rains, which could be intermittent or sometimes continuous. One unique feature of Zone D is the occurrence of Little Dry Season (LDS) – short period of rainfall minimum.

2.6 **The African Easterly Waves (AEW):** Found over West Africa during the West African monsoon (may – October).They are located on 700 hpa charts with a wavelength of about 2500 km. They have speed of about 6 to 8 degrees longitude in 24 hours and strengthen as they propagate westwards. Their origin is due to barotropic and baroclinic instability.

2.7 **Mid-Latitude Troughs (MLT):** These eastward-propagating Rossby waves are located in the temperate region; and become very important during the dry season in West Africa. As it passes through the regions of the Mediterranean and fringes of North Africa, the trough "tongue" makes an incursion into West Africa. This increase in amplitude ensures interaction between the wave and the ITD. The above scenario obviously has implications concerning dry season precipitation and dust haze clearance in West Africa.

2.8 **African Easterly Jet (AEJ):** Found between 700hpa - 650hpa levels on the synoptic charts. It plays a crucial role in the propagation, maintenance and sustenance of West African line squalls.

Part of its horizontal momentum is transferred to the propagating storms to achieve this. AEJ is found between about latitude 10^0N and 18^0N. It normally has winds of 30knots to 40knots. Sometimes, AEJ exhibits wavy form.

2.9 **Tibetan High Pressure Cell:** During the northern hemisphere summer, temperatures over the Tibetan Plateau rise to high values. At the same time, the high pressure cell undergoes intense anticyclogenesis. Thus winds of jet magnitude are generated from this source.

2.10 **Tropical Easterly JET (TEJ):** This jet stream emanates from the Tibetan high pressure cell. It transports the enormous heat energy from the Tibetan Plateau downstream, towards the West African environment. This compliments instability within the domain. TEJ has wind strength of 60 knots and above.

2.11 **Radiation:** West Africa is blessed with abundant solar radiation.. This is crucial for the formation of convection as well as the convective nature of precipitation in most parts. In fact, north of latitude 10^0N, about 80% of the annual precipitation is provided by thunderstorms. Indeed, instability is an inherent property of the West African atmosphere.

2.12 **Reserved Temperature Gradient:** Generally, temperatures decrease from the equator towards the poles. But over the West African domain, temperatures instead increase from the equator, polewards. This shows a reversal of temperature gradient. Hence it is seen that there is a high concentration of heat energy away from the coastal areas, towards the Sahel regions. However, this factor plays out mostly during during wet season.

2.13 **Orography:** During rainy season, a lot of convection take place over high terrain, especially by late afternoon/evening. With adequate moisture supply, hills and mountains sometimes behave as "thunderstorms generators". Oshogbo hills (Nigeria), Aii hills (Niger) and Futa Jalon highlands (Guinea) are examples.

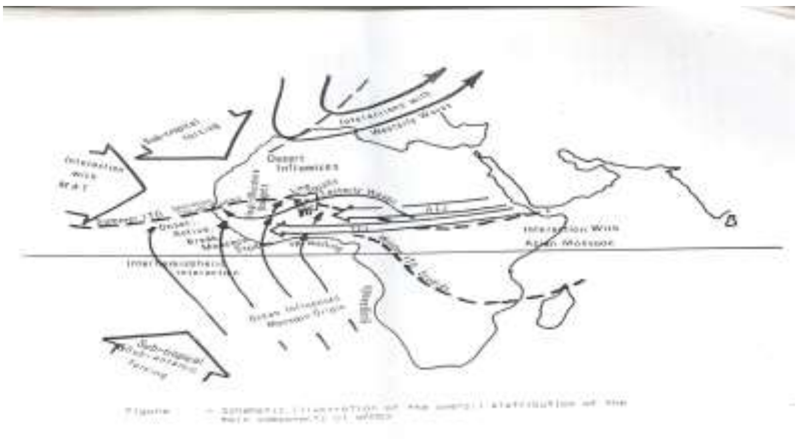


Fig. 1 FORCING FUNCTIONS IN WEST AFRICA

3.0 FUNDAMENTAL FRAMEWORK FOR FORECASTING

In this section, attention will be focused on the principles underlying the forecasting of various weather phenomena. They are rooted in the true nature of the West African environment. Those that are to be discussed include harmattan dust haze, thunderstorms, fog, widespread wet spells and little dry season.

3.1 **Harmattan Dust Haze;** Forcing functions involved are,

i. Sharan High Pressure Cell
ii. North-East Trades
iii. Mid-Latitude Trough (MLT)

STRUCTURAL REQUIREMENTS:

a. Dust raising

i. Surface charts V_s = 30 knots
P_s = 1032 Hpa

(Where V_s and P_s are surface wind speed and surface pressure respectively)

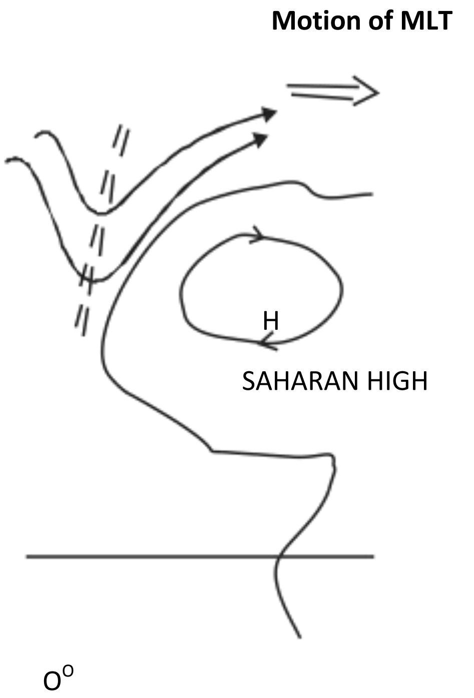
ii. **850 HPa Chart**: Well established anticyclonic flow.

b. **Dust Transport:** $V_{925} \geq$ 25 knots (where V_{925} is wind speed at 925 HPa level)

c. **Dust Clearance:** V_s < 15 knots
P_s < 1032 knots

At 850 HPa: Mid-latitude incursion into West Africa.

(See Figures 2, 3 and 4)



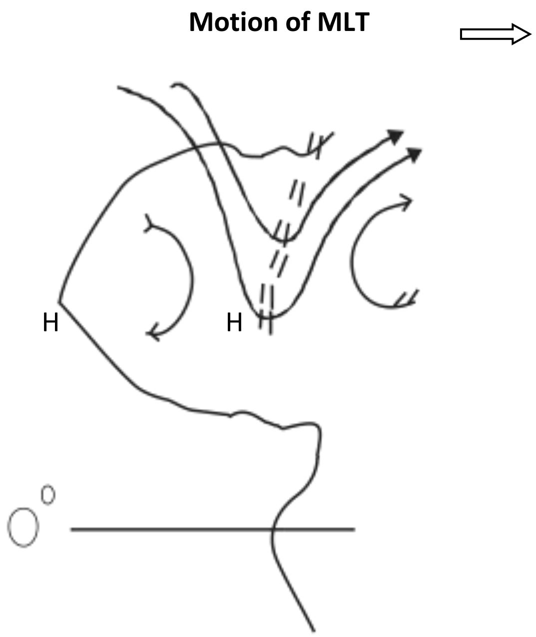


Figure 2.

ANTCYCLOGENESIS.

Occurrence of Harmattan Dust Haze

Figure 3.

Mid-Latitude through weakens

The SAHARAN High. Clearance of Harmattan Dust Haze

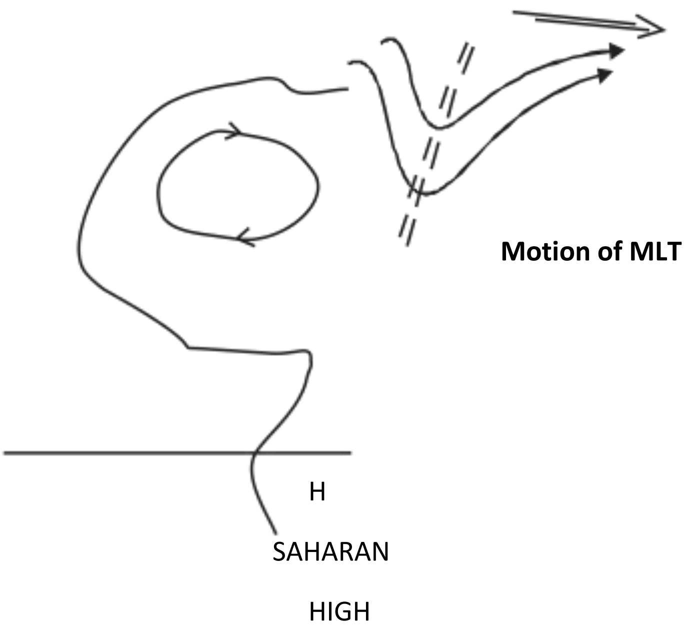


Figure 4.

O⁰ The SAHARAN High Intensifies Again.

3.2 Thunderstorms: Forcing functions involved are:

i. African Easterly waves (AEW's)
ii. African Easterly Jets (AEJ)
iii. Orography
iv. Solar radiation
v. Tropical Easterly Jet (TEJ)

3.2.1 Pre-Monsoon Storms

i. Constant T_{max} for at most 2 consecutive days (where T_{max} is maximum temperature).
ii. Falling surface pressure
iii. Backing of winds
iv. Increase in Relative humidity values.

3.2.2 Organized Thunderstorms (Line Squalls)

i. Adequate thermodynamic fluxes of heat and moisture.
ii. Lifting mechanism for vigorous and sustained upward motion – existence of vortex up to at least 850 HPa level.
iii. Presence of AEW's at 700 HPa level chart.
iv. Strong AEJ from 700 HPa to 650 HPa levels.
v. Presence of strong TEJ

3.2.3 Role of Orography:

Many times storms are generated over high terrain by late afternoon or evening. Examples are over Oshogbo hills (Nigeria), Aii hills (Niger Republic), Mambilla Plateau (Nigeria) e.t.c.

Vortices can sometimes be stagnated over a mountain barrier for up to twenty four hours (e.g. over Cameroun Mountain). On crossing the barrier, they move with increased kinetic energy.

Note 1: Heat lows serve as thunderstorms generators by July/August

Note 2: For severe storms (High Impact Weather)

i. Vortices up to 700 HPa level and beyond (i.e. 500 HPa level)
ii. Dry mid-troposphere i.e. low dew point (Td) values at 500 HPa level.

3.3 FOG Framework

No associated forcing function

Formation:

i. **At Surface**: High pressure over domain
ii. **At 850 HPa level**: Established high pressure or ridge over domain of forcast.
iii. Clear skies
iv. Very light surface winds (or calm conditions)
v. Cooling of air to its dew point.

Persistence: No appreciable change in the above conditions.

Clearance: i. Increased surface wind.

ii. Insolation reaching the surface by sunrise.

3.4 Widespread Wet Spells:

Forcing functions involved are:

i. Large scale low level convergence
ii. Large scale upper level divergence
iii. Strong TEJ
iv. Active ST. Helena high pressure cell coupled to monsoon trough to establish a sustained cross – equatorial flow.
v. North – South Component of winds at upper levels (Say 300 Hpa).
vi. Existence of a strong solenoidal field.

Note: The magnitude of upper level divergence should exceed that of lower level divergence, to ensure sustained vertical moisture transport. (See Figure 4).

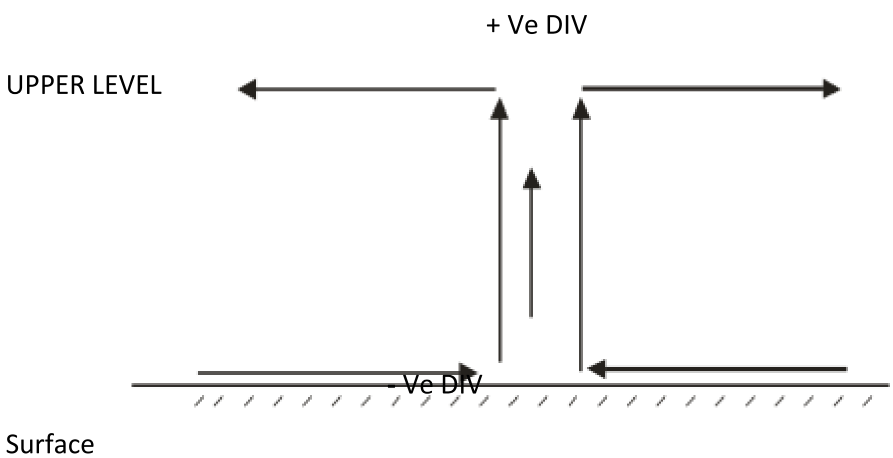


Figure 5.

Large scale low level convergence coupled to

Large scale upper level divergence.

3.5 **Little Dry Season:**

Associated forcing function is ST. Helena high pressure cell.

Required structure:

i. Positive velocity divergence at 850 Hpa level over coastal areas. This leads to stable conditions.

ii. Low SST over Gulf of Guinea.

(where SST is Sea Surface Temperature)

iii. Drop in static energy over the mid-troposphere.

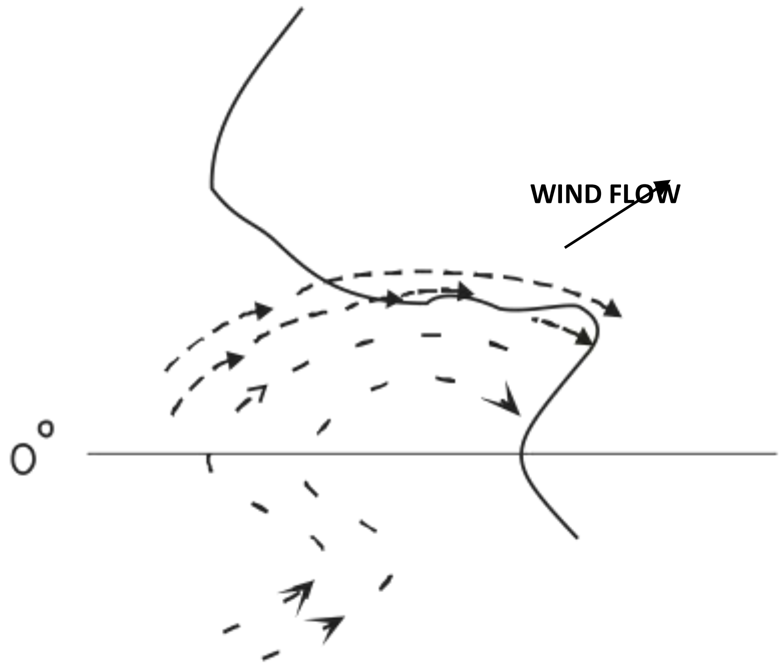
TEMPERATURE MODEL USING 850 Hpa LEVEL

ONSET = 16^0c

PERSISTENCE $\leq$ 16^0c

CESSATION > 16^0c

Note: This model is currently in use at all forecast offices in Nigeria.



St. Helena High

Figure 6.

Antcyclonic Flow over coastal Areas of West Africa on 850 Hpa Charts during LDS.

4.0 CONCLUSION

An attempt has been made in this paper to examine the fundamentals of weather forecasting in West Africa. In doing this, the complexities inherent in this domain due to many forcing functions has been discussed. Thus the forecaster can now appreciate the intricate structure of the West African atmosphere and invariably be in a better position to cope with his tasks.

The need to integrate background climatology into the forecast process is a compelling one as this will definitely lead to improved forecast skill.

REFERENCES

Adefolalu, D.O. 1974: On scale interactions and lower tropospheric summer easterly perturbations in West Africa. Ph.D Thesis, Florida State University, Tallahasse.

Burpee, R.W. 1972: The origin and structure of easterly waves in the lower tropshere of North Africa. J. Atmos Sci 19.

Chelam, E.V. 1979: Forecasting technique for widespread wet spells. Pre-WAMEX Symp. Ibadan.

Gbuyiro, S.O.; Orji B.N. and Ediang, A.O. 2005: Monitoring of Mid-summer drought in West Africa using Global Models. 1st AMMA Conf. Dakar.

Kalu A.E. 1979: The African dust plume: its characteristics and propagation across West Africa in winter. Morals C. (Cd) Sharan dust transport, John Wiley and Sons, Chichester.

Omotosho, J.B. 1983: Prediction of maximum gusts in West African line squalls. Nigeria Met. J. Vol. 1 No. 2

Orji B.N. and Gbuyiro S.O. 2005: On the behaviour of some upper air Parameters in relation to West African Line Squalls. 1st AMMA Conf. Dakar .

VARIATION IN OVERBURDEN DEPTH OF SELECTED WELLS IN FUNAAB AND ITS EFFECT ON WATER QUALITY

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ABSTRACT

Water is a finite resource that is very essential for Existence, Agriculture and Industry. Without any doubt, inadequate quantity and poor quality of water have serious impact on sustainable development. However, access to safe drinking water and sanitation is critical in terms of health, especially for children. Of all sources of freshwater on the earth, groundwater constitutes over 90% of the world's readily available freshwater resources with remaining 10% in lakes, reservoirs, rivers and wetlands. Water samples were taken from selected hand dug wells in the study area and the profiles of the wells were taken to obtain the water level for four months, head and depth. The geographical coordinate was taken using a GPS. The variation in the water levels was observed and the water quality data was correlated using SPSS and Microsoft Excel. The geographical coordinate as well as the well head was plotted on a contour map to obtain the groundwater flow direction. The flow directions of the observed wells are in the South-eastern, North-eastern and North-western direction which was obtained by plotting the geographical coordinates of the sampled wells and the Well Heads on a contour map. The well with the highest level of water from the surface is W1 located at SUB mosque with values ranging between 4.14m and 4.16m from May to August with a mean value of 4.15m. Major reason for variation across the sampling months is abstraction for use by residing neighbours. The maximum TDS was obtained at 'FUNAAB Male Hostel' with a value of 345mg/l and the minimum value was 68.5mg/l, obtained at 'Feedmill unit'. The quality of water obtained from the sampled wells in the study area does not differ significantly among the observed months. This might be attached to the fact that the samples were taken in June and August which both falls under rainy seasons. This can also be due to the absence of industries or other source of pollution that can compromise or change the quality of the water in the wells.

Keywords: Wells, Water Quality, Groundwater, Flow Direction

INTRODUCTION

Water is a finite resource that is very essential for Existence, Agriculture and Industry without any doubt; inadequate quantity and poor quality of water have serious impact on sustainable development. The scarcity of clean water and pollution of fresh water have therefore led to a situation in which one-fifth of the urban dwellers in developing countries and three quarters of their rural dwelling population do not have access to reasonably safe water supplies. Water is essential to maintain and sustain human life, animal and plant (*Patil and Patil, 2010*). Water therefore is important in that it is essential for growing food, for household water uses, as a critical input into industry, for tourism and cultural purposes, and for its role in sustaining the earth's ecosystem (*Mark et.al, 2002).* However, access to safe drinking water and sanitation is critical in terms of health, especially for children. For instance, unsafe drinking water contributed to numerous health problems in developing countries such as the one billion or more incidents of diarrhoea that occur annually (*Mark et al., 2002).* According to *Asonye et al., (2007),* availability of safe and reliable source of water is an essential prerequisite for sustained development. Groundwater differs from surface water because of the contrasting physical and chemical environment in which it occurs, although the water itself is essentially part of the same overall hydrological cycle. An increased awareness of groundwater in the hydrological cycle would result in better understanding of the resource, its susceptibility to pollution, and the need for increased efforts to protect its quality.

The traditional method of obtaining groundwater in rural areas of the developing world, and still the most common, is by means of hand-dug wells. However, because they are boulders are encountered. Some communities use the skill and knowledge of local well-diggers, but often the excavation is carried out, under supervision, by the villagers themselves. Hand-dug wells have been the sources of water for people in Nigeria for ages *(Sina et al., 2002)*, a record indicates that some of these wells are dug within close proximity to rivers, and these rivers are the main different contamination of groundwater and lake (*Karbassi et al., 2007)*. For a long time it has been found that the quality of groundwater supersedes that of most known surface water bodies or source, its quality maybe dependent on changes related to human or natural phenomena. The ultimate distance to which the pollution will be carried is dependent upon a number of complex and interlocking factors,

dug by hand, their use is restricted to suitable types of ground such as clays, sands, gravels and mixed soils where only small

namely wet and dry weather. In cases where agricultural land is located near a well, pesticides and nutrients (such as nitrate) are contaminants potentially found at land surface which could be transported to the subsurface along a deficient well seal *(Kinzelbach., 2002*

STUDY AREA

The Study area (Figure 1) is the Federal University of Agriculture, Abeokuta which lies on latitude 7°25´N and longitude 3°25´E and it has a landed area of 9,700 hectares which is situated northwest of Abeokuta Township. It is bounded to the west by Abeokuta- Opeji-Eruwa road and to the east by Osiele-Alabata road. The site falls within the geographical region of Odeda Local Government *(UNAAB Master Plan, 1991).*

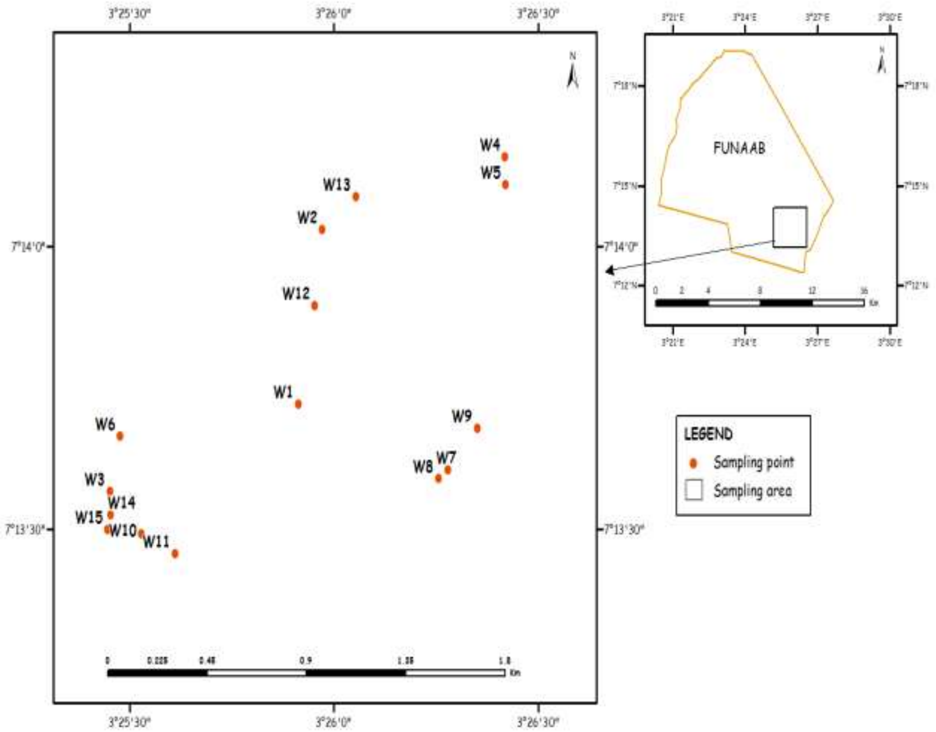

Figure 1: Map of Study Area

METHODOLOGY

DATA COLLECTION

Groundwater samples were collected from twenty (20) hand-dug wells inside the environment of the Federal University of Agriculture Abeokuta. The Geographical location of all the wells was obtained using a GPS. The depth of the wells was obtained. This was done by attaching a padlock to a measuring tape and lowered into the well until the bed was reached. The measuring tape was then read.

Groundwater samples from the wells were collected twice in properly labelled white plastic and glass bottles. This was done once in two months. The samples were analysed for the following physico-chemical parameters;

pH
Electrical Conductivity
Sodium
Potassium
Calcium
Magnesium
Sulphate
Nitrate
Chloride
Dissolved Silicate

3.2 METHOD OF ANALYSING PHYSICOCHEMICAL PARAMETERS

pH

The Instrument for pH determination is pH meter. The alternate instrument used is Lovibind Comparator. The Lovibond Comparator has a viewing glass through which a disc containing several colours is inserted. The disc was then manually rotated within the comparator until one of its colours corresponds to the sample colour. Bromoethymol (blue) indicator was added to 10mls of water sample in a test tube. The sample is then viewed against the colour of the disc in the Lovibond Comparator.

Electrical Conductivity

It was measured with the help of EC meter which measures the resistance offered by the water between two platinized electrodes. The instrument was standardized with known values of conductance observed with standard KCl solution.

Sodium

It was measured with the help of flame photometer. The instrument was standardized with the known concentration of sodium ion (1 to 100 mg/litre). The samples having higher concentration are suitably diluted with distilled water and the dilution factor was applied to the observed values.

Potassium

It was also measured with the help of flame photometer. The instrument was standardized with known concentration of potassium solution, in the range of 1 mg to 5 mg/litre. The sample having higher concentration was suitably diluted with distilled water and the dilution factor was applied to the observed values.

Calcium

It was measured by complexometric titration with standard solution of ETDA using Patton's and Reeder's indicator under the pH conditions of more than 12.0. These conditions were achieved by adding a fixed volume of 4N Sodium Hydroxide. The volume of titre (EDTA solution) against the known volume of sample gave the concentration of calcium in the sample.

Magnesium

It was also measured by complexometric titration with standard solution of EDTA using Eriochrome black T as indicator under the buffer conditions of pH 10.0. The buffer solution was made from Ammonium Chloride and Ammonium Hydroxide. The solution resists the pH variations during titration.

Sulphate

It was measured by nephelometric method in which the concentration of turbidity was measured against the known concentration of synthetically prepared sulphate solution. Barium chloride was used for producing turbidity due to barium sulphate and a mixture of organic substance (Glycerol or Gum acetia) and sodium chloride is used to prevent the settling of turbidity.

Chloride

It was measured by titrating a known volume of sample with standardized silver nitrate solution using potassium chromate solution in water or eosin/fluorescein solution in alcohol as indicator. The latter indicator was an adsorption indicator while the former makes a red coloured compound with silver as soon as the chlorides are precipitated from solution.

Silicate

This was measured spectroscopically. Yellow colour was developed from the action of silicate on Molybdate ion under strong acidic conditions. The intensity of the colour was directly proportional to the concentration of silicate in the sample.

Nitrate

This was determined using photometer.

Data Analysis

Water quality data obtained was subjected to descriptive statistics such as mean, medium, range, standard deviation and Variance. Regression analysis was used to obtained relationship between Electrical Conductivity and individual ions. Regression equation was obtained for each relationship.

The graph of the Electrical Conductivity against each ion was also plotted to observe the change in trends.

Frequency distribution was used to observe frequencies of occurrence of the observed data.

RESULTS AND DISCUSSIONS

The profile of the wells is presented in Table 1. Graph showing well depth across the sampling points is presented in Figure 2 while the graphs showing the trend of water quality parameters across the sampling point is presented in Figures 3 – 14. From the onsite measurement of the depth, it was obtained that the deepest well W5 located at Marble Lodge Block C with a depth of 9.9m. The well with the lowest depth is W13 located at Fadama with a depth of 6.06m. The mean depth of the selected wells is 7.6m. The well with the highest level of water from the surface is W1 located at SUB mosque with values ranging between 4.14m and 4.16m from May to August with a mean value of 4.15m. Major reason for variation across the sampling months is abstraction for use by residing neighbours. The implication of this is that the distance between the surface of water in the well and the ground surface is between 4.14m and 4.16m.

Table 1: Location and profile of the wells

Well Code	Sample	Latitude	Longitude	Altitude (m)	Depth (m)
W1	SUB mosque	7.228698N	3.431895E	121.21	7.51
W2	FUNAAB Male Hostel	7.233843N	3.432862E	119.10	6.65
W3	Piggery unit	7.226108N	3.4242E	111.21	7.79
W4	Marble Block A	7.235989N	3.440319E	108.48	8.35
W5	Marble Block C	7.235181N	3.440344E	124.55	9.90
W6	Pineapple Unit	7.227740N	3.424618E	102.73	6.74
W7	NASU Complex F	7.226758N	3.438002E	108.18	8.14
W8	NASU Complex B	7.226485N	3.437603E	107.27	8.00
W9	SSANU Complex	7.227982N	3.439183E	112.12	6.87
W10	Turkey Unit	7.224863N	3.425498E	108.48	7.61
W11	Breeding Unit	7.224280N	3.426865E	097.27	8.14
W12	IYAT Hostel	7.231589N	3.432564E	111.21	6.40
W13	Fadama	7.234823N	3.434237E	087.58	6.06
W14	Rabbitary Unit	7.225410N	3.424227E	148.00	7.97
W15	Feedmill Unit	7.224975N	3.424117E	113.33	7.88

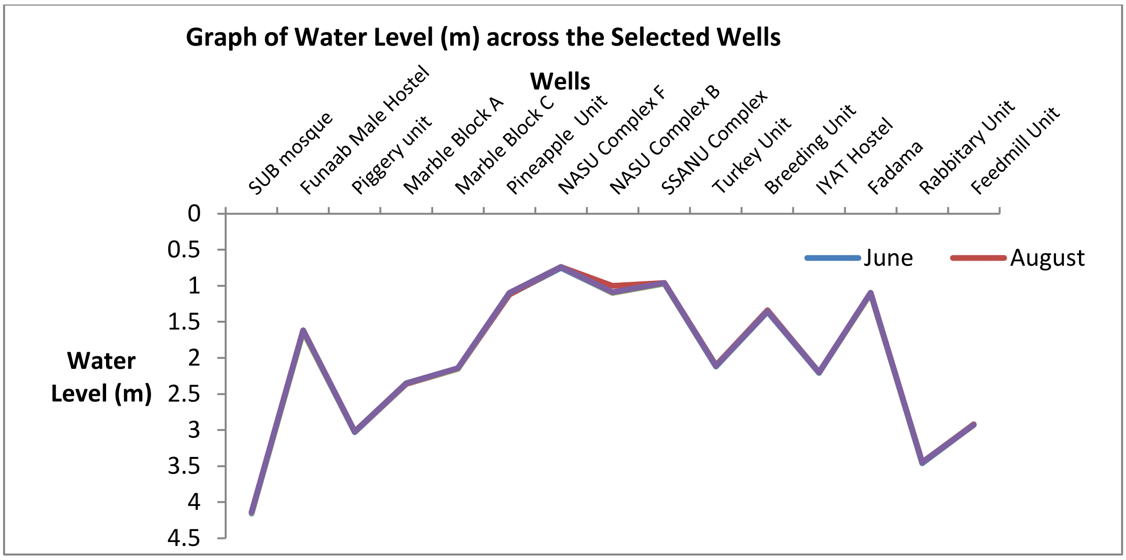

Figure 2: A graph showing the water level in the wells

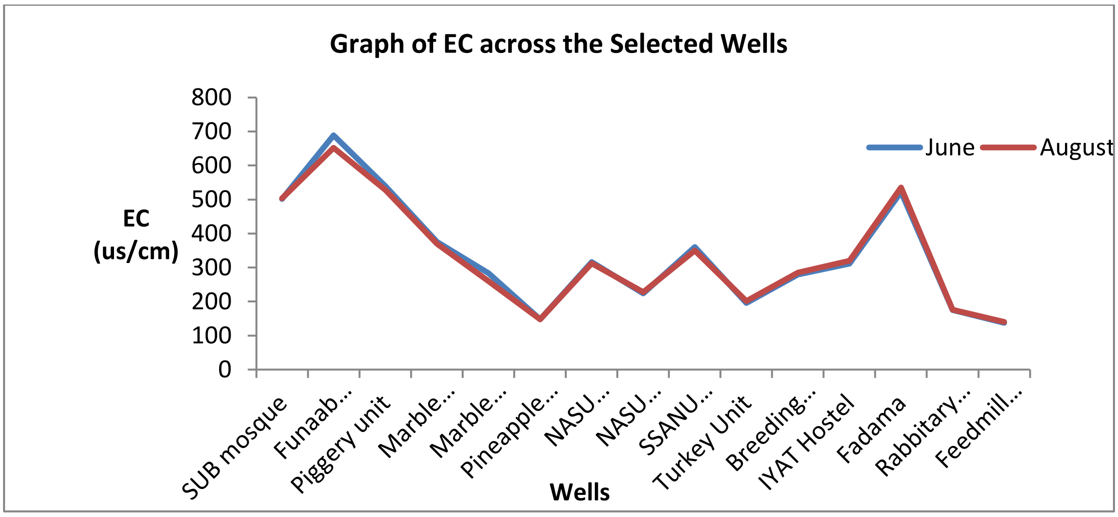

Figure 3: A graph showing the trend of EC across the wells

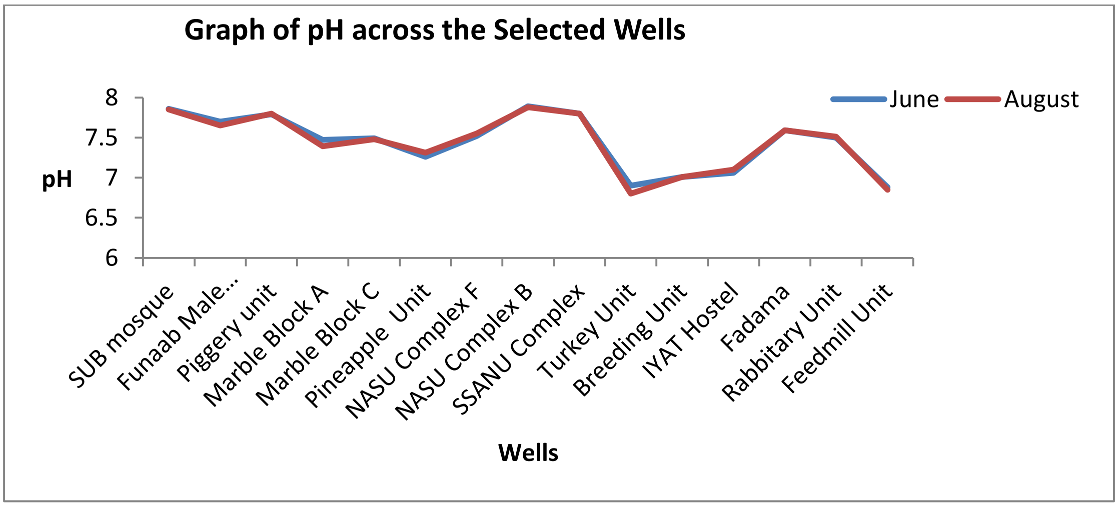

Figure 4: A graph showing the trend of pH across the wells

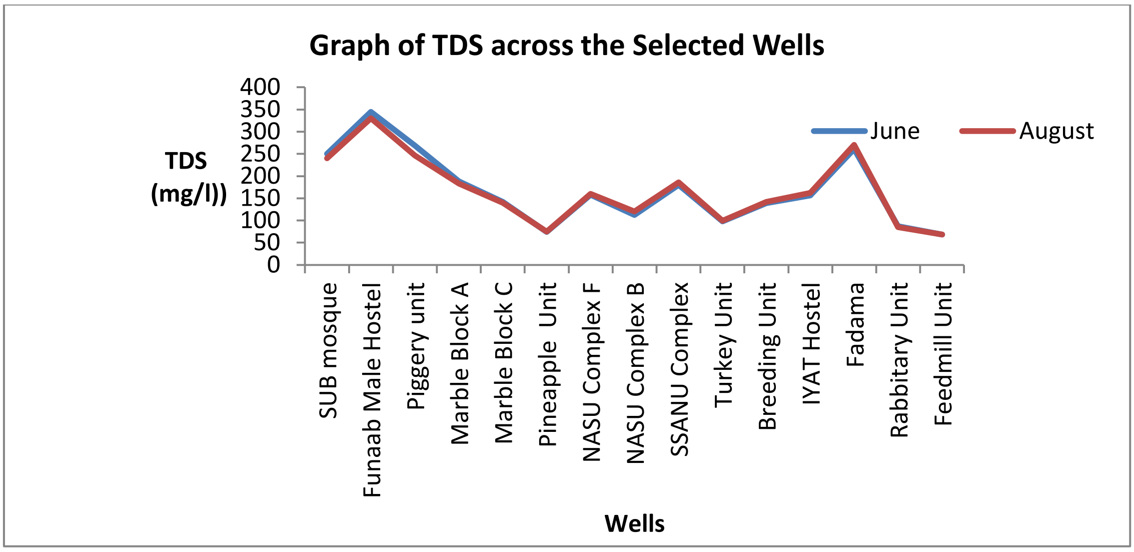

Figure 5: A graph showing the trend of TDS across the wells

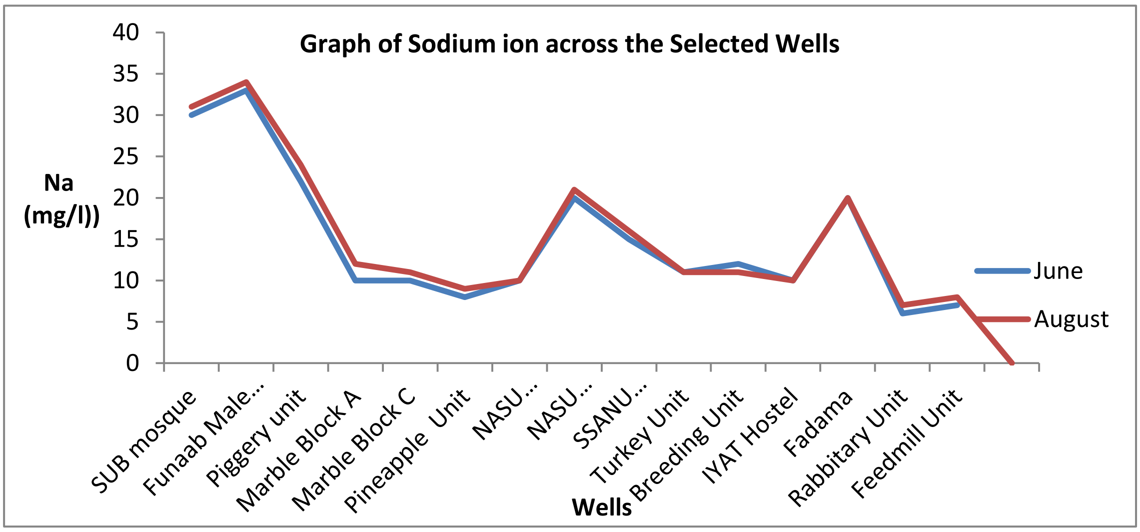

Figure 6: A graph showing the trend of Sodium across the wells

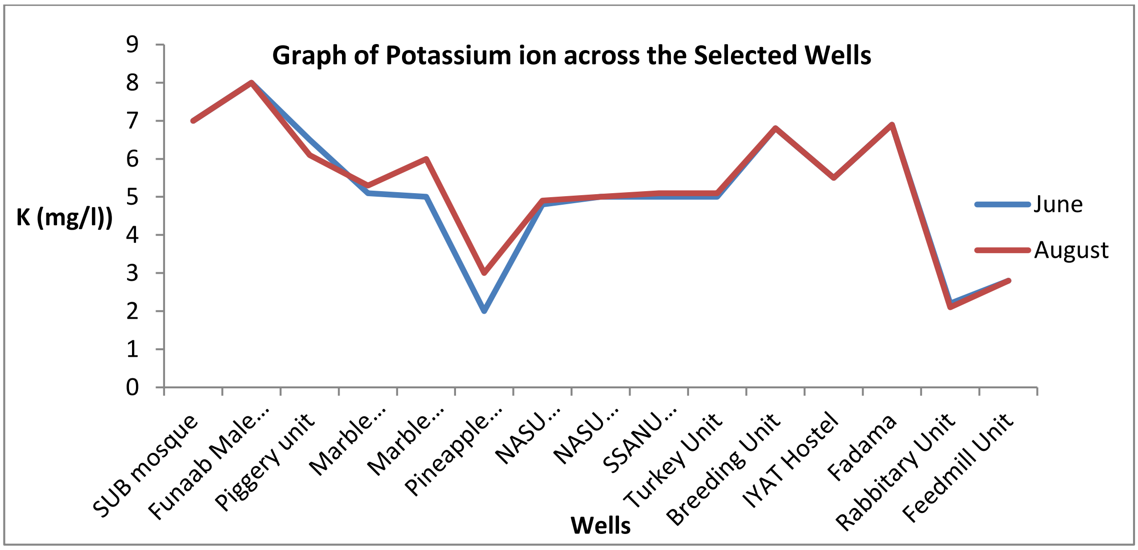

Figure 7: A graph showing the trend of Potassium across the wells

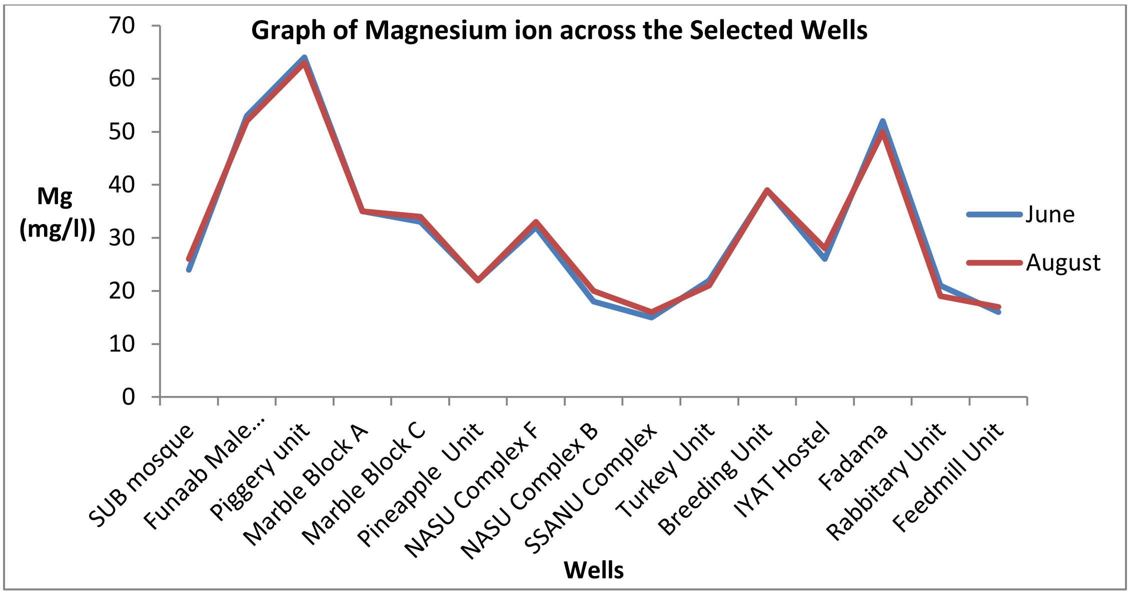

Figure 8: A graph showing the trend of Magnesium across the wells

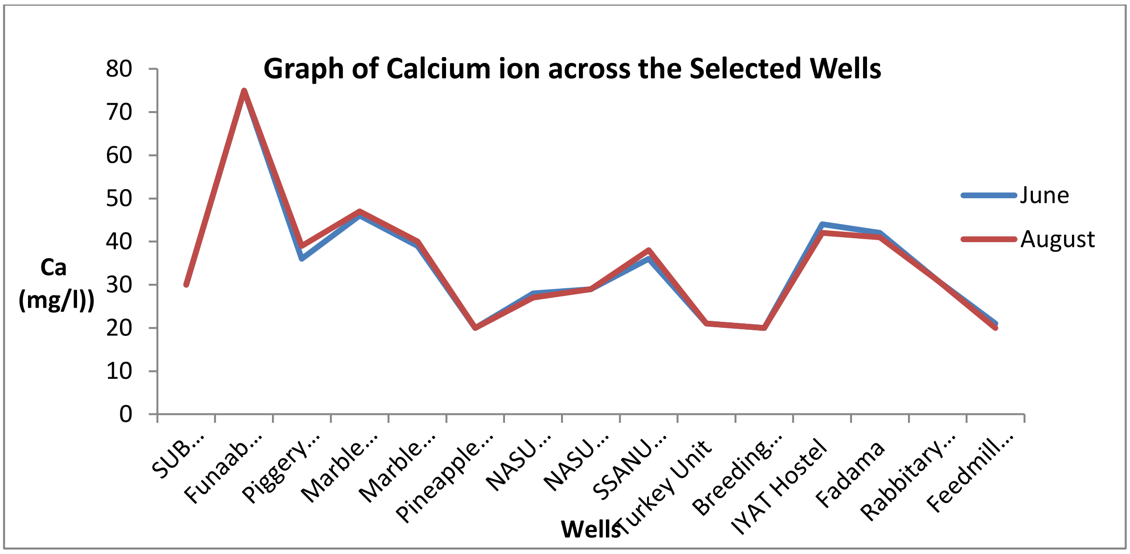

Figure 9: A graph showing the trend of Calcium across the wells

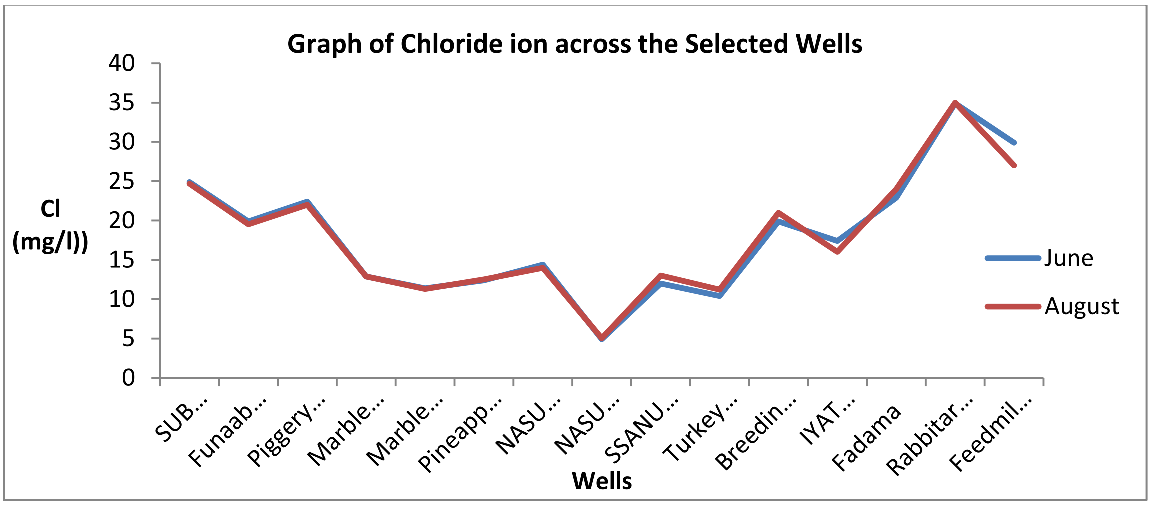

Figure 10: A graph showing the trend of Chloride across the wells

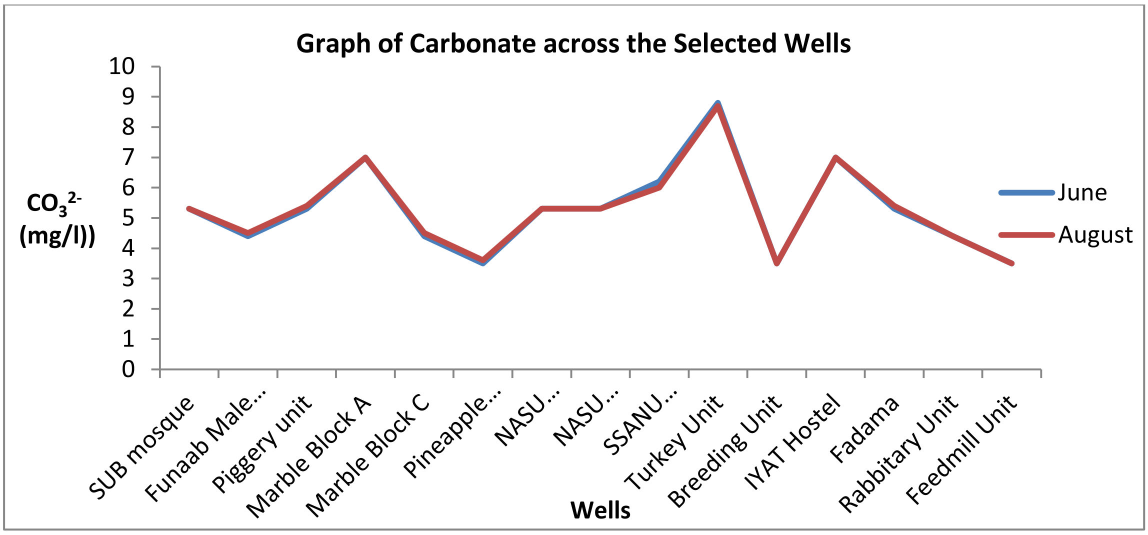

Figure 11: A graph showing the trend of Carbonate across the wells

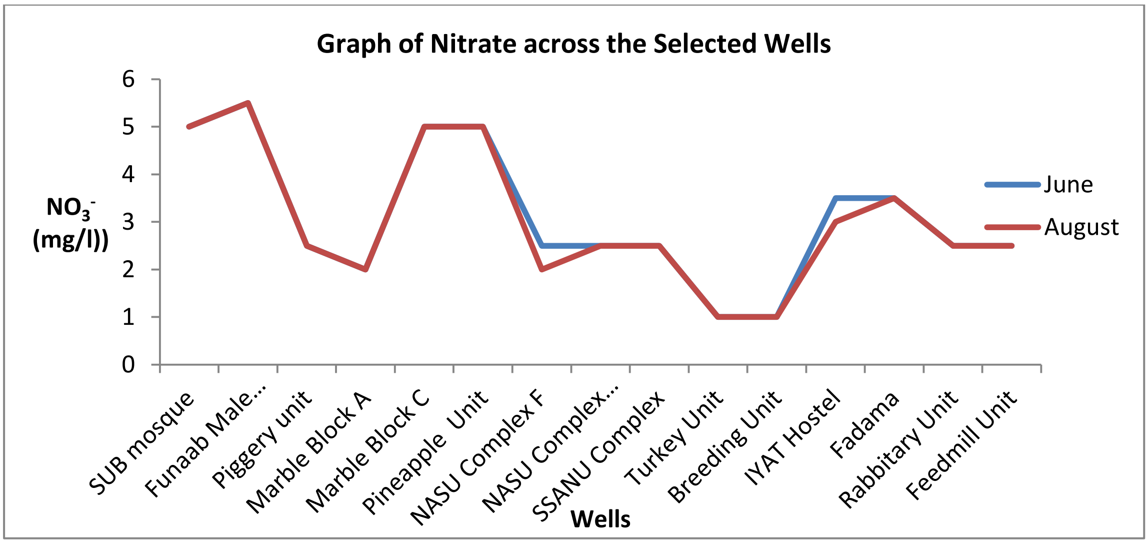

Figure 12: A graph showing the trend of Nitrate across the wells

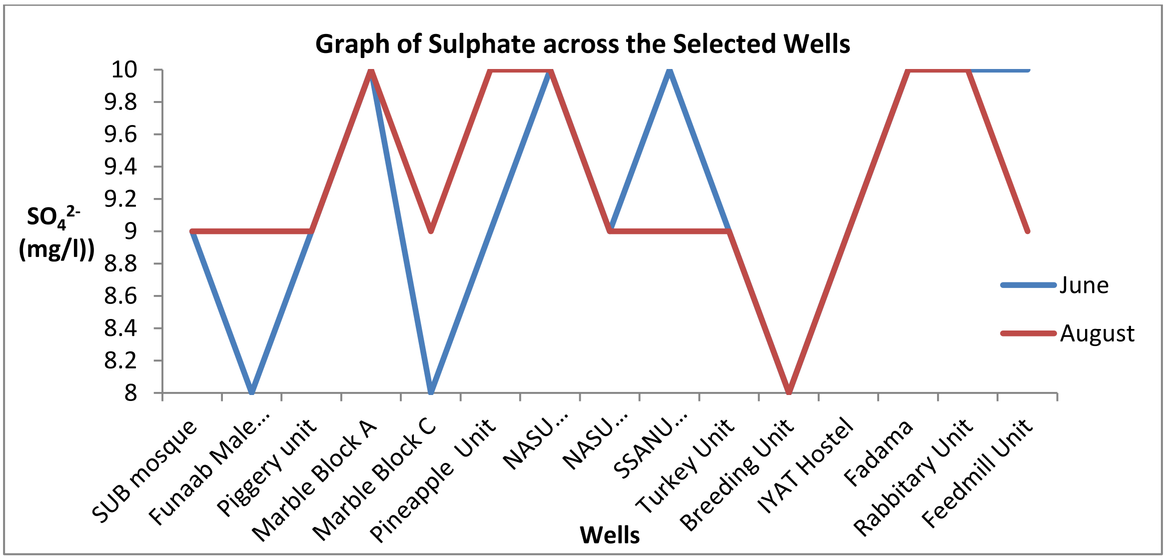

Figure 13: A graph showing the trend of Sulphate across the wells

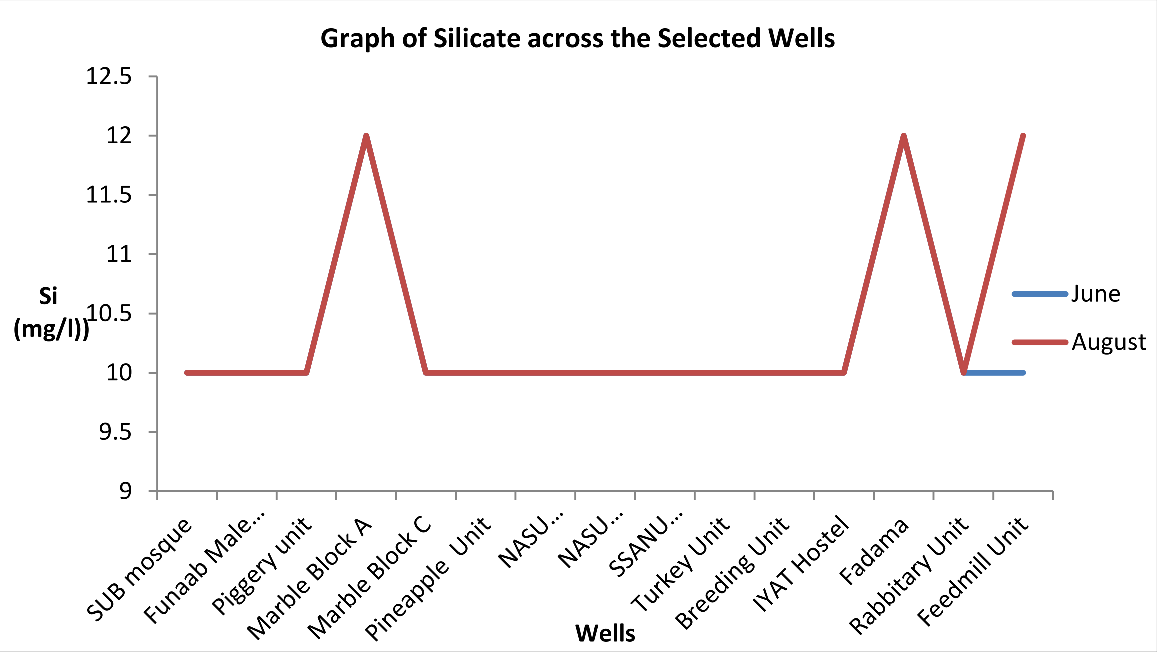

Figure 14: A graph showing the trend of Silicate across the wells

Obtaining the Direction of Flow of the Observed Wells

The geographical coordinates of the sampled wells and the Well Heads were plotted on a contour map to obtain the direction of groundwater flow as shown in Figure 14; simultaneous to the decrease in the well heads. The water flows from the contour with high head to that of lower heads. The implication of this is that the recharge at W1 depends on discharge at the other wells. This is because it falls on the contour that has the lowest head.

W2, W12, W4,W5 and W13 flow in Southwest direction, W1, W6, W3, W14, W15, W10 and W11 flow in Northeast direction and W7, W8 and W9 flow in Northwest direction. Generally the flow of the wells is in the South-eastern, North-eastern and North-western direction. Table 2 shows the flow direction according to the sampling points.

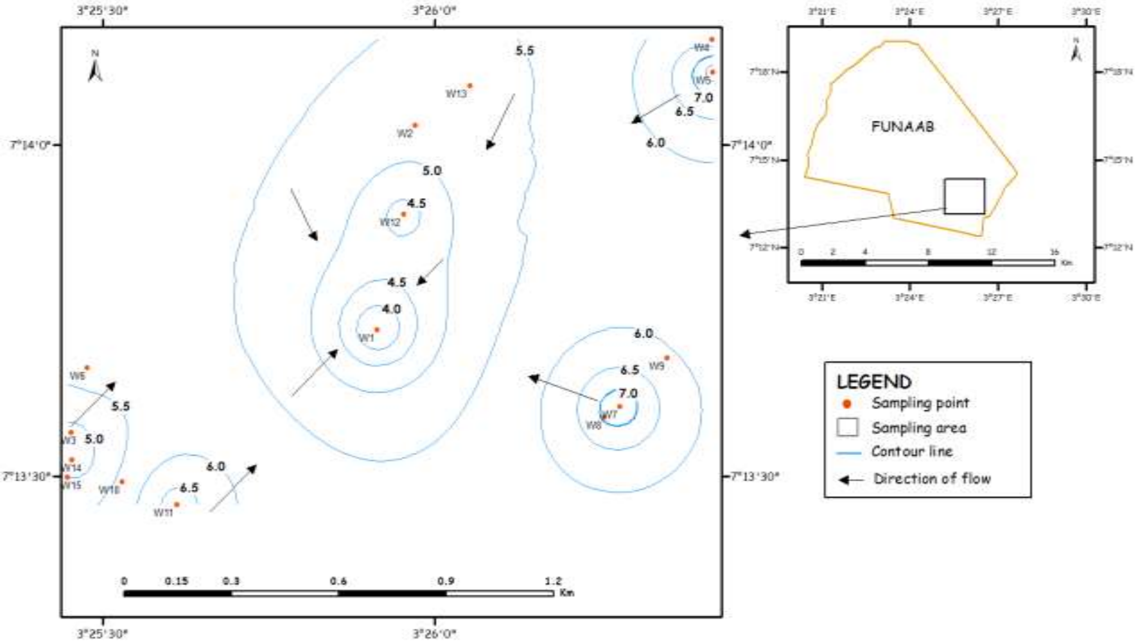

Figure 15: Contour Map of Well Head showing flow directions

Table 2: Classifications of the Wells Based on Flow Directions

Southwest Direction	Northeast Direction	Northwest Direction
FUNAAB Male Hostel	Piggery unit	SSANU Complex
Marble Block A	Pineapple Unit	NASU Complex F
Marble Block C	Turkey unit	NASU Complex B
IYAT Hostel	Breeding unit	
Fadama	Rabbitary Unit	
	Feedmill Unit	
	SUB Mosque	

VARIATIONS IN PARAMETERS ACROSS FLOW DIRECTIONS

Southwest Direction Wells

For the month of June: The result of water quality analysis for the month of June is presented in Table 3. The pH of the wells flowing in the Southwest direction ranges between 7.06 and 7.49. The mean EC and TDS are 436µs/cm and 218.4mg/l. Sodium and Potassium ion concentration ranges from 10 to 30mg/l and 5 to 8mg/l respectively.

The mean of Magnesium was obtained to be 39.8mg/l while that of Calcium concentration is 49.2mg/l. Chloride ion

Table 3: Water Quality Parameters for June

S/N	Well Code	Well Location	pH	EC (us/cm)	TDS (mg/l)	TA (mg/l)	Na^{+} (mg/l)	K^{+} (mg/l)	Mg^{2+} (mg/l)	Ca^{2+} (mg/l)	Cl^{-} (mg/l)	CO_3 (mg/l)	NO_3^{-} (mg/l)	SO4 (mg/l)	Si (mg/l)
1	W1	SUB mosque	7.86	501	250	6	30	24	30	24.9	5.3	5	7	9	10
2	W2	FUNAAB Male Hostel	7.7	689	345	5	33	53	75	19.9	4.4	5.5	8	8	10
3	W3	Piggery unit	7.79	539	269	6	22	64	36	22.4	5.3	2.5	6.5	9	10
4	W4	Marble Block A	7.47	375	188	8	10	35	46	12.9	7	2	5.1	10	12
5	W5	Marble Block C	7.49	283	142	5	10	33	39	11.4	4.4	5	5	8	10
6	W6	Pineapple Unit	7.26	148	73.9	4	8	22	20	12.4	3.5	5	2	9	10
7	W7	NASU Complex F	7.52	316	158	6	10	32	28	14.4	5.3	2.5	4.8	10	10
8	W8	NASU Complex B	7.89	224	112	6	20	18	29	4.9	5.3	2.5	5	9	10
9	W9	SSANU Complex	7.8	360	180	7	15	15	36	12	6.2	2.5	5	10	10
10	W10	Turkey Unit	6.9	196	97.9	10	11	22	21	10.4	8.8	1	5	9	10
11	W11	Breeding Unit	7.01	279	139	4	12	39	20	19.9	3.5	1	6.8	8	10
12	W12	IYAT Hostel	7.06	311	156	8	10	26	44	17.4	7	3.5	5.5	9	10
13	W13	Fadama	7.59	522	261	6	20	52	42	22.9	5.3	3.5	6.9	10	12
14	W14	Rabbitary Unit	7.5	175	87.3	5	6	21	31	34.9	4.4	2.5	2.2	10	10
15	W15	Feedmill Unit	6.88	137	68.5	4	7	16	21	29.9	3.5	2.5	2.8	10	10

concentration ranges between 11.4 and 22.9mg/l in the wells with the lowest obtained at Marble Block C.

The highest carbonate ion concentration was obtained at Marble Block A and IYAT hostel with a concentration of 7mg/l. Nitrate content among the observed wells ranges between 2mg/l and 5.5mg/l. The mean of Sulphate ion and Silicate ion concentration of the wells flowing in the southwest direction is 9mg/l and 10.8mg/l.

For the month of August: The result of water quality analysis for the month of August is presented in Table 4 The pH of the wells flowing in the Southwest direction ranges between 7.1 and 7.65. The mean EC and TDS are 427.4µs/cm and 217 mg/l. Sodium and Potassium ion concentration ranges from 10 to 34mg/l and 5.3 to 8mg/l respectively.

The mean of Magnesium was obtained to be 39.8mg/l while that of Calcium concentration is 49mg/l. Chloride ion concentration ranges between 11.3 and 24mg//l in the wells with the lowest obtained at Marble Block C.

The highest carbonate ion concentration was obtained at Marble Block A and IYAT hostel with a concentration of 7mg/l. Nitrate content among the observed wells has a mean of 3.8mg/l. The mean of Sulphate ion and Silicate ion concentration of the wells flowing in the southwest direction is 9.4mg/l and 10.8mg/l.

Northwest Direction wells

For the month of June: The pH of the wells flowing in the Northwest direction ranges between 7.52 and 7.89. The mean EC and TDS are 300µs/cm and 150mg/l. Sodium and Potassium ion concentration ranges from 10 to 20mg/l and 4.8 to 5mg/l respectively.

The mean of Magnesium was obtained to be 21.7mg/l while that of Calcium concentration is 31mg/l. Chloride ion concentration ranges between 4.4 and 14.4mg/l in the wells with the lowest obtained at NASU Complex B.

The highest carbonate ion concentration was obtained at SSANU Complex with a concentration of 6.2mg/l. Nitrate content among the observed wells was observed to be 2.5mg/l. The mean of Sulphate ion and Silicate ion concentration of the wells flowing in the Northwest direction is 9.7mg/l and 10mg/l.

For the month of August: The pH of the wells flowing in the Northwest direction ranges between 7.55 and 7.88. The mean EC and TDS are 297µs/cm and 155mg/l. Sodium and Potassium ion concentration ranges from 10 to 21mg/l and 4.9 to 5.1mg/l respectively.

The mean of Magnesium was obtained to be 23mg/l while that of Calcium concentration is 31.3mg/l. Chloride ion concentration ranges between 5.04 and 14mg/l in the wells. The highest carbonate ion concentration was obtained at SSANU Complex with a concentration of 6mg/l. The mean of the Nitrate Concentration among the wells is 2.33mg/l. The mean of Sulphate ion and Silicate ion concentration of the wells flowing in the Northwest direction is 9.33mg/l and 10mg/l.

Northeast Direction Wells

For the month of June: The pH of the wells flowing in the Northwest direction ranges between 6.88 and 7.86. The mean EC and TDS are 282µs/cm and 141mg/l. Sodium and Potassium ion concentration ranges from 6 to 30mg/l and 2 to 7mg/l respectively. The mean of Magnesium was obtained to be 29.7mg/l while that of Calcium concentration is 25.6mg/l. Chloride ion concentration ranges between 10.4 and 34.9mg/l in the wells with the lowest obtained at Turkey Unit. The highest carbonate ion concentration was obtained at Turkey Unit with a concentration of 8.8mg/l. Nitrate content among the observed wells ranges from 1 to 5mg/l.

Table 4: Water Quality Parameters for August

S/N	Well Code	Well Location	pH	EC (us/cm)	TDS (mg/l)	TA (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	Mg^{2+} (mg/l)	Ca^{2+} (mg/l)	Cl^- (mg/l)	CO_3 (mg/l)	NO_3^- (mg/l)	SO4 (mg/l)	Si (mg/l)
1	W1	SUB mosque	7.85	503	240	6	31	7	26	30	24.7	5.3	5	9	10
2	W2	FUNAAB Male Hostel	7.65	652	330	5	34	8	52	75	19.5	4.5	5.5	9	10
3	W3	Piggery unit	7.8	528	246.5	6	24	6.1	63	39	22	5.4	2.5	9	10
4	W4	Marble Block A	7.39	370	183	9	12	5.3	35	47	12.9	7	2	10	12
5	W5	Marble Block C	7.48	260	140	6	11	6	34	40	11.3	4.5	5	9	10
6	W6	Pineapple Unit	7.31	148	75	5	9	3	22	20	12.5	3.6	5	10	10
7	W7	NASU Complex F	7.55	312	160	6	10	4.9	33	27	14	5.3	2	10	10
8	W8	NASU Complex B	7.88	228	120	6	21	5	20	29	5.04	5.3	2.5	9	10
9	W9	SSANU Complex	7.8	350	186	7	16	5.1	16	38	13	6	2.5	9	10
10	W10	Turkey Unit	6.8	201	99	10	11	5.1	21	21	11.2	8.7	1	9	10
11	W11	Breeding Unit	7.01	285	142	5	11	6.8	39	20	21	3.5	1	8	10
12	W12	IYAT Hostel	7.1	320	162	9	10	5.5	28	42	16	7	3	9	10
13	W13	Fadama	7.59	535	270	7	20	6.9	50	41	24	5.4	3.5	10	12
14	W14	Rabbitary Unit	7.51	176	85.2	5	7	2.1	19	31	35	4.4	2.5	10	10
15	W15	Feedmill Unit	6.85	140	68	4	8	2.8	17	20	27	3.5	2.5	9	12

The mean of Sulphate ion and Silicate ion concentration of the wells flowing in the Northeast direction is 9.14mg/l and 10mg/l.

For the month of August: The pH of the wells flowing in the Northwest direction ranges between 6.85 and 7.85. The mean EC and TDS are 283µs/cm and 134mg/l. Sodium and Potassium ion concentration ranges from 7 to 31mg/l and 2.8 to 7mg/l respectively.

The mean of Magnesium was obtained to be 30.6mg/l while that of Calcium concentration is 25.9mg/l. Chloride ion concentration ranges between 11.2 and 35mg/l in the wells. The highest carbonate ion concentration was obtained at Turkey unit with a concentration of 8.7mg/l. Nitrate content among the observed wells was observed to have a mean of 2.8mg/l. The mean of Sulphate ion and Silicate ion concentration of the wells flowing in the Northeast direction is 9.14mg/l and 10.3mg/l.

STATISTICAL ANALYSIS

Results Correlation Between he Analysed Parameters

A positively significant correlation of 0.586 exists between pH and Electrical Conductivity as well as pH and Total Dissolved Solids (TDS). This shows that the parameters move in the same direction. A perfectly significant correlation of 1.000 exists between Total Dissolved Solids and Electrical Conductivity. A direct relationship exists between the two parameters. An increase in one causes a very significant increase in the other.

A positively highly significant correlation exists between Sodium and pH, Sodium and Electrical Conductivity as well as Sodium and Total Dissolved Solids (TDS) with a correlation coefficient of 0.644, 0.846 and 0.845 respectively. A very significant correlation exists between Potassium and Electrical Conductivity, Potassium and Total Dissolved Solids as well as Potassium and Sodium with a coefficient of 0.844, 0.844 and 0.782 respectively.

Magnesium has a positively significant correlation with Electrical Conductivity, Total Dissolved Solids and Potassium with correlation coefficient of 0.756, 0.756 and 0.655 respectively. Correlation Coefficient of 0.763 and 0.766 exists between Calcium and Electrical Conductivity as well Calcium and Total Dissolved Solids respectively. A slightly significant relationship was found when Calcium was correlated with Sodium, Potassium and Magnesium.

Chloride ion shows a significant correlation with water level having a correlation coefficient of 0.632. Correlation result between the well depth and the parameters shows an insignificant negative correlation indicating decrease in the parameters as the depth increases. This can be interpreted to mean that the deeper the well, the more likely to get water of better quality.

CONCLUSION

The quality of water obtained from the sampled wells in the study area does not differ significantly among the observed months. This might be attached to the fact that the samples were taken in June and August which both falls under rainy seasons. This can also be due to the absence of industries or other source of pollution that can compromise or change the quality of the water in the wells. Correlation result between the well depth and the parameters shows an insignificant negative correlation indicating decrease in the parameters as the depth increases.

This can be interpreted to mean that the deeper the well, the more likely to get water of better quality. It was also obtained that the water flows with decrease in the well heads. The water flows from the contour with high head to that of lower heads.

REFERENCES

Asonye C. C. , Okolie N. P., Okenwa E. E. and Iwuanyanwu U.G., (2007) *" Some Physicochemical Characteristics And Heavy Metal Profiles Of Nigerian Rivers, Streams And Waterways*". African Journal of Biotechnology Vol. 6 (5), pp. 617-624.

Patil, V.T. and. Patil P.R., (2010) "Physicochemical analysis of selected groundwater samples of Amalner town in Jalgaon district, Maharashtra, India". E J. Chem., &:111-116.

Mark, W.R., Ximing C. and Sarah A.C., (2002) "World Water and Wood To 2025: Dealing With Scarcity". International Food Policy Research Institute, NW, Washington, DC, USA.

Sina, D., Ngounoun, N.B, Mudy J., and Sarrol R.J., (2002) "*Assessment of Microbial Water Quality of handdug Wells in the Floodplains of Makurdi Metropolis, Benue State, Nigeria*". An Unpublished Master of Engineering thesis by the University of Agriculture Makurdi. Department of Agricultural and Environmental Engineering.

Karbassi., A.R. and G.O. Ayaz,(2007) "*Flocculation of Cu, Zn, Pb, Ni and Mn during mixing of Talar River Water with Caspian Seawater*". International Journals of Environmental Resources p p (1): 66-73.

Kinzelbach, W. (2002) "*Groundwater modeling: An Distribution of groundwater quality with Introduction with sample program in basic, Elsevier geo statistics (Case study: Yazd-Ardakan plain)"*

ASSESSMENT OF WATER QUALITY IN OGUN AND OSHUN RIVERS QUALITY FOR IRRIGATION PURPOSE

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ABSTRACT

This research study is an attempt to analyze the water quality of river Ogun and Oshun in Ogun-Oshun River Basin for irrigation purpose. Composite water samples were collected from thirteen sites in Ogun River Basin and ten sites in Oshun River Basin covering the wet and dry seasons. The samples were analyzed using standard methods for the examination of water and wastewater jointly published by the American Public Health Association. Water quality variables were measured in the river over a period of one year. The samples were analyzed for total dissolved salts (TDS), magnesium content (MC), sodium percent (SP), sodium adsorption ratio (SAR) and permeability index (PI). Study of all irrigation parameters characteristics indicates that both rivers in wet season are not suitable for irrigation purpose because of their high values of magnesium content and sodium percent

Keywords: Oshun River, Ogun River, Irrigation, wet Season, SAR

INTRODUCTION

Water is most essential for life. People can survive without food for long time but not without water. High quality water may be required only for drinking purposes while for other uses like agriculture and industry, the quality of water can be quite flexible and water polluted up to certain extent in general sense can be regarded as pure (Goel, 2006). Due to industrial development water sources has become polluted. This contamination become harmful to living things when these supplies pass on through cities or populated area. Pollution levels now compromise public health, and the livelihoods of impoverished fishing families have been jeopardized by widespread fish kill (DGWR, 2007). The concentration and composition dissolved constituents in water determine its quality for irrigation use. Quality of water is an important consideration in any appraisal of salinity or alkali conditions in an irrigated area. Good quality water has the potential to cause maximum yield while poor quality water can lead to various soil and cropping problems. However, conducting an adaptive guideline in managing of water quality to the specific local condition is necessary (Fulazzaky et al, 2010). For example, salinity tolerance of macro-invertebrate communities varies in Eastern Australia; hence, water quality guidelines should be developed at a local or regional scale (Dunlop et al., 2008). The nutrient pollution effects of moderate eutrophication on Ogun and Oshun Rivers need to be addressed by appropriate agricultural and environmental policies that relates to water pollution and land use .Therefore special management practices may then be required to maintain full crop productivity. Irrigated agriculture is dependent on an adequate water supply of usable quality. In irrigation water evaluation, emphases are placed on the chemical and physical characteristics of the water and only rarely are any other factors considered important. Here attempt has been made to assess the irrigation water quality of River Ogun and Oshun. The quality characteristics studied in the present investigations were as follows: Total dissolved salts (TDS), Magnesium content (MC), Sodium percentage (SP), Sodium adsorption ratio (SAR), and Permeability index (PI).

MATERIAL AND METHOD

Study Area

The Oshun River Basin is located approximately between latitudes 6^{o}30'N and 8^{O}20'N and longitudes 3^{o}23'E and 5^{O}l0'E. The major drainage system is that of the Oshun River, which rises in the Oke-Mesi

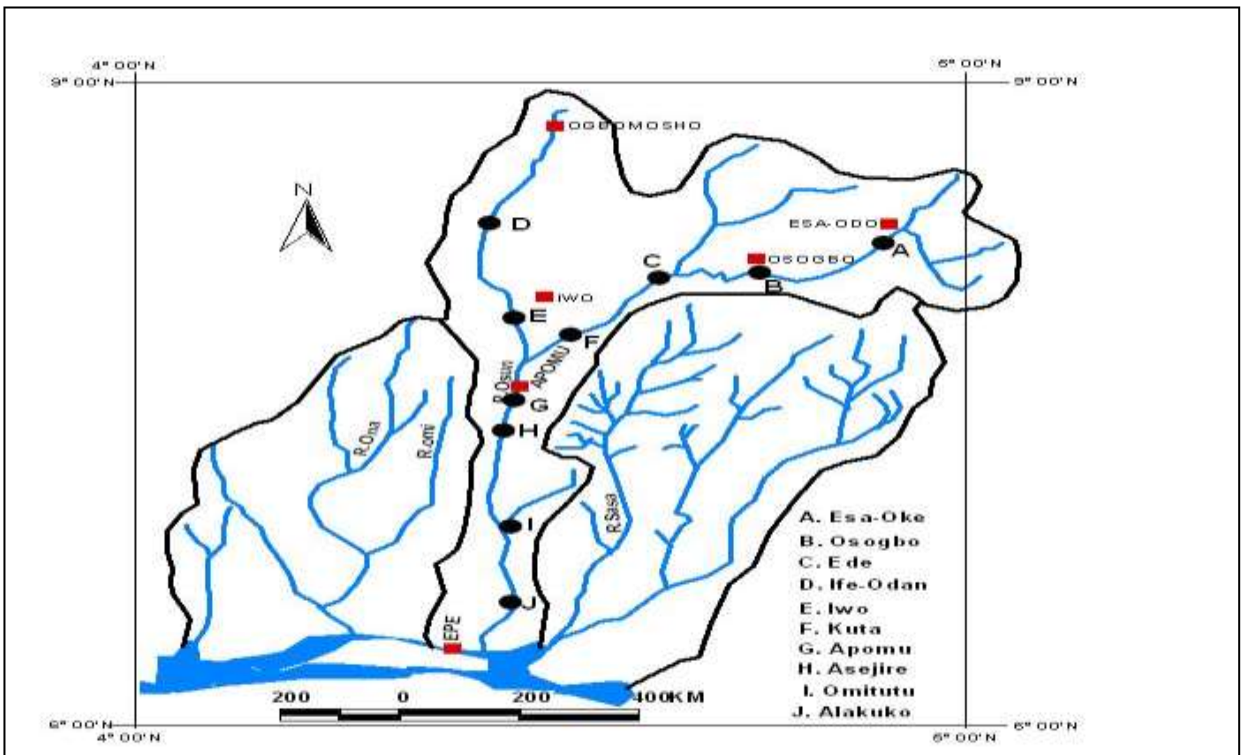

Figure 1 Oshun River Basin showing the Sampling Locations

ridge about 5 km north of EffonAlaiye on the border between Oyo and Ondo States and flows through the Itawure gap to latitude 7°53' 30"N before winding its way first westward through Oshogbo and Ede and then southward to enter the Lagos Lagoon about 8 km east of Epe.

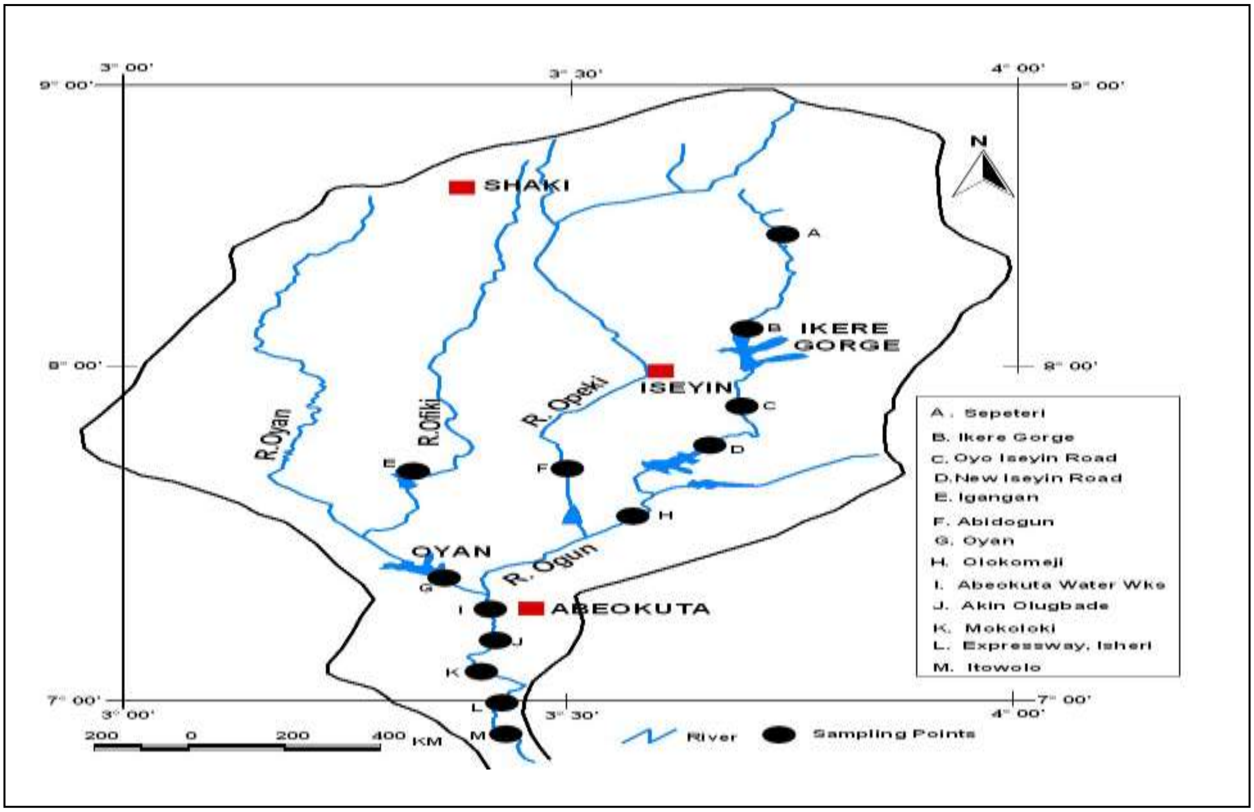

Figure 2 Ogun River Basin showing the Sampling Locations

The Ogun River Basin lies in South-Western Nigeria between latitudes 6° 33' and 8° 58' N and longitude 2° 40' and 4° 10' E, occupying a total area of approximately 23,700sq.km. The bulk of the river basin is located in Nigeria and less than 0.2 percent of its area extends across the border to the Republic of Benin. The Ogun River Basin falls within the boundaries of Lagos, Oyo and Ogun states.

Experimental

Water samples were collected for one year (June 2011 to May 2012), for dry and wet seasons. Samples were collected from thirteen sampling sites along the course of Ogun River and ten sampling sites along the course of Oshun River. Water samples were collected in plastic bottles with hard plastic screw caps. Grab sampling was generally applied during the sampling. Water samples were analyzed by standard methods (Villanveva *et al.,* 2008). MC, SP, SAR, and PI were calculated as follows:

Magnesium content

Magnesium content of water is considered as one of the most important qualitative criteria in determining quality of water for irrigation. Magnesium content was calculated by the following formula (Pitchaiah, 1995):

$$Mg\ Content = \left[\frac{Mg^{2+}}{Mg^{2+} + Ca^{2+}}\right] 100$$

(Concentrations are in meq/l)

Sodium percentage (SP)

Doneen method was used to calculate the sodium percentage (Pathak *et al.,* 2002)

$$Na\% = \left[\frac{Na^{+} + K^{+}}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}}\right] 100$$

(Concentrations are in meq/l)

Sodium absorption ratio (SAR)

Sodium absorption ratio is an important parameter to determine the suitability of irrigation water and was calculated by the following formula (Domenico and Schwartz 1990):

$$SAR = \frac{Na^{+}}{\sqrt{\left[\frac{Ca^{2+}+Mg^{2+}}{2}\right]}}$$

(Concentrations are in meq/l)

Permeability index (PI)

Permeability index was calculated by the formula:

$$PI = \left[\frac{Na^{+}+HCO_3}{Ca^{2+}+Mg^{2+}+Na^{2+}}\right] 100$$

PI is used to evaluate the sodium hazards of irrigation water. (Domenico and Schwartz 1990)

RESULTS AND DISCUSSION

The results obtained from analysis of water samples of both rivers are shown in Table 1 below

Table 1: Irrigation water characteristics of Ogun and Oshun River Water

PARAMETERS	Ogun River Water		Oshun River Water	
	Dry Season	Wet Season	Dry Season	Wet Season
TDS	165.19	153.21	110.78	86.88
MC	39.0	40.0	43.7	51.9
PS	35.62	67.72	53.29	67.41
SAR	0.752	3.512	1.493	2.895
PI	94.6	97.8	83.9	126.3

Total dissolved salts (TDS)

Water used for irrigation can vary greatly in quality depending on the type and quantity of dissolved salts. Salts are present in irrigation water in relatively small but significant amounts Water with TDS less than 450mg/lit is considered good and that with greater than 2000 mg/lit is unsuitable for irrigation purpose.

In the present study the minimum value of TDS was found in wet season with a value of 153.21 mg/lit and the maximum value was found in dry season with a value of 165.19 mg/lit in Ogun river while in Oshun river, the minimum value of total dissolved solids was found in wet season with a value of 86.88 mg/lit and the maximum value was found in dry season with a value of 110.78.0 mg/lit.

The TDS values for both rivers are within the desirable limit set by US Salinity Lab and therefore desirable for irrigation uses.

Magnesium content

Magnesium content of water is considered as one of the most important qualitative criteria in determining the quality of water for irrigation. According to US Salinity Laboratory, MC > 50 is considered harmful and unsuitable for irrigation use.

The magnesium content values of the water of river Ogun were 39.0 mg/l and 40.0mg/l in dry and wet season respectively while the magnesium content values of the water of river Oshun were 43.7 mg/l and 51.9 mg/l in dry and wet season respectively. So, water of Ogun River is suitable for irrigation purpose in terms of magnesium content in both seasons but water of Oshun River is unsuitable for irrigation purpose in terms of magnesium content in the wet season.

Permeability Index (P.I.)

The soil permeability is affected by long term use of irrigation water. Sodium, calcium, magnesium and bicarbonate content of the soil influence it. Accordingly, water can be classified into class I, Class II and Class III orders. Class I and Class II waters are categorized as good for irrigation with 75% or more maximum permeability. Class III water are unsuitable with 25% of maximum permeability. In the present study the minimum value of P.I. is 83.90. Hence both rivers water are of good irrigation quality.

Sodium Percent

Sodium percent is another important factor to study sodium hazard. It is calculated as the percentage of sodium and potassium against all cationic concentration. Sodium percent in water is a parameter computed to evaluate the suitability for irrigation. According to US Salinity Laboratory, SP value within 20 -30% is classified as Class I: Very Suitable, 40 – 60% as Class II: Suitable and 60 – 80% as Class III: Unsuitable. The sodium percent values of river Ogun were 35.62 in the dry season and 67.72 in the wet season while the sodium percent values of river Oshun were 53.29 in the dry season and 67.41 in the wet season. These values are high in wet seasons for both rivers. Gypsum can be added to the soil to reduce the effect of high percentage of sodium in irrigation water.

Sodium Adsorption Ratio (SAR)

Excess sodium in waters produces the undesirable effects of changing soil properties and reducing soil permeability (Dwivedi and Pathak 2007).Hence the assessment of sodium concentration is necessary while considering the suitability for irrigation. The degree to which irrigation water tends to enter into cation-exchange reactions in soil can be indicated by the sodium adsorption ratio, Sodium replacing adsorbed calcium and magnesium is a hazard as it causes damage to the soil structure. It becomes compact and impervious. SAR is an important parameter for the determination of suitability of irrigation water because it is responsible for the sodium hazard. The waters were classified in relation to irrigation based in the ranges of SAR values. Water with SAR ranging from 0 to 3 is considered good and with greater than 9 is considered unsuitable for irrigation purpose In the present study SAR were found to be 0.752 and 3.512 in dry and wet seasons respectively in Ogun river while in Oshun river, SAR were found to be 1.493 and 2.895 in dry and wet season respectively. The low value of S.A.R. for both rivers water in the dry season can be categorized as water of excellent category.

CONCLUSION

TDS, MC, SP, SAR and PI were found to be within permissible range except in wet season. In wet season, MC and PS were a little higher. Hence irrigation water qualities of both rivers were found to be good except in the wet season.

REFERENCES

Goel, P.K., (2006). Water Pollution, Cause, effects and control Second revised Edition, New Age international Publishers

Directorate General of Water Resources (DGWR)., (2007). Integrated Ciatrum water resources management project: Report on roadmap and program development. In: Technical assistance consultant’s report.

Fulazzaky, M.A., Teng, W.S,. Mohd Masirin, M.I. (2010). Assessment of water quality status for the Selangor river in Malaysia. Water, Air & Soil Pollution, 205(1): 63-77

Dunlop J.E., Horrigan N., McGregor, G., Kefford, B. J. Choy, S. and Prasad, R. (2008). Effect of spatial variation on salinity tolerance of macro-invertebrates in Eastern Australia and implications for ecosystem protection trigger values. Environmental Pollution, 151(3), 621-630

Villanveva S.F., Diego A.D., Madariaga J.M.,(2008) J. Marine Sys., 72, 332.

APHA (1998). Standard Methods for the Examination of Water and Wastewater,” 20th Edition, Published Jointly by American Public Health Association, American Water Works Association and Water Polition Control Federation,Washington

Pitchaiah P.S., (1995). Ground water, Scientific Publ Jodhpur, Rajasthan pp 304.

Pathak, S.S., Upadhyaya, K.K., Joshi, S.K., (2002) Him.J.Env.Zool, 151.

Domenico P.A., Schwartz F.W.,(1990) Physical and Chemical hydrology, John Wiley and sons, New York, 410

Dwivedi, S.L., Pathak, V., (2007). Studies of water quality of Mandakini River in Chitrakoot for irrigation purposes, IJEP, **27**(8)**:** 751-754.

ANALYSIS OF CLIMATIC TREND AND ITS IMPLICATION ON IRRIGATION FARMING SYSTEM ON THE JOS PLATEAU

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Abstract

Climate change is perhaps the most serious environmental threat to the fight against hunger, malnutrition, disease and poverty in Africa, mainly through its impact on agricultural productivity. In the light of this, the researcher attempts analysis of climatic trend and its implication on irrigation farming system on the Jos Plateau. Two sets of data were generated one on climatic variables and the other on the influence of climatic element on irrigation farming system using questionnaire. Findings from the climatic variables shows the period between 2010 and 2015 show increase. Findings from questionnaire reveals that there is increase in temperature (90%) and rainfall (97%). It is therefore recommended among other things that government, ministries, parastatals and voluntary organizations should be involved in mobilizing financial support to cushion the effect of climate change on the Jos Plateau. It is therefore concluded when implemented, these will improve the hardship experienced by these communities due to climate change impacts.

Keywords: *Climate change, malnutrition, agriculture, irrigation, rainfall and temperature*

INTRODUCTION

The recent disastrous incidence of climate change recorded at worldwide scale presents new challenges to agricultural production in developing countries (1), and particularly in sub-Sahara Africa (2); intergovernmental panel on climate change(3). In the past decades, the intergovernmental panel on climate (IPCC) had forecasted that, Africa is the most susceptible to climate change impacts due to the fact that anthropogenic activities which lead to climate change is increasing and there are no corresponding efforts to mitigate climate change(3). Uncertainty in weather forms, rainfall, drought and flooding happenings, have meant that rural farmers who implement regular annual farm business agenda risk total crop/livestock failure due to climate change effects.

Climate change is a complex biophysical process (5). It is difficult to predict precise future climate conditions, but consensus has emerged among scientists that global land and sea temperatures are warming under the influence of greenhouse gases, and will continue to warm regardless of human intervention for at least the next two decades(6). It has been reported that the increasing concentrations of greenhouse gases in the atmosphere are mainly due to the 80 per cent increase in annual CO_2 emissions since 1970. Most of this historical increase emanated from the industrial activities of developed countries in Europe, North America and Japan. Developing countries, especially those on the African continent have contributed little to the observed global warning. Increasing poverty tends to render African countries vulnerable to climate change impacts. Moreso, agricultural production and the biophysical, political and social systems that determine food security in Africa are expected to be placed under considerable stress by climate change (7).

The IPCC's Fourth Assessment Report describes a trend of warming at a rate faster than the global average, and increasing aridity in Africa. On balance higher temperatures are likely to increase evaporative demand throughout Africa. Annual rainfall is likely to decrease in much of Mediterranean Africa and the northern Sahara. Rainfall in Southern Africa is likely to decrease. Annual rainfall in East Africa is likely to increase but it is unclear how rainfall in the Sahel, the Guinean Coast and the southern Sahara will evolve(8).

Climate change exert multiple stresses on the biophysical as well as the social and institutional environment that underpin agricultural production. Some of the induced changes are expected to be abrupt while others involve gradual shifts in temperature, vegetation cover and species distributions. Climate change is expected to, and in parts of Africa has already begun to, alter the dynamics of drought, rainfall and heat waves, and trigger secondary stresses such as the spread of pests, increased competition for resources, the collapse of financial institutions, and attendant biodiversity losses. Predicting the impact of climate change on complex biophysical and socio-economic systems that constitute agricultural sectors is difficult In many parts of Africa it seems that warmer climates and changes in precipitation will destabilize agricultural production. This is expected to undermine the systems that provide food security(9). Whilst farmers in some regions may benefit from longer growing seasons and higher yields, the general consequences for Africa, are expected to be adverse, and particularly adverse for the poor and the marginalized who do not have the means to withstand shocks and changes.

The United Nations framework on climate change defines climate change as a change of climate which is attributed directly or indirectly to human activities that alter the composition of the global atmosphere and which is, in-addition to natural climate variability, observed over comparable time period (10,11, 12 as cited in 13). Climate Change is also defined as long-term change in the statistical distribution of weather patterns over periods ranging from decades to millions of years regardless of cause (13). Climate change is responsible for uncertainty in the rainfall pattern, especially the timing and amount of rainfall and these affect agricultural activities. Many places in Nigeria are experiencing late onset of rains, early ending of rainy season, and reduced annual amount of rainfalls, especially in the northern parts of the country(14 and 15). This has confines cultivation to short period of 3-5 months and also disrupts the usual pattern of seasonal water availability. The food and agricultural organization(16) predicts that by the year 2085, 11 per cent of arable land in developing countries (especially African countries) will be lost to climate change in various ways. This is because developing countries often lack the infrastructure and institutions for dealing with climate change: yet agriculture plays a vital role in their national economies. In another report (17), projects fall in agricultural productivity up to 30 per cent over the 21st century. This has already become manifested in Nigeria as reduction in crop yields are causing localized food price rises in many parts of the countries. (18 and 19).

There would be increase in the risk of crop failure as a result of higher frequencies of drought, flood, storms and other weather hazards to agriculture. Increasing temperatures, declining and more unpredictable rainfall, more frequent extreme weather and higher severity of pest and diseases are among the more drastic changes that would impact food production (20) cited n (21).

MATERIALS AND METHOD

Jos Plateau is located in the north central region of Nigeria and lies between latitude 8°3' and 10°30' North and latitude 7°30' and 8°37' East. The climate is characterized by two distinct seasons, wet and dry. The wet season last a period of 5 months (March – September) while the dry season covers the month of October to February. The appropriate maximum high temperature is about 22°C while the mean minimum low temperature is about 18°C.The weather on the Jos Plateau is therefore generally cold especially between December and February as a result of the harmattan (North East trade) winds(21).

Research Method

This study is a result of a combination of data collection procedures and analysis. Primary data source and secondary data source were used. The climatic data span a period of 33 years to enable the determination of climatic variability in terms of rainfall and temperature [22]. Questionnaire survey carried out on the Jos Plateau to capture the views and perceptions of men and women on the issue of climate change. Households selects to take part in the survey were located on 300 random points selected throughout the area. The sample size of respondents was determine using the population size of the area. There was also purposive targeting of the elderly men and women of 60 years and above, The elderly were targeted because they would be in a position to make significantly reliable comparisons with past climate scenarios. Older men and women have more experience with the natural climatic variability; (23 and 24) as cited in (25). The questionnaire was targeting the household head. In the absence of such persons the second influential person in the household were considered.

RESULTS AND DISCUSSION

TABLE:1 ANNUAL RAIN FALL AND 5 YEARS MOVING AVERAGE FOR JOS PLATEAU

YEARS	ANNUAL RAIN FALL	5YRS MOVING AVERAGE
1980	1148	
1981	1476	
1982	1231	
1983	1163	
1984	1453	1294
1985	1375	1339
1986	1470	1129
1987	1280	1348
1988	1164	1348
1989	1428	1358
1990	1451	1358
1991	1480	1358
1992	1330	1370
1993	1483	1434
1994	1486	1445
1995	1439	1443
1996	1470	1441
1997	1439	1463
1998	1303	1427
1999	1325	1395
2000	1410	1389
2001	1447	1384
2002	1226	1342
2003	1408	1363
2004	1308	1359
2005	1204	1029
2006	1396	1308
2007	1357	1334
2008	1260	1304
2009	1001	1243
2010	1493	1301
2011	1244	1271
2012	1467	1293
2013	1431	1327
2014	1437	1414
2015	1511	1417

Source of Data: University Jos Meteorological Observatory.

Figure 1 show the observed annual rainfall pattern of the study area.

The thirty six (36) year's annual rainfall data For Jos Plateau is presented in table 1. Analysis of data in table 1 shows that annual rain fall on the Jos Plateau is highly variable, with the lowest year been 2009 and the highest year been 2015 with values of 1001 mm and 1511mm respectively. The same area plotted and presented in figure 1.

This itself cannot tell us the direction of climate change on the plateau using rainfall data as a parameter. The research therefore employ the use of five years moving average, this was done to smoothen out excessive high and low values. The five years moving average was then super impose on the annual rainfall data. The result obtain was still not very clear. At this junction a trend line was fitted to both annual rainfall and five years moving average, results obtain shows that in spite of the variable nature of rainfall on the plateau, the trend line slope Deeping to the right slightly. This simply means that on the overall. Annual rainfall is slight y decreasing on the Jos plateau. A regression equation was fitted to the trend line and it yielded the equation Y=0.8996x + 1363 with an r^2=0.0089, this invariably means that there is a tendency of decrease in rainfall on the Jos plateau of about 90mm from an average of 1363 and this means that Jos Plateau records one percent (1%) decrease in rainfall annually from mean as indicated by the coefficient of determination (r^2) of **0.0089.** see figure 1.

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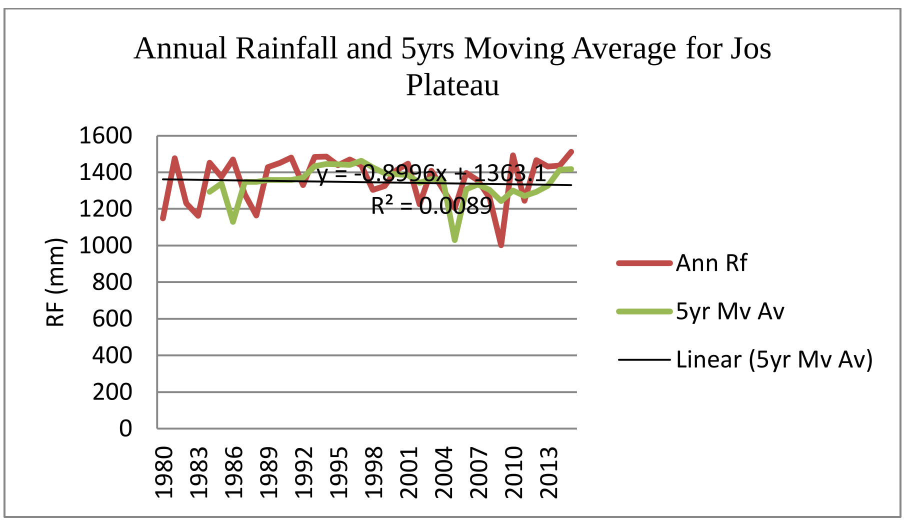

Figure 1

Figure 2: shows the observed temperature trend of the study area, on annual basis to temperature try to maintain a uniformity, however in 2006 the highest temperature of 24⁰C per annum was achieved, there after there appears to be a steady decline from 24⁰C to a lowest value of 18⁰C in 2009. Thereafter the values started increasing to the highest peak of 25⁰C in 2014.See Figure 1 and Table 1

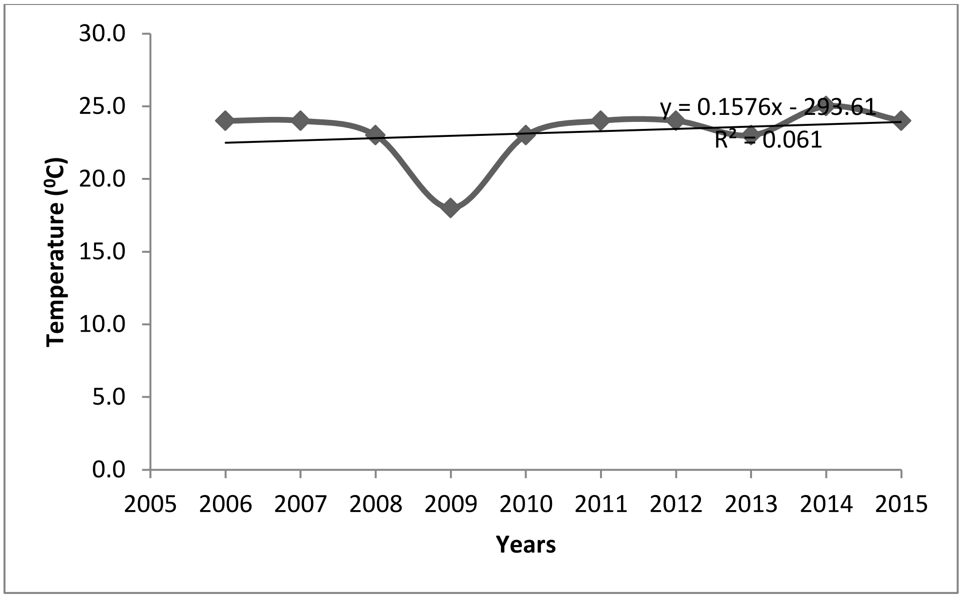

Figure 2: the observed temperature trend of the study area.

Table 1: Distribution of respondent according to their socio-economic characteristics

Characteristics	Frequency	(%)
Age		
Below 21	03	01
21 – 30	19	6
31 – 40	146	49
51 - 60	123	41
Above 60	09	03
Years of farming experience		
1 – 10	13	04
11 - 20 years	32	11
21 – 30 years	149	50
31 – 40 years	06	02
Above 40 years	100	33
Level of Education		

Religion	94	31
Primary	152	51
Secondary	51	17
Tertiary	03	01
Farm Size		
1 – 2 hectare	159	53
2 – 3 hectare	121	40
3 – 4 hectare	13	04
4 – 5 hectare	05	02
Above 6 hectare	02	01
Total	**300**	**100**

Source: Authors field survey (2016)

Data in table 1 reveal that majority (49%) of the farmers were between 31 to 40 years old with only few (3%) of them were between the age ranges below 21years old. The implication here is that majority of the sampled respondents were within active age for agricultural production.

About (50%) of the participant had 21 to 30 years of farming experience, while only (4%) of the respondent had 1 to 10 years of farm experience. This inferred that most of the respondents has been in the farming business for a long time. Years of farming experience were important because management skills improved with experience. With respect to the education attainment of the respondent (31%) claimed to have religious education only see table (1) while (69%) had primary, secondary and tertiary education. Formal education enables farmers to obtain useful information from bulletins, agricultural newsletter and other sources. Results in (table 2) indicate that (53%) of the respondents have farm size of 1 – 2 hectares, while (40%) have 2 – 3 hectares, (4%) have 3 – 4 hectares, (2%) have 4 – 5 hectares and only (1%) among the respondent above 6 hectares of farm size respectively.

Table 2: Responses on the knowledge and perception of climate change

Indicators of climate change	Freq	%
Increase in temperature	75	25
Change in rainfall pattern	82	28
Excess sunshine	73	24
Flooding others	70	23
Total	**600**	**100**

Source: Authors survey 2016

Data in table 2 reveals that most (28%) of the respondents perceived change in rainfall pattern while (25%) claimed increased in temperature in the area which in most cases result to unaware rising level Floods as the major indicators of climate change on the Jos Plateau. Knowledge and perception of the respondents critically identify high rainfall and temperature as key element of weather and climate that eventually contributed to other extreme climatic event in the study area alike the rising level floods among others (Table 2)). These findings corroborated the experts' reports that the mean temperature is increasing in Nigeria (26 and 27).

Table 3: Responses on the source of information on climate change

Source	Freq	%
Radio	165	55
Television	15	05
Newspaper	09	03
Fellow farmers	104	35
Extension Agents	07	05
Total	**300**	**100**

Source: Author's survey, 2016

Investigation into the source of information about climate change by the respondents reveal that (55%) claimed to radio programmes, fellow farmers (35%), Television (05%) Newspaper (3%) and Extension agents having the least (2%). The dominance of the radio as a major source of information about climate phenomenon is not surprising because of high level of addiction of the resident to their radio and most cases despite not being educated, the radio avail them with the opportunity to be informed about happenings in their immediate environment. This means that the respondents would not be able to know what climate change is all about without the presence of radio stations. These findings agree with that of (28) in their study of climate change awareness amongst resident of Jos North Local Government of Plateau State – Nigeria. The imperative for effective mitigation strategy at the same is in conformity with that of (29) in their study of effects and knowledge of climate change among farmers in Taraba South, Nigeria that radio is the major source of awareness about climate change among the sampled respondents.

Table 4: Responses on the perceived effects of climate change

Source	Freq	%
Drying and wilting of crops	08	03
Difficulty in predicting crop planting period	103	34
Wide spread of crop pest and diseases	61	20
Low crop yield	128	43
Total	**300**	**100**

Source: Author's survey, 2016

In an attempt to further gauge the perceived effect of climate change, the farmers perceived the following as a serious effect of climate change on agricultural production: Low crop yield (43%), difficulty in predicting crop planting period (34%) and widespread of crop pest and diseases (20%). This is in line with the report of IPCC (5), many natural systems seem affected by increasing temperature; in tropical region, high temperature is a constraint to crop production, it greatly influences not only the growth duration but also the growth pattern and the productivity of crops; especially in developing countries that are vulnerable to climate with low adaptive capacity.

CONCLUSION, IMPLICATION AND RECOMMENDATION

The Jos Plateau has its share of negative impacts of climate change despite its advantage in some cases. But these impacts are predicted to get worse with time necessitating more serious measures to be taken by the farmers themselves, the government, NGOs and other private sector organizations that may assist farmers.

The findings of the research conclude that annual rainfall is variable on the Plateau, the use of a trend line indicated that annual rainfall is on the decrease with a possible of 1% decrease from the mean. The implication here is that, the length of growing season might slightly be reduce, which in turn means that farmers should be encouraged to adopt the use of hybrid seedlings. For temperature is generally increasing the research therefore conclude that Plateau Agricultural Development Programme (PADP) through its extension workers sensitize farmers on the declining trend of rainfall on the Jos Plateau. This is because agriculture on the Plateau is rain fed in nature. Moreso, the establishment of climate change information systems by the government particularly at the local government level. These will provide awareness campaigns for members of public, provide weather forecast/early warming information service and provide training on how to adapt to climate change to farmers.

REFERENCES

1. Adebayo, A. A and Orunonye, (2003). An assessment of climate change in Taraba State, Nigeria. *Nigerian Journal of Tropical Geography, 4* (1), 602 – 612.

2. NEST, (2003). Climate change in Nigeria: A communication guide. Dev. Com. Nigerian Environment Society.

3. Inter-government panel on climate change, IPCC Fourth Assessment Report. AR4, Climate Change (2007). Impacts, Adaptation and Vulnerability, contribution of working group II to the Fourth Assessment Report of the Intergovernmental panel on climate change. M.L. Parry, O.F. Canziani, J.P. Palatikof, P.J. Van der Linden, C.E. Hassan, Eds. Cambridge University Press; Cambridge, U.K. 976 pp.

4. Ozor, N and Nnaji, C. (2010). Difficulties in adaptation to climate change by farmers in Enugu State, Nigeria. Journal of Agricultural extension Vol. 14 (2).

5. IPCC, (2007). Summary of policymakers in Climate change 2007: Impact, Adaptation and Vulnerability, contribution of Working Group II to the Fourth Assessment Report on the intergovernmental Panel on climate change, M.L. Parry, D. F. Canziani, J.P Palatikof, P.T. Ban der Linden and C.E., Hanson, Eds, Cambridge University press, Cambridge, UK, 7 – 32.

6. F.A.O Interdepartmental working group on climatic. 2007 Climate change and food security: A framework for action. Rome 8 Gregory, P.J., Ingram, J.S.I and Bralacich M. (2005). Climate change and food – Security. Philosophical Transaction of the royal society B. Vol. 36:2139-2148.

7. Gina, Z., Anton C. Adriaan T., Adejuwon J., Zermoglion F. Moliehi S. and Smith B. (2008).

8. Aliyu, S.B. (2008). "An Appraisal of climate change risk and institutional adaptation strategies in Kano State, Nigeria" in

proceedings, 50th annual conference of the Associaiton of Nigerian Geographers (ANG) held at the University of Calabar, 25 – 28 August, 2008. Pp 103 – 112.

9. Aketeyon, I.S. and Ogundale, F.O. (2008). "Climate change and Health in Nigeria: Incidence of vector-born diseases (Malaria)" in proceedings, 50th Annual Conference of the Association of Nigeria Geographers (ANG) held at the University of Calabar, 25 – 28 August, 2008. Pp 103 – 112.

10. Anyadike, R.N.C. (2009). "Climate change, National Development and STI Policy Planning in Africa". Paper presented at the international conference and capacity building workshop on Africa". Response to Global Challenges through sciences, Technology and Innovation, Abuja Nigeria.

11. Onokala, P.C. (2011). Climate change and the need for Curriculum Development in Geography, the Nigeria Geographical Journal, 7 (2): 1-17.

12. Oladipo, E. O. (2013). Contemporary climate change science: opportunities for Multidisciplinary Research Approach. Public Lecture delivered at the Federal University, Dutsin-Ma, Katsina State 15th May, 2013.

13. Adejuwon, J.O. (2006). Food crop production in Nigeria; Potential Effects of Climate Change. Climate Reseach, Vol. 32, Pp 229 -245.

14. Adefolalu, D. O. (2007). "Climate change and Economic Sustainability in Nigeria", paper presented at the International Conference on climate change and economic sustainability held at Nnamdi Azikiwe University, Enugu, Nigeria June, 12 – 14.

16. F.A.O. (2006). Food Security Statistics in Nigeria. Food and Agricultural Organization Statistics, FAOSTAT, Rome.

17. Richards, M. (2003). Poverty reduction, equity and climate change. Global governance synergies. Oversees development institute, Globalization and poverty programme.

18. Yusuf, R.O. (2012). Coping with Environmental induced changes in tomato production in Rural Settl4ment of Zuru Local Government Area of Kebbi State. Environment Issues, Vol. 5, Pp 47 – 54.

19. Ayoade, J.O. (2003). Climate: A synopsis of its nature. Causes, Effect and Management". Spectrum Book. Ibadan.

20. Labiru, M.A. Obidike – Ugwu, E. O, Martha, U (2015). Analysis of climatic trends and its implication on agroforestry practice in Barkin Ladi. In proceedings, 2015 International Conference and

29th Annual General meeting held at UDUS Sokoto, Nigeria.

21. Labiru, M.A. (2016). Analysis of rainfall and sunshine duration variability as evidence of climate change on the Jos Plateau, Nigeria. Paper presented at the 57th Annual Conference of the Association of Nigerian Geographers (ANG) held at the University of Lagos, ANG – 264, 11th-14th April, 2016.

22. De Jonge, E. A. (2010). Farmers perception on adaptation to climate change: A case study of irrigators in the Riverland, South Australia. Unpublished M.Sc Department of Land Degradation and development in partial fulfilment of the Degree of Master of Science in international land and water management at Wageningen University, the Netherlands.

23. Dhaka, B.L., Chayal, K. and Poonia, M.K. (2010). Analysis of farmer perception and adaptation strategies to climate change. Libya Agriculture Research Centre Journal Internaitonal, 1 (6): 388 – 390.

24. Bako, A. E., Jajere, I.A, Abimiku, E. S. and S. Abba (2016). Peasant farmer's perspective on the challenges of climate change in Kaduna State, Nigeria. In proceedings, 57th Annual Conference of the Association of Nigerian Geographers (ANG) held at the University of Lagos, 11th – 14th April, 2016.

25. Odjugo, P.A. O (2009). The impact of climate change on water resources: Global and Nigerian analysis. *FUTY Journal of Environment*, Vol. 4, No. 1.

26. Umar, A. T. (2011). Climate change in Nigeria: Evidence from meteorological parameters. Paper presented at 2011 Association of Nigerian Geographers conference at Usmanu Dan Fodio University, Sokoto.

27. Labiru, M.A., Sadiku, Y, Hussaini Y, and Adedire, O. (2016). Climate change awareness among residents of Jos North Local government of Plateau State – Nigeria, the imperative for effective mitigation strategy. Paper present at the 57th annual conference of the association of Nigerian Geographers (ANG) held at the University of Lagos, 11th – 14th April, 2016.

FLOODING AND SOLID WASTE DISPOSAL ON THE JOS PLATEAU – NORTH CENTRAL NIGERIA.

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Abstract

Flooding is one of the consequences of poor environmental management. Undoubtedly, improper wastes disposal is contributing to poor environmental management in no little way. Inversely occurrence of flooding in a particular area is a clear evidence of climate change. Reports revealed that municipal solid waste management is one of the greatest challenges facing environmental protection agencies in developing countries such as Nigeria Jos Plateau inclusive. Over the years, as a result of indiscriminate wastes disposal and anthropogenic activities on the Jos Plateau, environmental disasters such as flooding had been witnessed. Consequently, the impact of flooding disaster on the environment has been threatening and disheartening. In some cases, flood affects and displaces more people than any other disaster. Flooding has also caused a lot of damage to properties. In recent time, Jos Plateau experienced ravaging disasters in which flood claimed several lives and continue causing more property damage than any other natural phenomena. This paper reviews the phenomenon of poor waste disposal and anthropogenic activities as the drivers of flood disasters on the Jos Plateau.

Keywords: Climate change, environmental management, flooding, disaster, lives, anthropogenic activities

INTRODUCTION

Jos Plateau is a state in northern Nigeria which has faced an increase in severe flood during the rainy season of t he past decade. Possible causes of the increase in flood severity on the Jos Plateau ranging from inadequate flood management practices to the poor waste management. An urban flood occurs when drainage systems, gutters and other storm control devices spill to its plains and overflow to flood control devices during heavy rains. In developing countries such as Nigeria Jos Plateau inclusive, there are many communities, which are unplanned and are occupied by squatter and illegal settlements. Jos Plateau has many fast growing, low income communities with no infrastructure for waste disposal. Wastes wash into drainage ways and is hypothesized to cause increase flooding Judging form the rate at which urbanization is taking place on the Jos Plateau, and considering the fact that individual builders of houses as well as community developers are building houses within flood-prone areas, flooding and flood losses will continue to increase.

Flooding, a global acclaimed major effect of climate change, threatened the livability of cities across the world Douglas (2007) remark that flooding is seen as one of the factors preventing poor people from improving their quality of life. It greatly aggravate poverty, because it denies many people access to work for a long period. The people denied access, as a result of flooding. Suffer income and possible job loss (Sheila et al, 2015) opined that in sub-Sahara Africa, hydro-meteorological related disasters such as floods, account for the majority of the total number of natural disasters. Over the past century, floods have affected 38 million people, claimed several lives and caused substantial economic losses in the region. Widespread flood events were recorded in 17 states of the federation in 2015. In spite of the late onset of rain, flooding was reported in many parts of the country between June and September, 2015. For instance, severe floods were reported in Lagos and its environs in June due to days of consecutive downpours. Isolated cases of flash flood caused by measurably heavy rainfall of short duration also affected other state e.g Adamawa, Kano, Ogun, Edo, Cross River Jos, Plateau Inclusive (Nimet 2015). Floods are hydrological events characterized by high discharges and high water levels. During a flood, stream and channels are unable to convey the amount of water that has been generated through the runoff process, consequently there is an overspill of water over the river banks. This can lead to inundation of flood plain regions. In general, floods are caused by intense rainfall. Occasionally, other causes like failure of embarkments, landslide, ice jams, tsunamis or human activities also create floods (Carlin, 2009) cited in Labiru*et al* (2016). Flooding is one of the most common and widely distributed natural risk of life and property worldwide. It has special place in natural hazards and accounts for approximately one third of all natural disasters in both developed and developing world (Olajuyignbe, 2012).

Solid waste management is a large and growing problem for countries in developing world and is often a neglected aspect of urban management. However, poor waste management can contribute to the impact of urban flooding by blocking drainage, increasing debris and harbouring disease vectors (Lamond*et al*, 2012). Globally, millions of tons of municipal solid waste are generated every day. Urban waste management is drawing increasing attention, as it can easily be observed that too much garbage is lying uncollected in the streets, causing inconvenience, environmental pollution, and posing a public health risk (Ramatta*et al,*. 2014). Solid waste have been defined as non-liquid and nongaseous products of human activities, regarded as being useless. It could take the forms of refuse garbage and sludge (Leton and Omotosho, 2004). The problem of solid, liquid and toxic waste management in Africa has come with urbanization in the developing world. An important feature of the urbanization of the developing world is the rapid growth of cities and metropolitan areas. The high rate of urbanization in African countries implies a rapid accumulation of refuse. Social and economic changes that most African countries have witnessed since the 1960s have also contributed to an increase in the waste generated per capital (Douglas, 2007). Proper waste management is a public benefit and obligation. Improper waste disposal by the individual affects the entire citizenry, so as a policy, countries have tasked every individual, establishment or institution to contribute significantly to the process of keeping their community and environment clean (MLGRD, 2011).

FLOOD, RISK: AN OVERVIEW

Climate change manifest itself in, amongst other things, storm occurrence and flooding. This problem is further compounded by unguided rapid urbanization and limited capacity of urban local authorities o address this issue. For example most of the informal settlements lack stormwater drainage channels that are designed and built to engineering standards. The lack of stormwater drainage channels settlements that are rapidly densifying is a major cause of flooding. This is due to the fact that densification increases, water run-off from roofs of building alters the urban land cover and land surface, including blocking existing natural stormwater drains. Poor solid waste management in the settlement further complicates the problem.

The woes of Plateau State have continue unabated as no fewer than 25 persons are feared death in Jos on Sunday after torrential rain led to mass flooding in Jos North. The flood also destroyed property worth several millions. The rain started at about 9.00pm on Sunday when most of the inhabitants of the affected communities of AngwanRogo, Gangare and Rikkos parts of the state capital had gone to bed. One of the worst hit areas is the Gangare suburb were a stream, over-flowed its banks. 30 houses were destroyed by the flood in the areas. At the same vein the rain also affected the people of AngwanRogo, a suburb community close to the University of Jos, killing another four people (Scan News 23rd July, 2012). Tragedy struck in Jos, Plateau State capital, Sunday night, when a rampaging flood swallowed over 35 people and also destroyed more than 15 people have also been declared missing. The heavy rainfall was reported to have forced a dam to overflow causing flooding which submerged several houses, rendering many people homeless. Areas most affected were parts Rukuba Road, AngwanRukuba, Rikkos, Gangare and Faringada.

In a study which covers urban poor settlement in Accra (Ghana) Kampala (Uganda), Lagos (Nigeria), Maputo (Mozambique), Jos (Nigeria), and Naisrobi (Kenya), Doughlas et al (2008) provide a summary of the messages that emerge from flooding in urban area.

- * Climate change which manifest in changing patterns of rainfall increases storm frequency and intensity and hence leads to flooding.
- * For the urban poor, the impact of flooding is becoming more frequent and increasingly severe.
- * Housing development in floodplains, inadequate waste management and lack of maintenance of stormwater drainage channels (where existent) further aggravate the flooding problem. The question is: how do people living in informal settlement cope with these challenges? What will happen in the future if corrective measures are not taken?

Table 1: Flood events across Nigeria in 2015

S/No	Location	Date
1.	Anambra	24th July
2.	Adamawa	5th Aug. 20th Sept.
3.	Bauchi	8th August
4.	Benue	7th August
5.	Cross River	7thOctober
6.	Delta	6thOctober
7.	Edo	5th October
8.	Jigawa	5th September
9.	Kano	6th Sept. and 23rd June
10.	Kebbi	22nd August
11.	Ogun	2nd June
12.	Katsina	27th Aug. and 17th Sept.
13.	Kaduna	5th August and 20th Sept.
14.	Zamfara	7th Sept.
15.	Yobe	5th Aug. and 13 Sept.
16.	Sokoto	4th Aug and 3rd Sept.
17.	Lagos	9th June.

Source: NMETS (2015)

IMPROPER WASTE IN JOS IN NIGERIA

Amoo-Onidundu, et a (2013) remarked that the quality of solid wastes generated in urban areas and industrialized countries is higher than in developing countries; still municipal solid waste management remain inadequate in the latter. Solid wastes in developing countries differ from developed countries. The wastes are heavier, wetter more corrosive in developing cities, Jos Plateau inclusive, have solid waste management problems different from those found in industrialized countries in terms of composition, density, political and economic framework, waste amount, access to waste for collection, awareness and attitude waste are indiscriminately disposed by commuters, pedestrains, market people, households, industries, factory workers and stakeholders in the public sectors. The volume of solid waste being generated continues to increase at a faster rate than the ability of the agencies to improve on the financial and technical resources needed to parallel this growth. Hence, accumulation of these huge wastes on lands and along water courses is a common place in Nigeria Jos Plateau (Geoddrey, 2005). Several authors (Awosike and Folorunsho, 20010, Geoffrey, 2005; Ogwueleka, 2009p and Amoo-Onidundu et al, 2013). Remark that blockage of drainages and water ways with heap of wastes, coupled with poor drainage system are major causes of overflow of rivers in Nigeria Jos Plateau inclusive (See figure 1, 2, 3, 4,). It is quite unfortunate that due to the erroneous belief that the wastes are carried away whenever it rains, more solid wastes are dumped into the river and other water bodies (Ogweleka, 2009). Consequently, the costly assumption has led to blocking of water ways which in most cases lead to overflowing or outburst of water (Geoffrey, 2005' Ogwueleka, 2009, Amoo-Oidundu et al, 2013).

Figure 1: heap of waste disposed along waterway

Figure 2: Houses build along waterways (AngwanRogo)

Figure 3: Waste dispose along wetter way/ high around Bauchi junction in Jos

Figure 4: Houses build along water ways (Rikkos)

Figure 5: Wastes disposed in drainage (Bauchi Road)

Figure 6: Waste disposed in drainages (Bauchi road)

Figure 7: Waste disposed along river valley (Rikkos)

CONSEQUENCES OF FLOODING

It is no gain saying that flood is like a monster which can unleash great terror on lives and properties. Much causality is always recorded as the aftermath of flooding. Flood disasters render people homeless, devastating and jobless. Valuable items (such as certificates, credentials, and other documents) are lost as a result of flooding (Amoo-Onidundu*et al,* 2013). Flood have large social consequences for communities and individuals. As most people are well aware, the immediate impact of flooding include loss of human life, damage to property, destruction of crops, loss of livestock, and deterioration of health conditions owing to waterborne disease (see figure 9)

Figure 9: Remains of affected after flooding

CAUSALITIES OR LOSS OF LIVES

Most unfortunate is the alarming death recorded in recent times. Nigeria has lost both young and old to death due to flood disasters in many part of the country – Jos Plateau inclusive. Recent incidence were recorded in Oyo, Plateau, Kogi, Ogun, Adamawa and Benue State. According to Vanguard Newspaper of 17th July, 2012. At the same being Daily Trust of 13th August 2016 reported that no fewer than 52 houses have been destroyed by a downpour that turned into a flood in Wurno Local Government Area of Sokoto State. The problem was aggravated by indiscriminate dumping of waste products which blocked some waterways in the affected areas, assorted farm produce worth millions of naira which include onions, garlic, rice, wheat and beans, among others, following the submerging of hundreds of farmlands.

Major causes of Flooding on the Jos Platea

- Excessive rainfall
- Refuse dumping
- Poor drainage system or lack of culverts
- Establishment of settlements along river channels
- Erection of buildings on water sheds, road and culvert sides
- Presence of steep slopes
- Inadequate urban planning

Likely Solution to flooding in relation to waste management on the Jos Plateau

- Establishment of waste collection centres
- Certification and authentication of buildings in accordance with appropriate urban and regional planning.
- Demolution of existing illegal structures and building along waterways with compensation.
- Proper maintenance of existing drainage system (General public)
- Construction of adequate drainage systems.
- Educating public on consequences of flooding through media
- Execution of offenders
- Provision of adequate waste disposing sites and items
- Recruitment and employment of adequate waste disposing personnel.
- Legislation against indiscriminate dumping of waste/refuse and the erection of buildings on waterways.

CONCLUSION, IMPLICATION AND RECOMMENDATION

Poor wastes management disposal on the Jos Plateau is one of the factors that is responsible for flooding. It is unfortunate that floods had force thousands of people from their homes while many people have lost their lives to flooding at different time and in different locations on the Jos Plateau. Considering the far – reaching effect of poor waste disposal in Jos. Every individual should inculcate good waste disposal culture and avoid indiscriminate refuse dumping. Moreso, improper methods of waste disposal should be viewed as one of the factors threatening human lives. Also, there is the need for urgent collaborative effort both by individuals, government and stakeholders to support own planning, engineering and other environmental protection agencies towards combating flood disasters in Nigeria. At this juncture it becomes imperative to look seriously into the suggested solution on waste disposal and management in order to guard the phenomenon of flood disaster in Jos Plateau and Nigeria inclusive.

REFERENCES

Amoo-Onidundu, O.N., Areghan, S. E., Olajide, O.B and Egunjobi, A. J. (2013). Flooding and solid wastes disposal in Nigeria. Paper presented at the conference of Forestry Association of Nigeria (FAN) 2013. Ibadan.

Awosika, L and Folorunsho, R. (2001). Flood mitigation in Lagos, Nigeria through wise management of solid waste: a case of Ikoyi and Victoria island; Nigeria paper presented at the UNESCO – CSI Workshop, Maputo 19 – 23 November 2001.

Carlin, N. (2009) Spatial analysis using geographical information system (GIS) to evaluate areas susceptible to repeat flash flooding in La crose country, Wisconsin, 11:12 p. paper s in Resource Analysis, Saint Mary's University of Minnesota Central Services Press, Winona, MN.

Douglas, I. (2007) Flooding and the urban poor. In :Tiempo, issue 64. Pp 3 – 8.

Douglas, I., Alam, K., Maghenda, M, Mcdonnel, Y.M Mclean, L and Campbell, J., (2008) Unjust water. Climate change, flooding and the urban poor in Africa; Environment and Urbanization 20 (1), 187-205.http://dx.doi.ng/10-1177/0956247808089156.

Geoffrey, I.N. (2005). The urban informal sector in Nigeria. Towards economic development, Environmental health and association, harmony. Global Urban Development Magazine (1).

Labiru, M.A., Sadiku, Y and Ahonsi, G.C.(2016). Assessment of people's awareness and perception of flooding in Jos Nigeria. Paper presented at 7th International Conference and Annual General Meeting of Nigeria Association of Hydrological and Science held at Federal University of Technology, Minna, Niger State – Nigeria.

Lamond, J., Bhatacharya N and Bloch R. (2012). The role of solid waste management as a response to urban flood risk in developing countries.

Leton, T.G., Omotoso, O. (2014). Landfill operation in Niger Delta region of Nigeria. Engineering geology 73 (1 – 2): 171-177.

Ministry of Local Government and Rural Development (2011) Environmental Sanitation Policy. 1999, Accra: MLGRD.

Nigerian metrological Society "Nimet" (2015) Nigeria climate review bulletin Pp 36 – 37.

Ogwuelka, T.C. (2003). Analysis of urban solid waste characteristics and management in Nigeria. Iran

Journal of Environmental Health Science Eng 2009, Vol. 6, No. 3, Pp 173-180.

Olajuyigbe, C. (2012) Assessment of flood hazard in Nigeria, The case study of Mile 2, Lagos Nigeria.

Ramatta, M.Y., Denis, C and P.B.A. (2014). Domestic waste disposal practice and perceptions of private sector waste management in urban Accra. BMC Public Health 2014: 14.697 DOI: 10.11.86/1471-2458-14-697 © Yoadaet; Licensec Biomed Central Ltd, 2014.

www.scan news 23rd July – 2012.

www.vanguardngr.com/2012/07/35-killed-200-houses-destroyed-in-Jos-Flood

CLIMATE CHANGE PERCEPTION AND VULNERABILITY ASSESSMENT ON THE JOS PLATEAU

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Abstract

The study examines the rural communities' people on the Jos Plateau perceived climate change. The study analyzed recent trends in rainfall and temperature for 34 years (1980 – 2015) in order to compare people's perception of climate and observed data. The vulnerability of the rural people to the changing climate was also assessed. A total of 490 copies of questionnaires were administered to the households head in eleven selected communities in the study area. Descriptive statistics was employed to describe and summarize the collected primary data (questionnaire). Result from climatic variables revealed that temperature and rainfall have been increasing in the study area. Findings also reveal that majority of the rural people have a very good knowledge of climate change in terms of increasing rainfall and temperature, high rainfall intensity and the occurrence of extreme weather and climate event such as flood. The study further revealed that the poor, livestock tender, and children are the most vulnerable individual to the impact of climate change. Agricultural activities was also found to be the most vulnerable economic sector to the impacts of climate change due to its sensitivity to climatic element particularly rainfall and temperature. The study recommends massive enlightenment programs, measures should be taken for effective management of environmental resources, and stimulate both agricultural intensification and diversification of livelihoods away from risky agriculture. Finally, these vulnerable areas should be targeted for rural infrastructural investment by government.

Keywords: *Rural communities, rainfall, temperature, perception, climate change, vulnerability.*

INTRODUCTION

Climate change and its impact on relevant socio-economic sectors on major threat to sustainable agriculture and human livelihood. Most of the sub-Sahara African population lives in vulnerable environment, and highly dependent on natural resources such as rain-fed crop production for their livelihood thus, making the zone one of the most vulnerable to climate change/variability impact. Climate change impact is compounded by anthropogenic activities such as over cultivation, overgrazing, poor land management among others. These have been escalating natural resource degradation of land, water and vegetation (Abdulakadir et al, 2015). Climate change effects societies in many ways. Human activities have dramatically altered the world's climate, ocean, lands, ice cover and ecosystem. The impact is on almost every sector including human health, agriculture, infrastructure and natural resources. Developing countries are most vulnerable as they have limited resources and capacity to adapt to the effects of climate (Wardekker, 2011) cited in (Yusha'u and Abaje, 2015).

Climate change is a complex biophysical process (Gina et al., 2008). It is difficult to predict precise future climate conditions, but consensus has emerge among scientists that global land and sea temperatures are warming under the influence of greenhouse gases, and will continue to warm regardless of human intervention for at least the next two decades (IPCC, 2007). It has been reported that the increasing concentrations of greenhouse gases in the atmosphere are mainly due to the 80 per cent increase in annual $C0_2$, emissions since 1970. Most of this historical increase emanated from the industrial activities of developed countries in Europe, North America and Japan. Developing countries, especially those on the African continent have contributed little to the observed global warming. Increasing poverty tends to render African countries vulnerable to climate change impacts. Moreso, agricultural production and the biophysical, political and social systems that determine food security in Africa are expected to be placed under considerable steps by climate change (FAO, 2007).

The IPCC Fourth Assessment report describes a trend of warming at a rate faster than the global average, and increasing aridity, in Africa. On balance higher temperature are likely to increase evaporative demand throughout Africa. Annual rainfall is likely to decrease in much of Mediterranean Africa and the northern Sahara. Rainfall in Southern Africa is likely to increase. Annual rainfall in East Africa is likely to increase but it is unclear how rainfall in the Sahel Guinean Coast and the southern Sahara will evolve (Gina et al., 2008).

Climate change exerts multiple stresses on the biophysical as well as the social and institutional environments that underpin agricultural production. Some of the induced changes are expected to be abrupt, while others involve gradual shifts in temperature, vegetation cover and species distributions. Climate change is expected to, and in parts of Africa has already begun to, alter the dynamics of drought, rainfall and heatwaves, and trigger secondary stresses such as the spread of pests, increased competition for resources, the collapse of financial institutions, and attendant biodiversity losses. Predicting the impact of climate change on complex biophysical and socio-economic systems that constitute agricultural sectors is difficult. In many parts of Africa it seems that warmer climates and changes in precipitation will destabilise agricultural production- This is expected to undermine the systems that provide food security (Gregory et al., 2005). Whilst farmers in some regions may benefit from longer growing seasons and higher yields, the general consequences for Africa, are expected to be adverse, and particularly adverse for the poor and the marginalized who do not have the means to withstand shocks and changes cited in (Adeniyi, 2009).

In Nigeria, climate change is one of the most serious threat to poverty eradication and sustainable development that is because the country has a large rural population that is directly depending on the natural resources for their subsistence and livelihood which are climate sensitive (Oladipo, 2008). It is a well established fact that climate change in the average pattern of weather over a long period of time, green house gases play an important role in determining climate and causing climate change (IPCC, 2007).

CLIMATE CHANGE PERCEPTION AND VULNERABILITY

Perception is a process by which organisms interpret and organize sensation to produce a meaningful experience of the world. Perception is the process by which we receive information or stimuli from our environment and transform it into psychological awareness, (IPCC 2001). Perception to climate change according to de jonge (2010) refers to how people see and interpret their experiences that lead to particular understand.

Basically necessity is the mother of inventions, societies experience perturbation, an equilibrium shift that stress systems. How the society responds to pertubations or to this shift, is determined by its vulnerability. Vulnerability is the degree to which geophysical, biological and socio-economic system are susceptible to, and unable to cope with, adverse impacts of climate change, including climate variability and extremes. It is a function of the character, magnitude and rate of climate change and variation to which a system is expected is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007). Vulnerability is also defined as the capacity to suffer harm or to react adversely, most recently, researchers now recognize that vulnerability of a community, is a function of its exposure to climatic conditions and its adaptive capacity to deal with those exposure. Exposure depends on the frequency, magnitude and extent of climate related risks (Abdullahi *et al.,* 2015). As the rise in the number of natural catastrophes is predominantly attributable to weather-related events like storms and floods, with no relevant increase in geophysical event such as earthquakes, tsunamis and volcanic eruptions, there is some justification in assuming that changes in the atmosphere and global warming in particular, play a relevant role (Peter, 2016).The increase vulnerability necessitate the need to identify the varying vulnerability levels and factors at community level for the development and identification of community based strategies for coping with current climate change thereby providing good starting point for disaster risk reduction. The vulnerability of developing countries and their populations to increase climate variability and change is of great concern and has attracted considerable research interest over the past decades with call for increased funding for adaptation (Patt, *et al.*, 2010).

Despite the fact that effort have been made toward fighting climate change in Nigeria, vital information regarding urban and rural communities awareness, perception and vulnerability to climate in Northern part of the country is still lacking (Labiru et al., 2015). This forms the basis of this research with particular reference to some rural communities on the Jos Plateau North Central region of Nigeria.

MATERIALS AND METHOD

Table 1: Selected Rural Communities and number of respondents

S/No.	Selected Communities	Number of Respondents
1.	Babale	58
2.	Maza	50
3.	Jengre	45
4.	Buji	48
5.	Mista'Ali	35
6.	Du	40
7.	Vom	27
8.	Darawon Babuje	33
9.	Mai Idon Taro	24
10.	Fobor	19
11.	Federe	25
12	Dogo na Hauwa	28
13.	Jebu Bassa	30
14	Gero	28

Source: Authors survey, 2016

METHODOLOGY

In the conduct of this study, data was sourced through two major sources. Primary data were obtained through the administration of questionnaire to select residents of the selected community on the Jos Plateau. Secondary data were obtain from published materials such as journals, textbooks, internet and climatic records from university of Jos weather Observatory. Location of key areas of the study were selected through purposive sampling entails direct selection of respondents who resides within the oldest parts of the selected communities. Systematic sampling was adopted to select household heads from the study area. The operationalization of the systematic sampling involves selecting every 10th household head. Through this technique a total of 490 respondents were successfully sampled and administered with questionnaire on the Jos Plateau. The questionnaire was design to acquire and elicit responses on a range of issues such as perception of climate change, vulnerability and impacts of climate change. Data collected were subjected to descriptive statistical analysis/frequency distribution table and percentage for each variable. Also, 33 years (1980-2005) monthly data of rainfall and temperature were collected from university of Jos weather observatory.

4. RESULTS AND DISCUSSION

4.1 Observed Climate Changes

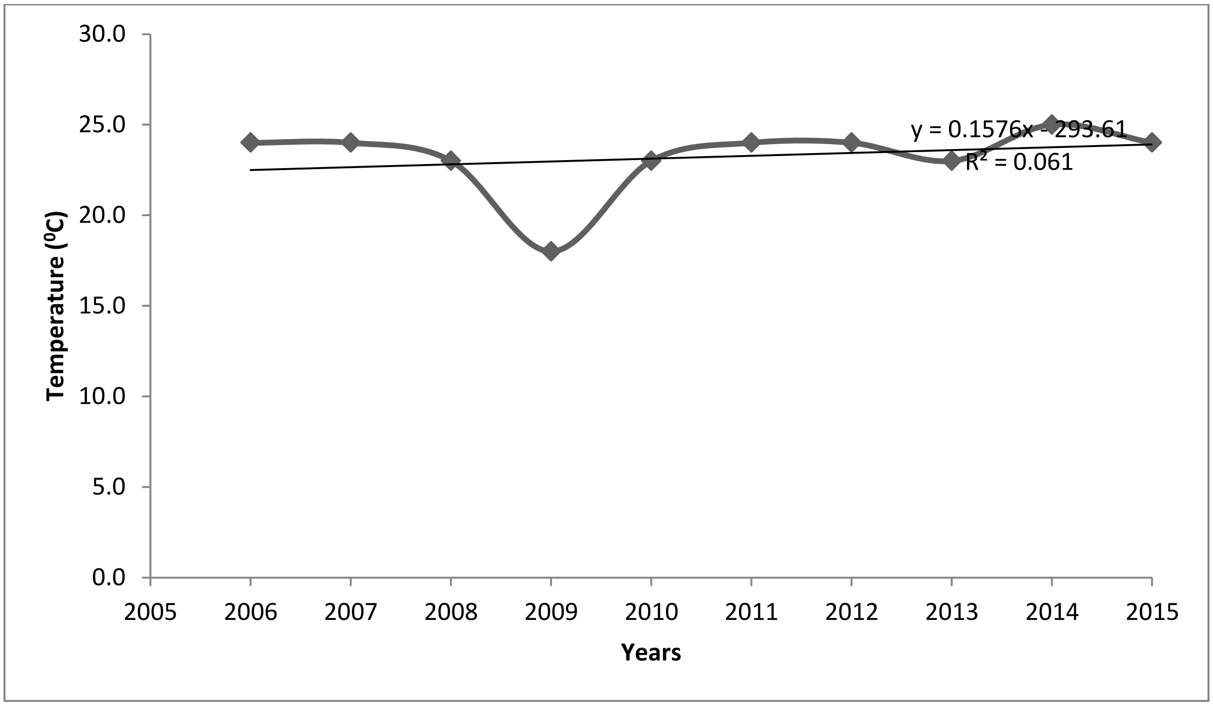

Figure 1: Annual Average Temperature Pattern on the Jos Plateau

Figure 1: shows the observed temperature trend of the study area, on annual basis temperature try to maintain a uniformity, however in 2006 the highest temperature of 24⁰C per annum was achieved, there after there appears to be a steady decline from 24⁰C to a lowest value of 18⁰C in 2009. Thereafter the values started increasing to the highest peak of 25⁰C in 2014.See Figure 1 and Table 1

The thirty six (36) year's annual rainfall data. For Jos Plateau is presented in table 1. Analysis of data in table 1 shows that annual rain fall on the Jos Plateau is highly variable, with the lowest year been 2009 and the highest year been 2015 with values of 1001mm and 1511mm respectively. The same area plotted and presented in figure 1. This it cannot tell us the direction of climate change on the plateau using rainfall data as a parameter. The research therefore employ the use of five years moving average, this was done to smoothen out excessive high and low values. The five years moving average was then super impose on the annual rainfall data. The result obtain was still not very clear. At this junction a trend line was fitted to both annual rainfall and five years moving average, results obtain shows that in spite of the variable nature of rainfall on the plateau, the trend line slope Deeping to the right slightly. This simply means that on the overall. Annual rainfall is slightly decreasing on the Jos plateau. A regression equation was fitted to the trend line and it yielded the equation Y=0.8996x + 1364 of with an r^2=0.0089, this invariably means that there is a tendency of decrease in rainfall on the Jos plateau of about 90mm from an average of 1364 and this means that Jos Plateau records one percent (1%) decrease in rainfall annually from means as indicated by the coefficient of determination (r^2) of 0.0089. see figure 2.

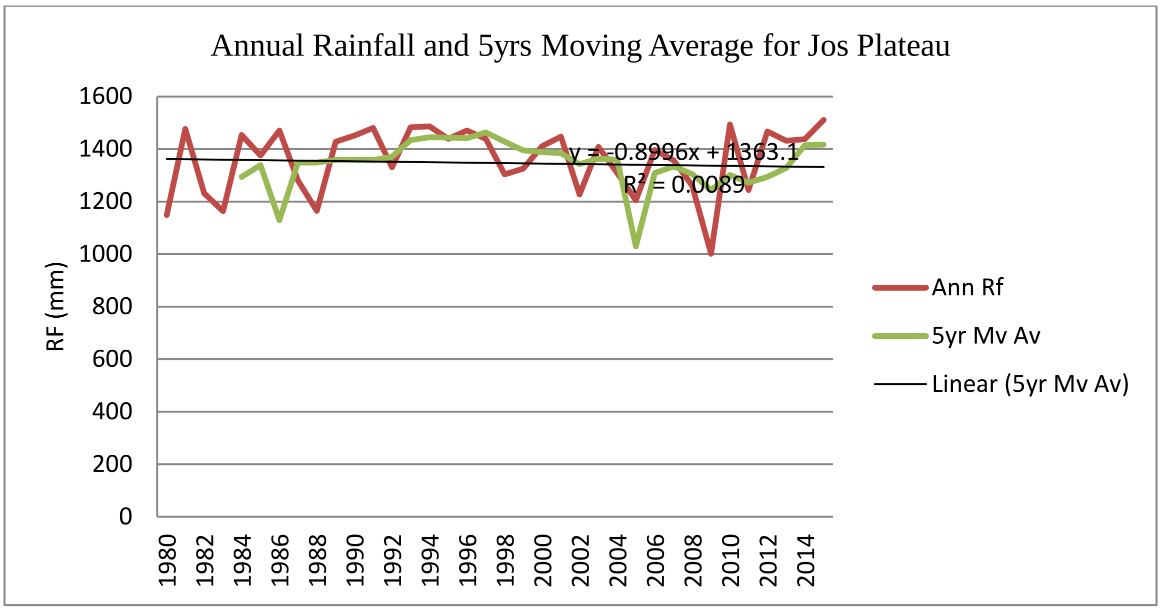

Fig 2: Annual rainfall pattern

In order to confirm the probability of climate change annual rainfall on the Jos plateau, a decadal analysis for the research time frame was undertaken and the results presented. In table2, the time frame was divided into ten, years interval, the annual rainfall was computed and the mean obtain. Results shows that the first decades which span (1980-1989) had a decadal mean of 1319mm, while the second decade (1990 – 1990) had a decadal mean of 1420mm. the third decade (2000- 2009) had 1302mm as a decadal mean while last segment of the study period (2010 – 2015) had a mean rainfall of 1430mm. A close observation of the decadal mean shows that the second decade recorded more annual rainfall than the first decade, this situation however, drop in the third decade the last part of the study period thus, it does not contain 10years somehow shows a tendency of increasing rainfall on the Jos Plateau.

4.2 Perception towards Climate Change

Table 2 shows the respondent's perception towards climate change in the study area. Majority of the respondents (32%) believed that temperature has increased over the years and is likely to increase in our lifetime as agreed by (5%) of the respondents. Respondents perception on increasing rainfall is in line with the observed data in which temperature has been increasing over the years. Rainfall according to 29% of the respondents is increasing significantly on the Jos plateau. Only 22% opined that there is a significant decrease in rainfall. In terms of extreme events, 12% responded that there is increase in the rate of flooding occurrence (see table 2) these findings corroborated the experts reports that the mean temperature is increasing in Nigeria (Umar, 2011 and Odjugo, 2009) an increase in rainfall leading to inundation of farmland in Delta State (Ojeh and Victor-Oriroh, 2014, Ojeh et al 2015).

Table 2: Perceived Climate Changes

Response	Freq	percentage
Flooding occurrence is increasing	60	12
Rainfall period is decreasing	106	22
Rainfall intensity is increasing	143	29
Temperature is likely decreasing	23	05
Temperature has increased over the years	158	32
Total	**490**	**100**

Source: Authors Survey 2016

4.3 Economic Sector most Vulnerable to the impacts of Climate Change

Data in table 3 reveal that most vulnerable economic sector to the impact of climate change (67%) of the respondents agree that agriculture is the most vulnerable sector to climate. Their main reason of choosing agricultural is that it is climate/weather sensitive and therefore, when there is an abnormality in climate especially temperature and rainfall, it will directly affect agricultural productivity. (14%) of the respondent claimed that business is the economic sector most vulnerable to the impacts of climate change. Their main reason is that businessmen depend directly or indirectly on farmers for trading, therefore, when there is an irregularity in climate , agriculturalist will not be affected because the little they produced will be used for their immediate consumption thereby rendering the business sector most vulnerable. 10% of the respondents agreed that civil servant will be most affected because they mainly depend on business for survival, in which due to climate change, there will be scarcity of food stuffs in the market which will lead to a significant increase in the price of those items. Only about (9%) of the respondent believed that manufacturing industries are most vulnerable to the impacts of climate change simply because irregularity in climate leads to shortage in supply of raw materials which are used by manufacturing industries see table 3. This result is congruent with the one reported by Yusha'u and Abaje (2015), in their study of climate perception and vulnerability assessment in Futua local government area of Katsina State, Nigeria.

Table 3: Economic sector most vulnerable to climate change impacts

Response	Freq	%
Manufacturing industries	45	9
Agriculture	326	67
Business	68	14
Civil service	51	10
Total	**490**	**100**

Source: Authors survey, 2016.

4.4 Most vulnerable individuals to the impacts of climate change

The result in table 4 gave us an insight into the respondents view on the most vulnerable individuals to the impacts of climate change. Investigation into the vulnerability reveals that (31%) of the respondents claimed that poor people are most vulnerable to the impacts of climate change. This is simply because they lack the financial means of adapting or coping to climate change impacts. This is also in agreement with the work of Balgis (2010) which point out that developing countries are characterized with poor standard of living, limited resources and capacity to adapt to the effect of climate change are most vulnerable. 27% of the respondents said that livestock rearers are most vulnerable to the impacts simply because livestock depend on posture (natural resources) which are climate dependent. Change in climate will definitely bring about shortage of grazing land for animals which may result to malnutrition in the livestock. Among others (21%) of the respondents believe that children are most vulnerable to the impacts of climate change simply because they need full balance diet for their growth and they are prone to malnutrition disorders. This confirms the work of Yusha'u and Abaje (2015). About (14%) claimed that aged people are the most vulnerable because they cannot withstand the situation. While only (7%) affirms that youths are most vulnerable group see table 4.

Table 4: Individual most vulnerable to climate change

Response	Freq	%
Children	103	21
Youth	32	07
Aged people (old)	73	14
Livestock rearers	132	27
Poor	150	31
Total	**490**	**100**

Source: Authors survey, 2016.

4.5 Source of Information about climate change

In an attempt to further gauge the source of information about climate change by the respondents, findings reveal that (58%) claimed to radio programmes, television (22%), newspaper (08%), family and friends (07%) and meteorological stations having the least (05%). The dominance of radio as a major source of information about climate phenomenon is not surprising because of high level of addiction of the residents to their radio and most cases despite not being educated, the radio avail them with the opportunity to be informed about happenings in their environment. On the Jos Plateau for instance there are six (6) public and private radio station. The implication here is that, the sampled respondents would not be able to know what climate change is all about without the presence of the radio station. See table 5.

Table 5: Source of information about climate change

Response	Freq	%
Radio	284	58
Television	106	22
Newspaper	40	08
Family/friends	32	07
Meteorological station	28	05
Total	490	100

Source: Author's survey, 2016.

5. Conclusion and Recommendation

The industrial revolution which began some 150 years ago has been identified as the turning point of mass human induced climate change action have shown that, there is an appreciate increase in carbon dioxide concentration in the atmosphere which help to trap heat and also act as condensation nuclei. This has been tight to climate change in several studies. It is for this reason that the present study made use of rainfall and temperature to detect climate direction on the Jos Plateau. Finding shows that annual rainfall is highly variable on the Plateau, the use of trend line indicated that annual rainfall is on the decrease with a possible of 1% decrease from the mean. The implication here is that, length of growing seasons might slightly reduce. People interviewed in the area have a very good knowledge of changes in temperature, rainfall amount and occurrence of extreme event such as flooding. Agriculture as the mainstay of rural food and economy suffers a lot from erratic weather patterns such as heat stress, longer dry seasons and uncertain rainfall. Declined in crop yields due to unfavourable weather and climate will lead to vulnerability in the form of food insecurity, hunger and shorter life expectancies. The most vulnerable groups are the poor, livestock rearers and children.

In order to combat climate change impacts and vulnerability effectively on the Jos Plateau, the following recommendations are made:

i. Plateau Agricultural Development Programme (PADP) through its extension workers begin to sensitize farmers on the declining trend of rainfall on the Jos Plateau.

ii. Government, non-governmental organizations (NGOs) and civil society organizations should intensify efforts in environmental education and awareness campaign on climate perception and vulnerability on the Jos Plateau. State owned television and radio stations and other media houses is an important platform for such campaign.

iii. The state Ministry of Environment should prepare a strategic plan for combating climate change and other environmental problems. This can be done with joint efforts from environment experts from the state.

iv. Estimations of the sensitivities of different economic activities to climate change.

v. General public on the Jos Plateau should also avoid all kinds of anthropegic activities which may lead to changes on the environment.

vi. Government and non-governmental organizations, and development partners should provide basic support and farm implements such as fertilizers, tractors, improve seeds, among others in order for household to increase their food production levels. This will go a long way in reducing climate vulnerability on the Jos Plateau.

REFERENCES

1. Abdulkadir, A. Abdullahi J. Christie, L.Y, Muhammad, M. Liman H.M. and Hassan, A. B. (2015). Climate change and vulnerability of the Riverine Communities in Niger State, Nigeria. The Nigerian geographical Journal, Nur series volume 10 No. 2 (2015) Pp 14 – 15.

2. IPPCC (2007). Summary for policymakers. In: climate change 2007: impacts, adaptation and vulnerability. Contribution of working group II to the Fourth Assessment Report of the intergovernmental panel on climate change, M.L. Parry, D.F. Canziami, J.P. Palutikof, P.J. Van der Linden and C.E. Hanso, Eds, Cambridge University Press, Cambridge, UK, 7 – 22.

3. FAO Interdepartmental working Group on climate change. (2007). Climate change and food security: A framework for action. Rome.

4. Gina Z, Anton C., Adriaan T., Adejuwon., Zermoglio F., Molichi S. and Smith B. (2008).

5. Gregory, P.J., Ingram, J.S.I. and Brklacich, M. (2005). Climate change food security. Philosophical transactions of the Royal Society B. Vol. 36:2139-2148.

6. Adeniyi, S.A. (2009). Adaptation to climate change impacts on water resource and agricultural production in African. A sustainable watershed management approach. Paper presented at the international conference on climate change and sustainable development held at the Osun State University Oshogbo, December, 2009.

7. Oladipo, E. (2008). Climate change and sustainable livelihood. Greening options for Nigeria. Report of the first national environmental summit on the theme: Greening the environment for sustainable environment (Pp 83- 94). Federal Ministry of Environment, Housing and Urban Development.

8. IPCC (2009). Climate change 2007. Synthesis Report. In Panchaim, R.K. and A. Raisinger, (eds) contribution of working groups I, II and III to the fourth assessment report of intergovernmental panel on climate change, Geneva, Switzerland.

9. IPCC (2001). The report of working Group II of the intergovernmental panel on climate change survey for policy makers. Pp 879 – 884.

10. Abdullahi, M. Dantum, D.M.S., Buhari, M.G. (2015). Climate change in Nigeria: Adaptation and mitigation strategies in the

31st Century. Paper presented at the International Conference of Nigerian Meteorological Society (NMETs) and 29th Annual General Meeting held at the Usmanu Danfodiyo University, Sokoto, Nigeria, in proceedings. Pp 248 – 253.

11. Peter, H. (2016). Trends in weather related disaster consequences for insurers and society. Weather and climate extremes 11: 70 – 79.

12. Patt, A. G., Tadross, M. Nussbaumer, P., Asante, K.I Metzger, M. Rafael J., Goujon, A. J. Brundrit, G. (2010). Estimating least developed countries' vulnerability to climate-related extreme events over the next 50 years. Proceedings of the National Academy of Science 107:1333-1337.

13. Labiru, M.A., Sadiku, Y.; Hussaini, Y., and Adedire, O. (2015). Climate awareness amongst residents of Jos North Local Government of Plateau State – Nigeria. The imperative for effective mitigation strategy. Paper presented at 57th Annual Conference of the Association of Nigeria Geographers (ANG) held at the University of Lagos main campus Akoka Yaba, Lagos, Nigeria in proceedings.

14. Odjugo, P.A.O. (2009). The impact of climate change on water resources: Global and Nigerian analysis. FUTY Journal of Environment, Vol. 4, No. 1.

15. Ojeh, V.N. and Victor-Orivo, A. F. (2014). Natural Hazard and Crop Yield in Oleh, South-South Nigeria. Flooding in perspective. J. Earth Sci Climate Change. 5L 181.doi.10.44172/2157-7617.1000181

16. Umar, A. T. (2011). Climate change in Nigeria: Evidence from meteorological parameters. Paper presented at 2011 Association of Nigeria Geographers Conference at Usmanu Danfodio University, Sokoto Nigeria.

17. Ojeh, V.N., F. ozabor, M.A., Labiru, M.I., Atuma (2016). Awareness of climate change impacts and adaptation in Delta State, Nigeria. Paper presented at the 57th Annual Conference of the Association of Nigerian Geographer (UNILAG ANG – 2016). 10th-15th April, 2016. Lagos.

18. Wardekker, J.A. (2011). Climate change impact assessment and adaptation under uncertainty. Ph.D dissertation. Utrecht University, Utrecht.

19. Yusha'u, N and Abaje, I.B. (2015). Climate change perception and vulnerability assessment in Futua Local Government Area of Katsina State, Nigeria. In the proceedings: Nigeria meteorological society, 2015 international conference and 29th Annual General Meeting held at the Usmanu Danfodiyo University, Sokoto, Nigeria.

20. Balgis, O.E. (2010). African's vulnerability to climate change and opportunities for adaptation. Tiempo climate Newswatch. Retrieved from http://www.tiempocyberclimate.org

CHALLENGES OF ADAPTATION TO CLIMATE CHANGE AMONG RURAL AGRICULTURAL COMMUNITIES IN SOUTHERN SENITORIAL DISTRICT OF PLATEAU STATE, NIGERIA

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ABSTRACT

In Nigeria weather-related events such as dry season, floods, mud slides, extreme rainfall, and delayed/early rains have become more frequent and/or intense. This has left most of the farmers food insecure and their livelihood threatened. Despite this, the incident of decreasing agricultural production still persists. On this note, this paper is to examine the challenges confronting rural agricultural communities in the southern senatorial district of Plateau state in the southern senatorial district of Plateau state in their adaptation to climate change. A total of three hundred and ninety (390) comes if questionnaires were randomly administered to form household heads in six selected communities found in Langtang South, Shendam and Quan'pan local government areas of Plateau Northern Senatorial District. The data were analyzed using descriptive statistics. The research findings revealed that 85% of the farmers were aware of climate. The result further reveals that majority of the rural farmers (91%) claimed to have suffered decreasing crop yields due to climate change. The combined adaptation measures among the rural farmers include planting of cover crops, application of fertilizer and organic manure, use of irrigation and change in crop varieties. The study further reveals that most adaptation challenges to climate change are poverty, illiteracy level and decreasing access to seedlings fertilizer and organic manure. The study therefore recommends that government should intensity efforts towards increasing accessibility to seedlings and also make fertilizer and other farm inputs available to the poverty stricken farmers at no cost.

Keywords: Nigeria, Agriculture, Crop yield, fertilizer, adaptation.

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Introduction

Climate change is a serious threat to agricultural production and sustainable development in Nigeria. This is because the country has a large rural population directly depending on agriculture. According to the International Fund for Agricultural Development [1], the agricultural sector employs approximately two-thirds of the country's labour force and provides a livelihood for about 90 percent of the rural population. It also contributes about 40 percent of Gross Domestic Products (GDP). This important sector is inherently sensitive to climatic conditions and is among the most vulnerable sector to the risks and impacts of global climate change [2,3]. Agriculture as a major component of rural livelihood and production system in Nigeria is greatly influenced by climate change. Notable among the effects of climate change in the country as reported in literature are persistence decrease in rainfall amount, increase in temperature, severe recurrent drought, scarcity of water for agriculture and land degradation [4,5,6]. Findings from these studies revealed that there is a decline in crop yields and increase cost of food crops as a result of climate change most especially in the northern part of Nigeria [7].

Tropical region is plagued with many weather-related disasters ranging from drought, flood, food insecurity, starvation, tropical disturbances, etc. The direct and indirect consequences of these problems are starvation, war, widespread mortality and diseases, etc. Classic examples are numerous including recurrent drought and famine in the Sahara/Sahel regions as well as in the regions of Africa. The overall impacts of these extreme weather and climate events obviously affect agriculture, fresh water, health and shelter. Tropical agriculture is predicted to be especially vulnerable to climate change because the region already endures high heat and low precipitation, agriculture is a large fraction of the economy, and farmers in the tropics rely on relatively basic technology(8 and 9). Despite this dire prediction, there have been relatively few empirical studies of effect of climate change in tropical agriculture(10). There have been handful of agronomic studies, largely of grains, that suggest that warming would have extensive harmful effects [11]. There have also been a few economic analyses of specific crops or specific regions[12]. These study all suggest that warming would have adverse effect. However empirical analysis of farmer's adaptation is limited in current research.

The Climatic Change , Agriculture and Food Security challenge unites the research in agriculture and environment and their respective partners, to address the most pressing and complex challenge to food security in the 21st Century. It is a response to accumulating evidence that the food security and livelihoods of hundred of millions of people who depend on small scale agriculture are under significant threat from climate change. The goal is to overcome the additional threats posed by changing climate to attaining food security, enhancing livelihoods and improving environmental management[13].

ADAPTATION STRATEGIES

Adaptation can be defined as adjustments of system to reduce vulnerability and increase the resilience of the system to change. Therefore, in terms of climate, it could be a response to climatic change that seeks to reduce the vulnerability of biological system to its effects. In other words, climate change adaptation are anticipation or monitoring of change thereby undertaking necessary action to address the consequences of that change (14). Therefore adaptive capacity refers to the ability of a community to prepare for and cope with or recover from exposure to climate related risks. Adaptive capacity is however determined by community characteristics such as health, equalities, political and social stability, access to infrastructure, institutional supports and social capital all which can facilitate to deal with related risks (15) with the above regards, communities need to improve their capacity to deal with a change be it natural or man made and to adapt wherever possible making the best of new conditions even if it means changes in lifestyle. Climate change adaptation is more important in Nigeria (Plateau State inclusive) since the country predicted to bear the menace effect of climate change. These strategies in general include among others – early planting crop rotation and intercropping, planting of early-maturing and drought resistant crop varieties, manure and fertilizer application, changing crop varieties and off-farm employments, planting of cover crops to enhance moisture storage, and various soil conservation technique (16). Despite various adaptation measures adopted by farmers to reduce vulnerability, agricultural production and access to food in Nigeria is projected to be severely compromised. The implication is the increased cost of food crops.

Aim and Objectives of the study

The specific objectives of this study among others are to:

i. identify socio-economic characteristics of respondents and sought their awareness about climate change.

ii. examine the impact of climate change on crop yields and

iii. identify the challenges of adaptation to climate change among the rural farmers in southern Plateau State.

Study Area

The study area comprises of Langtang South, Shendam and Quan'pan local government area which are situated in the southern part of Plateau State Nigeria. Latitude 8°3' and 10°30' North and latitude 7° 30' and 8°37' East. The climate is characterized by two district seasons, wet and dry. The wet season last for a period of 5 months (March-September) while the dry season covers the month of October to February as a result of the Harmattan (North East Trade) winds. The southern plateau (adjourning lowland) state however has a contrasting climate from that of upland plateau. The lowland areas are marked by relatively hot temperature with mean maximum of about 32°c and mean minimum of 22°c. These two climates are mainly influenced by the movement of the ITCZ. From April when the ITCZ moves northward the state is dominated by the wet southern trade winds or the tropical maritime wind which brings rain up to October. From November to March however, the ITCZ moves southward and the dry northeast trade (harmattan) winds or tropical continental winds dominate the state characterized by dryness and dust. Generally the mean annual rainfall varies from 131.75cm in the southern part of the state (Leeward side of Jos plateau) to 146cm on the Jos plateau(17).

MATERIALS AND METHOD

The study is based mainly on primary data obtained through the administration of a well-structured consisting of open and close-ended questions. Multi-stage sampling technique was adopted. The first stage involves purposive selection of three (3) rural agricultural communities in each of the three local government areas of study. A total of nine (9) communities were selected in all to reflect those mainly involved in crop production. These are Magama, Bulgam and Karkashi in Langtang South Local Government Area; Kuka, Shimankar and Ajikamai, we have Kurgwi, Kwa and Dumak in Quanpan. In the final stage, the administration of the questionnaire involve random selection of head of farm households based on availability and willingness of the respondents to supply the needed information contained in the questionnaire (17). For the analysis of data collected, descriptive statistics such as mean and percentage were used.

Table 1: Sampling Frame for the study

S/No.	L.G.A.	Agricultural Communities
1.	Langtang South	Magama, Bulgam and Karkashi
	Shendam	Kaka. Shimamkar ad Ajikamai
2.		Kurgwi, Kwa and Dumak
	Qua'an pan	
3.		
	No .of Questionnaire	
		Total 390

Source: Authors survey, 2016.

DATA ANALYSIS AND DISCUSSION OF FINDINGS

Table 2: Socio-economic characteristics of the respondents

Characteristics	Frequency	(%)
Sex		
Male	252	65
Female	137	35
Age		
1 – 30	58	15
31 – 60	305	78
Above 60	27	07
Education		
No formal education	185	47
Islamic./Qur'anic	80	20
Primary	53	14
Secondary	46	12
Tertiary	26	07
Farm Size in Hectares		
1.1-3	163	42
4.1 – 6	128	33
6.1 – 10	74	19
Above 10	25	06
Total	390	100

Source: Author's survey, (2016).

The result in table 2 gave an insight into the socio-economic characteristics of sampled respondents. Investigation into the sex of respondents reveal that (65%) of the farmers in the study area were male while 35% were females. This indicates that men participate majorly in crop production in the study area. This result is congruent with the one reported by Yahaya and Isa (7) that male participate more in crop production in Katsina State and that of Tunde (16) which reported that nearly 86% of respondents in his study of Adaptation to climate – induced. Reduction in crop yield among rural women In Kwara State Nigeria. But this result is at variance with Labiru *et al* (18) which reported that women participate more than men in agroforestry (73% against 23%) in their study of women perception and participation in agroforestry practice in Barkin Ladi – Plateau State. Perhaps this could be attributed to the variation in the study area in which the northern zone of the state allows women to participate in crop production more than the southern zone. With respect to the age of the respondent majority of respondents (78%) of the farmers fall within the age bracket of 35 – 60 years. The implication here is that economically active age adults participate prominently In farming production in the area and this shows their active commitment to farming as a livelihood option. These findings corroborates the experts' report that economically active age adults participate in farming activities in Katsina State (6 and 7) the marital status as shown in table 2 reveals that half of the respondents had no formal education while the remaining half comprises of those with Islamic/Qur'anic education (20%), primary (14%), secondary (12%) and tertiary had (7%)/ These findings disagree with the findings of Yahaya and Issa (7) that half of the respondents had Qur'anic education in Katsina State. Data on table 1 also reveal that (42%) of the respondents worked on between 1 – 3 hectares of farm land, while (33%) of them operated 4 – 6 hectares, and about (19%) had between 6 – 10 hectare of farmland, only a few (6%) were those who cultivate above 10 hectares of land. This indicates that majority of the respondents are small scale farmers operating at subsistence level using traditional farm equipment.

Table 3: Awareness and Impact of Climate Change

Response	Frequency	(%)
Yes	298	76
No	92	24
Impact of climate change	180	46
Variation in rainfall	140	36
Increase temperature	70	18
Reduction in crop yield		
Total	**390**	**100**

Source: Author's survey, 2006

Respondent's knowledge of the general awareness about climate change and its impact was assessed. This become necessary in order to know their readiness to adopt adaptation measures ad confront the adaptation challenges/ When asked to assess the trend of temperature (hot das) in recent years, about (36%) of the respondents claimed that the number of hot days are increasing at the same vein, (46%) claimed that amount of rainfall and number of raining days is increasing (Table 3). These findings corroborate with experts reports that mean temperature is increasing in Nigeria. Odjugo, Umar (19 and 20). Labiru et al (17) and increasing rainfall leading to inundation of farmland in Delta Ojeh et al (21). The result further reveal that (18%) claimed to have experience reduction in crop yield as a result of climate change.

Climate change Adaptation Strategies

Effective response of farmers to climate change means higher food security and any increase in food security translates into livelihood sustainability for the rural poor. Based on this, information was gathered on the various adaptation strategies adopted by the respondents as presented in Table 4.

Table 4: Respondents; adaptation measured to climate change

Strategies	Frequency	(%)
Planting of cover crops	63	16
Switching to other crops	106	27
Fertilizer/manure application	43	11
Adjusting planting date	158	41
Seasonal migration to cities	20	05
Total	**390**	**100**

Source: Author's survey, 2006

Table 3 shows that (41%) of the respondents claimed to have adjusted planting date as a measure to cope with climate change. Other adaptation strategies among them include switching to other crops (27%), planting of cover crops (16%), fertilizer/manure application (11%) and (05%) seasonal migration to cities in search of survival mechanism to cope with the impact of changing climate. It can be inferred from the result that application of fertilizer and use of irrigation happen to be the least adopted adaptation strategies.

CHALLENGES OF ADAPTATION TO CLIMATE CHANGE

Data in table 5 reveals that the major challenges confronting the farmers in adopting to climate change is inadequate financial resources in coping with the effect of changing climates (42%). It is pertinent to hear that majority of the respondents said they cannot afford to buy fertilizer and some other farm inputs at exorbitant prices been sold at the market. The poor financial resources base of the respondents translate to general poverty. Furthermore (25%) of the respondent attributed their constraint to illiteracy level which had prevented them from benefiting in most government programmes/grants aimed at cushioning the effect of climate change. This is in line with the work of (7) and (6) that poverty and illiteracy are ranked most important challenges of adaptation to climate change. It is not surprising while African continent has been highlighted as particularly vulnerable to climate change in future. Primarily due to its low adaptive capacity and its sensitivity to many of the projected changes (22). According to international fund for agricultural development report, poverty is especially severe in rural areas of Nigeria, where up to 80% of the population lives below the poverty line, and social services and infrastructure are limited. The country's poor rural women and men depend on agriculture for food and income. About 90% of Nigeria's food is provided by small scale farmers who cultivate small plot of land and depend on rainfall rather than irrigation system (22). It is pertinent to state here that poverty, low level of education, outbreak of pest and disease are rated the most important challenges of adaptation to climate change among farmers in the Plateau Southern senatorial zone.

CONCLUSION, IMPLICATION AND RECOMMENDAITON

The Plateau State Southern Senatorial zone has had its shares of negative impact of climate change despite its advantage in some cases. But these impacts are predicted to get worse with time necessitating more serious measures to be taken by the farmers themselves, the government, NGOs and other private sector organizations that may assist farmers. Based on this, a number of policy recommendations are proffered. Firstly government must make sure that any national policy related to climate change in Nigeria should integrate poverty eradication programmes as priorities of rural farmers, particularly northern Nigeria. It is necessary that inadequate provision of fertilizers and other farm inputs be made at lowest cost or preferably at no cost to poverty-stricken farmers. In order to reduce the risks, adapt properly, and overcome the challenges of adaptation to climate change herein identified, it is important to develop a more holistic approach which will situate local farmers and their knowledge at the centre of policy formulation and implementation in order to adequately reduce poverty and subsequently improve household welfare.

REFERENCES

1. IFAO (2010) Enabling poor rural people ot overcome poverty in Nigeria. Rural poverty in Nigeria. International Fund for Agricultural Development. Retrieved online at http://www/ofad.org/operations/

projects/pa/factsheets/org on 06.05.2016

2. Parry,.M. L. and Carter, T. R. (2008). An assessment of the effects of climate change on Agriculture. Climate change 15:95 – 116.

3. Oladipo, E. O. (2013). Contemporary climate change science: opportunities for multidisciplinary Research Approach. Public lecture delivered at Federal University, Dutsin-Ma, Katsina State 15th May, 2013.

4. Ekpoh, I. J. (2007). Climate change and society in Northern Nigeria: Rainfall Variability and farming. The International Journal series on tropical Issues, 8 (3): 157 – 162.

5. Odjugo, P.A.O (2010). General overview of climate change inputs in Nigeria. Journal of Human Ecology, 29 (1): 47 – 55.

6. Abaje, I.B., Sara, B.A. and Ati, O.F. (2014). Climate variability and change, impact and adaptation strategies in Dutsn-ma Local Government Area of Katsina State, Nigeria. Journal of Geography and Geology; 6 (2); 103 – 112.

7. Yahaya, D. Y. and Isa, .S O. (2016). Challenges of adaptation of climate change among rural agricultural communities in Northern Katsina, Nigeria in the proceedings, 57th Annual conference of Association of Nigerian Geographers (ANG) held at the University of Lagos, 11thg – 14th April, 2016 Pp 1 – 3.

8. McCarthy, J.C. and Dokken, C. D. (2001) Climate change 2001: Impact, adaptation and vulnerability, contribution of working group II to the third assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge, UK.

9. WEF (2008). Global Risk (2008). http:///www.keform.org/pdf/globalrisk/report2008.pdf

10. Kurukulasuriya, P. Mendelsohn, R., Hassan, R, Benhin, J, Deressa, T, Drop, M, Eid, Hm, Fosu, KY, Gbetibono, G, Jain, S, Mahamadou, A, Mano, R and Dinar, A. (2006) will African agriculture survive climate change? World Bank Economic Review 20, 367-88.

11. Dressa, T., Hassan, R and Poonyth, D. (2005). Measuring the economic impact of climate change on South Africa's Sugarcane growing regions. Agreko 44 (4), 524 – 42.

12. Gleandow, R, (2009). Food crisis looms as climate threatens cassava, others" proceedings of the conference on climate change and implications on Tropical crops. University of Glagow, Scotland.

13. Okoye, I.G. and Onieta, J.A. (2009). Climate change, agriculture and food security, implications for the tropical regions. Paper presented at the

International Conference on Climate Change and Sustainable Development (NMETs) 009, held at the Osun State University, Oshogbo – Nigeria.

14. Jones, L. (2010). Overcoming social barriers to adaptation. Overseas Development Institute(ODI) Background Note, www.odi.org.uk/50ears Accessed January, 2011.

15. Mortimore, M. and Adams, W. M. (1999). Working the Sahel. Environment and Society in Northern Nigeria. Routledge, London, 226 Pp.

16. Tunde, A. M. (2012). Adaptation to climate change-induced Reduction in crop yield among rural women in Kwara State Nigeria. Environmental Issues, Vol. 5, Pp 55 – 64.

17. Labiru, M.A, Sadiku, Y. Ahonsi, G.E., Abdulkadir, A. T, Umar, A.A., and Lafinhan, D. A (2016). Awareness of climate change impact and adaptation in the three senatorial district of Plateau State Nigeria. Paper presented at the maiden conference of tropical Journal of Agricultural Research, TROJOARCH.

18. Labiru, M.A., Sadiku, Y, Binbol, N.H and T.O. Iirdu (2016). Women perception and participation in agroforestry practice in Barkin Ladi LGA. Plateau State Nigeria, in the proceedings, 57th Annual Conference of Association of Nigeria Geographers (ANG) held at the University of Lagos 11th – 14th April, 2016 Pp 7 – 10.

19. Odjugo, P.A.O. (2009). Perception of climate change on water resource: Global and Nigeria analysis. FUTY Journal of Environment, Vol. 4, No. 2.

20. Umar, A. T. (2011) Climate change in Nigeria: Evidence from meteorological parameters. Paper presented at 2011 Association of Nigeria Geographers Conference at Usmanu Danfodio University, Sokoto.

21. Ojeh, V.N., Ozabor, F, M.A. Labiru and Mi. Atuma (2016). Awareness of climate change impacts and adaptation in Delta State Nigeria. Paper presented at 2016 Association of Nigeria Geographers Conference at Usmanu Danfodio University, Sokoto.

22. IFAO, (2010). Enbaling poor rural people to overcome poverty in Nigeria: Rural poverty in Nigeria. International Fund for Agricultural Development Retrieved online at http:///www.ifad.org/operations/projects/pa.factsheets/ng on 8/8/2016

PUBLIC PERCEPTION OF CLIMATE CHANGE AND ITS IMPACT ON HEALTH AND ENVIRONMENT IN TARABA SOUTH, NIGERIA

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Abstract

The unprecedented rapid changes on the earth's climate/environment have been witnessed over decades. Certain technological progress and demographic pressure, more than the natural changes have either aggravated the natural changes or lead entirely to new dimensions at climate/environmental changes. Natural phenomena such as global warming, ozone depletion, desertification and general environmental degradation are some of the issues causing widespread of some diseases. On this note, this paper is to examine the public perception of climate change, health and the environment in Taraba State. Data on public perception of climate change, health and the environment were obtained using structured questionnaire on 490 sampled respondents. Simple random sampling was used during the administration of the questionnaire. Findings revealed that 78% of the respondents are well aware of climate change. The major source of information about climate change was electronic media (television and radio) 76%. Age occupation and level of education influenced the respondents' knowledge on climate change. Climate change has negative impacts on health and environment. Based on these findings, the research therefore recommends a comprehensive environmental education to educate citizens on the causes and effects of climate change.

Keywords: Climate change, desertification, Ozone deflation, Environment, Health, public perception.

INTRODUCTION

Despite the technological advancement in medical sciences, the health of the human population is still affected to a larger extent by weather and climate (Akibobola and Omotosho, 2005). Climate affects health in a number of ways, these effects may be direct as with heat stress, or indirect as with infectious diseases such as malaria and meningitis (Caroline, 2015). Changes in climate plays a significant role in people's health changes in temperature, precipitation patterns and extreme event such as floods, drought and heat waves could enhance the spread of some infectious disease worldwide (Environmental Protection Agency (EPA), 2010). Human comfort and health are affected more by climate than any other element of the physical environment. The physiological functions of the human body respond to changes in weather (Zemba, 2003). The climatic elements that affects the physiological functions of human body include radiation (sunshine), temperature, relative humidity and atmospheric pressure. Several authors (Ayoade, 2004; Zemba 2003; Esptein, 2005), Binbol and Uzochukwu; 2009) agreed that human comfort and health are influence most by temperature and humidity variations. Man is constantly exposed to the atmospheric environment whether outdoors or indoors. Therefore, his body feelings will be at a certain thermal equilibrium where it derives comfort to inhabit in a region.

Climate exercises an influence on man and his activities thus, the essentials of life for mankind namely air, water, food, clothing and shelter are all weather dependent or weather related. Certain illnesses are climate induced while several 0diseases that afflict man show close correlation with climatic condition and season in their incidence. Human physical and mental vigour are generally reduced by high temperature and relative humidity. On the other hand, extremely low temperature or very dry air may impair physical vigour (Binbol and Uzochukwu, 2009).

Climate does not really cause disease, but basically contributes to the factors that operate together to result to the disease, its severity and spread of the disease. Climate plays a certain roles in the determination of human diseases, the first is that climate affects the resistances of the human body to particular diseases and helps in the recovery process from these diseases. Secondly, climate can determine the types and population of diseases.

Climate change is arguably the biggest current threat to public health, contributing to the global burden of disease and premature death (IPCC 2007). Variant climate patterns and global warming will alter the pattern and prevalence of infections and vector-borne diseases (Haines *et. al* 2006). Disease burden may also increase as a result of climate change related migration of reservoir hosts (Hales *et. al* 2000). Additionally, climate variability will lead to resurgence and increased edmemicity of tropical diseases (Haines *et al* 2006) globally, an estimated 166,000 deaths result from change in climate annually, relative of the average baseline measurements between 1961 – 1990 (Michael *et al*, 2004). Diarrhea, the leading cause of under-five death in developing countries is estimated to increase by 2 – 5% by 2020. Furthermore, annually, 5.5 million disability adjusted life years (DALYs) can be attributed to climate change (WHO, 2002). An earlier study reported five categories of health outcomes which are most likely to be affected by climate change: temperature-related morbidity and mortality; health effects of extreme weather event (storms, tornadoes, hurricanes, and precipitation extremes): air-pollution related health effect, water borne and food borne diseases; and vector-borne and rodent borne diseases (Patz, 2014).

PERCEPTION OF CLIMATE CHANGE

Perception is a process in which an organisms interpret and organize sensation to produce a meaningful experience of the world. Perception is the process by which we receive information stimuli from our environment and transform it into a psychological awareness IPCC (2001).

Impacts of Climate Change

Climate change is a fundamental element of the environment and a change in climate will consequently cause a change in the entire environment affecting other elements of the environment. Climate change present significant threat to the achievement of the millennium development goals especially those relating to promoting environmental sustainability, poverty eradication and disease. Climate change is not just an environmental issue, it has impacts on all facets of life in developed and developing nations alike. It has implications not only on the health and well-being of the earth's ecosystems but also on the economic enterprises and social relationships. The effects of climate change which include rising temperature and changes in precipitation are undeniably clear with impacts already affecting ecosystems and people. In both developed and developing countries (Oderide and Amosum, 2009). One of the greatest impacts of climate change is the worsening condition of extreme weather events like droughts, flood, rainstorms, among other Odjugo (2008) opined that the frequency and magnitude of wind and rainstorm did not only increase, they also killed 199 people and destroyed property worth N85.03 billion in Nigeria between 1992 and 2007 at the same vein Odjugo (2010) noted that climate change had lead to a shift in crop cultivation in the northern Nigeria climate would have directly or indirectly affected population and human settlement in Nigeria. In general, about 15% of the country's population is presently affected by climatic variation and sea level changes. With climate change between 50% and 760% of the population would be affected.

Health Implications of Climate Change

Human beings are exposed to global warming through changing weather condition such as temperature, precipitation, seal-level rise and indirectly through changes in water, air and food quality. In addition, there may be changes in ecosystems, agriculture, industry and settlements and the economy Confalonieri, *et al* (2007) opined that climate change had altered the seasonal distribution of some allergic pollen species, the distribution of some infectious diseases, vectors, increased heat wave-related deaths. Moreover, the health status of millions of people would be affected through increases in malnutrition, epidemic diseases, increased deaths and injury due to extreme weather events; increased occurrence of cardio-respiratory diseases due to high concentrations of ground level ozone gas particularly in urban areas as result of climate change Stem (2006). In addition, by changing spatial pattern of distribution of some infectious diseases, climate change would bring some benefits in temperature areas, such as fewer deaths from cold exposure, and some mixed effects such as changes in range and transmission potential of malaria in Africa. IPCC (2007) had remarked that expected benefits would outweigh negative health effects of rising temperatures, especially in developing countries. The spatial distribution, intensity of transmission, and seasonality of common malaria is influenced by climate. In Sub-Saharan Africa, Conflanonieri *et.al* (2007) malaria is strongly influenced by climate Transmitted by Anopheles mosquitoes. Malaria kills almost 1 million people every year mainly African children under five years old. However, rainfall can be a limiting factor for mosquito populations and there is some evidence of reductions in transmission associated with decadal decreases in rainfall.

Vorosmarty *et al* (2000) noted that climate change effects the fundamental requirements for human health such as clean air, safe drinking and sufficient food. Extreme heat with high temperatures contributes directly to deaths from cardiovascular and respiratory diseases, particularly among elder people. High temperatures also raise the levels of ozone gas and other pollutants in the air that exacerbate cardiovascular and respiratory diseases. Urban air pollution, pollen and other aeroallergen levels are also higher in extreme heat and they can trigger asthma, which affects millions of people. Ongoing temperature increases are expected to heighten the risk of a range of health effects, ranging from mental disorders, communicable diseases, reduction in the supply of fresh water, and can lead to water scarcity, drought and famine.

Adefila (2011) reported that food borne diseases and nutrition emanating from global warming can be associated with staple food shortages, malnutrition, and food contamination from sea-food, chemical contaminants, pathogenic microbes and pesticides. Water-borne disease increase in water, precipitation, distribution and intensity, evapo-transpiration rates and changes in coastal system could increase the incidence of water contamination with harmful pathogens. Weather-related morbidity increase in the incidence and intensity of extreme weather event such as strong storms, floods, drought, and wildfires which may adversely affect people's health.

Study Area

Taraba State is located between latitude 6°25'N to 9°30'N longitude 9°30'E to 11°45'E with tropical continental type of climate with a land area of about 60.291km^2, the second largest in Nigeria, has a total population of over 2.3 million people provisionary census figure (NPC, 2006) and annual growth rate of 3.1% per annum. The state is located on the mountain ranges in the eastern borderland of Nigeria separating Nigeria and Cameroun Republics, it is bordered on the west by Nasarawa State and Plateau State, to the north by Bauchi and Gombe States and Adamawa State to the Northeast. Taraba Southern senatorial zone consist of five local government areas namely Wukari, Donga, Takum, USSA and Ibi Local Government. The area consist of undulating landscape dotted with a few mountaineous features. This includes the scenic and parts of prominent Mambilla Plateau. The climate is characterized by two distinct seasons, wet and dry. The wet season last a period of 7 months (April – October) while the dry season covers the month of November to March. The mean temperature is about 28°C, mean annual rainfall is about 1850mm in Taraba State.

METHODOLOGY

In the conduct of the study, data was source through two major sources, primary data were obtained through the administration of questionnaire to select residents of the selected communities in Taraba southern senatorial zone. Secondary data were sought from published materials, such as journals, textbooks, internet and other relevant published materials.

Location of key areas of the study were selected through purposive sampling entails direct selection of respondents who resides within the core areas of the selected communities. Systematic sampling was adopted to select household heads from the study area. The operational of the systematic sampling involves selecting every 10th household head through this technique a total of 490 respondents were successfully sampled and administered with questionnaire in the study area. The questionnaire was designed to acquire and elicit responses on a range of issues such as level of awareness of climate change, perception, impact on health and perceive effects of climate change. Data collected was subjected to descriptive statistical analysis/frequency distribution table and percentage for each variable. Fourteen (14) communities were selected using simple random and systematic sampling methods (Table 1)

Table 1: Selected communities and number of respondents

S/N	Selected communities	Number of respondents
1.	Ibi	50
2.	Sarkin kudu	30
3.	Damfar	20
4.	Wukari	50
5.	Dorowa	25
6.	RafinKada	25
7.	Takum	35
8.	Chachangi	45
9.	Kashinbila	35
10.	Donga	40
11.	MarabaBa'isa	35
12.	Kumbo	35
13.	Ussa	40
14	Kongo	25
	Total	**490**

Source: Author's field work

RESULTS AND DISCUSSION

Socio-economic characteristics of respondents

Personal characteristics of respondents are important human attributes that lay a significant role in the study of climate, variables assessed here include age, educational, attainment and duration of study.

Table 1: Socio-economic characteristics of respondents

Characteristics	**Frequency**	**Σ**
1-30	20	4
31-60	381	78
More than 60	89	18
Education	283	58
Non-formal		
Primary	94	19
Secondary	75	15
Tertiary	38	08
Duration of study		
1-10	00	00
11-20	05	01
21-30	140	29
More than 30 years	345	70
Total	490	100

Source: Author's field, work, 2016

Data in table 1 shows the socio-economic characteristic of the sampled respondents. Investigation into the age of respondents reveal that 78% of the sample respondents are within the age bracket of 31-60 years while 18% are above 60years. The implication here is that the respondent are matured to respond to key questions regarding climate based on the experience they have acquired over the years in southern Taraba, with respect to level of education, majority of respondents (58%) acquired non-formal education,19 and 15% attended primary and secondary school. By implication, majority of the respondents are illiterates and semi-illiterates in terms of western education. Their responses will therefore be on the basis of their local experiences and understanding. In terms of duration of stay within the study area, majority (70%) have been in the study area for over 30 years, 29% for 21-30 years and only 1% for 11-20 years. These findings is in line with that of Dankani and Raliya (2016) which reported that the level of western education among the resident of Kano and Zaria in their study of climate change awareness among residents of Kano and Zaria walled cities. At the same view the above findings is in congruent with that of Labiru *et.al* in their study of awareness of climate change impact and adaptation in the three senatorial district of Plateau state, Nigeria. Which reveals that majority of the respondents have an Islamic education (non-formal). But this result disagree with the one reported by Esther (2014) which reveal that the educational attainment of residents of southwestern Nigeria is high. Perhaps this could be attributes to long history of western education in the region.

2: Public awareness of climate change issues

Awareness	**Respondent**	**%**
Yes	380	78
No	110	22
Total	490	100

Sources: Author's field work 2016

It is true, that issue of climate change is no longer news but a reality as its signs are all around ustoday. Awareness is having a knowledge or understanding of a subject, issue or situation. Table 1 shows the public awareness to climate change issues, data on Table 1 revealed that (74%) of the respondent (public) are aware of climate change issues in Taraba southern senatorial district and its environment

Table 3: Source of information about climate change

Response	Frequency	%
Radio	373	76
Television	44	09
Newspaper	31	6
Family/friends	14	3
Personal Observation	28	6
Total	490	100

Source: authors field work 2016.

Investigation into the source of information about climate change by the respondents reveal that (79%), claimed to radio programme, television (9%), Newspaper (6%), family and friend (3%) and personal observation (6%). The dominance of radio as a major source of information about climate change phenomenon is not surprising because of high level of addiction of the resident to their radio and most cases despite not being educated, the radio avail them with the opportunity to be informed about happenings in their environment. This result confirm with that of Ismail et al (2016) in their study of effect and knowledge of climate change among farmers in Taraba State, that 42% of their respondents get information about climate change through the radio.

Table 4: Perceived change in the occurrence of disease in the past decades

Response	Frequency	%
Yes	346	71
No	144	29
Total	490	100

Source: Authors field work, 2016.

When question was post on whether the respondent perceived change in the occurrence of disease in the past decade majority (71%) of the respondents claimed that diseases were on the increase compare to the past decade.

Table 5: Perceived change in the occurrence of certain diseases during raining season

Response	Frequency	%
Yes	385	79
No	105	21
Total	490	100

Source: Author's field work 2016.

The above table shows that 70% of the public in the study area perceive change in the occurrence of certain disease during raining.

Table 6: Changes observed by respondents

Response	Frequency	%
Increase in temperature	202	41
Change in rainfall pattern	141	29
Change in overall weather	89	18
Flooding	58	12
Total	490	100

Source: Author's field work, 2016.

Data in table 6 shows the perception on weather and climate change indices was analyzed, 41% of the respondents perceive that temperature is getting warmer, 29% notice change in rainfall patter; 18% observe a general change in weather pattern in their community. Incidence of flooding was also reported by 12% of the respondents respective (see table 6).

Conclusion and Recommendations

The study was on public perception of climate change and its impact on health and its impact on health and environment in Taraba South, Nigeria. Arising from the data analysis, the conclusion drawn from this study is that the general public in Taraba South are aware of the impact of climate change on health and environment. Its manifestation in terms of climate change impact on health and environment are known. For effective mitigation and adaptation to climate in Taraba State, the following recommendations are made:

i. Government, Non-governmental organization (NGOs) and civil society organizations should intensity efforts in environmental education awareness campaign on climate change impacts, mitigation and adaptation in the state owned television and radio stations and other media houses is an important platform for such campaign.

ii. Massive awareness campaign should be intensified so as to keep the populace abreast with the causes and consequences of climate change.

iii. Studies on climate change, adaptation, strategies and other environmental issues should be integrated into the primary, secondary and tertiary curriculum.

iv. The State government through Ministry of environment should provide basic weather observation equipment for climate/weather monitoring in different senatorial districts in the state. This will enable the state to have a data base for past and present weather which can be used in operational weather system forecast.

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Competing interest

The authors declare no competing interest

Author's contribution

MLA conceived the research work

AGC, SY and MLA coordinate the field level data collection

MLA, AGC and MMS carried out the data analysis.

MLA wrote the draft of the manuscript

MLA, AGC, SY and MMS contributed in the literature review, interpretation of results and manuscript revision. All the authors contributed in the revision of the paper and agreed on the final manuscript.

References

1. Akinbola, A and Omotosho, J.B. (2004). Relationship between meteorological variables and some common diseases in some selected stations. Paper presented at the department of Meteorology, Federal University, Akure, Nigeria.
2. Caroline, N.U. (2015) Effect of weather on the occurrence of some common diseases in Gboko Town, Benue State – Nigeria in proceedings, 29th Annual Conference of the Nigerian Meteorological Society (NIMETS) held at the Usmanu Dan Fodio University Sokoto Nigeria, 23rd – 26th November, 2015 Pp 535 - 535.
3. Environmental Protection Agency. EPA (2010). Climate Change Science Fact. US. Environmental Protection Agency, Washington DC, USA.
4. Zemba, A. A. (2003) Analysis of micro climate variation sin Jimeta-Yola Nigeria.
5. Esptein, P. R. (2005). Climate change and Human Health. Journal of Meteorology and Environmental management.
6. Ayoade, J.O. (2004). Introduction to Climatology for he tropic, Spectrum Books Limited, 250 – 251.
7. Binbol, N.L. and Uzochukwu, C.T. (2009). Climate and Human control in Abuja, Nigeria. Paper presented at the Annual Conference of Nigerian Geographers (ANG) held at Osun State 2009 Pp 323 – 325.
8. IPCC Climate change 2007 Synthesis Report, contribution of working Group I, II and III to the forth assessment. Report of the intergovernmental panel on climate change (Cambridge: Cambridge University Press).
9. Haines, A., Kovats, R.S., Campbell –Lendrum, D and Corvalan C., (2006) Climate Change and human health: impacts,

vulnerability and public health 120:585-96 crossref.

10. Hales S., Kovats and Woodward, A. (2000) what EL-Nimo can tell us about human health and global climate change Glo. Change. Human Health 1:66 – 77 Cross ref.
11. Michael A. J., Campbell – Lendrum D, Kovats R.S., Edwards S and Wilkinson, P. (2004). Comparative quantification of Health Risks Factors (Geneva: World Health Organization).
12. World Health Organization (2002). The World Health report 2002: Reducing Risk, Promoting Health Life (Geneva: World Health Organization).
13. Patz, U. (2014). The potential health impacts of climate change variability and change for the United States. Executive summary of the report of the health sector of the US National Assessment Journal of Environmental Health 64:20-8
14. Oderinde, F. O., and Amosun, P.A. (2009). Climate Changes and the environment: the need for environmental education. Paper presented at the annual conference of Nigeria geographers (ANG) held at Osun State Nigeria, 2009. Pp 43 – 44.
15. Odjugo, P.A.O (2008). Quantifying the cost of climate impact in Nigeria: Emphasis on wind and rainstorms. Journal of Human Ecology (in press).
16. Odjugo, P.A.O. 92010). Regional Evidence of climate change in Nigeria in Journal of Geography and Regional Planning, Vol. 3 (6), Pp 142 – 150, June 2000. Available online at http://www.academicjournal.org/JGRP. ISSN 2070 1845 © 2010 Academic Journals.
17. Confalonieri, J.P., Grasso, M, and Costello, A. (2007). Managing the Health Effects of Climate: Lancet and University London Institute for Global Health Commission. The Lancet, 373, 1693 – 1733.
18. Stem, G.S. (2006). Adolescents perception on Environmental change and health risk in Two Division of Bagladesh, Open Journal of Social Science, 3, 71 – 79.
19. Vorogmarly, A. A. (2000). American Risk Perceptions: Is Climate Change Dangerous? Risk Analysis, 25, 1433 – 1442.
20. Adefila, J.O. (2011).Assessment of Global Warming. Effects on soico-economic development in Sub-Saharan Africa. In proceedings of Nigeria Meteorological Society (Nimets), Zaria, 2011.
21. Esher, A.O. (2014). Public Perception of Climate Change and its impact on healt and environment in Rural Southwestern Nigeria.
22. Ismail, U.I. and Rabiu, A.G. (2016). Effects and Knowledge of Climate Change among farmers in Taraba South, Nigeria. Paper Presented at the 57th Annual Conference of the Association of Nigerian Geograhers (UNILAG AND – 2016). ID: ANG 2016 – 428.
23. Dankani, I.M. and Raliya, H.M. (2015). Climate change awareness among residents of Kano and Zaria walled cities: the imperative for effective mutigation strategy in the Proceedings of Nigerian meteorological society (Nmets) 2015 international conference and 29th AnnualGeneral meeting held at the UsmanuDanfodio University, Sokoto, Nigeria.

24. Labiru, M.A.Sadiku, Y., Ahonsi, G.E., Abdulkadir, A.T., Andre, A. U. and Lafinhan, O.A. (2016). Awareness of climate change impact and adaptation in the three senatorial district of Plateau State, Nigeria. Paper presented at the Maiden Conference of the tropical Journal of Agricultural research Vom, Plateau State, Nigeria

Vulnerability of Crop Water Use and Irrigation Water Requirement of Cucumber to Seasons and Climatic Period

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Abstract

Poor knowledge of water requirement limits irrigation water management to produce crops throughout the year. Crop water use and irrigation water requirement of cucumber were therefore investigated theoretically at National Horticultural Research Institute, Ibadan (7° 22'N, 3° 50'E), southwestern Nigeria, using Blaney-Cridle equation. Seasonality comprised dry season (December, January,February and March) and wet season (May,June,July and August). Climatic period comprised 10 and 5years average. Crop water use of cucumber did not differ between seasons and climatic periods. Mean seasonal crop water use were 482.17 and 482.8mm for dry and wet seasons respectively. Mean seasonal irrigation water requirements was 369.36mm in the dry season and zero in the wet season to enhance judicious use of water resources to produce cucumber throughout the year in southwestern Nigeria. Applying 370mm of irrigation water seasonally is recommended for dry season cropping. Under rain-fed cropping, supplementary irrigation is not necessary.

Key word: Crop Evapotranspiration, Cucumber, irrigation water requirement

1. Introduction

The doctrine of intergenerational equity (Weiss 1992) does not only confers on us the right to use natural resources on trust to satisfy the present needs but also the obligation to conserve these resources for the future generations. One approach to resource conservation is to quantify resource input for production to avoid wastage. Agriculture in this part of the country is not sustainable since it is rainfed and the rainfall patterns over the years are changing (Odekunle and Eludoyin, 2008). The ET information helps in understanding farm water and soil management for improved water use or introduction of non-native vegetation in the areas. Crop evapotranspiration (ETc) is a principal factor of crop productivity in humid and sub-humid tropics. In these regions, when soil water is available, ETc can reach or even exceed 10 mm day-1 under low atmospheric humidity and high wind velocity conditions (Fasinmirin and Olufayo, 2009). Information on ETc and crop coefficients (Kc) is useful for normal irrigation planning and management purposes, for the development of basic irrigation schedules, and for most hydrologic water balance studies (Tyagi et al., 2000; Suleiman et al., 2007).

Cucumber (*Cucumis sativus* L.) is the fourth most important vegetable crop after tomato, cabbage and onion in Asia (Tatlioglu, 1993), the second most important vegetable crop after tomato in Western Europe (Phu, 1998). It is thought to be one of the oldest vegetables cultivated by man with historical records dating back 5000 years (Wehner and Guner, 2004). In tropical Africa, the place of the crop has not been ranked. The objective of this study was to assess vulnerability of estimate crop water of cucumber in both dry and wet seasons, using medium term climatic data.

2. Materials and Methods

The study was based on climatological data (Table 1), collected from the National Horticultural Research Institute, Ibadan , Oyo State, Southwest Nigeria. Seasonality comprised dry season (December, January, February and March) and wet season (May, June, July and August). Assumed planting and harvesting periods of the crop at both seasons are shown in Table 3. Computations were based on a total growth period of 120days for cucumber (Allen, 1993). This was aggregated into 20, 35, 40 and 25 days respectively with their corresponding crop coefficients of 0.45, 0.74, 0.9 and 0.75 for initial, crop development, mid -season and late season stages of growth (Chukwu 1995). The ET crop was estimated with the formula of Blaney-Criddle (1950) as described by Brouwer and Heibloem (1986). Data were analyzed using analysis of variance.

The crop evapotranspiration (ET crop) of cucumber was estimated using:

$ET\ crop = ET_o\, K_c$; …………………… (1.0)

where ET_o is the reference crop Evapotranspiration and K_c is the mean crop coefficient at stage of growth as they are given by Allen *et al* (1996). Calculation of mean daily reference crop evapotranspiration (ET_o) was done using Blaney-criddle equation from agrometeorological data of 10 years (2000-2010).

$ET_o = p \cdot (0.46 \cdot T_{mean} + 8)$……………….(2.0)

Where:
ET_o is the reference evapotranspiration [mm day^{-1}] (monthly)
T_{mean} is the mean daily temperature [°C] given as $T_{mean} = (T_{max} + T_{min})/2$
p is the mean daily percentage of annual daytime hours.

The effective rainfall was calculated with the method of USDA (Soil Conservation Service) (1970) as

$P_e = P_{tot}\,(125-0.2\,P_{tot})/125$ for P_{tot} <250mm……………………(3.0)

$P_e = 125+0.1P_{tot}$ for P_{tot} >250mm……………………(4.0)

Where P_e is the effective rainfall and P_{tot} is the total monthly rainfall

3. Results

Table 4 shows monthly crop coefficient of cucumber at NIHORT, Ibadan. Monthly Kc for dry season was highest in February (0.9) followed by March (0.75), then January (0.74) while the least value was observed in December. Wet season follow a similar pattern with May having 0.45, June (0.71), July (0.9) and August

(0.75). The Kc month^{-1}rose steadily from the first months of planting (December and May), attained maximum values at the third months (February and July) and declined.

The mean crop Evapotranspiration (ET Crop) due to seasons was as shown in Table 5. Monthly Crop Evapotranspiration for dry season was highest in February (156.64mm) followed by March (132.18mm), then January (119.55mm) while the least value was observed in December (73.8mm). Wet season follow a similar pattern with May having 78.29mm, June (125,25mm), July (156.12) and August (124.16mm). The mean ET crops due to seasonality were 482.17 and 483.8mm for dry and wet seasons respectively. Irrespective of season monthly ET crop followed the same trend.

Table 6 is on effective rainfall and irrigation water requirements of cucumber in the dry season due to climatic period. Irrigation water requirements were zero in the wet season but 369.36 and 391.54mm respectively in the dry season for 10 years and 5 years average climatic periods. It is evident from the table that the irrigation water requirement of cucumber in dry season ranged from 70.6-73.5 mm for initial stage (December) followed 100.8-101.34mm for crop development stage (January) then 122.27-122.10mm for mid-season stage (February) while at late season stage cucumber will require between 76.29-94.60mm of irrigation water.

4. Discussion

Crop growth lasted longest in each of February and July which fell within the mid-season stage. This stage is characterized by maximum vegetative cover, optimum photosyhtetic activity and the translocation of photosyhnthesis into the sink (Dupriez and Leener 1992). All these metabolic processes requires a lot of water. At the mid-season stage transpiration losses of water is therefore expected to be at its peak. This explained the highest Kc month $^{-1}$ recorded in February and July. The established seasonal ET crop 484.17 and 482.8mm for dry and wet season are similar to the one reported by chukwu (1995) and a range of 400-675mm (Dupriez and Leener 1992). Effective rainfall was higher than ET crop from May through August but less than ET crop from December through February. This explained none requirement of irrigation in the wet season while supplementary irrigation is necessary in dry season.

5. Conclusion

The ET crop of cucumber did not vary widely in the dry and wet seasons irrespective of climatic periods in southwestern Nigeria. It varies from 484mm in the dry season to 482mm in the wet season. Applying 370mm of irrigation water seasonally is recommended for dry season cropping. Under rain-fed cropping, supplementary irrigation is not necessary.

References

Allen, R.G. 1993. New approaches to estimating crop evapotranspiration. Acta Horticulturae, The Hague, n.335, p.287-293.

Allen, R.G., Smith, M., Pereira, L.S. and Pruitt, W.O. 1996. Proposed revision to the FAO procedure for estimating crop water requirements, Proc. Of the 2nd int. Symp. On Irrigation of horticultural crops, K.S. Hartzoulakis *(ed)*, Vol. 1, p 17-33.

Allen, R.G.; Pereira, L.S.; Raes, D.; Smith, M. 1998. Crop evapotranspiration: guidelines for computing crop water requirements. Rome: FAO. 300p. Irrigation and Drainage Paper, 56.

Aiyelaagbe,I.O.O,Adegbite,I.A and Adedokun,T.A. 2007. Response of cucumber to composted city refuse in southwestern Nigeria. In Proc. 8th African Crop Science Conference 27-31 October 2007, Minia University, El-Minia, Egypt. Part1. Pp 333-337.

Blaney H.F and W.D. Criddle. 1950. Determining water requirements in irrigated area from climatological and irrigation data. Division of Irrigation and water Conservation, Soil Conservation Service, USDA SCS-TP-96 Washington DC.

Brouwer,C. and M. Heibloem. 1986. Irrigation water needs. Irrigation Water Management Training Manual No. 3 FAO, Rome, Italy, p. 50.

Chukwu, G.O. 1995. Crop irrigation water needs of sweet potato (*Ipomoea batatas*). African Journal of Root and Tuber Crops 1(1): 35-38.

Fasinmirin JT, Olufayo AA (2009). Yield and water use efficiency of jute mallow *Corchorus olitorius* under varying soil water management strategies. J. Med. Plants Res., 3(4): 186-191.

Odekunle TO, Eludoyin AO (2008). Sea surface temperature patterns in the Gulf of Guinea: their implications for the spatio-temporal variability of precipitation in West Africa. International Journal of Climatolology DOI: 101002/joc1656

Phu NT (1998). Nitrogen and potassium effect on cucumber yield. ARC/AVRDC Training Bangkok, Thailand, pp. 1-4.

Tatlioglu T (1993). Cucumber (*Cucumis sativus* L.). In Genetic improvement of vegetable crops (G.Kallo and B.O.Bergh eds.) Pergamon Press, Ltd; Tarrytown New York, pp. 197-227.

U.S.D.A., Soil conservation service, 1970. Irrigation water requirements. Tech. Release No 21,92-94.

Weiss E.B. 1992. In fairness to future generations. Environment 32 (3); 9.

Table 1 Mean monthly climatic data for a 10 year period (2000-2010)

Month of the year	Total Rainfall	Max air Temp (°C)	Min air Temp (°C)	Relative humidity (%)	No of rain days	Soil temp (0-5cm)	W/speed (km/day)
Jan	19.35	34.4	20.9	76	2	28.1	48.3
Feb	36.50	35.9	22.7	78	2	29.6	64.5
Mar	62.05	35.8	24	83	6	31.1	65.4
Apr	145.92	33.7	23.5	84	8	30.3	64.8
May	179.74	32.4	22.9	84	11	29.6	56.9
June	225.30	30.8	22.6	86	16	28.1	55.7
July	190.87	29.5	22.5	89	17	27.1	59.9
Aug	136.62	28.7	22.2	89	16	26.4	63.7
Sept	263.16	30.2	22.2	89	19	27.3	53.9
Oct	187.67	31.6	22.8	87	14	28.0	43.8
Nov	32.75	33.4	22.8	85	3	28.7	39.5
Dec	3.19	34.8	21.8	82	1	28.6	43.5

Table 2: Crop Stages of Development

Stage	**Indicators**
Initial	This is the period from sowing or transplanting until the crop covers about 10% of the ground.
Crop development	This period starts at the end of the initial stage and lasts until the full ground cover has been reached (ground cover 70-80%); it does not necessarily mean that the crop is at its maximum height.
Mid season	This period starts at the end of the crop development stage and lasts until maturity; it includes flowering and grain-setting.
Late Season	This period starts at the end of the mid season stage and lasts until the last day of

		the harvest; it includes ripening.

Table 3: Planting date and growth stages of cucumber in each season

Crop stage	Dry season	Wet season
Planting date	1 December	1 May
Initial stage, 20 days	1Dec -20 Dec	1 May -20 May
Crop development, 35 days	21 Dec-24 Jan.	21 May-24 June
Mid season, 40 days	25 Jan-5 March	25 June-5 August
Late season, 25 days	6 -30 March	6 -30 August
Last day of harvest	30 March	30 August

All months are assumed to be 30days

Table 4: Monthly crop coefficients of cucumber as affected by seasonality

Months	Dry season Kc values	Months	Wet season Kc values
December	0.45	May	0.45
January	0.74	June	0.71
February	0.9	July	0.9
Marc h	0.75	August	0.75

Table 5: Mean crop Evapotranspiration (ET_{crop}) of cucumber determined from 10-years (2000-2010) climatic data.

Months	Dry season ET_{crop} (mm)	Months	Wet season ET_{crop} (mm)
December	73.8	May	78.29
January	119.55	June	125.23
February	156.64	July	156.12
March	132.18	August	124.16
Seasonal ET_{crop}	484.17		482.8

Table 6: Effective rainfall (Pe) and Irrigation Water Requirements (IWR) of cucumber in the dry season due to climatic periods

	Climatic Periods			
	10 years Average		5 years Average	
Months	Pe	IWR	Pe	IWR
	(mm)		(mm)	
December	3.17	70.6	0.8	73.5
January	18.76	100.8	18.08	101.34
February	34.36	122.27	33.47	122.10
March	55.88	76.29	38.08	94.60
Total	112.17	369.36	90.04	391.54

MITIGATING THE EFFECT OF CLIMATE CHANGE ON SOME HYDROLOGICAL PROPERTIES OF OGUN AND OSHUN RIVER BASIN USING REMOTE SENSING AND GIS.

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Key Word: ***Climate Change, GIS, Remote Sensing, Ogun and Oshun River Basin, hydrological properties.***

ABSTRACT
Concern for climate change has been gaining greater attention in the political agenda for most countries and all authorities concerned. Climate change is beginning to transform life on earth. Without action, the impacts of climate change treaten to catastophically damage our world. Reducing the effect on the earth atmosphere and biosphere (humans and animals) has become so pertinent. This mitigation effect is also necessary as it affects river basins which are the closest hydrological unit to man. Ogun and Oshun River basins are the case study, being part of the river basins that affect us in the south western part of the country. Determining the effect of climate change on both Ogun and Oshun river basins, datas on some hydrological properties were used to decipher the effect of climate change and to profer probable solutions in mitigating these effects.

1. Introduction
The world is being faced with the biggest environmental challenge our generation has ever seen. Everthing we really care about is affected by cimate change. Without action, the impacts of climate change treaten to catastophically damage our world www.wwf.org.uk. Reducing the effect on the earth atmosphere and biosphere (humans and animals) has become so pertinent. The Ogun and Oshun river basins are vulnerable to climate change due to its geographic location at the southern edge of western Nigeria. Years to come, waterbodies would face considerable uncertainties on future demand and availability of water.

This study was carried out to mitigate the effect of climate change on some hydrological properties of Ogun and Oshun River Basins using Remote Sensing and GIS.

Since climate is the average weather usually calculated over a period of time, landsat imageries of a period of 30 years would be used in determining the effect of climate change on both basins. Hydrological properties of Ogun and Oshun River Basins were computed by carrying out the land use land cover analysis of a the basins from 1986 to 2014 and the morphometric analysis of the basins on some parameters such as stream order, total stream length, drainage density, stream frequency, drainage texture, elongation ratio, circularity ratio.

Temperature, relative humidity, precipitation, biomass and vegetation patterns may be discerned using remote sensing and GIS and provide evidence of how ecosystems change to adapt to climate change. All these parameters gave an insight into the rate at which climate change is affecting the basins and the residual effect in future.

2. Objectives

The main objective of the research is to apply remote sensing and GIS data to mitigate the effects of climate change on the Ogun and Oshun river basins

The other objectives are to

1. Build a base data of the distribution of features in the basins using Landsat data which will involve analysing the Land Use Land Cover Classes within the basin
2. Examine the trend of these features over the study period – change detection analysis.

These objectives would be assessed to determine how climatic factors especially rainfall, precipitation, sunshine hours, relative humidity etc. have one way or the other contributed to the results gotten so as to give probable solutions for its mitigation.

3. The Study Area

The study area is the Ogun and Oshun Basin. Both basins are under the Authority of Ogun Oshun River Basin Development authority among three others which are the Yewa, Ona and Sasa basins. Both basins cut across four states which are Lagos, Ogun, Oshun and Oyo States (Fig. 1 and 2).

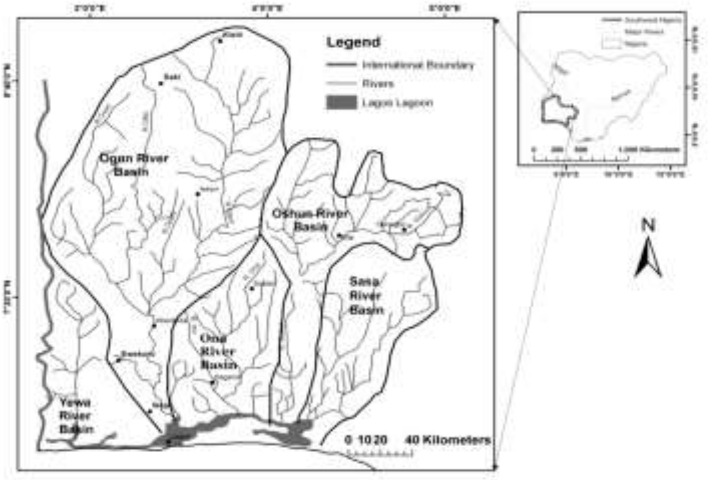

Figure 1: Ogun and Osun River Basins and the Adjacent Basins (Adapted from Oke et al, 2015).

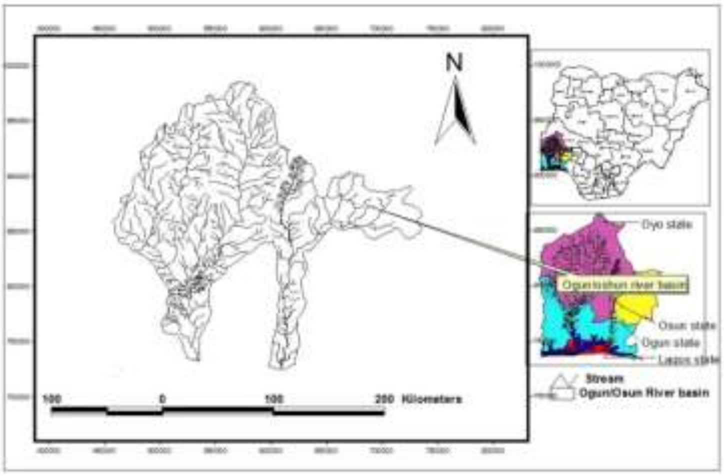

Figure 2: The study Area. – Ogun and Oshun Basins.

4. Materials and Methods

Landsat satellite imageries of three decades were used in the Analysis using Arc View GIS Software. The Years compared were: 1986, 2000 and 2014. The three set of imageries downloaded were classified into Land Use and Land Cover Classes (LULC). The classes used in the classification were **Built Up / Open Land, Vegetation, Waterbodies / Reservoir.** The trends of occurrence in the basins as per the LULC classes were considered in terms of climate change to determine its effect on the basins so as to create probable mitigating measures.

5. Result and Discussion

Analysis of Land Use Land Cover was done for three classes which are built up/open land, vegetation and waterbodies/reservoir. The analysis showed that built up kept increasing throughout the study period while vegetation is on the decrease. Water bodies also increased. The increase of the waterbody is small so it appears insignificant.

Built up and Open Land increased at the expense of vegetation and waterbodies. Urbanization and increase in population probably made it so. Encroachment into the waterbodies in the study area is also visible. This may have been to accommodate the increasing population and urbanization which is in agreement to similar work done by Oyinloye and Kufoniyi for the Land Use Land Cover and Urban Expansion in Akure (2011).

It is also important to note that the rate of change of the waterbody between 1986 – 2000 and between 2000 to 2014 is very small. However, the rate of change between 1986 – 2000 is more than that of 2000 – 2014. This can be explained that the reservoirs built that really caused a change in the waterbody was built in the first 14 years of the research. There is no significant change in the last 14 years of the research work.

There is however an increase in the rate of change from 2000 – 2014 to the change between 1986 – 2014 in the built up/open lands within the study area. This showed that up till present more built up/open lands are evolving.

Vegetative lands are increasing in the negative direction – a decrease. Not much forest areas or farmlands were converted to other purposes between 1986 to 2000 but the figure increased between 2000 and 2014 which showed that a lot of vegetative land are being lost to civilization – urbanization and industrialization.

Table 1 shows the result of the classification of the land use land cover classes. Figure 3 to Figure 5 shows the classified classification of 1986, 2000 and 2014 imageries. The imageries shows the concentration of Built Up/Open Land, Vegetation, and waterbodies.

Relating the result to climate change, the more the lands that are exposed and open up, the more heat islands that we have. Industries and urbanization emits gas emissions which are highly sensitive to greenhouse emissions. De-greening of the earth surface which also relates to loss of vegetation also opens up the land for precipitation. Increase in precipitation increases the water loss over the surface of the earth. Increase in industrialization increases the green house emmissions ehich have increased the green house effect and caused earth's surface temperature to increase.

Reduction in vegetation also affect the plant canopy as rays of the sun get directly on the earth surfce. This also increases the rate of precipitation which in turn reduces the water available on the earth surface.

When large areas of forests are razed for commercial reasons or dried up by climate change – warming climate, it is disastrous for the local species and communites that rely on them. Dying trees emit their source of carbon di oxide, adding to atmospheric green house gases and setting us on a course for runaway global warming www.wwf.org.uk.

As waterbody increases maginally, it represents the water that comes back in the water cycle as rain and as fog. Percolation is high due to the shape and the morphometry of both bains which have permeable bedrock. This helps to retain water within the basins. Climate change is having serious impacts on the world's water systems through more flooding and drought. Warmer air can hold a higher water content, which makes rainfall patterns more extreme. This imaginal increase showed that waterbody within the two basins are already under excessive pressure from drainage, dredging, damming, pollution, extraction, silting and invasivespecies.

To mitigate the effect of the climate change on both basins, tree felling should be discouraged except where necessary. More dams should aslo be constructed so to indirectly control loss of water through the surface.

6. CONCLUSION

Conclusively, the LULC analysis showed a rapid growth increase in the Built up/Open land between 1986 and 2014 (49.72% to 66.14%), Waterbody/Reservoir had a marginal increase from 0.81% to 2.26% within the study years while Vegetation witnessed a reduced from 49.44% to 31.45%. It is concluded that more land were opened up basically for urbanization (industrial and residential) with just a very few reservoirs built while forests and farming reduced. (Adeniyi, 1985, Igbokwe, 1997, Mashi et. al., 2004 and Ufoegbune, 2004).

The result above will encourage and give rise to more effects of climate change on both basins. There will be increase in Urban heat causing it to become an Urban heat Island. Land and sea breeze is also altered especially the land breeze which causes land to cool because. Plant canopy is also reduced as deforestation increases in a bid to open up more lands. This makes percolation increase and also terminates the existence of plants and animals that survive under such canopies.

Extremes of drought and flooding will become more common causing displacement and conflict of our water bodies if a continual decrease or maginal increase is recorded.

To therefore mitigate the effects of climate change on Ogun and Oshun basins, it is adviced that lands should still be set aside for tree planting and agriculture purpose.

There has to be an agreement with relevant authorities on the land that would be opened up either for buildings, industrialization and urbanization and the lands that would be left for vegetative cover be it forest zones or farmlands. This is necessary so that all lands would be properly allocated for different purposes.

Government should encourage tree planting at all levels and reduce tree felling so as to combat the Green House Effect. Government should take into cognizance of Land use and Land cover to ascertain changes that are taking place so as to prevent more urbanization at the expense of human health.

The greener our environment, the lesser the effect of climate change on our river basins.

TABLE 3: THE LULC ANALYSIS OF OGUN AND OSHUN BASIN

Land Use Land Cover Categories	**1986 (ha)**	**2000 (ha)**	**2014 (ha)**
Waterbody/Reservoir (Dams)	24,310.200	56,409.500	67,825.700
Built Up/ Open Land	1491740.687	1709813.557	1984733.077
Vegetation	1483623.000	1234478.000	943751.000
Cloud Cover	1027.170	0.000	4391.280
TOTAL LAND AREA	**3000701.057**	**3000701.057**	**3000701.057**

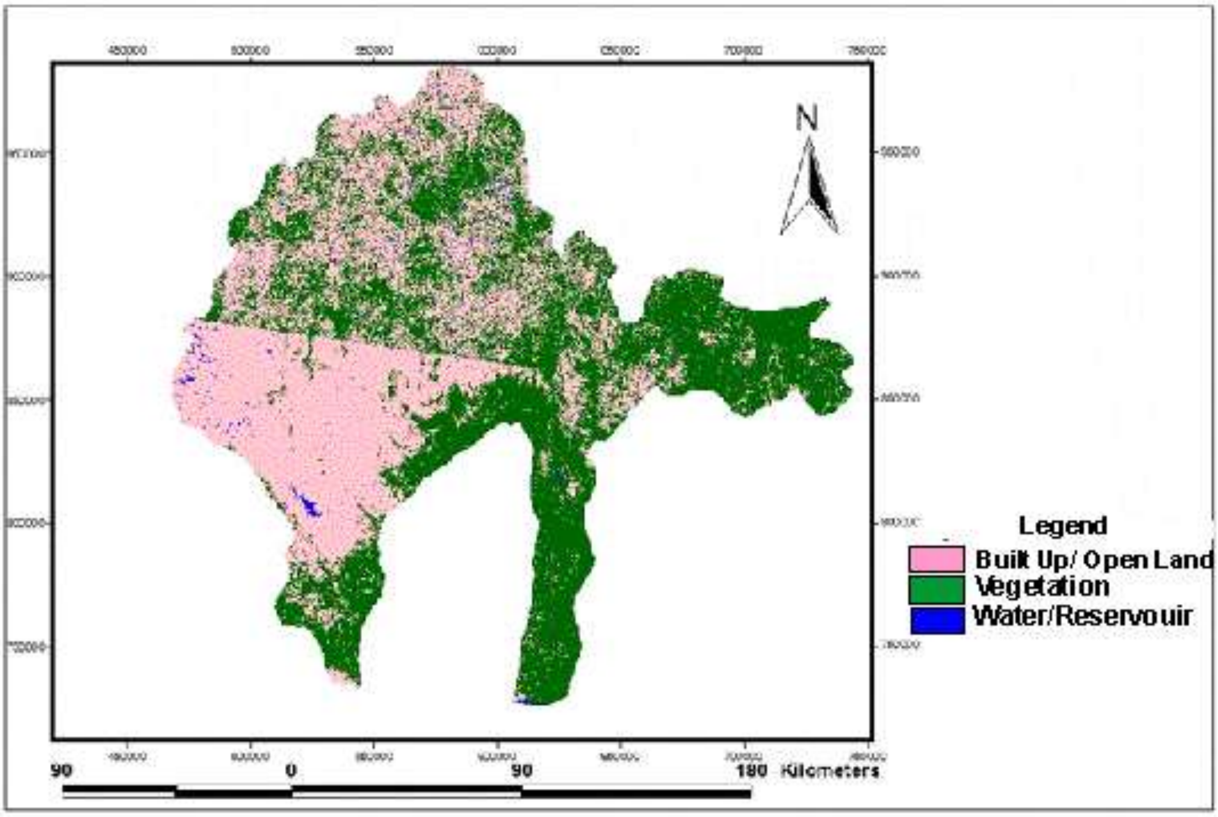

FIGURE 3: SUPERVISED CLASSIFICATION 1986 IMAGE

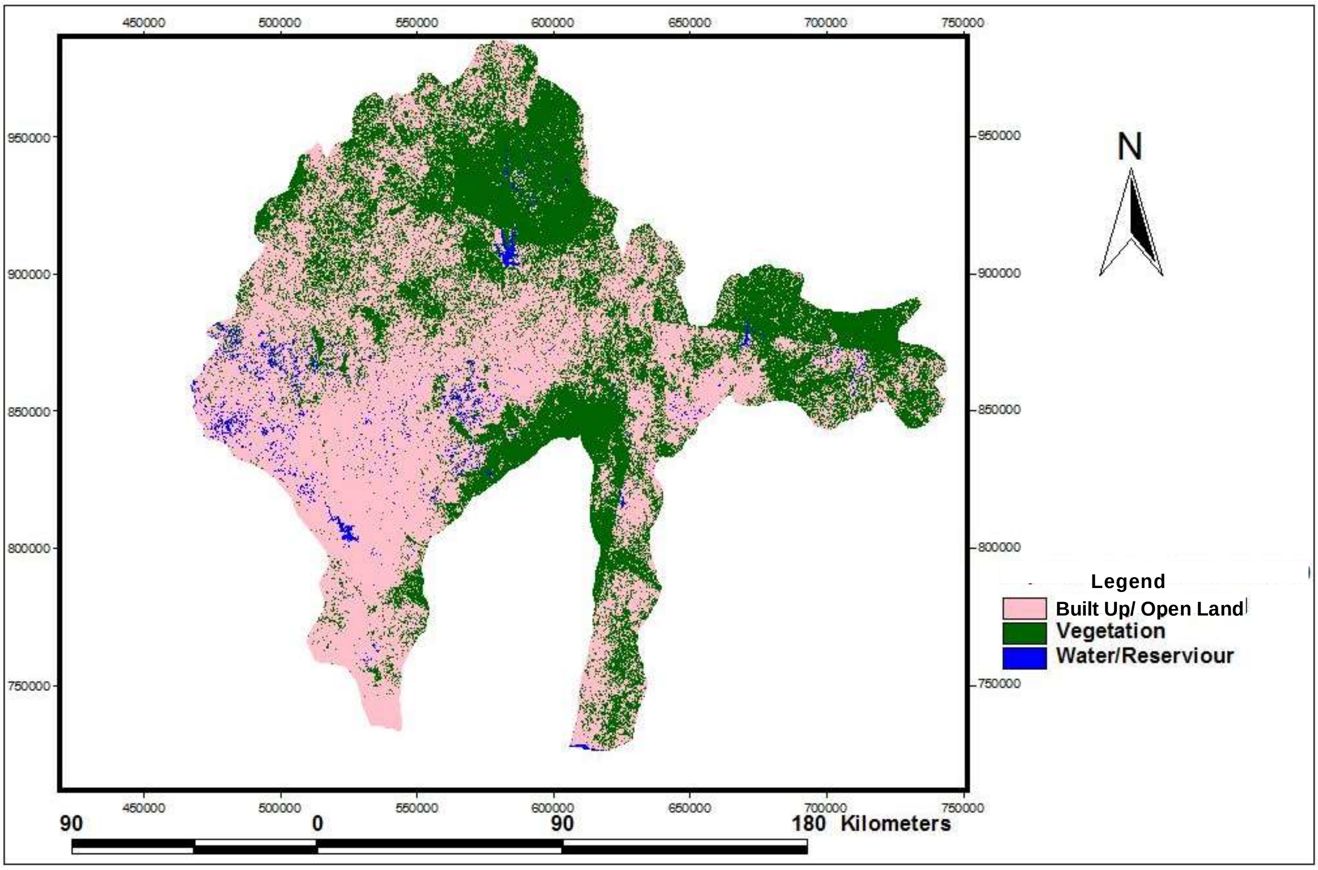

FIGURE 4: SUPERVISED CLASSIFICATION 2000 IMAGE

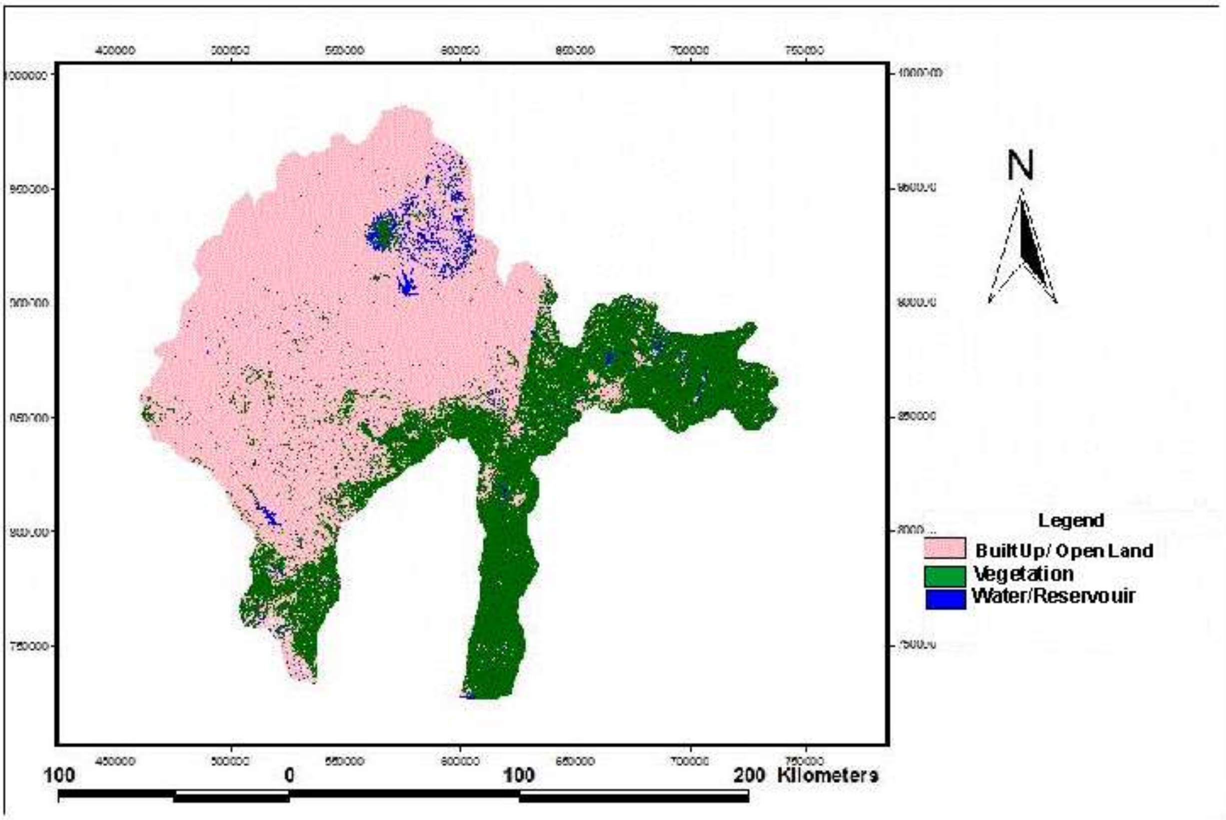

FIGURE 5: SUPERVISED CLASSIFICATION 2014 IMAGE

Refrence

- Adeniyi, P. O. 1985. Agricultural Land Use Inventory and Mapping in Nigeria. In Eden and Parry (Eds.). Application of Remote Sensing to Tropical Land Management. John Wiley and Sons Limited.
- Clarke, J.I. 1966. Morphometry Essays on Geomorphology. Elsevier Publ. Co. New York. Pp.235-274.
- Chopra, R., Dhiman, R. D., Sharma P. K . 2005. Morphometric analysis of subwatersheds in Gurudaspur district, Punjab using Remote sensing and GIS techniques,
- University, Department of Geology, ONR, New York.
- Milton L.E. 1966. The geomorphic irrelevance of some drainage network laws. Australian Geographical Studies.4:89-95.
- Nag, S.K. 1998. "Morphometric analysis using remote sensing techniques in the Chaka sub basin Purulia district, West Bengal", Jour. Indian Soc. Remote Sensing,26,pp 6976.
- Oyinloye M.A. and Kufoniyi O. 2011. Analysis of Land Use, Land cover, and Urban Expansion in Akure, Nigeria.

Journal of Indian Society of Remote Sensing, 33(4), pp 531–539.

- Igbokwe, J.I. 1997. Mapping of Landcover/Landuse changes using Satellite Remote Sensing; Environmental Review. 1:1.
- Jensen, J.R.. 2006. Remote Sensing of the Environment, Dorling Kindersley (India) Pvt. Ltd., New Delhi, 1st edition,.
- Miller, V.C. 1953. A Quantitative geomorphic study of drainage basin characteristics in the Clinch Mountain area, Virginia and Tennessee, Proj, NR 389-402, Tech rep 3. Columbia

Journal of Innovative Research in Engineering and Sciences 2(4), (234 – 248) , June 2011. ISSN 2141-8225. Global Research Publishing.

- Orunoye E.D, Ezekiel B.B, Atiku H.G, Baba E, and Musa N.I. 2016. Drainage Basin Morphometric Parameters of River Lamurde. Implication for Hydrologic and Geomorphic process. Journal of Agriculture and Ecology Research Int.
- Ufoegbune, G.C. 2004. Land use classification of Northern Chanchaga using Aerial Photography; EBAN,

12th Annual Conference (Proceedings): Pp 18-22.

- www.wwf.org.uk the effects of climate change .

TEMPORAL VARIATION OF THUNDERSTORM RAINFALL IN ILORIN METROPOLIS

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Abstract

Thunderstorm rainfall due to local convection is one of the major forms of rainfall over Nigeria at large. In Ilorin, thunderstorm rainfall contributes immensely to yearly changes in river regime, flooding and erosion due to its high intensity and torrential characteristics. Using a 30-year daily thunderstorm rainfall and rainfall without thunder data of Ilorin (1984–2013), sourced from Nigerian Meteorological Agency Oshodi Lagos and broken into three decadals (1984-1993, 1994-2003, 2004-2013), this paper examined the temporal variations in thunderstorm rainfall on six- hourly basis (0001-0600, 0601-1200, 1201-1800, and 1801-0000), the monthly trend of thunderstorm rainfall six- hourly basis and the trend of thunderstorm rainfall against rainfall without thunder. Descriptive statistics was employed and the results showed that 1801-0000 has the number of years (24 years) with the highest amount of thunderstorm rainfall, followed by 1201-1800 (6) years) while 0001-0600 and 0601-1200 have the lowest amount of thunderstorm rainfall throughout the period. It was also observed that throughout the 30 years, 1801-2100 hours recorded the highest number of months (ten months) with highest amount of rainfall, with the month of September recording the highest thunderstorm rainfall value (1600 mm). Result also showed that throughout the 30 years period, thunderstorm rainfall was higher than rainfall without thunder thus confirming that thunderstorm contributes greatly to total rainfall in Ilorin.

KEY WORDS: Ilorin, Thunderstorm rainfall, 6-hourly rainfall, decadal.

INTRODUCTION

Thunderstorm rainfall due to local convection is one of the three major rainfall types experienced in Nigeria and West Africa at large. The other two types are squall line rainfall and ordinary monsoon rainfall due to large scale convergence (Kamara, 1986; Desbois *et al*., 1988). This classification is based on the synoptic origin of rainfall. Thunderstorms are an elementary unit of larger tropical disturbances and produce a large proportion of the rainfall in most tropical areas. In Nigeria, the percentage contribution of thunderstorms to total wet season rainfall increases significantly from the coastal areas inland, with the coastal, middle belt and northern sections of the country recording 17.8%, 30.4% and 35.8%, respectively (Adelekan, 1998).

Thunderstorms are highly localized and largely stationary weather systems affecting a limited area of about 20–50 km2, depending on the size of the cumulus tower. They are associated with shower clouds in which electrical discharges can be seen as lightning and heard as thunder on the ground, and they represent an advanced stage in the development of convection in moist air. The importance of rainfall generated by thunderstorms lies in the fact that it is largely torrential and of high intensity, and as a result much is lost as runoff which causes flooding.

Studies have revealed that the largest amount (with about 70%) of the annual rainfall of West Africa countries comes from deep convective systems (Adelekan, 1998; Omotosho, 1985). This has been discovered to be largely as a result of the occurrence of thunderstorm systems that contribute mostly to the summer rainfall (Byers and Braham, 1949; Balogun, 1981).

Thunderstorm is one of the major contributors to flooding and soil erosions (Adelekan, 1998), which leads to loss of lives and causing great damages to properties worth millions of dollars in Nigeria (IFRC and NEMA, 2012 reports). Thunderstorm contributes as much as about 60% to the annual rainfall in some places in Nigeria (Obasi, 1974), while according to Omotosho, (1984) about 70% or more of annual rainfall is associated with the moving belt of thunderstorms. Orisakwe (2015) in his work, posit that in Nigeria, the greatest of the three rainfall systems is thunderstorm, producing about 45.7% of the total summer rainfall.

Several works have been carried out on thunderstorm rainfall, perhaps due to the associated phenomena they produce; heavy rainfall, lightning, hail, gusty winds, etc (Changnon, 2001a; Omotosho, 1985; Adelekan, 1998). Others worked on the seasonal distribution of thunderstorm days (Mulero, 1973), the distribution of thunderstorm rainfall (Balogun, 1981) discussed the seasonal and spatial distribution of thunderstorm, while Omotosho (1985) worked on the separate contributions of thunderstorm, squall lines and rainfall to the total rainfall in Nigeria. Ologunorisa (1999) and Dai (2001) use data from over 15000 stations throughout the world to study global precipitation and thunderstorm frequency, while Ologunorisa and Alexander, (2004, 2007) dwelt on the annual thunderstorm trend and fluctuations. However, none of these researchers dwelt on temporal variation of thunderstorm rainfall in hourly basis for a particular station, hence the justification of this study.

In Ilorin the most frequent extreme weather events are flooding and rainstorms. Rainstorm and flood events have generated multiple dimensions of vulnerability on the livelihood of Ilorin residents for long. Data of cases of flood and rainstorm in Ilorin from the Kwara State office of the National Emergency Management Agency (NEMA) between 2002 and 2006 revealed that there were about 22 cases of flood and rainstorm events in Ilorin. During this period about 480 houses were blown off involving about 1061 households. It was also gathered that incident of malaria and diarrheal cases were reported among children during the period. Hence the need to carry out a temporal study of thunderstorm rainfall dynamics which leads to flooding and rainstorm in Ilorin.

MATERIALS AND METHODS

The study Area

Ilorin, the study area (lat 8° 28ˡN, long 4° 38ˡE) is located on the northern part of the Guinea savannah climatic belt of Nigeria. The landscape of Ilorin consists relatively flat and undulating land with intersperse hills and valleys. A large proportion of the land is characterised by ferruginous tropical soils and crystalline acid rocks. Ilorin experiences two seasons, the rainy season and the dry season. The total annual rainfall of Ilorin ranges from 800mm to 1000mm which lasts for 8 months between March and October with a little dry spell in August. The dry season starts from November and lasts till February. The mean monthly temperature of Ilorin is about 28°C. This range places Ilorin within the transitional zone between the climatic and vegetation types of the north and southern Nigeria. The vegetation comprises the guinea savannah, derived savannah and the rain forest, of which the derived savannah is the predominant.

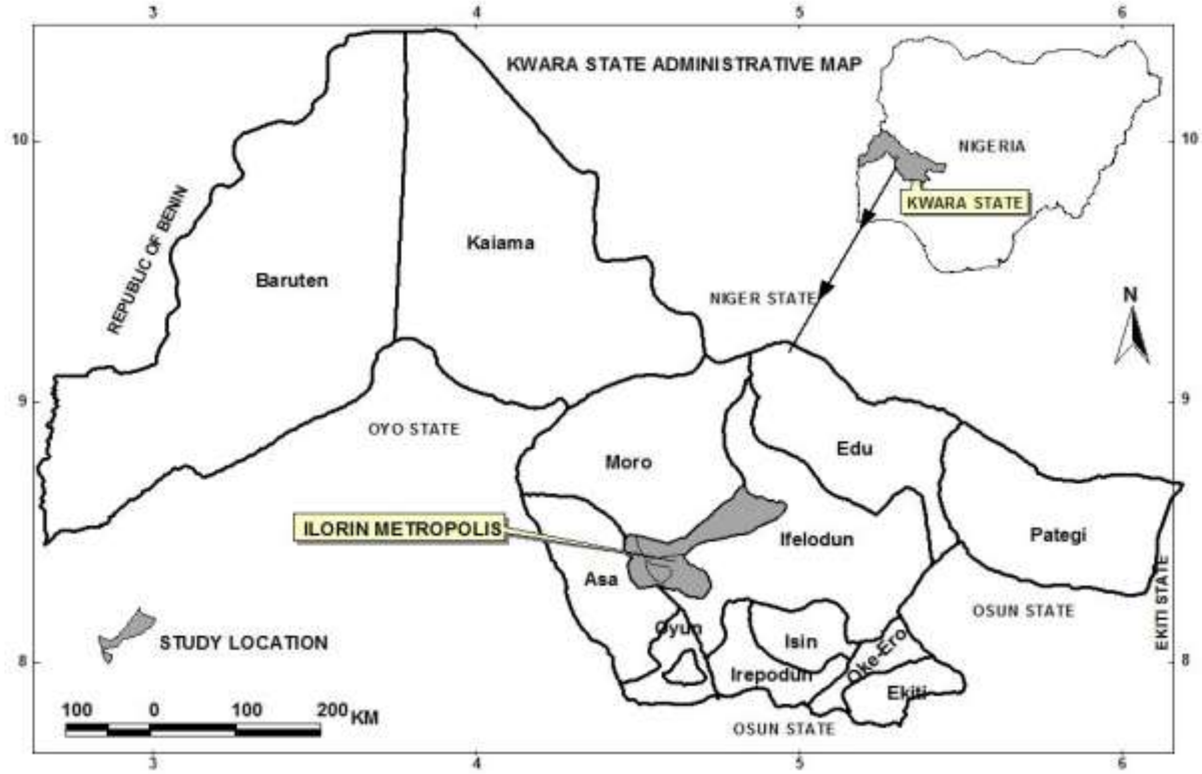

Figure 1: Kwara State showing the study area

Data Collection

Using a 30-year (1984–2013) daily thunderstorm rainfall data of Ilorin broken to three decades(1984-1993, 1994-2003, 3004-2013) and sourced from the Nigerian Meteorological Agency Oshodi Lagos, this paper examined the variations in thunderstorm rainfall on a six-hourly basis: 0001-0600, 0601-1200, 1201-1800 and 1801-0000, for the three decades, the variation of thunderstorm rainfall on monthly bases for the thirty years, trend of thunderstorm rainfall against rainfall without thunderstorm and correlation of thunderstorm rainfall and rainfall without thunder. Descriptive and Inferential statistics were applied in the study. The descriptive statistics was used to determine thunderstorm rainfall on 6-hourly basis for the period of 30 years as well as for each month within the period. It was also employed to determine the difference between thunderstorm rainfall and rainfall without thunder both monthly and yearly for the 30 years period. Inferential statistics was employed to determine the correlation and strength of relationship between thunderstorm rainfall and rainfall without thunderstorm.

RESULT AND DISCUSSION

The trend of thunderstorm rainfall at the first decadal (1984-1993) showed that for about 6 years, (984-1987, 1989 and 1990), the 6 hourly period of 1801-0000 hours recorded the highest thunderstorm rainfall amount, with 1987 recording as high as 568.9 mm. However for the remaining four years (1988, 1991, 1992 and 1993), the 6 hourly period of 0601-1200 hours recorded the highest thunderstorm rainfall amount, with 1991 recording as high as 500.7 mm. The 6 hourly periods of 0001-0600 and 0601-1200 recorded the lowest thunderstorm rainfall amount throughout the 10 years period with 0601-1200 recording as low as 17.2 mm in 1992.

The trend in the second decadal (1994-2003) showed that for about 8 out of the 10 years period (1994-2003), the 6 hourly periods of 1801-0000 hours recorded the highest thunderstorm rainfall amount, in which 1997 recorded the highest thunderstorm rainfall of about 900 mm. The 6 hourly periods of 1201-1800 hours followed by recording the highest thunderstorm rainfall amount for 1994 and 1995 and 1995 recorded 602 mm of thunderstorm rainfall. The 6 hourly periods of 0001-0600 and 0601-1200 recorded the lowest thunderstorm rainfall amount throughout the 10 years period, with 0601-1200 hours recording as low as 8.5 mm in 1994.

At the third decadal (2004-2013), the trend of thunderstorm rainfall showed that the 6 hourly periods of 1801-0000 maintained the dominance by having a record of the highest thunderstorm rainfall amount throughout the 10 years period (2004-2013). Year 2004 recorded the highest thunderstorm rainfall amount of 820.4 mm. 1201-1800 hours followed, with year 2013 recording as high as 450 mm. The 6 hourly periods of 0001-0600 and 0601-1200 recorded the lowest thunderstorm rainfall amount (7.3 mm) was recorded for 0601-1200 hours in 2010.

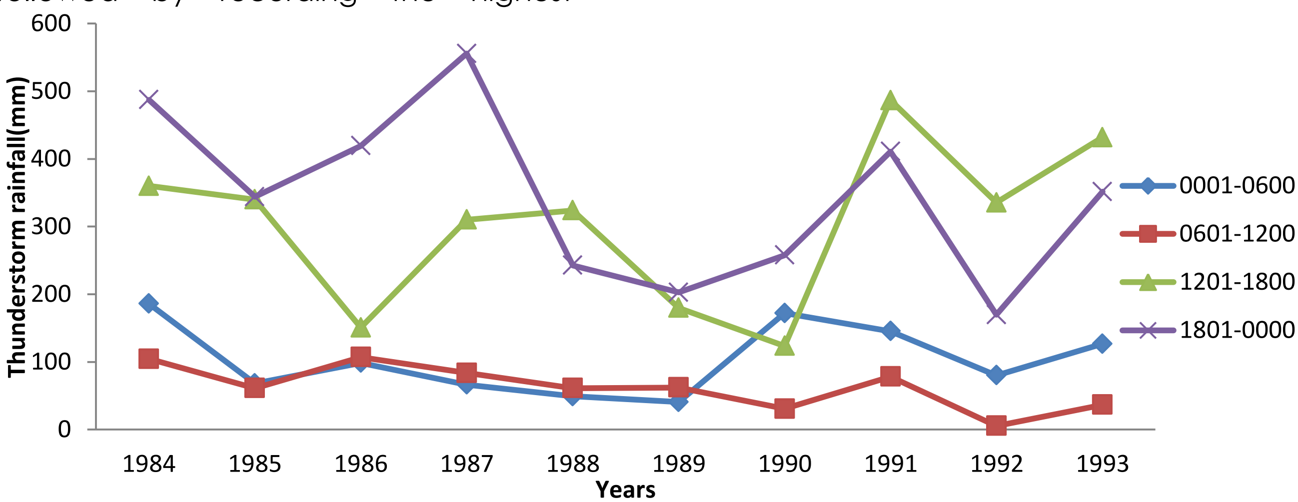

Fig.2 Trend of thunderstorm rainfall on 6-hourly basis at 1st decadal (1984-1993,)

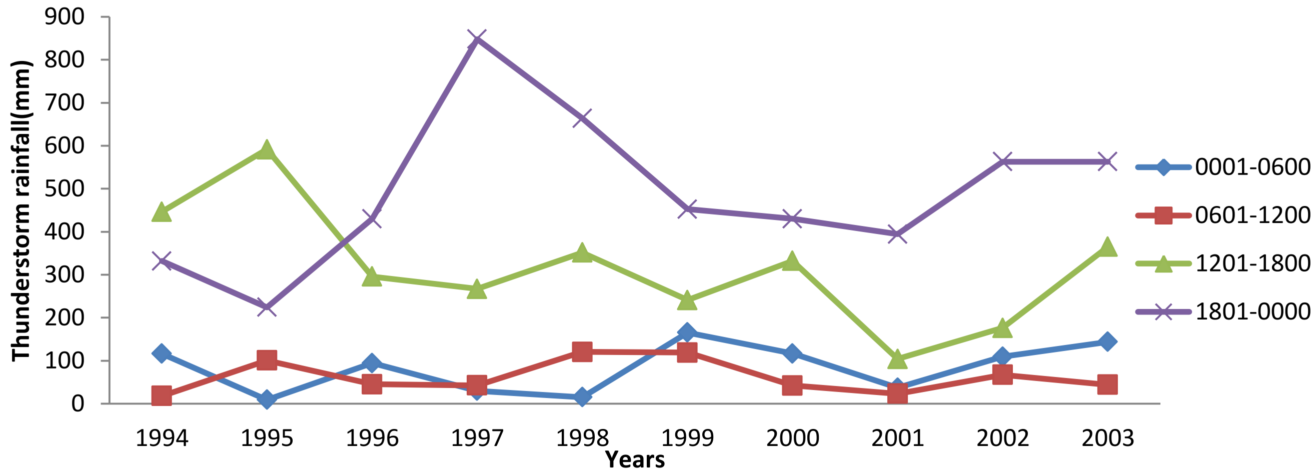

Fig.3 Trend of thunderstorm rainfall on 6-hourly basis at 2nd decadal (1994-2003,)

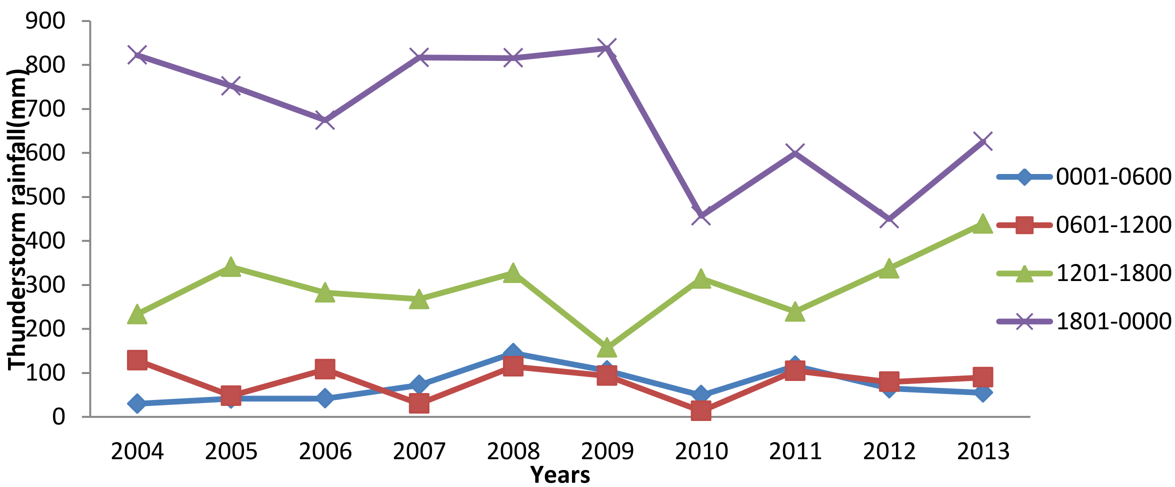

Fig.4 Trend of thunderstorm rainfall on 6-hourly basis at 3nd decadal (2004-2013,)

From figure 5 below, the monthly trend of thunderstorm rainfall on 6-hourly bases for the thirty years period (1984-2013) was determined. It was observed that the period 1801-0000 hours recorded the highest thunderstorm rainfall amount throughout the rainy months (February-October) within the thirty years period. However for the dry months of November to January, the period 1201-1800 hours recorded the highest thunderstorm rainfall amount and the month of January recording about 5.7 mm. The 6 hourly periods of 0001-0600 and 0601-1200 recorded the lowest thunderstorm rainfall amount for all the months was and 0601-1200 recorded as low as 0 mm thunderstorm rainfall amounts for the month of December.

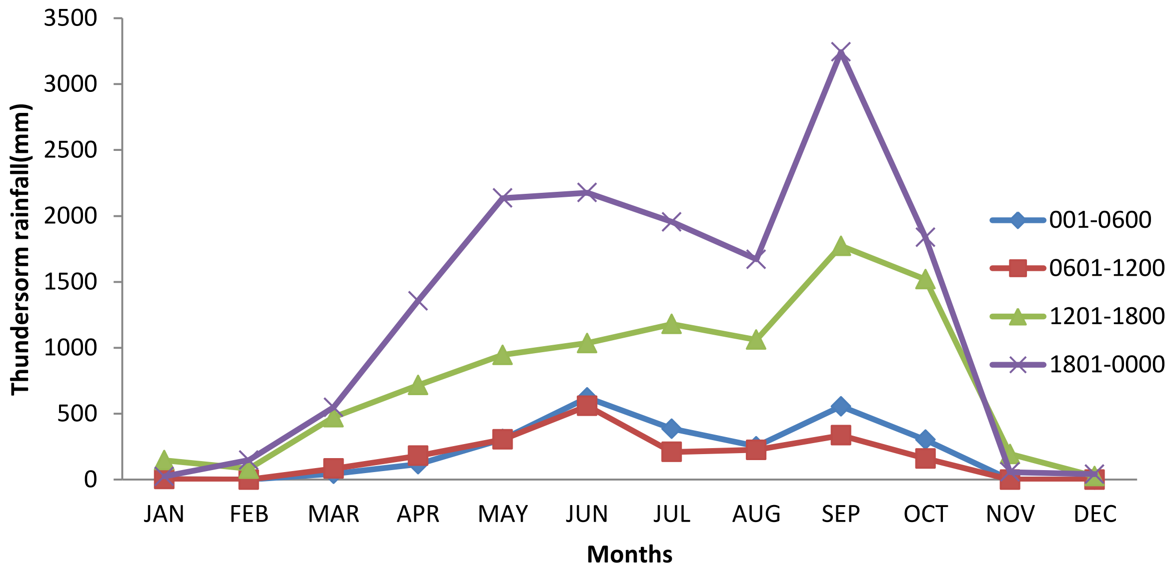

Fig.5 Trend of monthly thunderstorm rainfall on 6-hourly basis (1984-3013)

The figures 6, 7 and 8 below show the trend of thunderstorm rainfall and rainfall without thunder at 1st d 2nd and 3rd decadal (1984-1993, 1994-2003, 3004-2013). At the first decadal in figure 6 (1984-1993), thunderstorm rainfall was higher than rainfall without thunder throughout the period with 1984 recording the highest thunderstorm rainfall of 1150 mm while 1989 recorded the lowest of 520 mm. The highest amount of rainfall without thunder recorded was 600 mm for 1986 while the lowest record of 100 mm recorded for 1984. In figure 7, throughout the 2nd decadal (1994-2003), thunderstorm rainfall was higher than rainfall without thunder. The year 1997 recorded the highest thunderstorm rainfall of 1200 mm, while year 2001 recorded the lowest amount of 500 mm. However rainfall without thunder recorded 570 mm in 1997 as the highest value while year 2002 recorded the lowest value of about 10 mm. At the 3rd decadal in figure 8, (2004-2013), thunderstorm rainfall was also higher than rainfall without thunder throughout the period with year 2008 recording the highest thunderstorm rainfall of 1400 mm while year 2010 recorded the lowest of 800 mm. The highest amount of rainfall without thunder recorded was 100.5 mm for year 2010 while the lowest record of 13.5 mm for 2004.

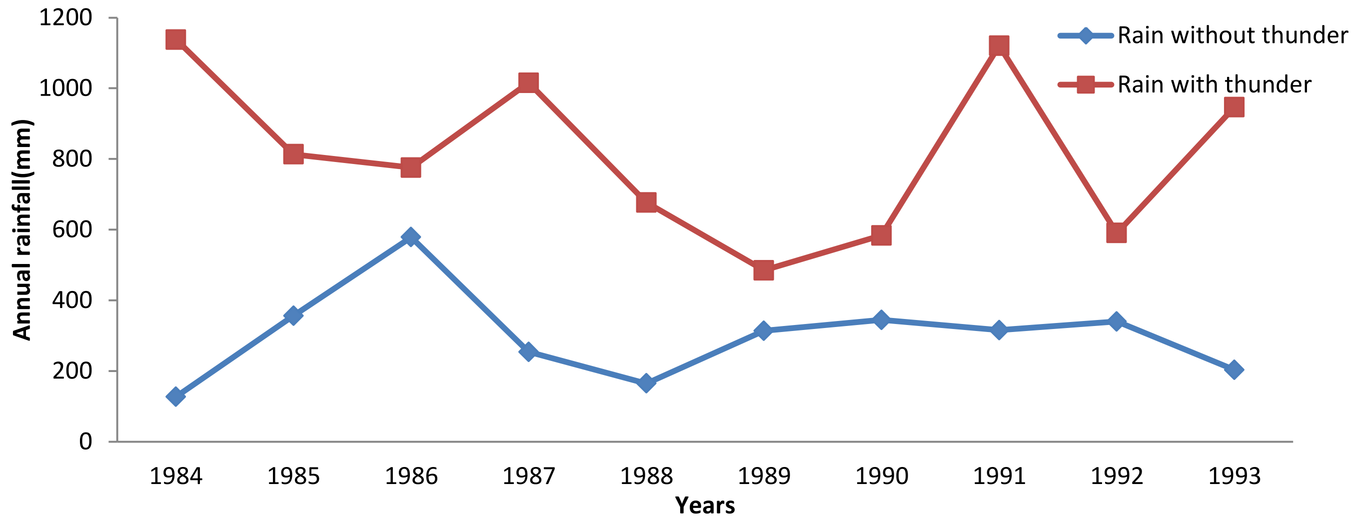

Fig. 6 Trend of thunderstorm rainfall and rainfall without thunder at 1st decadal (1984-1993)

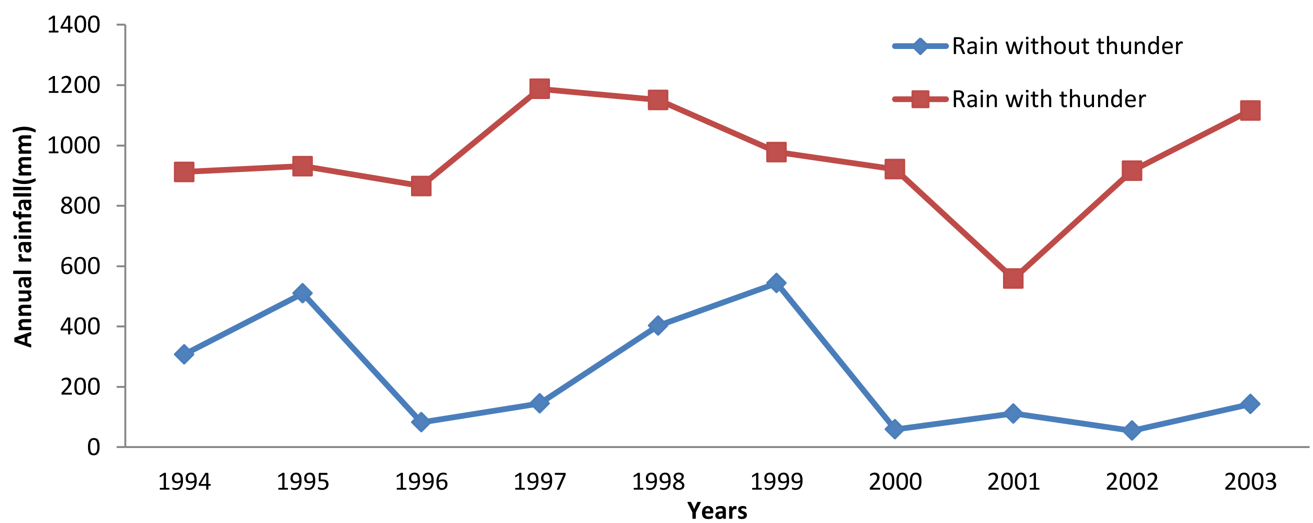

Fig. 7 Trend of thunderstorm rainfall and rainfall without thunder at 2nd decadal (1994-2003)

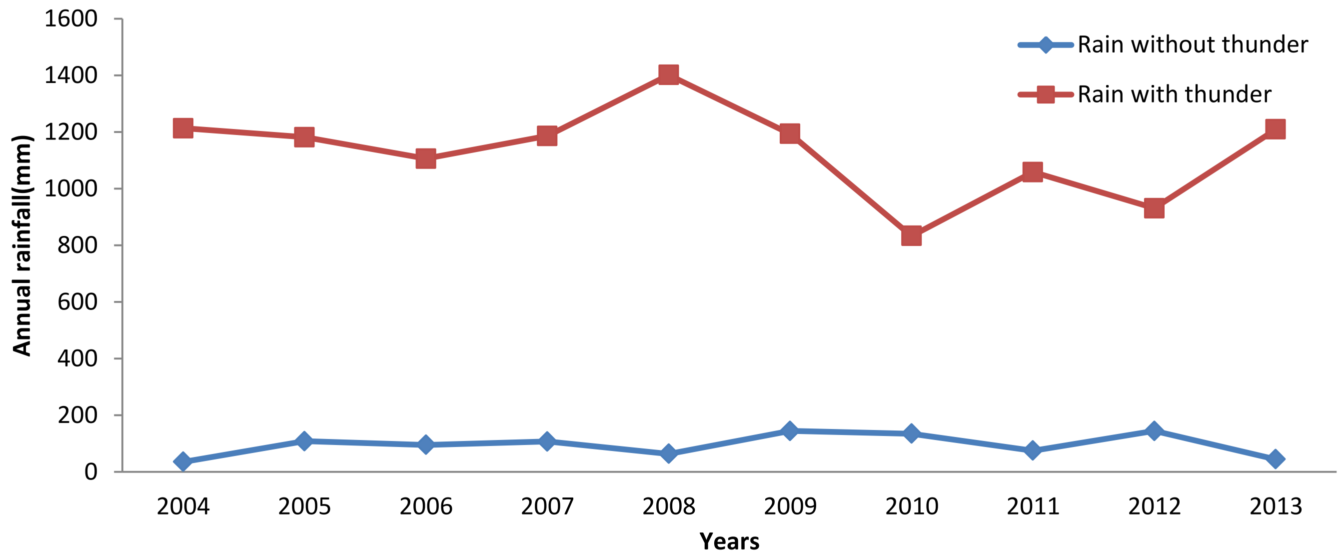

Fig. 8 Trend of thunderstorm rainfall and rainfall without thunder at 3rd decadal (2004-2013)

Conclusion

In this study It was observed that thunderstorm rainfall accounted for most of the rainfall in the city of Ilorin throughout the thirty years of investigation. Because of the position of Ilorin in the north central where sunlight was high, it was also observed that the heaviest thunderstorm rainfall occurred within the 1801-0000 hours, confirming convectional nature of precipitation during the day due to solar insolation as well as nocturnal rainfall during the night period. As thunderstorm rainfall increases, rainfall without thunderstorm also increases but at low rate. Throughout the thirty years thunderstorm rainfall was higher than rainfall without thunderstorm and was also predominant for each month and year within the thirty years period.

Recommendation

Investigation of temporal variation of thunderstorm rainfall in Ilorin will in no small way help us to study the dynamics of the rainfall pattern so as to take measures to reduce its occurrence and to mitigate the damages caused. The most frequent extreme weather events in Ilorin are flooding and rainstorms due to thunderstorm rainfall. Because rainstorm and flood events generate multiple dimensions of vulnerability on the livelihood of Ilorin residents, it is recommended that according to Kyoto protocol of 2012, the government takes necessary steps to keep the rise in global temperature below two degrees celcius. Tree planting should be encouraged to check desertification and erosion. There should be conservation and restoration of natural resources to serve as checks to flood and rainstorms. Use of floodplains for residential and agricultural activities should be disallowed. Recharge basins and reservoir should be constructed to take much of water during storm flow at peak periods of rainy season. Desertification of all forms in the Ilorin which exposes the town to both high temperatures that increases the thermal level of the environment as well as subject the city to erosion and flooding should be discouraged.

REFERENCES

Adelekan I.O, (1998). "Spatio-Temporal Variations in Thunderstorm Rainfall over Nigeria". *Int. J. Climatol*. 18:1273-1284.

Balogun E.E, (1981). "Seasonal and Spatial Variations in Thunderstorms Activity over Nigeria". Weather 36(7):192-197.

Changnon S.A (2001a). Thunderstorm Rainfall in the Contaminous United States", Bull. Am. Metorol. Soc. 82(9):1925-1940.

Changnon S.A (2001b). "Damaging Thunderstorm Activity in the United States". Bull. *Am. Meteorol. Soc. 82:597-608*.

IFRC. (2012). International Federation of Red Cross and Red Crescent (IFRC) disaster relief emergency team report of 2012.

Obasi G.O.P, (1974). Some statistics concerning the disturbances lines of West Africa. Symposium Tropical Meteorology, Part II, Nairobi. pp. 52-66.

Ologunorisa, E.T (1999). "Diurnal and Seasonal Variation of Thunderstorm in Ondo State Nigeria". *Geo. Res. 2(2):47-51*.

Ologunorisa E.T, Alexander, B.C (2004). "Annual Thunderstorm Trends and Fluctuations in Nigeria", *J. Meteorol. UK, 29(286):39–44*.

Ologunorisa E.T, Alexander B.C (2007). "The Diurnal Variation of Thunderstorm Activity over Nigeria". *Int. J. Met. UK, 32(315):19–29.*

Omotosho J.B, (1984). Spatial and seasonal variation of line squalls over West Africa. *Arch. Metereol. Geophs. Bioclimatol. Ser. A33:143*.

Omotosho J.B, (1985). "The Separate Contributions of Line Squalls, Thunderstorms, and the Monsoon to the total Rainfall in Nigeria". *J. Climatol. 5:543-552*.

Orisakwe, I.C, (2015). "Disaggregation and Quantification of Rainfall Associated with the three Rainfall Producing Systems in Nigeria". Unpublished M. Tech Thesis, FUTA, Nigeria. 47pp.

Byers, H.R. 1951. *Thunderstorms*, Compendium of Meteorology, American Meteorological Society Boston, MA, pp. 681–686.

Desbois, M., Kayiranga, T., Gnamien, B., Guessous, S., and Icon, L. 1988. 'Characterization of some elements of the Sahelian climate and their interannual variations for July 1983, 1984 and 1985 from the Analysis of Meteosat ISCCP Data'
J. Climate, **1**(9), 867–904.

Kamara, S.I. 1986. 'The origins and types of rainfall in West Africa', *Weather*, **41**, 48–56.

Mulero, M.A. 1973. 'On seasonal distribution of thunderstorm days in Nigeria', *Quart. Meterol. Mag.* **3**, 73–78.

VULNERABILITY OF AGRICULTURAL PRACTICES TO CLIMATE INDUCED FLOODS IN COMMUNITIES DOWNSTREAM OF KAINJI DAM, NIGERIA

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Abstract

Discharge from Kainji Hydro Electric Power Dam entail large water outflow which cause flooding to adjoining lands downstream of the dam. Rural settlements on the downstream flood plain of the dam are predominantly agrarian that depend on the water resources for their livelihood. Floods have not only threatened basic infrastructure but also destroyed farmlands and disrupt activities. Structured questionnaires and interview methods were utilised to generate data on the existing agricultural practices in the area and their vulnerability to floods. Digital Elevation Model (DEM) of the Study Area at 30meter resolution was utilised to depict the nature of the terrain, buffering analysis was carried out at 30meter, 50meter and 70meter respectively, leading to flood vulnerability mapping indicating highly vulnerable, moderately vulnerable and safe zones. The results indicate that crop, livestock and fish farming are the dominant agricultural practices. Farmers have also lost substantial amount of their products to flood. This is largely to their inadequate adaptive capacity to cope with floods. The DEM result shows elevation of the communities ranging between 81meters to 298meters above mean sea level.

Keywords: Vulnerability, Floods, Agricultural Practices, Downstream, Flood plain, Dam

1. Introduction

Flooding is one of the major environmental crises one has to contend with within the century. This is especially the case in most wetlands of the world. The reason for this is the general rise in sea level globally, due to climate change and global warming as well as the saturated nature of the wetlands in Nigeria. Periodic floods occur on many rivers, forming a surrounding region known as flood plain. Rivers overflow for reasons like excess rainfall. The good thing about river overflows is the fact that as flood waters flow into the banks, sand, silt and debris are deposited into the surrounding land. After the river water has subsided and goes back to its normal flow, the deposited materials will help make the land richer or more fertile. The organic materials and minerals deposited by the river water keep the soil fertile and productive making it suitable for agricultural purposes (Abowei and Sikoki, 2005). In Nigeria, flood has been the major natural disaster experience from the time past till now, claiming lives and properties, inundating houses, rendering inhabitant homeless, causing health implication and socio-economic problem, destroying farm lands and economic crops and causing food insecurity to the people affected. (Ojigi, Abdulkadir and Aderoju,(2013).

Floodplain agriculture typically consists of three cropping systems, each adapt to the rise and fall of floodwaters rather than directly to the short rainy season. First, as floodwaters rise, rice is cultivated. Second, as the water recedes, crops such as sorghum or cowpeas are planted that are able to grow using only the residual moisture in the soil. Third, crops such as tomatoes, onions and peppers are planted under irrigation in the dry season on the banks of rivers and where water lingers in the floodplain. These floodplain cropping systems are integrated economically (and often within one household) with dry land cultivation systems (typically of millet, sorghum and groundnuts) away from the river. They are also integrated in time and space with other economic activities inside and outside the floodplain, such as the seasonal movement of livestock and different kinds of fishing activity (David & William, 1999)

The operation of Hydro Electric Power dams often leads to environmental and ecological problems. When inflows are low energy output from Hydro Electric Power sources is limited. Water may not be released in adequate quantities from the reservoir, a situation that can affect ecological balance of the river below the Hydro Electric Power dam. On the other hand discharge from Hydro Electric Power dams can entail large water outflow which can cause flooding to adjoining lands downstream of the dam. Where the flood plains are regions of economic, social and agricultural activities extensive damages will be incurred in the process. In Nigeria this is particularly so, as the riverbanks are used for farming and are inhabited by farming communities (David and Adebayo, 2010).

Globally, Riverine Communities are naturally susceptible to flooding. In recent times, the devastating effect of flood in Nigeria became so severe that it was seen as a national calamity. Rural settlements on the downstream of Kainji dam are predominately agrarian communities, who depend on the land and water resources for their socio-economic livelihood. Flood events in these communities not only threaten basic infrastructure but also have destroyed farmlands and economic trees (Musa 2016).

Planners and decision makers in the agricultural sector in Niger State requires both current and historic information on these downstream communities to ensure sustainable agricultural production. The study therefore, examined the agricultural practices and he level of destruction, map the communities to determine their vulnerability with a view to create a better understanding to human management of the environment.

2. The Study Area

The Study Area which is the downstream communities of Kainji dam, located in Borgu Local Government Area of Niger State. The selected communities are; Fakun, Awuru Emighi, Awuru, Sabon Leaba, Chegun and Doko located between Longitude $04^{0}35$ 00" – $04^{0}38$ 00" meridian and Latitude: 09^{0} 45 00 – $09^{0}50$ 00".

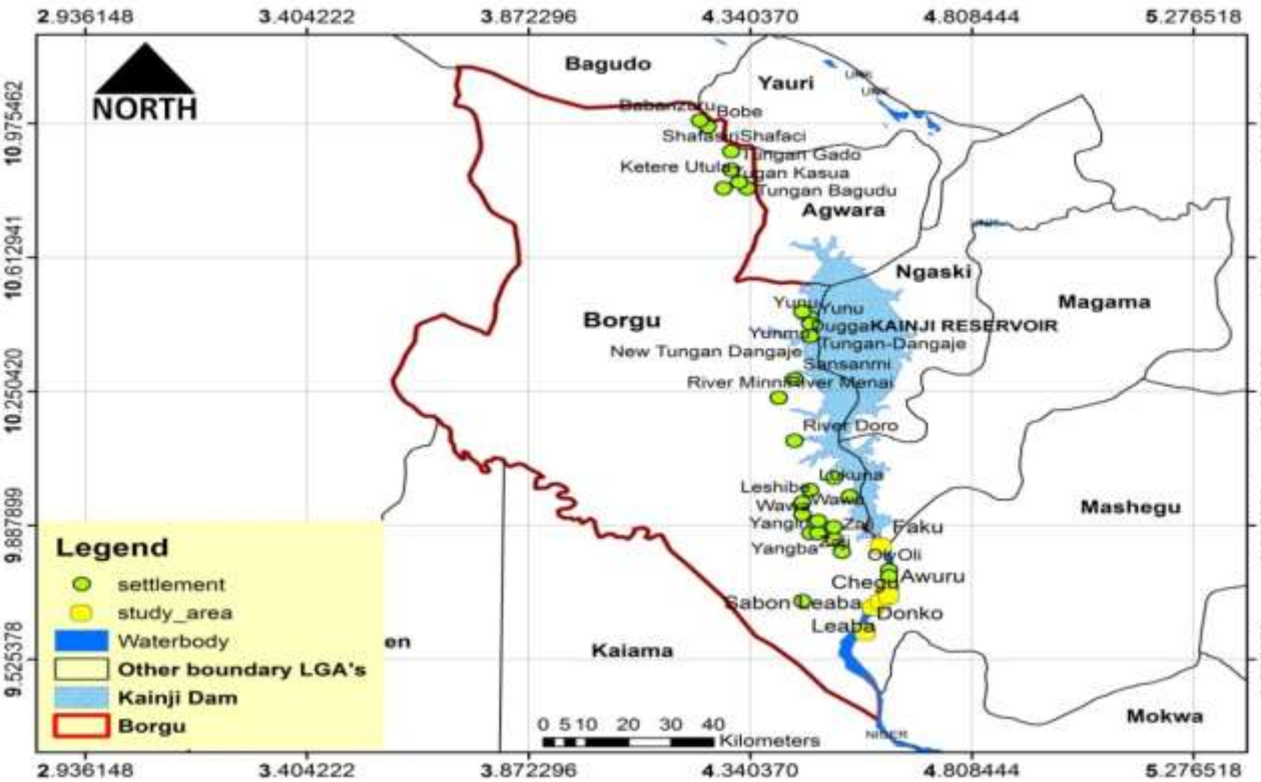

Figure 1: The Study Areas (Downstream Communities of Kainji Dam, Niger State, Nigeria)

Source: Ministry of Land and Housing, Niger State (2015)

3. Materials and Methods

The study utilised structured questionnaire, interview schedule, reconnaissance survey and Global Positioning System (GPS) receiver to obtain ground coordinates points of the different themes (classes). Thematic map of Niger State, Satellite Imageries obtained from Google Earth and Digital Elevation Model (DEM) of the Study area at 30m resolution. The image registration was executed with the ArcGIS 10.1 software from ESRI. The images were registered to the 1984 World Geodetic System Universal Transverse Mercator (WGS '84 UTM) in the Geographic Coordinate System. Although the images were already geo-referenced to the Geographic Coordinate System, they were re-projected to UTM '84 Zone 32 N so as to ensure that they are allocated their correct ground coordinates.

Buffer zones of specific distance were created along the drainage channel to determine the settlement vulnerability to flood. Flood vulnerability map of the area was developed to ascertain the degree of vulnerability of each settlement.

During the field survey, questionnaires were administered to 332 (5%) of the population, selected using purposive sampling, the questionnaires were administered only to people who had lived in the area for at least 10 years and above. Statistical Package for Social Sciences (SPSS) 17.0 and Microsoft excel window 7 versions was used to analyze quantitative data. The results were presented in Tables, Figures and Charts. Maximum likelihood classification and area calculation in hectares was used to analyse the nature of the terrain.

4. Results and Discussion

Figure 1 shows the major agricultural practice in the study area with crop production accounting for 88.0%, Livestock farming 6.3%, Fish farming both Cultured and Captured 5.7%. Farmers integrate crop with livestock and fisheries with a high level of diversification of agricultural production, with about 45% of the population involved in other different vocations apart from farming.

Figure 2 revealed that the most common commodities that farmers are involved in production based on the frequencies of mention are maize, rice, groundnut, horticultural plants and millet. The less common commodities based on the frequencies of occurrence in their mention are yam, tree plants, melon, soya beans and sugarcane.

Figure 3 shows that Goats are widely raised animal in the study area accounting for 76.6%, Sheep 66.5%, Poultry 55%, Cattle 22.0%. Pig, Donkey, and Dog all account for 0.5%, 1.9% and 3.3% respectively.

Figure 4 indicates that 58.5% of the fish farmers practices only captured fisheries, 31.1% are into cultured fisheries while 10.4% practice the two.

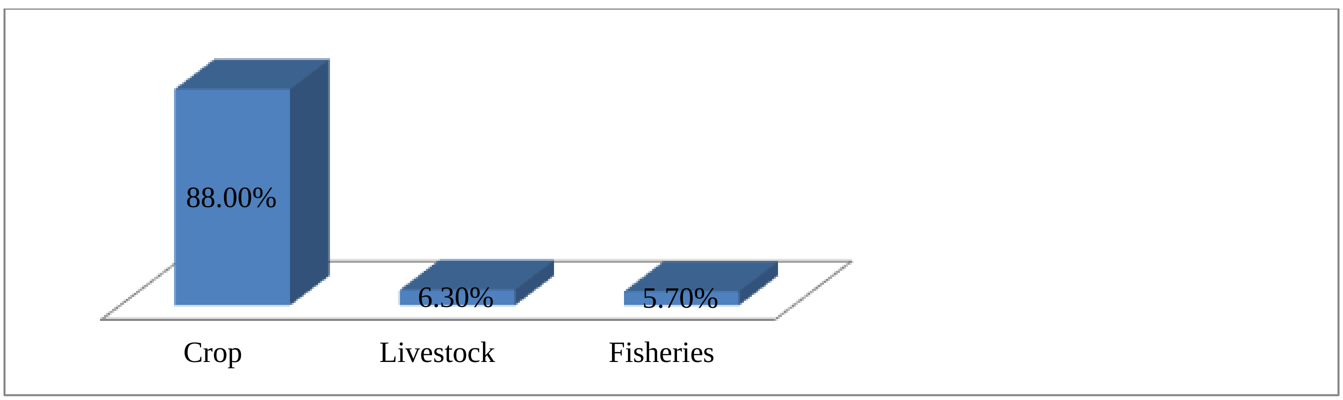

Figure 1: Major Agricultural Practices in the Study Area

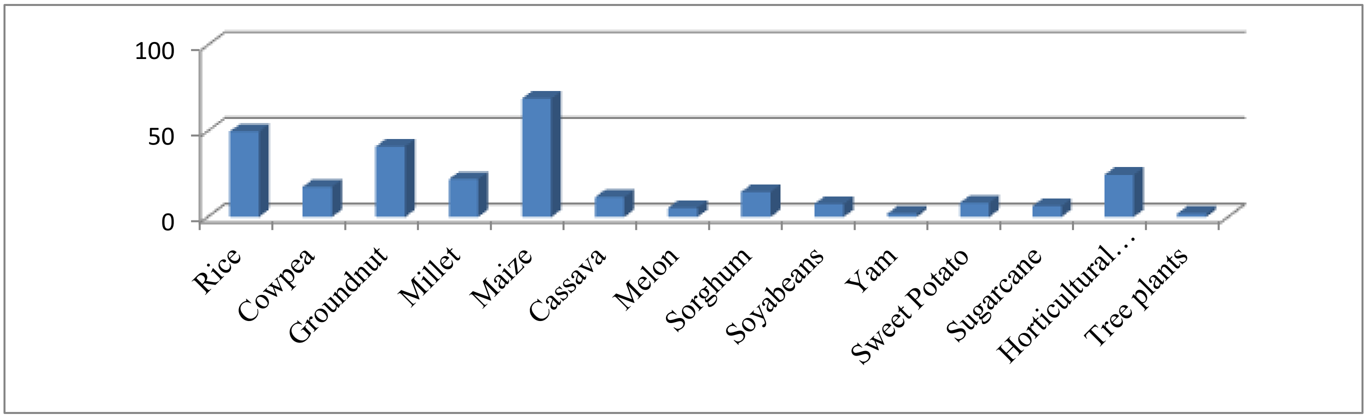

Figure 2: Distribution of Crops Cultivated.

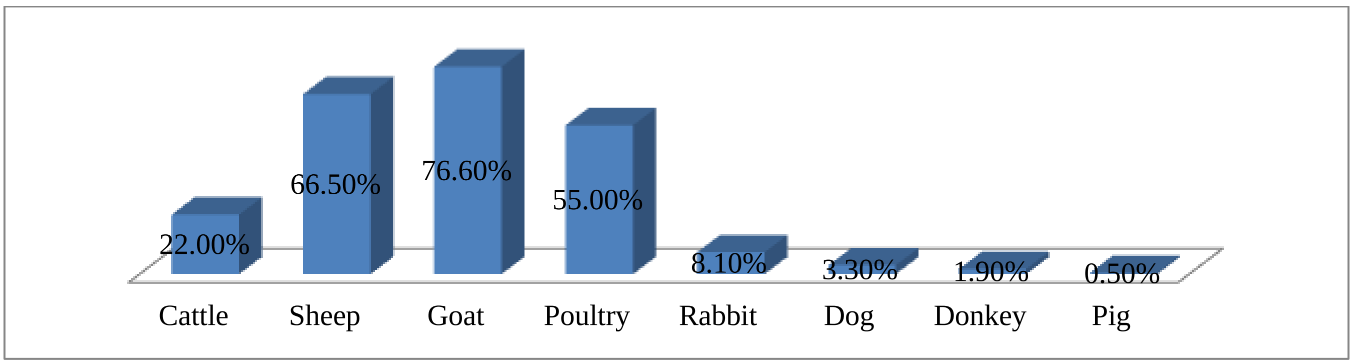

Figure 3: Distribution of Animals owned by Respondents.

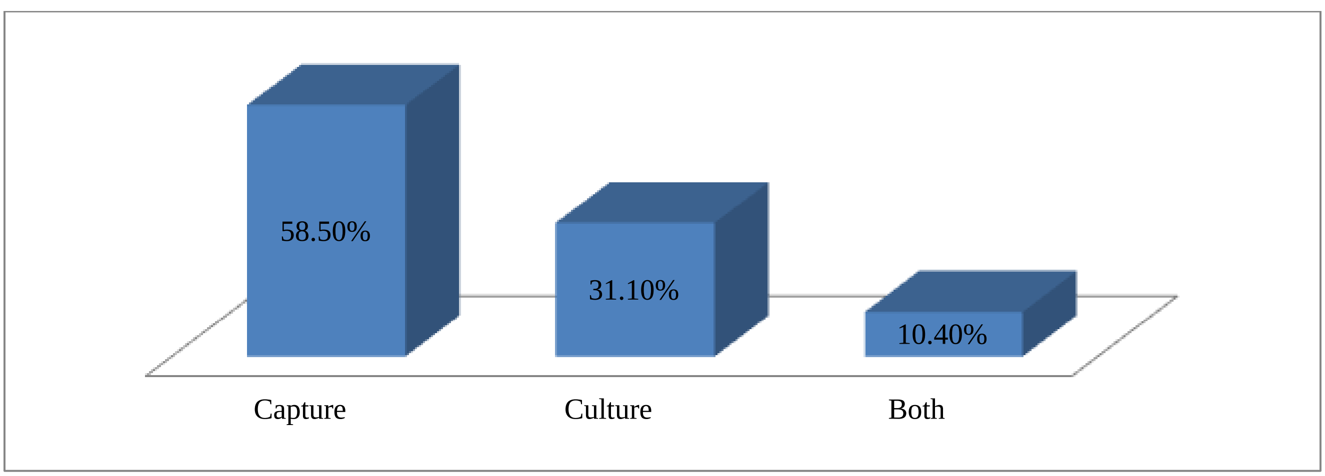

Figure 4: Distributions of Fish Farming Practices.

Figure 5, shows the distribution of sizes of farm lands affected by flood, 49% of the population indicates losses in the scale of less than 1 acres, 27% loss between 1 to 2 acres of farm size, 1.6% reported a loss of 2 acres and above while 23% affirmed not been affected by flood in the last ten (10) years.

Figure 6, shows that about 73% of the population agreed that flooding affect soil nutrient negatively, as it washes away top soil, thereby reducing the nutrient level of the soil, without any alluvial deposit as the study area is in the vicinity of the Kainji dam,

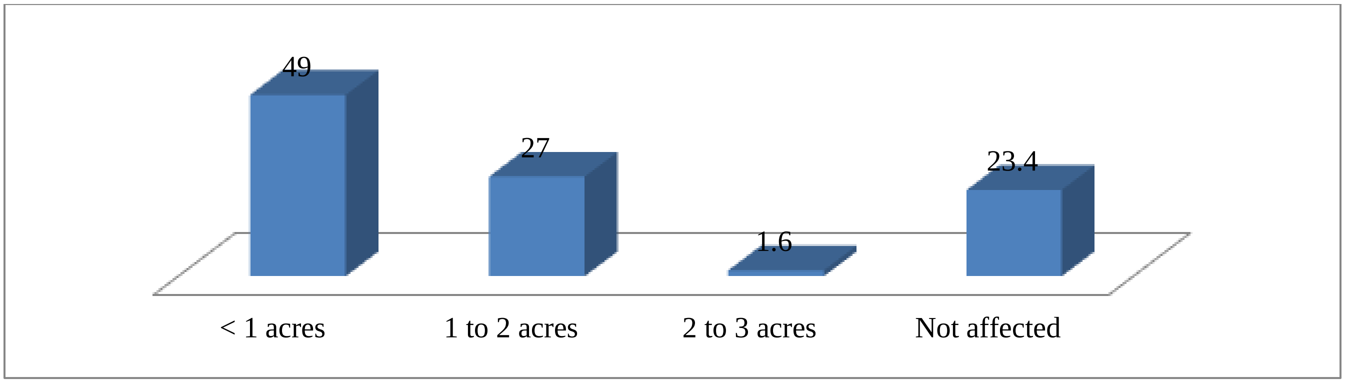

Figure 5: Distribution of Farm Sizes Affected by Flood

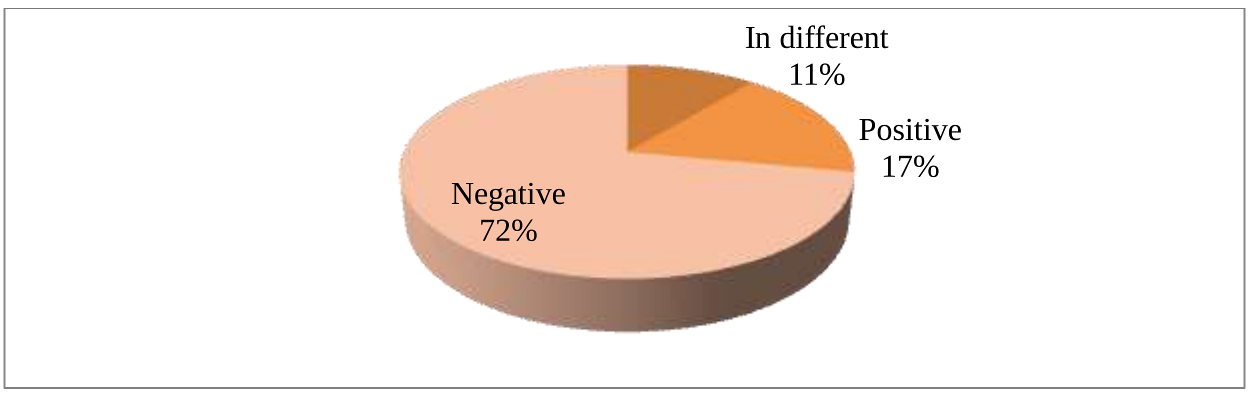

Figure 6: Impact of Flood on Soil Nutrient Status

Figure 7, summarizes the distribution of animals loss during the period under review, about 54% of the population confirm losing less than ten (10) animals, 8% loose between 10 to 20 animals, while 36% are not affected. Responses from the interview conducted with selected farmers reveals that apart from loss of animals to flood water, there is also a high rate of disease prevalence which mostly account for losses incurred by farmers.

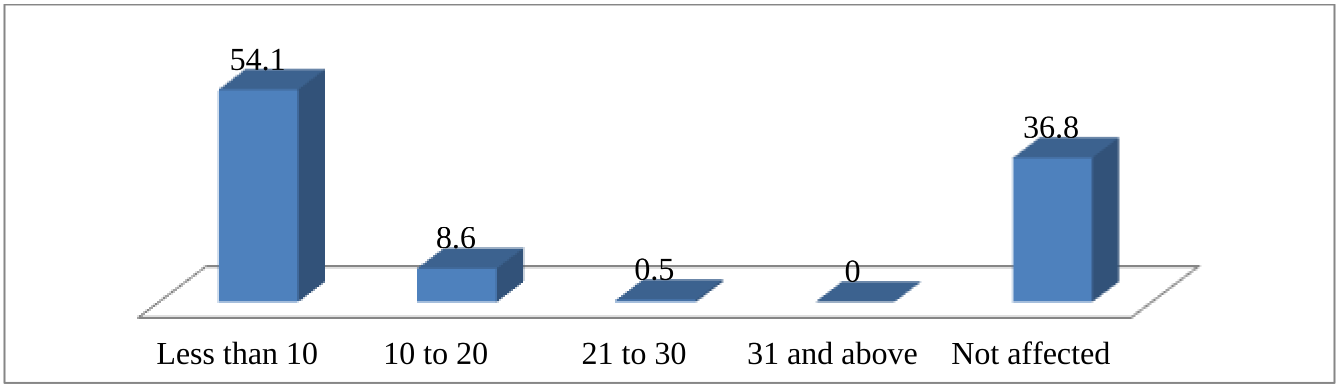

Figure 7: Distribution of Animal Affected by Flood

Figure 8, reveals that most (90.3%) of the captured fish farmers records less fish catch during flood period, 6.5% agreed that flood water comes with some advantages especially when the water recedes, harvest is mostly at increase. 3.2% indicates no challenge. From the interview conducted with selected farmers it was discovered that fishing equipment are mostly loss during flood period.

Figure 9, shows that 51.8% of the cultured fish farmers loss between 1 to 5 ponds during the period under review, 3.6% loss between 6 to 10 ponds to flooding. The result confirms that flooding is affecting activities of cultured fish farmers in the Study Area.

Figure 10, reveals that 71% of the population greed that water surplus is a major challenge during flood, 16% responded that high mortality rate is recorded during flood year, while 12% affirmed that prevalence of diseases is always at increase during flood event. The result shows that flood is having significant effect on the survival of cultured fish farming in the study area.

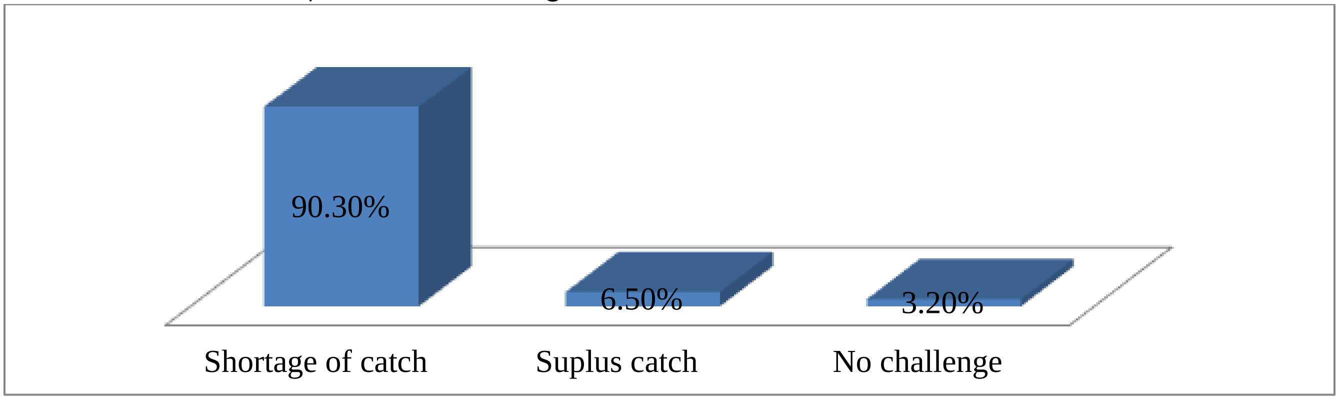

Figure 8: Impact of Flood on Captured Fish Farming

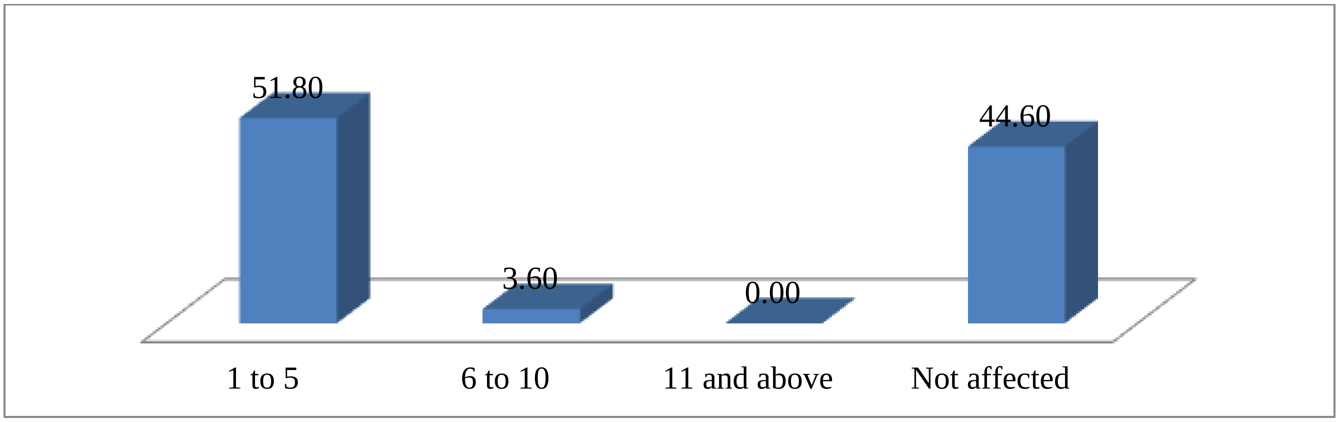

Figure 9: Distributions of Fish Ponds Affected by Flood

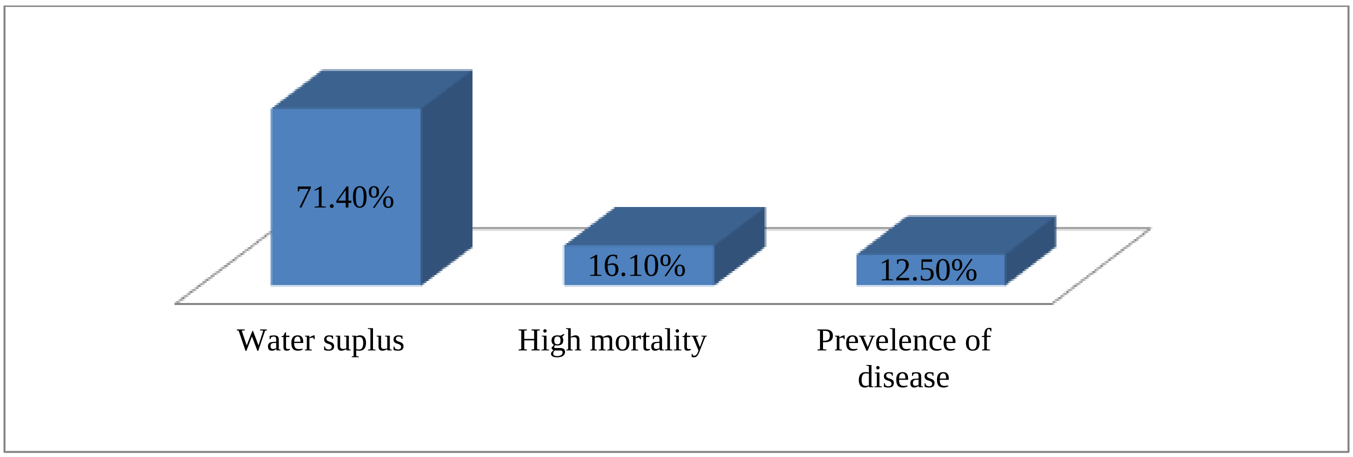

Figure 10: Impact of Flood on Cultured Fish Farming

The Digital Elevation Model (DEM) of the study area extracted from SRTM data of 30m resolution depicts the elevation of communities within the study area. The highest elevation is 298 metres while the lowest elevation of 81 metres above mean sea level.

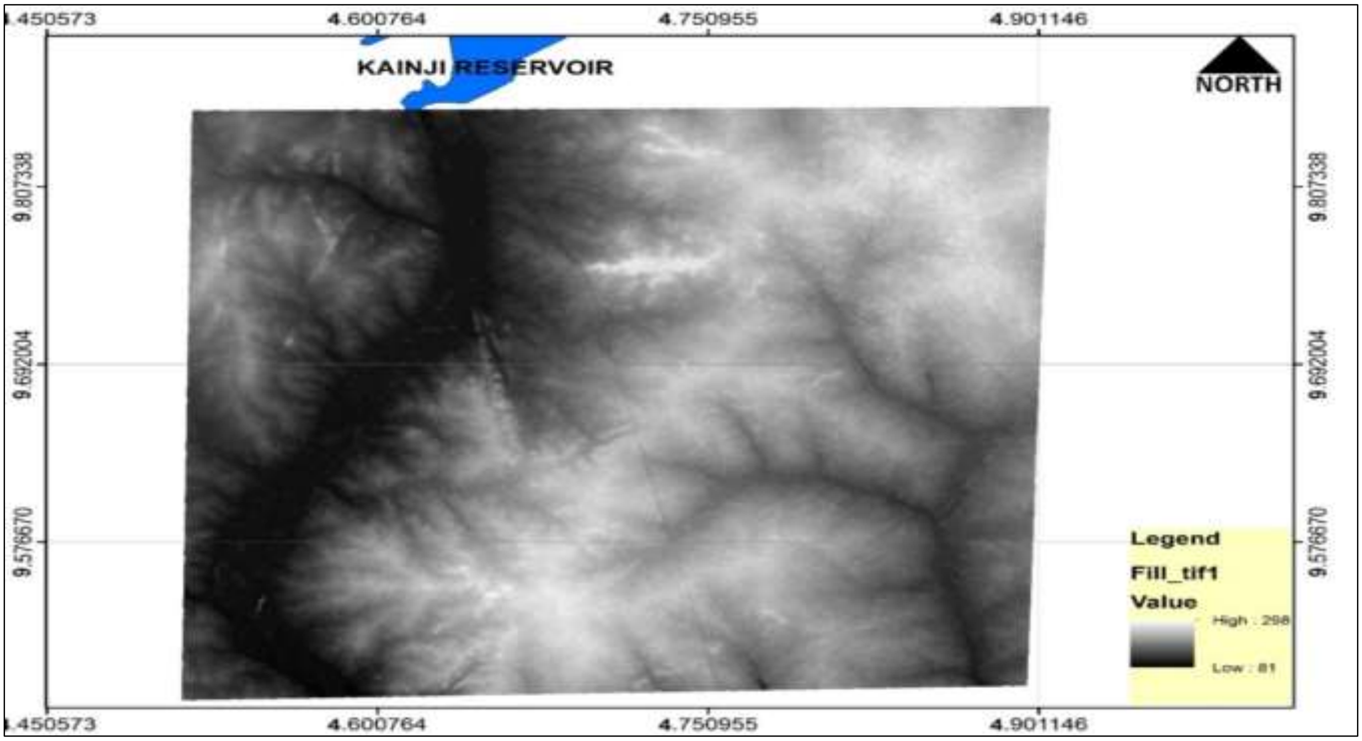

Figure 11: Digital Elevation Model of the Study Area

Figure 12, shows the flood vulnerability map of the study area, the result depict settlements with low vulnerability, moderate vulnerability, high vulnerability and save zones respectively.

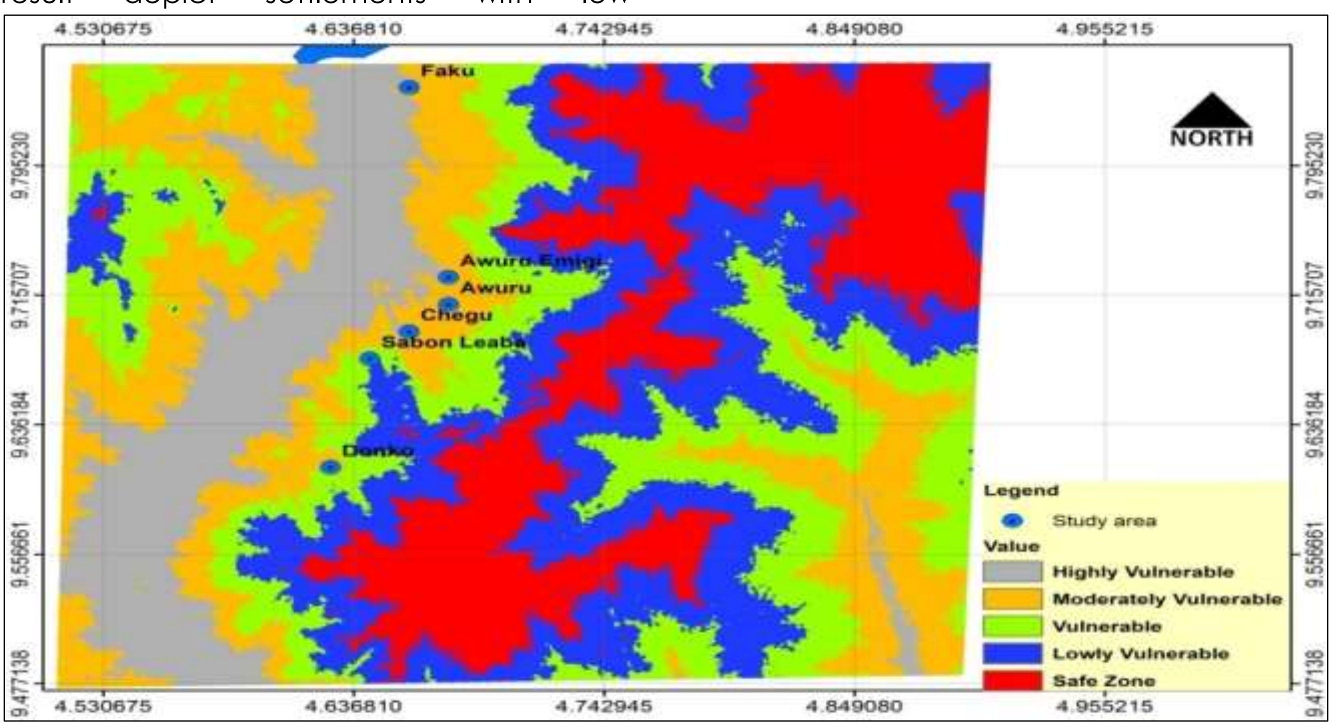

Figure 12: Flood Vulnerability Map of the Study Area.

5. Conclusion and Recommendations

It is evident that farmers in the affected communities experienced flood at varying degrees, more often when the spill ways of Kainji dam had to be opened during the peak of the rains. These have affected farming operations and thus, lead to low productivity, increased mortality, stunted growth and susceptibility of livestock and fish to diseases and death. Therefore, there is urgent need for a decision support system to alert stakeholders and the communities about the risk of farming along floodplains especially those that are identified as highly vulnerable to water releases. Continuous monitoring of the climate should be intensified to create awareness on flood regime.

References

Abowei, J. F. N., & Sikoki, F. D. (2005). Water pollution management and control, Port Harcourt: Double Trust Publication Co., 236

David, H. L.T., & William, M. A. (1999). Adaptation to dam: agrarian change downstream of the Tiga Dam, Northern Nigeria. *Journal of World Development*. 919-935

David O. Olukanni., and Adebayo W. Salami (2010). Assessment of impact of hydropower dams reservoir outflow on the downstream river flood regime. Nigerian's experience.

Ogiji M. L., Abdulkadir, F. I., & Aderoju, M.O. (2013). Geospatial Mapping and Analysis of the 2012 Flood Disaster in Central Parts of Nigeria, 8th GIS Symposium, Damman, Saudi Arabia, 14.

Musa, M. (2016). Impact of Floods on Agricultural Practices on Downstream Communities of Kainji Dam, Niger State, Nigeria. Unpublished M. Tech. Thesis, Department of Geography, Federal University of Technology Minna, Nigeria

Perceived Effects of Climate Variability on Food Crop Agriculture in Uhunmwode Local Government Area of Edo State, Nigeria

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Abstract

This study examined the perceived effects of climate variability on food crop agriculture in Uhunmwode Local Government Area of Edo State. It adopted the survey research design. The local government area was first stratified into nine (9) based on existing towns in the area; after which four (4) villages were randomly selected from each town using the geographic cardinal points. On the basis of this stratification, 180 copies of questionnaire were administered in the area. The simple percentage analysis was adopted for data analysis. Results showed that 78% of the respondents observed that there are changes in patterns of weather/climate variables such as rainfall and temperature: While rainfall is decreasing, temperature is increasing. Also, majority of farmers (83%) said that planting periods have changed due to shift in the onset of rain. This climate variability is adversely affecting yields of food crops, and has been attributed to man's activities by 45% of the farmers interviewed; 23% believed that the god's are angry. To improve crop yields, 38% of respondents said that they have increased their farm sizes; 12% are using fertilizers; and 25% are appeasing the gods etc. This implies that many farmers are yet to understand what is happening to weather/climate. Therefore, the study recommends that the farmers should be made to be aware of the changing patterns of weather/climate. Seeds and seedlings that suit the changes should be introduced and the farmers re-orientated to adapt to the situation.

Key Words: Agriculture; Food Crop; Variability; Weather; Climate; Uhunmwode.

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Introduction

Before the discovery of crude oil in Oloibiri, Bayelsa state, agriculture was the major economic activity most Nigerians were engaged in. This discovery made most Nigerians to feel that, it was a waste of energy and other resources to engage in agriculture, whether food crop production or animal husbandry. In Nigeria, as it is in most parts of the world, agriculture largely depends on climate (Agbo, Ayra & Okonkwo, 2015), most so food crop agriculture. In Nigeria, food crop agriculture, which refers to the cultivation of lands for the growing of edible plants for either commercial gains or subsistence benefits. Such agriculture in most developing countries is rain-fed. As a result food crops are often in abundance during the rainy season. The dry season is usually a period of lack for most crop farmers because only very few are privileged to have access to irrigation facilities. Even with the known dry and rainy seasons, the amounts of rainfall and duration vary from year to year. The extent of variation from the previous seasons will determine the amount of food crops that will be available.

However, with the dwindling fortune from crude oil and the ever increasing population of Nigeria, there an awakening call to go back to agriculture, in particular food crop agriculture. The price of crude oil dropped from over 100 dollars per barrel in late 2014 to less than 50 dollars in early 2016. Also, restiveness in the Niger Delta region of Nigeria has resulted in low production of crude oil for export and by extension reduced revenue for the country. This has made the importation of food by Nigeria very difficult, making increase in food crop production or a return to it where it has been abandoned, a must for the country. Food crop agriculture remains one of the only ways to alleviate poverty in the developing countries, restore their economics and ensure economic sustainability (Poudel & Shaw, 2016). Thus, Agriculture may as well become not only a way to revamp the Nigerian economy but also improve the economic wellbeing of rural dwellers. Factors responsible for these negative impacts of weather on food crop agriculture at least in Nigeria have been long enumerated to include, lack of information to assist the local farmers in carrying out their farm practices (Mintewab et al, 2014), continuing with seeds that have become out dated due to changes in climate (Cao, 2008), lack of climate information and other data for farmers (Agbo *et al*., 2015) etc.

But going into agriculture, in particular food crop production in a changing climate (Adiku, Dayananda, Rose & Downona, 1997, Intergovernmental Panel on Climate Change (IPCC), 2001; United States National Climatic Data Center (USNCDC), 2001; Ityo, 2010; Adejuwon, 2010; Ifabiyi & Omoyoseye, 2011; Adamgbe & Ujoh 2013; Kase, Ampadu & Yalevu 2014; Nwagbara, 2015; Nwagbara and Ibe, 2015; World Food Summit, 2016) may be an effort in futility if prevailing climate and weather were not seriously taken into consideration. The relationship between climate variability and crop yield has been documented (for example, Dowing, 1992; Zierovogel, Nyong, Osman, Conde & Cortes, 2006; Eboh, 2009; Schlenker & Lobell, 2010; Tunde, 2011; Kasei *et al*., 2014; Musiyiwa, Filho, Harris & Nyamangara, 2014; Egbe, Yaro, Okon & Bisong 2014). Countries where agriculture is climate dependent, there is the need to advise the farmers continually on the way forward in the face of climate variability (Mendelsohn & Dinar, 2009; Stage, 2010; Cao, 2008; Timmins, 2006; Mintewab, Salvatore & Alemu, 2014).

Uhunmwode Local Government Area (LGA) of Edo State, Nigeria is by no means immune to the effects of climate variability especially with regard to food crop production which is a common sight in the area. The way the farmers view these effects matters a lot in determining measures they may take to mitigate the adverse ones and on how to take advantage of the favourable ones. This would determine level of food crop production in the area As a result; it is the compelling to investigate how crop farmers in the LGA perceive the effects of climate variability.

Materials and Methods

Uhunmwode LGA is situated in Edo state and has its headquarters at Ehor. It is bounded by Latitudes 6°31' to 6°32'N and Longitudes 6°02' to 6°32E' (Figure 1) and occupies a total area of 2033km^2; with a population of 120,813 (NPC, 2007). The area enjoys the tropical climate with average annual rainfall of1475 mm. Rainfall is double maxima with the peaks occurring in the months of July and September. Mean temperature ranges between 29℃ in the hottest months of December through February and 26℃ in the coolest months of June and July. This climate type thus, encourages the tropical rainforest and agriculture in the area. The climate of the state is changing due to the influence of man on the climate of the area through anthropogenic activities (Ozabor, 2014). This is thought to be having some effects on food crop agriculture in the area. Incidentally, the major employer of labour in the LGA is agriculture, which provides more than 70% of the food that is consumed there (Ozabor, 2014).

In terms of methodology, the study adopted the survey research design which involved the use of questionnaire in the area. The area was first stratified into nine (9) based on existing towns in the LGA; after which four (4) villages were randomly selected from each town using the geographic cardinal points (See Table 1).

On the basis of this stratification 180 copies of questionnaire (5 for each village) were administered in the area. However, for a farmer to be selected the following criteria were adopted: a) farmer must have cultivated land in the area for 10years or above; b) have the habit of cultivating 5plots or more per year; c) must have experience in the cultivation in more than one food crop. However to carry out the data analysis, simple percentage was adopted.

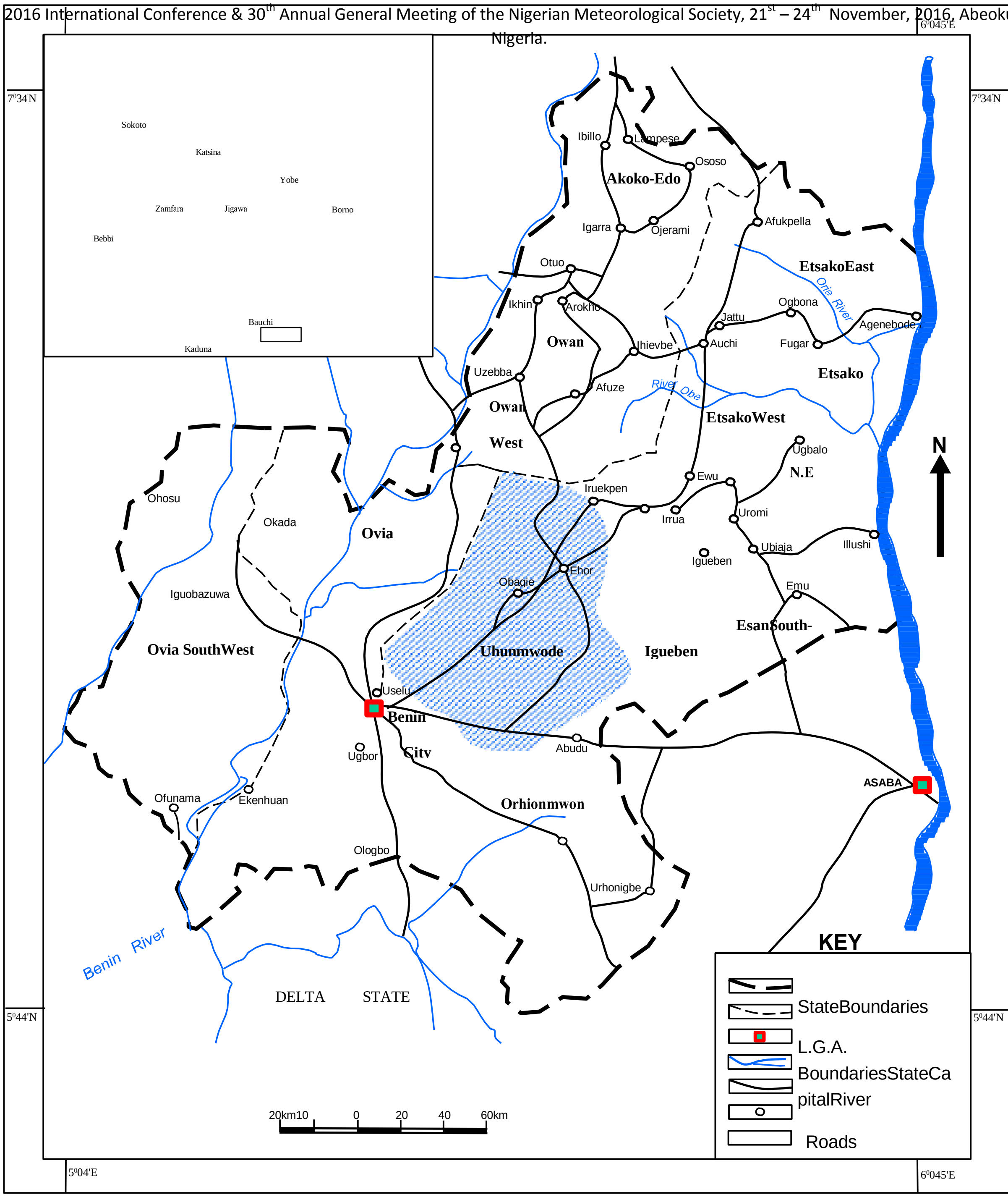

Figure 1: Study Area: Uhunmwode Local Government Area, Edo state

Table 1: Systematic selection of sample location for the study.

Towns	Villages	Selected villages
Ehor	Abumwenre, Ehor, Okemue, Ugbiyaya, Ugbiyokho, Ugiamwen, Ukpogo	Ugbiyaya, Ugbiyokho, Ukpogo, Ugiamwen
Irhue	Ekpan-Irhue, Irhue, Oke-Irhue, Orhua, Umokpe	Umokpe, Ekpan-Irhue, Irhue, Oke-Irhue
Isi South	Ekae, Erhuan, Evbowe, Evguogho, Iguagba, Iguagbe, Iguezomo, Iguiyase, Ilobi, Izikhiri, Obanisi	Erhuan, Evbowe, Izikhiri, Iguezomo
Uhi	Egbisi, Irhiborhibo, Obagie, Obazagbon, Ugueghudu, Uhi, Uhimwento	Egbisi, Ugueghudu, Uhi, Obazagbon
Umagbae North	Azagba,Ekuigbo,Igueuwangue, Iguevbiahianwen, Iguevbiobo, Iguezevbaru, Iguomo, Ikhueniro, Irighon, Ogheghe, Ogueka, Okhuo, Okpagha, Uma, Urhokuosa	Ekuigbo,Igueuwangue, Iguomo, Ikhueniro
Umagbae South	Agiyamu, Ahor, Ayen, Egba, Ekoken, Ekomufua, Evboikhuendo, Ewedo, Eyean, Idumwugha, Iguosula, Ikiyete, Orio, Ute, Uzalla	Ayen, Egba, Idumwugha, Iguosula
Isi North	Eguaholor, Igueoke, Iguesogban, Iguomo, Ike, Iyanomo, Oghada, Okhuokhuo, Ugbezee, Urbenisi	Eguaholor, Oghada, Ugbezee, Iguesogban
Egbede	Aduhanhan, Ekhonidunolu, Ekhoniguokuen, Ekhoniro, Ekhonuwaya, Ekhuaihe, Emuhu, Evbosawe, Igbogiri, Okekpen, Okeze, Okogo, Ugboyon, Ugomoson, Ugoneki, Ugonoba, Uvbe	Igbogiri, Ugomoson, Evbosawe, Uvbe
Igieduma	Erhua-Nokhua, Igieduma, Irhiwe, Obagie, Otofure, Ugha, Uteni	Igieduma, Otofure, Ugha, Irhiwe

Source: Authors' field work (2016)

Results and Discussion

The age distribution of respondents (Table 2) reveals that very few of the young people there are engaged in agriculture. In the table respondents in the age cohorts of 25-30 are only 6% of the total respondents, while the greater proportion of the respondents are those of the above 40 years cohorts.

Table 2: Age distribution of respondents

Age Group	Frequency	%
25-30	12	6.7
31-35	17	9.4
36-40	35	19.4
Above 40	116	64.4
Total	180	100

Source: Authors' fieldwork (2016)

It therefore follows that, most young men with high ambitions have either migrated out of the local government area in search of white-collar jobs or a better source of income or have changed source of livelihood due to poor return on investment in agriculture.

Of the total respondents (180), 92.8% (that is, 167 respondents) were males whereas the female respondents were 7.2% (that is, 13 respondents) (Table 3). This means that there are more men engaged in agriculture in the area than women.

Table 3: Gender distribution of respondents

Gender	Frequency	%
Male	167	92.8
Female	13	7.2
Total	180	100

Source: Authors fieldwork (2016)

Table 4 shows the level of education of the respondents. From the table it can be deduced that the farmers are mostly not well educated. This is because the majority (51.7%) of the respondent had as their highest qualification Basic 6.

Table 4: Highest education qualification of respondents

Education	Frequency	%
Basic 6	93	51.7
Basic 9	76	42.2
First Degree	11	6.1
Total	180	100

Source: Authors fieldwork (2016)

Similarly, those with Basic 9 represented 42.2% of the total respondents while only 6.1% of the total respondents had First Degree. This indicates the extent to which farmers would be able to have access to current information on how to practice food crop agriculture in the face of a changing climate.

Table 5 reveals that the farmers have noticed some changes in weather variables. This is because 78.3% of the total respondents (that is, 141 respondents) said that they were aware of changes in climate/weather parameters. Only 21.7% stated otherwise.

Table 5: Farmers perception of changes in weather variables

Aware of weather change	Frequency	%
Yes	141	78.3
No	39	21.7
Total	180	100

Source: Authors fieldwork (2016)

This implies that the farmers are beginning to notice the impacts of climate variability on their food crop production. This is consistent with the findings of Cortes (2006) and Egbe, Yaro, Okon & Bisong (2014).

In Table 6, 76.7% of the total respondents said that they have observed changes in air temperature patterns. The remaining 23.3% of the respondents stated that they have not noticed any changes in air temperature patterns.

Table 6: Noticed changes in air temperature

Noticed changes in Temperature	**Frequency**	**%**
Yes	138	76.7
No	42	23.3
Total	180	100

Source: Authors fieldwork (2016)

When the respondents were asked to identify the direction of changes in air temperature, 69.4% of the total respondents said that it was rising, 21.7% of the total respondents indicated that air temperature has been the same over the years (Table 7).

Table 7: Direction of changes in air temperature

Temperature	**Frequency**	**%**
The Same	39	21.7
Reducing	16	8.9
Rising	125	69.4
Total	180	100

Source: Authors fieldwork (2016)

The remaining 8.9% stated that it was reducing. A rising air temperature could mean much trouble for food crop farmers. This is corroborated by Tunde (2011).

Table 8 reveals that there is a change in patterns of rainfall in the area. This is because the majority of respondents (78.3%) indicated that they have noticed changes in rainfall patterns while only 21.7% stated otherwise.

Table 8: Noticed changes in Rainfall

Noticed changes in Rainfall	**Frequency**	**%**
Yes	141	78.3
No	39	21.7

Total	180	100

Source: Authors fieldwork (2016)

However, when respondents were asked to state the direction of changes in rainfall, 70% of respondents indicated that, there is increase in rainfall amounts (Table 9). Of the total respondents, 21.7% said that rainfall amounts have remained the same. The remaining 8.3% stated that rainfall amounts are reducing.

Table 9: Direction of change in Rainfall

Rainfall/ Rain days	**Frequency**	**%**
The Same	39	21.7
Reducing	15	8.3
Rising	126	70
Total	180	100

Source: Authors fieldwork (2016)

This finding confirms that the present climate change varies from one area/region to another. Whereas most respondents in the study area said that rainfall was increasing in amounts, Poudel & Shaw (2016) stated that rainfall was reducing in Nepal.

Table 10 shows the perceived causes of climate variability by respondents in the study area. In the table, only 11.6% of the total respondents (that is 21 out of 180) stated that the changes in climate pattern are as a result of gods being angry. On the other hand, greater number of respondents, that is 138 out of 180 (76.7%), listed 'man's influence' via bush burning, altering of the atmospheric gases and other anthropogenic activities as the factor responsible for changes in patterns of climate.

Table 10: Perceived factors responsible for changes in climate patterns

Perceived causes of climate variability	**Frequency**	**%**
The gods are	21	11.6

angry		
Man's influence	138	76.7
Over cultivation	128	71.1
Natural change	37	20.6

Source: Authors fieldwork (2016)

Next to man's influence as a factor of climate variability is 'over cultivation of land' with 128 out of the 180 (that is, 71.1%). This finding is consistent with those of Kasei *et al*. (2014) and Musiyiwa, Filho, Harris & Nyamangara (2014).

Table 11 shows the perceived effects of climate variability on food crop production in the study area. From the table, only 32 respondents (17.8%) out of 180 said they now farm elsewhere as a result recent climate variability. Highest number of the respondents, that is 150 (83.3%) said climate variability is causing changes in planting season.

Table 11: Perceived effects of climate variability on crop production

Effects	Frequency	%
Farming elsewhere	32	17.8
Poor crop yields	128	71.1
Multiple planting	132	73.3
Increase in cost of farming	138	76.7
Change in occupation	109	60.6
Changes in planting season	150	83.3

Source: Authors fieldwork (2016)

In table 12, 141 farmers (respondents) (78.3%) being the highest stated that they have increased the sizes of their farmland as a strategy to reduce the adverse effects of climate variability in the study area. On the other hand, only 21 respondents (that is, 11.7%) listed 'Appeasing the gods' as a means to find solution to the effects of climate variability.

Table 12: Coping strategies with changes in climate patterns by farmers

Options	Frequency	%
Use of fertilizer	138	76.7
Increase in size of farm land	141	78.3
Mixed cropping	127	70.6
Appeasing the gods	21	11.7

Source: Authors fieldwork (2016)

Conclusion and Recommendations

Food crop agriculture in Uhunmwode LGA does not only provide food for the inhabitants of the area, nearby local government areas and cities but also employs labour. Therefore, in the current economic recession in Nigeria, food crop agriculture would be one of the easiest way out as it would reduce the demand for foreign exchange for the importation of food and employ labour. However, the changes in patterns of climate/weather elements are a huge challenge to progress in agriculture.

Therefore, it is expedient that least NIMET as a body should improve on the network density of weather stations for the monitoring of climate/weather elements. As such, a weather station should be established in the LGA. This would help generate climate information that would help agro-climate scientists advise the farmers on the implication of climate data so generated. Similarly, farmers should be educated on best ways to carry out food crop agriculture in the face of changing climate pattern, since most their current agricultural practices are now outdated. Therefore, a team of agriculturists and climatologists should be deployed to the area via the Edo State Ministry of Agriculture and Natural Resources to create awareness on changing climate among the food crop farmers. Farmers should be provided new seedlings that suit the current climate pattern of the area. Equally, Farmers should be exposed to information regarding what over cultivation would do to crop yield. This is because; in the face of a changing weather pattern it would be very important to approach agriculture with the best practice. Finally, more studies should be carried out to ascertain the severity of the effects (in particular the adverse ones) of climate variability on food crop agriculture in the area.

References

Adamgbe., E. M., & Ujoh F (2013). Effect of Variability in Rainfall Characteristics on Maize Yield in Gboko, Nigeria. *Journal of Environmental Protection, 4, pp. 881- 887.* http://dx.doi.org/10.4236/jep.2013.49103

Adiku S. G. K., Dayananda., P. W. A, Rose., C. W, & Dowuona., G. N. N. (1997). An analysis of the within-season rainfall characteristics and simulation of the daily rainfall in two savanna zones of Ghana. *Agricultural and Forest Meteorology*, *86, pp 51-62.*

Agbo, F. U., Arua, R. N. & Okonkwo, E. A. (2015). Effects of climate variability on the choices of livelihood among farm households in Anambra State, Nigeria. *African Journal of Agricultural Research, 10(44), pp. 4134-4141. DOI: 10.5897/AJAR2015. 9663.*

Cao, J. (2008). Reconciling Human Development and Climate Protection: Perspectives from Developing Countries on Post-2012. International Climate Change Policy. *Discussion Paper 08-25. The Harvard Project on International Climate Agreements, Kennedy School of Government, Harvard University.*

Downing, T. E. (1992). Climate Change and Vulnerable Place Global Food Security and Country Studies in Zimbabwe, Kenya, Senegal and Chile. *Discussion Paper on Environmental Change Unit, University of Oxford, Oxford.*

Eboh, E. (2009). *Implications of Climate Change for Economic Growth and Sustainable Development in Nigeria*: In: Eboh E, Ozor N, Onuoha C, Amaechi C. Enugu Forum Policy Paper 10 Debating Policy Options for National Development. Africa Institute for Applied Economics.

Egbe, C. A, Yaro, M. A, Okon A. E, & Bisong F. E. (2014). Rural Peoples' Perception to Climate Variability/Change in Cross River State, Nigeria. *J. Sustain. Dev. 7(2). pp. 25-36.*

IPCC (2001): *Climate Change 2001: The Scientific Basis*. New York: Cambridge Univ. Press.

Kasei., R.A, Ampadu., B. & Yalevu., S. (2014). Impacts of Climate Variability on Food Security in Northern Ghana. *Journal of Earth Sciences and Geotechnical Engineering, 4(3), pp 47-59.*

Mendelsohn, R., & A. Dinar. (2009). Climate Change and Agriculture. An Economic Analysis of Global Impact, Adaptation and Distributional Effects. *Elgar:Cheltenham.*

Mintewab., B., Salvatore D., & Alemu M. (2014). On the Impact of Weather Variability and Climate Change on Agriculture Evidence from Ethiopia. *Environment for Development Discussion Paper Series. EfD DP 14-15.*

Musiyiwa. K., Filho W.L, Harris D & Nyamangara., J. (2014). Implications of Climate Variability and Change for Smallholder Crop Production in Different Areas of Zimbabwe. *Research Journal of Environmental and Earth Sciences, 6(8), pp.394-401,ISSN: 2041 0484; e-ISSN: 2041-0492*

Nigerian Population Commission (NPC).(2007). Excerpts of the 2006 Census.

Nwagbara, M.O. (2008): Landcover change in relation to climate change in northern Nigeria using GIS techniques. A Ph.D. Thesis: Department of Geography and Planning, Abia State University, Uturu, Nigeria.

Nwagbara, M.O. & Ibe, O.K. (2015): "Climate Change and Soil Conditions in the tropical rainforests of Southeastern Nigeria". *Journal of Geography and Earth Sciences, Vol. 3(1), pp. 99 – 106.*

Ozabor, F. (2014). *Analysis of Rainfall Regimes in Nigeria*. Unpublished M.Sc thesis submitted to the Department of Geography and Regional Planning, DELSU.

Poudel S & Shaw R (2016). The Relationships between Climate Variability and Crop Yield in a Mountainous Environment: A Case Study in Lamjung District, Nepal. *Climate*, 4(13), pp. 1-19. doi:10.3390/cli4010013

Schlenker W, & Lobell., D.B. (2010). Robust Negative Impacts of Climate Change on African Agriculture. *Environ. Res. Lett*. 5. 014010.

Stage, J. (2010). Economic Valuation of Climate Change Adaptation in Developing Countries. Annals of the New York Academy of Sciences 1185 Pp150-163.

Timmins, C. (2006). Endogenous Land use and the Ricardian Valuation of Climate Change. *Environmental and Resource Economics, 33(1). pp. 119-142.*

Tunde, A. M (2011). Perception of Climate Variability on Agriculture and Food Security by Men and Women Farmers in Idanre L.G.A, Ondo State. Nigeria. Ethiopian Journal of Environmental Studies and Management, 4(2), pp. 19-32. http://dx.doi.org/10.4314/ejesm.v4i2.3

United States National Climatic Center (2001): *Global Temperature Changes* (1880-2000). Washington DC.

World food Summit (2006). http://www.who.int/trade/glossary/story028/en/ accessed on 23/06/16.

Zierovogel. G, Nyong. A, Osman. B, Conde. C, & Cortes D.T. (2006). Climate Variability and Change: Implications for Household Food Security. *The AIACC Project Office, International START Secretariat Washington DC, USA. AIACC Working Paper No. 20.*

Pattern of Rainfall Anomalies and Rural Water Supply in Sudano-Sahelian Region of Nigeria

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Abstract

The pattern of rainfall anomalies have been largely neglected in the literature on climatology in Nigeria in spite of their significance to rural water supply. This paper examined the pattern of rainfall anomalies and trends from 1961-2010 with a view to understanding its causal factors and possible implications for rural water supply. Monthly rainfall data for five meteorological stations located in the Sudano-Sahelian region of Nigeria were obtained from the Nigerian Meteorological Agency. Other category of data used for the study included monthly Sea Surface Temperatures (SSTs) of the Atlantic and Pacific oceans and Southern Oscillation Index (SOI) obtained from the Climatic Prediction Center (CPC). Stepwise multiple regression model and simple linear regression analysis were used for data analyses. Simulations were run with Water Simulation Model (WaSim) for the stated period using daily rainfall and atmospheric temperature to predict the rate of recharge to groundwater table in response to rainfall anomalies in the region. The result showed that the El-Nino/Southern Oscillation (ENSO) and sea surface temperature anomalies over the tropical oceans together combined and deprived the Sudano-Sahelian region of Nigeria the copious moisture required for abundant rainfall in the region. It was also found that the annual and seasonal rainfall amounts in the region exhibited a downward trend over the period of the study. Recharge to the groundwater table is found to be highly sensitive to annual rainfall anomalies in the region and this significantly affects the rural water supply. The paper recommends that the ENSO and SSTs factors should be considered for forecasting of rainfall anomalies in the region. The conjunctive use of surface and ground water sources should also be adopted in order to mitigate the adverse effects of rainfall anomalies on rural water supply in the region.

Keywords: Rainfall Anomalies, Water Simulation Model, Sea Surface Temperatures, Sudano-Sahelian,

Introduction

Rainfall is one of most critical elements that determine the availability or otherwise of both the surface and groundwater in semi-arid environments that are characterized by high rainfall variability. This is responsible for the increasing concern particularly amongst hydrologists and climatologists on the potential implications of climate change and variability on the rural water supply in the Sudano-Sahelian region of Nigeria in particular and West Africa in general. Nyong and Kanaroglou (1997, 1999) argued that water availability was a major concern in the drought-prone semi-arid zone of Nigeria given the high rates of population growth in the region which contributed significantly to the increase in water consumption. Hassan *et al* (2013) emphasized the need for massive rainwater harvesting with corresponding reservoir as complementary measure of water supply as a way to reduce the effects of the frequent droughts experienced in some selected villages of Sahel Savannah Ecological Zone in Borno State of Northeastern Nigeria over the period 1980-2009. Brett *et al* (2007), on the other hand advocated for a *Platform* approach to rural water supply management that can mobilize the assets and insights of different social actors to influence decision making at all stages, including the design and choice-of-technology stages, in water supply interventions as against the community-based approach; which will not necessarily proffer sustainable rural water supply in semi-arid region.

Maaten and Jacek (2006) analyzed the changes in surface water supply across Africa with predicted climate change and argued that a decrease in perennial drainage due do climate change-induced predicted precipitation changes would significantly affect present surface water access across 25% of Africa by the end of this century. One of the key uncertainties surrounding the impacts of a changing climate in Africa is the effect that it will have on the sustainability of rural water supplies. Alan *et al* (2009) examined the potential impact of climate change on rural groundwater supplies in Africa and concluded that the low yielding sources in poor aquifers are most at risk and that the predicted increased rainfall intensity might also increase the risk of contamination of very shallow ground water. Roger and Alan (2009) examined the question on '*what will climate change mean for groundwater supply in Africa*?' and reported that the occurrence of groundwater depends primarily on geology, geomorphology and rainfall and that climate change would superimpose itself by modifying rainfall and evaporation patterns, raising questions about how such changes might affect groundwater availability and, ultimately, rural water supplies. Kumar (2012) reported a direct link between the groundwater resources and climate change through direct interaction with surface water resources such as lakes and rivers, and indirectly through the recharge process. Tarhule and Woo (1997) showed that the beginning of the rainy season presents a particularly precarious situation for water supply because runoff generated by the rainstorms renders the shallow wells unusable, but the deep wells are not yet recharged and the stream beds contain little more than several stagnant ponds of muddy, polluted water. Thus, there is heavy dependence on any deep groundwater wells that may still be viable, and on the erratic rainfall

From the foregoing, it is obvious that the major sources of rural water supplies –

groundwater based sources such as hand-dug wells, hand-pumped boreholes, reservoirs, and surface water-based sources such as rivers, lakes, ponds and streams are climate-dependent. It is in recognition of this fact that government especially at local levels embarked on so many rural water supply projects, with limited success, in addressing the problems of rural water supply in their communities. Though several studies have been carried out in different parts of Africa with the aim of understanding the impact of climate change on groundwater supplies, no attempt was made to examine the pattern of rainfall anomalies and its implications for rural water supplies in Sudano-Sahelian region of Nigeria over the period 1951-2000. The objectives of this paper are three-fold: (i) to determine the trend in annual and seasonal rainfall for selected stations in the

Sudano-Sahelian region of Nigeria. (ii) to identify the causal factors of rainfall anomalies in the Sudano-Sahelian region of Nigeria. (iii) to highlight the possible implications of rainfall anomalies for rural water supply in Sudano-Sahelian region of Nigeria.

Materials and Methods

Monthly rainfall data for Katsina, Nguru, Maiduguri, Kano and Sokoto meteorological stations located in the Sudano-Sahelian region of Nigeria (see figure 1) were collected from the Nigerian Meteorological Agency (NiMet), Oshodi, Lagos, Nigeria.

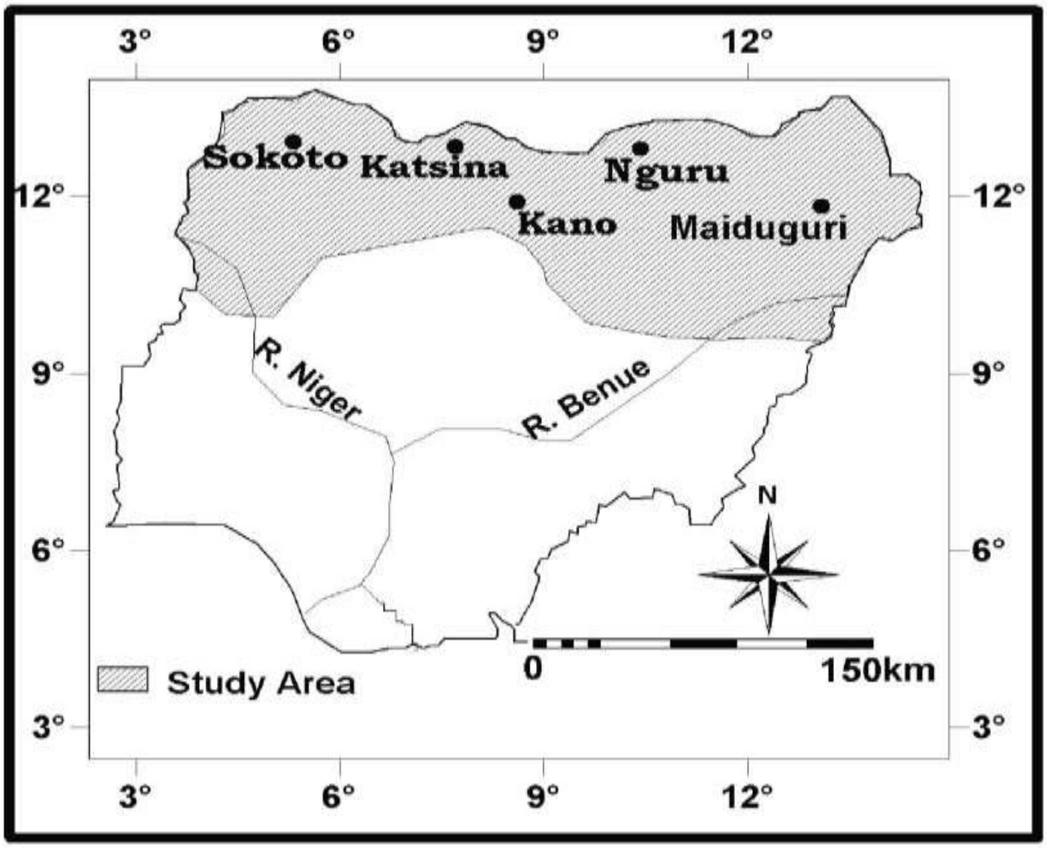


Figure 1. *Generalized map showing the areal entent of the Sudano-Sahelian region of Nigeria* (After Odekunle *et al*, 2008)

The Sudano-Sahelian region of Nigeria like other parts of the country, enjoys a tropical continental climate characterized by two distinct rainy seasons viz: the wet season and the dry season. The country receives rainfall from the south westerlies which invade the country from the Gulf of Guinea coast, i.e. the tropical Atlantic. This moist air stream is overlain by the northeast trades which originate from above the Sahara and therefore are dry and dust laden. The zone of contact of the two air masses at the surface is a zone of moisture discontinuity and it is known as the Inter-Tropical Discontinuity (ITD). The ITD advances inland as far as 22-25^0 N in August at the margin of the Sahara i.e. considerably beyond Nigeria's northern border (Ayoade, 2011) while it does not retreat equatorward beyond 4^{0}N latitude during the 'Harmattan' dry season (see Odekunle *et al*, 2008; Ayoade, 2011). The five weather zones that are associated with the ITD over Nigeria are illustrated in figure 2. Zone A lies to the north of the ITD and hence is rainless as well as zone B to the immediate south because they do not contain rain-producing clouds. Rainfall in the ITD occurs in zones C and D where conditions favour the development of clouds of great vertical extent. Thunderstorms and squall lines are associated with zone C weather and monsoon rains with zone D weather. Consequently, rainfall is spatially discontinuous when zone C weather prevails. On the other hand, the monsoon system gives continuous rains which may last 12 hours or more (see Olaniran, 1986, 1991, 2005). Overall, rainfall occurs at a distance of about 500km south of the surface location of the ITD, 4-6 weeks behind it in its annual cycle. When the fifth weather type associated with the ITD i.e. zone E, prevails over an area, light rainfall usually occurs because Zone E weather is dominated by layered stratiform clouds. The amount, seasonal distribution, type of rainfall and the length of the rainy season as well as the general weather conditions experienced in the course of the year at any given location in the West African region depend primarily on its location relative to the position of the ITD and the associated weather zones (Ayoade, 2005).

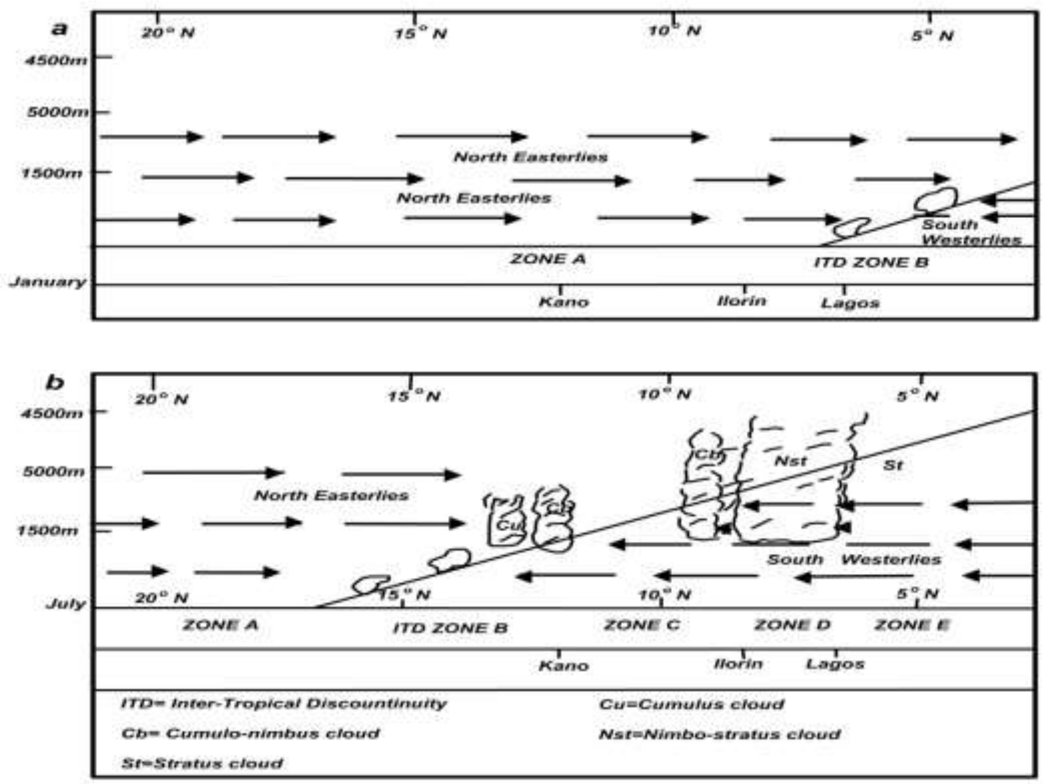


Figure 2 *The ITD and the weather zones in an idealized atmospheric cross-section from South to North over Nigeria (After Ojo, 1977)*

Other category of data collected are the monthly Sea Surface Temperatures (SSTs) and Elnino/Southern Oscillation (ENSO) index over the tropical Atlantic and Pacific Oceans over the period 1951-2000. These data were sourced from the archives of the Climatic Prediction Centre (CPC). The annual and seasonal rainfall trends were analyzed using the simple linear regression model where by the values in the time series (*y*) were regressed on time (x). The equation of the line of best fit was then computed using the least square criterion by which the sum of squares of

the deviation of each observation from the trend line is minimized. The equation is as follows: $Y = a + b\overline{x}$+e Where ***a*** = intercept of the regression, ***b*** = regression coefficient and ***e*** = error term or residuals of the regression. The annual rainfall series for each of the stations is utilized for a 50-year period (1951-2000). A composite of (Jun + Jul + Aug) rainfall is also derived for each station within the same period (1951-2000). The Sudano-Sahelian stations considered in this study receive the bulk of their rainfall during these months in any given year. Both series are then subjected to stepwise multiple regression analysis in an attempt to determine the causal factors of rainfall anomalies in the region.

The independent variables used in the stepwise multiple regression model include: (1) The SOI index, (2) **Global Tropics (10°South-10°North, 0-360⁰)** SST anomalies (3) Niño 1+2 (0-10°South)(90°West-80°West) SST anomalies (4) Niño 3 (5°North-5°South)(150°West-90°West) SST anomalies (5) Niño 3.4 (5°North-5°South)(170-120°West) SST anomalies (6) Niño 4 (5°North-5°South)(160°East-150°West) SST anomalies (7) **South Atlantic (0-20°South, 30°West-10°East)** SST anomalies (8) **North Atlantic (5-20°North, 60-30°West)** SST anomalies. The dependent variables are the annual and seasonal rainfall time series for each of the stations.

The WaSim model was used for soil water balance simulation to estimate recharge into the sub-surface aquifer and to monitor the groundwater level movement in response to weather and irrigation where appropriate. Simulations of up to 30 years duration can be undertaken using WaSim and up to 3 crops can be specified in rotation. The model consists of several layers of soil with the upper boundary as the soil surface and the lower boundary as the impermeable layer and water is stored between these two boundaries in five stores. The first, compartment 0, is the surface layer compartment (0 – 0.15m), followed by the active root zone compartment 1 (0.15m – root depth), then, compartment 2 is the unsaturated compartment below the root zone (root depth – water table), then, compartment 3 is the saturated compartment above drain depth (water table – drain depth) and lastly, compartment 4 is the saturated compartment below drain depth (drain depth – impermeable layer). Soil water moves from upper layers to layers below only when the soil water content of the compartment exceeds field capacity. In this case, the drainage flow is a function of the amount of excess water.

Discussion of Results

Rainfall trends in Sudano-Sahelian Region of Nigeria

The results of the trend analysis showed that annual rainfall series at Katsina, Nguru, Maiduguri and Sokoto stations exhibited a significant downward trend over the period 1951-2000 while Kano annual rainfall did not show any discernible trend over the period of the study. The seasonal rainfall pattern in the region also showed similar rainfall trends (see table 1). This model uses daily rainfall and reference evapotranspiration as inputs.

Table 1. Rainfall trends in Sudano-Sahelian region of Nigeria (1951-2000)

Station	*R*		Significance level %	
	Annual	Seasonal	Annual	Seasonal
Katsina	-0.32	-0.38	0.05	0.05
Nguru	-0.24	-0.29	0.05	0.05
Maiduguri	-.0.51	-0.57	0.01	0.01
Kano	0.00	0.00	-	-
Sokoto	-0.72	-0.78	0.01	0.01

Similar results were obtained by Umar (2010) using annual rainfall series for the period 1941-2000 at Katsina, Maiduguri and Sokoto stations as presented in figure 1.The implication of this rainfall pattern is that if persisted, it will further put more stress on rural water sources and undermine the efforts at providing water for domestic use in the rural communities located in the region.

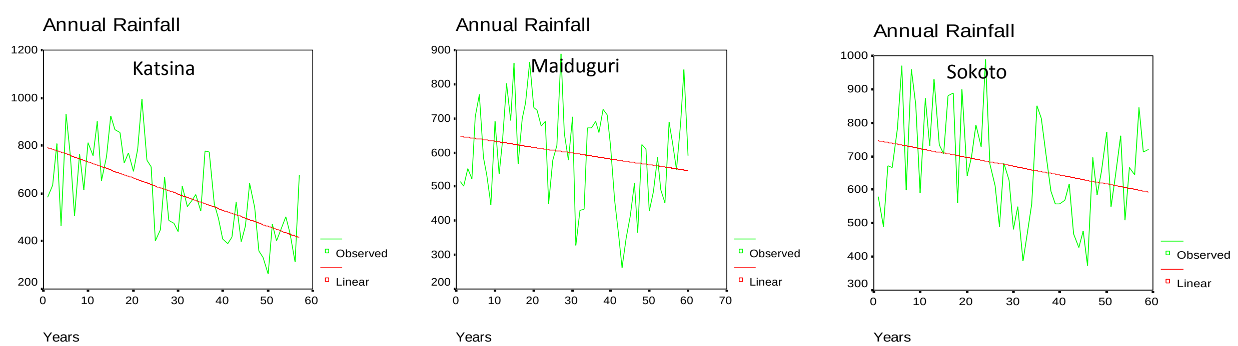


Figure 3. *Annual rainfall trend for selected stations in the Sudano-Sahelian region of Nigeria*

(After Umar, 2010)

Rainfall Anomalies in Sudano-Sahelian Region of Nigeria

The results of the stepwise multiple regression model for annual rainfall series at each of the stations considered in this study are presented in table 2. It could be observed from table 2 that the most critical variable that dominates the inter-annual variability of rainfall at Katsina is NINO 3.4 SSTs which accounts for 44.2% of the explained variance. Table 2 further shows that

the Global SSTs exercises greater control on inter-annual variability of rainfall at Nguru and accounts for 33.9% of the explained variance. It could also be observed from table 2 that the most critical variable that controls annual rainfall variability at Maiduguri is North Atlantic SSTs and accounts for 28.8% of the explained variance. It could also be observed that the only critical variable that modulates annual rainfall variability at Kano is North Atlantic SSTs which accounts for 20.7% of the explained variance in inter-annual variability in rainfall at Kano. However, at Sokoto, South Atlantic SSTs accounts for only 16.0% of the explained variance in inter-annual variability of rainfall.

Table 2. Summary of the regression of annual rainfall on SSTs and ENSO indices at the selected Sudano-Sahelian stations of Nigeria

Station	Critical Variable (s)	*R*	r^2	Significance
Katsina	Global SST	0.45	0.198	0.00
	North Atlantic SST	0.60	0.359	0.00
	NINO 3.4 SST	0.67	0.442	0.00
Nguru	South Atlantic SST	0.52	0.274	0.00
	Global SST	0.61	0.366	0.00
Maiduguri	Global SST	0.36	0.129	0.01
	North Atlantic SST	0.54	0.288	0.00
Kano	North Atlantic SST	0.46	0.207	0.00
Sokoto	South Atlantic SST	0.40	0.160	0.00

Table 3 provides a summary of the result of the Step-Wise Multiple regression of wet season rainfall of selected stations in the Sudano-Sahelian region of Nigeria on indices of SSTs and ENSO. It could be observed from table 3 that sea surface temperature variations in the East-Central Pacific region (NINO 3.4 SSTs) dominate the intra-seasonal variations in rainfall at Katsina and it accounts for 40.8% of the explained variance. Table 3 further shows that Global SSTs has the highest level of explanation as it accounts for 37.7% of the explained variance in intra-seasonal variability of rainfall at Nguru. The ENSO represented by the SOI dominates the

intra-seasonal variability of rainfall at Maiduguri as it accounts for 21.8% of the explained variance. The North Atlantic SSTs accounts for 20.7% of the explained variance in intra-seasonal variability of rainfall at Kano while at Sokoto, the South Atlantic SSTs is the only critical variable recognised and accounts for only 15.1% of the explained variance in intra-seasonal variability of rainfall. The results presented in tables 2 and 3 confirm the links between the Sea Surface Temperatures (SSTs) anomalies over the tropical Atlantic and Pacific Oceans and rainfall anomalies in the Sudano-Sahelian region of Nigeria. Such extra ordinary warming was found to significantly reduce the meridional gradient of SST south of the Inter-Tropical Discontinuity or (ITD), and as result, leads to a weakened Hadley meridional circulation. The weakened circulation reduces the intensity of the south-west monsoon flow into West and central Africa and consequently reduce rainfall in the region as demonstrated by Folland *et al*. (1986).

Table 3. Summary of the regression of wet season rainfall on SSTs and ENSO indices at the selected Sudano-Sahelian stations of Nigeria

Station	Critical Variable (s)	*R*	r^2	Significance
Katsina	Global SST	0.44	0.189	0.00
	North Atlantic SST	0.54	0.290	0.00
	NINO 3.4 SST	0.64	0.408	0.00
Nguru	South Atlantic SST	0.54	0.294	0.00
	Global SST	0.61	0.377	0.00
Maiduguri	South Atlantic SST	0.35	0.121	0.01
	ENSO Index	0.47	0.218	0.00
Kano	North Atlantic SST	0.46	0.207	0.00
Sokoto	South Atlantic SST	0.39	0.151	0.01

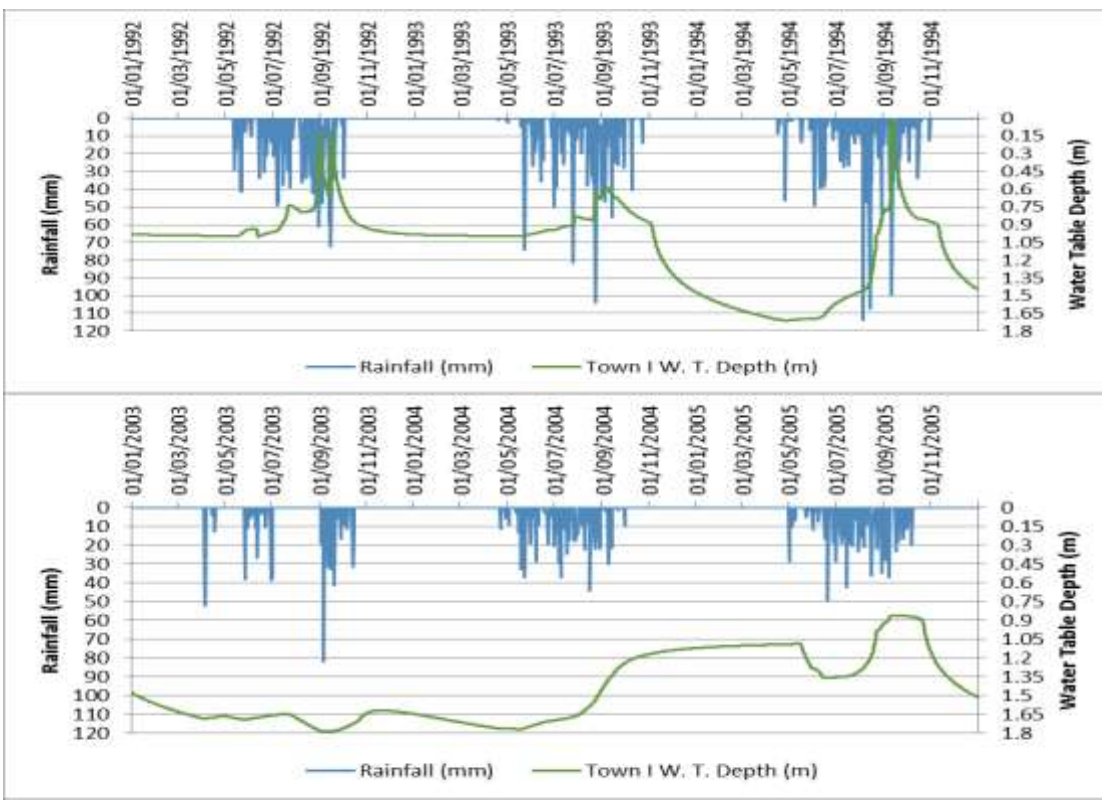
Implications for Rural Water Supply in Sudano-Sahelian Region of Nigeria.

Population increase and demand for more water in the Sudano-Sahelian region of Nigeria is putting more pressure on the already stressed available water resource. The frequent failure of boreholes and dryness of hand dug wells reported by many researchers in the region (Oteze, 1979, JICA, 1990, Oduvie, 2006, Gada, 2016, and Offodile, 2002) is not only associated with decrease in rainfall but also due to over abstraction. During the fieldwork interview, the local people confirmed that 10 – 20 years back, some of the hand dug wells that dry up in the dry season used to have water throughout the year. When the current population (2013) of the area was compared with that of 15 years back (1991), it shows that the population almost tripled, implying triple increases in water demand.

A soil moisture balance was carried out from which recharge is estimated. This recharge enters an aquifer system which is exploited for domestic purposes, for livestock and for irrigation. The Wasim model represents both the soil moisture zone and the aquifer with its storage as a single unit.

It has been found in this study that the larger parts of the anomalies in rainfall in Sudano-Sahelian region of Nigeria over the period 1951-2000 were caused by the air-sea interaction phenomena of the Sea Surface Temperatures (SSTs) and the El-Nino/Southern Oscillation (ENSO) over the tropical Atlantic and Pacific Oceans. The anomalies in rainfall are aspects of the variability in rainfall which could be too high, leading to floods, or too low, leading to droughts of various magnitudes. Thus, the most notable indicator is the reduction in recharge as indicated in the response of water table to rainfall input in Figure 4.

Figure 4: Daily rainfall and water table depth for Town Areas in the wet and low rainfall years



The groundwater table usually responds to rainfall infiltration and subsequent recharge whenever there is heavy downpour or continuous rainfall for few days consecutively. During the high rainfall years, the water table rises higher close to the surface as shown in the first part of Figure 4 for the years 1992 and 1994. During the low rainfall years (2003 – 2005) however, the water table always remains at shallow level indicating low or complete absence of water table movement in response to rainfall. The response of groundwater table movement is not dependent on only rainfall occurrence, but also the density by which it occurs. This behavior generally controls the distribution and availability or otherwise of groundwater within the study area.

Since the major sources of rural water supply (e.g. hand-dug wells, hand-pumped boreholes, rain harvesting, ponds, streams, lakes, and rivers) are climate dependent as noted in the previous studies in the African Sahel, it is obvious that perturbations in climate as symbolized in the occurrence of rainfall anomalies, could have some implications on the availability and reliability of both the ground and surface water supplies in the rural communities in the Sudano-Sahelian region of Nigeria. These implications may include the following:

1. In the event of anomalously low rainfall in the region, the already poor yield aquifers will be badly affected in form of natural water recharge of which is mainly rain-fed, and consequently pose serious water stress in the region.
2. The contamination of the '2-15groundwater may occur due to excessive too much rainfall in the region in any given year. When rainfall is anomalously high, there will be huge run-off in the region and this could lead to washing away of various industrial toxics and other pollutants that are not well-disposed off. These pollutants will eventually find their way to groundwater through natural water recharge. This may impair the groundwater quality and pose health threat to people when such water is extracted and used for domestic purposes.
3. Acute water scarcity in the event of anomalously low rainfall in region could trigger communal crises that may arise from stiff competition among population for limited water in the region. The cattle rearers for example, may clash with farmers under such conditions, since the former has to feed his animals and provide water for them even in the face of serious water scarcity in the region. He may want to continuously extract the limited water from the hand-dug wells around to give his animals while the farmer at the same time may want to extract this limited water for irrigating his crops. Hence, the clash is inevitable.
4. The rural population who rely on the flow of water in rivers and streams for fishing activities may suffer serious economic losses in the event of anomalously low rainfall in the region. The stream and river droughts may worsen if rainfall amounts continue to decline far below the long term mean in the region. The water vendors in the region are likely to suffer similar fate if rainfall anomalies in the region persist, especially in the case of anomalously low rainfall.

Conclusions

The paper examines the pattern of rainfall anomalies and trend over the period 1951-2000 and highlights its possible implications for rural water supply in the Sudano-Sahelian region of Nigeria. Both annual and seasonal rainfall series were found to exhibit a significant downward trend over the period of the study at four out of the five stations considered. Evidence of atmospheric teleconnections between rainfall in the region and anomalous Sea Surface Temperatures (SSTs) over the tropical Atlantic and Pacific Oceans were also found. The paper concludes that major sources of rural water supply in the region are at the mercy of climate. It is recommended that the ENSO and SSTs factors should be considered for forecasting of rainfall anomalies in the region. The conjunctive use of surface and ground water sources should also be adopted in order to mitigate the adverse effects of rainfall anomalies on rural water supply in the region.

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References

Alan, M. M., Roger, C. C., David, M. J. M., George, W. D., Brighid, E. O. D. 1999. What impact will climate change have on rural groundwater supplies in Africa? J. Hydrological Sciences. 54(4), 690-703.

Ayoade, J. O. 2011. Introduction to Climatology for the Tropics, Second ed. Spectrum Books Limited, Ibadan, Nigeria.

Ayoade, J. O. 2005. Introduction to Agroclimatology, Second ed. University Press Plc, Ibadan, Nigeria

Brett, A. G., Margaret, M. K., Tammo, S. 2007. Analysis of a rural water supply project in three communities in Mali: Participation and Sustainability. J. Natural Resources Forum. 31, 142-150.\

Folland, C.K., Palmer, T. N. and Parker, D. E. 1986. Sahel rainfall and world-wide sea surface temperatures. J. Nature. 320, 602 - 607.

Gada, M.A. 2016. Challenges of Water Resource Management in Sokoto Basin: A Water Balance Approach to inform decision making. In Dogara Bashir (Eds): *Water and Energy*, Proceedings of the 5th National Water Conference held at Giginya Coral

Hotel,, Western Bypass Sokoto, Tuesday 25th – Thursday 28th November, 2014

Hassan, T. I., Ajayi, P. A., Abdulrahman, A. S. 2013. Complementing water supply through rainwater harvesting in some selected villages of Sahel savannah ecological zone in Borno State, Northeastern Nigeria. J. Water Resources and Protection. 5, 200-207.

Kumar, C. P. 2012. Climate change and its impact on groundwater resources. J. Engineering and Science. 1(5), 45-60.

Maarten, D., Jacek, S. 2006. Changes in surface water supply across Africa with predicted climate change. J. Science. 311, 1917-1921.

Nyong, A. O., Kanaroglou, P. S. 1997. Demographic structure of a northern Nigerian village. Unpublished Manuscript. School of Geography and Geology, McMaster University, Hamilton, Ont.

Nyong, A. O., Kanaroglou, P. S. 1999. Water use in rural semi-arid Africa: A case study of Katarko village in Northeastern Nigeria. J. Human Ecology. 27(4), 537-555.

Odekunle, T. O., Oniarah, A., Sholademi, O. A. 2008. Towards a wetter Sudano-Sahelian ecological zone in the twenty-first century. J. Weather. 63(3), 66-70.

Ojo, O. 1977. The climate of West Africa. Heineman, London.

Olaniran, J. O. 2005. Rainfall anomalies in Nigeria. The contemporary understanding. An inaugural lecture delivered at the University of Ilorin, Nigeria., 55Pp.

Olaniran, J. O. 1991. Rainfall anomaly patterns in five wet and dry years over Nigeria. J. Climatology. 8, 542-559.

Olaniran, J. O. 1986. On classification of tropical climates for a study of regional climatology: Nigeria as a case study. J. Geografiska Annalar. 68a. 4: 543-555.

Roger, C., Alan, M. 2009. What will climate change mean for groundwater supply in Africa? Background note for Water Science and Policy Work Stream (WASP).

Tarhule, A. A., Woo, M. K. 1997. Characteristics and use of shallow wells in a stream fadama. A case study in Northern Nigeria. J. Applied Geography. 17(1), 29-42.

Umar, A. T. 2010. The changing climate: Need for effective adaptation mechanisms in Nigeria. in: Akoshile, C. O., Adeloye, A. A., Fayeye, T. R.., Ajibola, T. B. (Eds.), Climate Change Impact and Adaptation Conference, held at the University of Ilorin, Ilorin, Nigeria, November, 1 – 4, 2010, 24-37.

SUGARCANE FARMERS' PERCEPTION, CHALLENGES AND RESPONSE TO CLIMATE CHANGE IN KADUNA STATE, NIGERIA

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Abstract

Sugarcane production is important to the economic development of Kaduna State. It has contributed greatly in creating employment and serving as sources of income to farmers and the government. However, like other parts of the world, sugarcane production in Kaduna state is greatly affected by climate change. This paper therefore examined the perception, challenges and response by sugar cane farmers to climate change in Lere Local Government Area of Kaduna State. To achieve this, a total of 200 farmers were randomly sampled and administered questionnaire through the help of Sugarcane Farmers and Marketers Association in the Local Government Area. The results were summarized and presented by means of frequencies and percentages in tabular forms and charts. The study revealed that 58% of the farmers have perceived the continuous increase in temperature which has positively increased sugarcane growth during the dry season, although, such temperature increase has resulted in increased irrigation needs; temperature increase has led to the prevalence of weeds, diseases and insect pests of sugarcane; increase in rainfall amount in recent years has resulted to devastating floods which usually destroyed most of the sugarcane farms and sometimes washed away the entire farmlands along the floodplains; water stress is experienced during the dry season. While inadequate access to water for irrigation and information on weather forecasting and lack of knowledge on adaptation methods are some of the challenges farmers are faced with. The study revealed several adaptation measures adopted by the farmers to cope with the effects of climate change, among which are; introduction of new hybrid-black sugarcane; local boreholes and Planting of trees along river valleys to prevent landslide. The study recommended the need for climate change awareness/education by relevant authorities; creation of small earth dams; government and NGOs interventions to sugar cane farmers in form of loans, grants and subsidies to boost sugarcane production in the study area.

Key Words: Adaptation strategies, Challenges, Climate change, Perception, Sugarcane farmers.

Introduction

Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC, 2007). It refers to any change in climate over time, whether due to natural variability or as a result of human activity. Climate change impacts necessitate responses and adjustments to the biophysical and social conditions which together determine exposure to climate hazards. These responses may occur in form of autonomous action or through public as well as private planned, individual and institutional mechanisms. Sugar cane farmers respond to climate change through adaptation. Adaptation is the ecological, social, or economic systems in response to actual or expected climate stimuli and their impacts. Adaptation refers to changes in processes, practices, or structures to moderate or offset potential damages or to take advantage of opportunities associated with changes in climate (IPCC, 2001). It involves adjustments to reduce the vulnerability of communities, regions or activities to climatic change and variability. Adaptation is important in the climate change issue in two ways: one, to assess the impacts and vulnerabilities, two, to develop and evaluate adaptation options (Smit and Skinner, 2002).

Perception is a process by which organisms interpret and organize sensation to produce a meaningful experience of the world. Perception is the process by which we receive information or stimuli from our environment and transform it into psychological awareness (UNEP 1998). Pointedly, the Oxford Dictionary defines perception *"as the way in which something is regarded, understood or interpreted"*. In this study, sugarcane farmers' perceptions will be understood as different understandings, and/or utterances with regards to climate change deliberations. As can be imagined, these vary from person to person. Perceiving climate variability is the first step in the process of adapting agriculture to climate change (Deressa, Hassa and Ringler, 2011). A better understanding of farmers' concerns and the manner in which they perceive climate change is crucial to design effective policies for supporting successful adaptation of the agricultural sector. Further, it is also important to have precise knowledge about the type and extent of adaptation methods being taken up by farmers and need for further advances in existing adaptation setups. Hence, understanding how farmers perceive changes in climate and what factors shape their adaptive behavior is useful for adaptation research (Mertz, Mbow, Reenberg and Diouf, 2009; Weber, 2010)

There is a growing understanding that climate change poses serious challenges to development in Nigeria. The reason for this is that the mainstay of the economy of the study area is rain-fed agriculture, which is heavily sensitive to climate change and variability. According to farmers, climate related hazards, namely, flood, drought, erratic rainfall, pest and disease, hailstorms, and land slide were not new phenomena to them, but their socio-economic and biophysical effects had increased in intensity and coverage across decades. Even though they are exposed to those hazards and have a low adaptive capacity, they have survived and coped by making tactical responses to these changes.

There are critical challenges being faced by the Nigerian agriculture in trying to adapt to the problem of climate change. Both government and the private sector, which should drive the agricultural sector through consistent policies, robust funding and infrastructure development, have failed to accord agricultural adaptation the priority it deserves. In Nigeria, the traditional and predominant method of clearing farm land is through bush burning. These activities increase the concentrations of greenhouse gases (GHGs) in the atmosphere trapping heat and causing global warming, climate change and sea level rise (Medugu, 2009).

Further, there is the problem of deforestation. Garba, (2006) noted that one of the major causes of poverty is destruction of natural resources, leading to environmental degradation, high temperature, drought and consequently reduced productivity. Nigeria's forest is being depleted because of rising population, migration, land hunger, poverty and starvation. As global warming accelerates, it is expected that agricultural adaptation to climate change can only be meaningful, if irrigated agriculture gains prominence (Anselm and Taofeeq 2009). The consequences are that the increasing frequency and severity of droughts are likely to cause: crop failure; high and rising food prices; distress sale of animals; de-capitalization, impoverishment, hunger, and eventually famine. Households will probably try to cope with their cash and food shortage by cutting and selling more firewood thereby exacerbating land degradation and accelerating the onset of desertification, and by moving temporarily or permanently to more favoured areas.

Land tenure and fragmentation systems could also limit the capacity of farmers to adapt to climate change. Among most Nigerian people, farmland is not owned but held in trust by the present generation on behalf of their future descendants. It could be held by individual families, extended families or entire village communities and then fragmented to individual farmers, who only enjoy user rights. The fragmented nature of farmland could hamper the farmers' capacity to adopt innovative farming practices that may be necessary for climate change adaptation. IFAD (2010) reported that about 90% of Nigeria's food is produced by smallholder farmers who cultivate small plots of land, usually less than 1 hectare of land per household.

The prices of most agricultural export commodities have been falling in recent times as a result of decline in international prices. The farmers' incomes (producer prices) from export will therefore be static at best, if not dropping; hence, it becomes fairly difficult to sustain production (Anselm and Taofeeq 2009).

In addition, lack of access to loan or savings is another challenge. The result of a study conducted by Centre for Environmental Economics and Policy in Africa across African countries showed that lack of access to credit or saving is one of the major problems encountered by farmers in adapting to the effects of climate change. According to Ikpe, Sawa, Idoma, Ejeh and Meshubi (2016), lack of money is a major constraint to adaptation by farmers.

Inconsistent agricultural policies: Anselm and Taofeeq (2009) stated that weak infrastructure and inconsistency in government policies have always been major snags in the development of agriculture in Nigeria. Some of the problems that could result from inconsistent agricultural policies in Nigeria include: high apathy on the part of the farmers regarding anything from government because nobody knows how long such may last; erratic import policies characterized by frequent changes in both import tariffs and quantitative import restrictions, thus creating much uncertainty for producers and failure to set up a satisfactory credit system for farming and agro-processing (Anselm and Taofeeq 2009).

At the moment, there are scanty and ill-equipped weather stations, and agricultural infrastructure (Odjugo, 2010). The World Bank (2006) reported the existence of inadequate storage facilities and dilapidating agricultural infrastructure in Nigeria. The shortage of storage facilities poses serious threats to farmers in food preservation, most especially during harvest periods. As a result, most crop farmers are often in a rush to send farm produce to market immediately after harvest, not minding the associated low prices. This could act as a disincentive to investment in agriculture and hence portend serious threats to agricultural adaptation to climate change, (Mogues, et al. 2008).

Lack of education, information and training is frequently a key limiting factor to smallholder development. The report of IFAD (2010) confirmed that the poor state of the country's education has also had its toll on the poor people, majority of who are farmers in rural areas. In addition, they are faced with limited social services and infrastructure. FAO (2008) reported that about 90 per cent of Nigeria’s food is produced by small-scale farmers who cultivate small plots of land and depend on rainfall rather than irrigation systems as a result of their low knowledge base, access to facilities and poor financing.

Institutional factors often considered in the literature to influence adoption of new adaptive strategies are access to information via extension services (climate information and production technologies), access to improved varieties of grain seeds, access to loan credit. Agricultural extension enhances the efficiency of making adoption decisions (Ikpe et al., 2016).

Ikpe, et al. (2016), noted that farmers in Sokoto State are faced with the problem of lack of current knowledge on adaptation methods as a challenge to adaptation strategies; lack of access to water for irrigation; lack of improved seeds; inadequate information on weather incidence and lack of access to credit facilities. According to Caviglia-Harris (2002), any fixed investment requires the use of owned or borrowed capital. Hence, the adoption of a technology requires a large initial investment, which may be hampered by lack of borrowing capacity. Wealth is believed to reflect past achievements of farmers and their ability to bear risks. Thus, farmers with higher income and greater assets are in better position to adopt new farming technologies.

In Nigeria, sugarcane is an annual crop that depends on rainfall and irrigation. According to Gawander (2007), the amount and duration of precipitation, humidity, moisture content, temperature and soil condition has great impact on sugar cane production. Sugarcane production is an important agricultural activity in Northern Nigeria. According to Kaduna State Agricultural Development Project (2013), sugarcane is produced and sold in many local government areas (LGAs) of the state, which includes Makarfi, Giwa, Lere, Kubau and Kudan. About twenty thousand (20,000) households in the state grew sugarcane in 2013. This indicated that many employment opportunities are available within the sugarcane industry. Given these contributions, any factor affecting the industry has an impact on its contribution to the total GDP of agriculture and hence to the overall economy. Just like other agricultural sectors, sugarcane farming is expected to be affected by climate change (Deressa, Hassan and Poonyth, 2005). Several studies have been conducted to assess the impacts of climate change on agriculture, (e.g. Nzeadibe *et al*., 2011; Ishaya and Abaje, 2008; Apata, Samuel and Adeola 2009; Nze and Eboh, 2011). Most of these studies paid more attention on farmers' perception and adaptation strategies to climate change on rain-fed crops unlike sugarcane production which depends on rainfall and irrigation. To the best of the researchers' knowing, there has not been any study to assess the impacts of climate change on sugarcane production and adaptation strategies in the study area. Thus, a paucity of the study – Sugarcane farmers' perception, challenges and response to climate change in Kaduna state was carried out.

Study Area

The study Area (Lere Local Government) is located between latitudes 9^0 30' N and 10^0 10' N, longitude 7^0 20' E and 8^0 00' E (see figure 1). The local government is bounded by Kano State and Kubau LGA to the north; Bauchi and Plateau States to the east, Kauru LGA of Kaduna State to the west. It has a total landmass of 2567sq.Km^2 and population of 331,161 (NPC, 2006). The LGA experiences a tropical continental type of climate with distinct wet and dry seasons. The area has a mean annual rainfall of 1,500mm and mean monthly temperature rising from 22^0C in January and attaining a maximum of 32^0C in April. The relief of the area is generally undulating, varying in altitude from 600m to 850m above sea level. The area is surrounded by Kudaru hills on western part rising up to 2,600m, Yage hills to the northeast which rises up to 2,800m above sea level which forms the boundary with Bauchi State. The soils of the study area are basically derived from the basement complex rocks. The soils are basically leached ferruginous tropical soils, Wikipedia (2014).

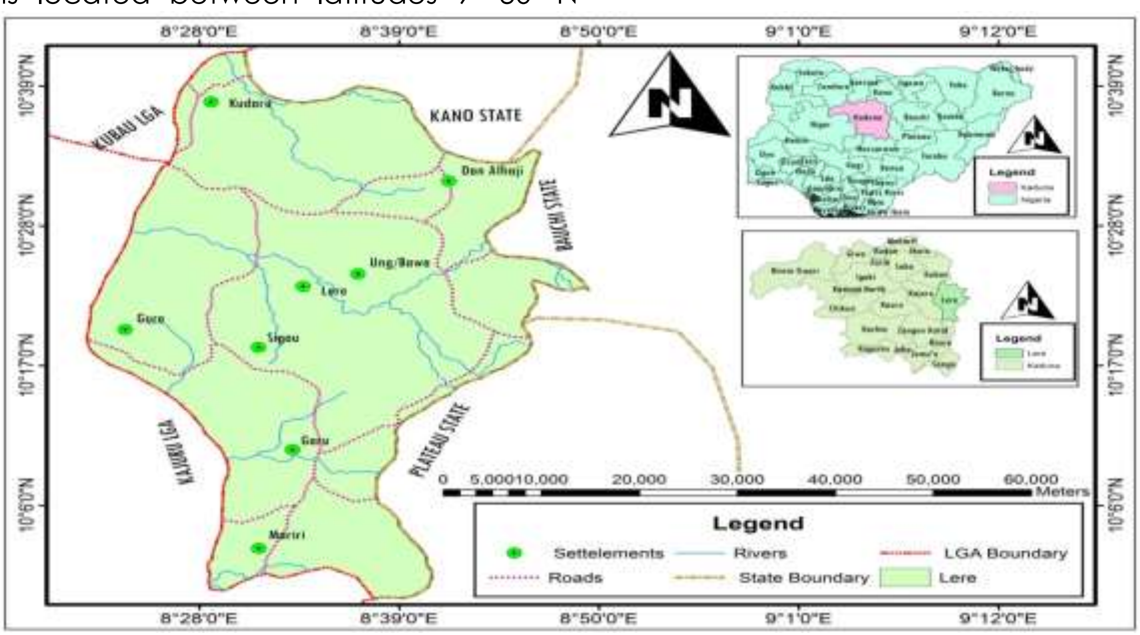


Fig. 1: Map of the Study Area

The Local Government is dissected by many rivers: rivers Rahama, Garu, Mariri, Karambana and river Gurza. These rivers and their tributaries are largely ephemeral in character and their flow regimes are highly irregular following rainfall events in the stream. Several other small streams which are the tributaries of the major rivers are found in the area. The rivers are characterized by extensive flood plains that favour the cultivation of rice, sugarcane and tomatoes in commercial quantity. The head waters of most of the rivers are experiencing gully erosion, Wikipedia (2014).

Materials and Method

Purposeful sampling technique was used to determine the respondents for the study. Households' Heads above twenty (20) years that were willing and concerned to make relevant contributions to the study regarding the incidence of climate change in the study area were purposively selected. Two hundred (200) respondents were selected and administered questionnaire from twenty (20) sugarcane farming villages in the study area (Mariri, Wauna, Gamagira, Lere, Sugau, Wauna, Lazuru, Juran Kari, Unguwan Zakari, Damau, Marji, Lugura, Jamaan Iya, Garu, Babban Fadama, Dallahaji 1, Dallahaji 2, Waila and Tudai). Only villages that were easily accessible were randomly selected. The two hundred (200) questionnaire were shared proportional to the population of each village, but due to the non-availability of population figures for each village from the 1991 and 2006 census results, the questionnaire were distributed equally among the twenty (20) villages. Ten (10) questionnaires were administered in each of the sugar cane farming communities. Out of the 200 copies of the questionnaires administered in the field, a total of 191 copies were retrieved and analyzed. The data were analyzed and presented using tables, percentages and charts.

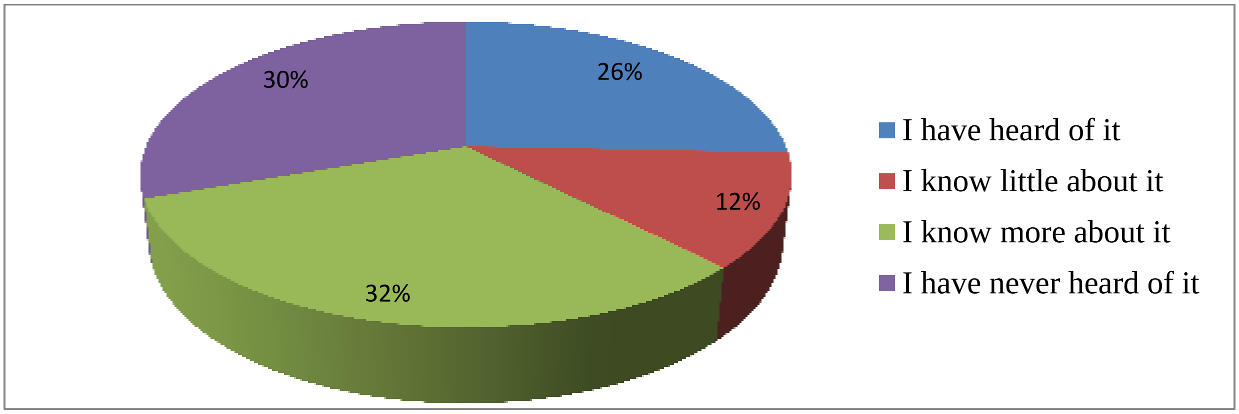
1. RESULTS AND DISCUSSIONS

Table 1: Personal Data of the Respondents

Parameters	Options	No. of Respondents	Percentages (%)
Age (years)	20 – 30	63	33
	31 and above	128	67
		191	**100**
Gender	Male	183	96
	Female	08	4
		191	**100**
Level of education	SSCE/GII	61	32
	Degree/HND	02	1
	NCE/Diploma	05	3
	No Formal Education	123	64
		191	**100**

Source: Field Work 2015

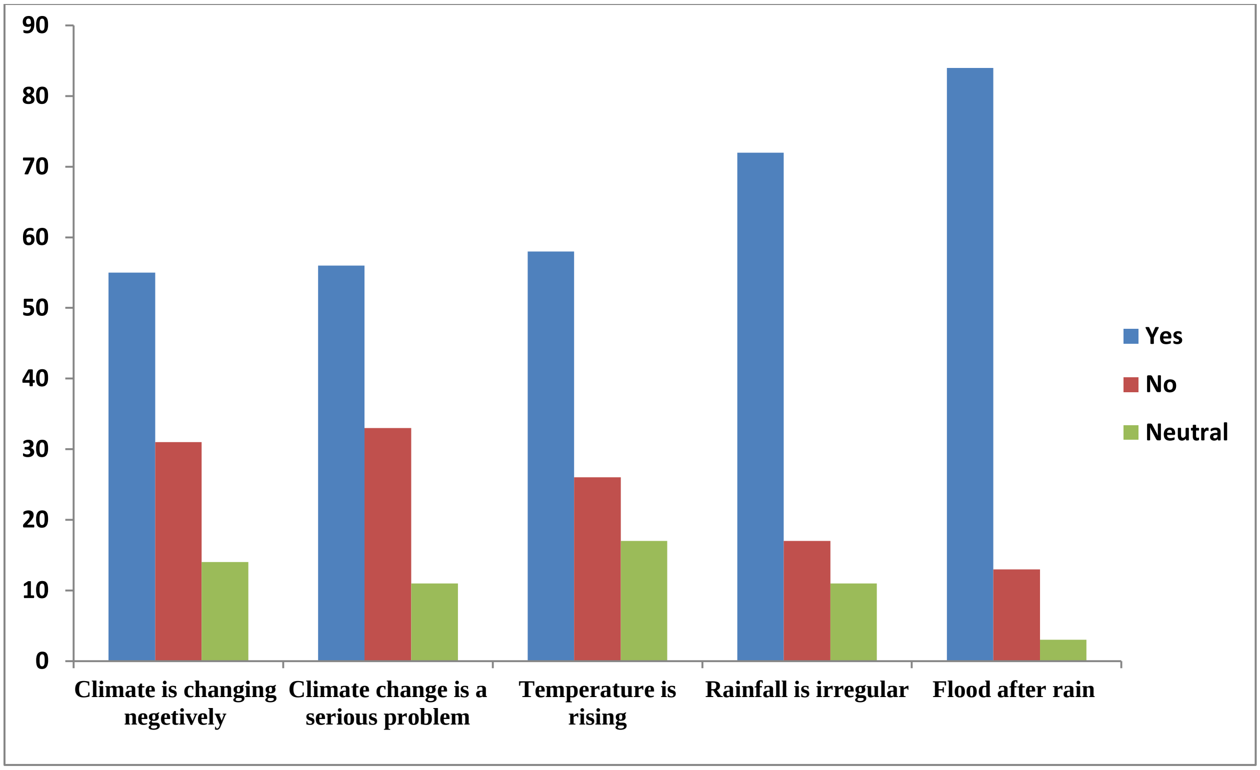
Table 1 showed that majority of the respondents (67%) falls between the ages of 30 years and above. This is an indication that the respondents were quite qualified to give information about the changes that is occurring in their environment. 96% of the sampled farmers were males while 4% were females. The results also showed that majority of the respondents (64%) did not attend formal education; this is followed by those that obtained only SSCE certificate or Grade II (32%), while 1% of the respondents are first degree holders.



Source: Field Work 2015

Figure 2: **Climate Change Awareness among Sugarcane Farmers**

Figure 2 showed that 32% of the respondents reported that they know much about climate change, 30% said they have never heard of it, while only 12% reported that they know little about climate change in the study area. The results indicated that the farmers are aware of climate change in the study area. Concerning their sources of information about climate change issues, 64% reported that they obtained their information on climate change from radio, 16% from television, while 20% from the internet, newspaper and other printed materials like fliers and posters.



Source: Field Survey, 2015

Fig. 3: Climate Change Perception among Sugarcane Farmers

As shown in Fig. 3, the results of the study showed that 55% of the respondents reported that climate change has negative effects on their environment; 31% reported that the climate is not changing negatively. 56% perceived climate change as a very serious problem in the environment; 33% reported that climate change is not a problem at all. Again, 58% of the respondents agreed that temperature in their environment is rising seriously, while 26% reported that there is no temperature increase; 73% of the respondents agreed that rainfall is becoming irregular and unpredictable each year and 84% observed that there has been an incidence of flood after rain of recent. The findings here are in agreement with scientific findings (Odjugo, 2009, 2010, 2011; Idowu, Ayoola and Ikenweiare 2011; Mishek, 2013), which reported the indicators of climate change as increasing temperature, irregular and unpredictable pattern of rainfall including prolong dry-spells, acute drought among others.

Table 3: Adaptation Strategies by Sugarcane Farmers

Adaptation Option	Yes
1. Introduction of new hybrid black sugarcane breed	90%
2. Small earth dams using used-cement bags to block streams	54%
3. Use of local implements to dig the dry river valley for water	65%

4.	Digging of local bore-holes	83%
5.	Use of Pumping machines to replace local method of pumping water	92%
6.	Planting of trees along river valleys to prevent landslide	41%
7.	Shifting away from land that is prone to landslide	55%
8.	Use of chemical fertilizer to boost sugarcane yield	95%
9.	Mulching to protect sugarcane from water loss	61%

Source: Field Survey, 2015

Sugarcane farmers in Kaduna state adopt several adaptation strategies as a way of coping with the impacts of climate change on sugarcane production in the study area. Table 2 illustrated the several adaptation strategies by sugarcane farmers to cope with the impacts of climate change. 90% of the respondents reported that they have replaced the traditional breed of sugarcane with a more improved variety which is capable of enduring the harsh climatic condition of the environment; 54% reported that in order to cope with extreme water shortage during the dry season, they usually create local earth dams by blocking the streams with used bags of cement filled with sand and then utilize the water in the dam during water stress. In line with this also, majority of the respondents use local implements, like hoes (small and big), shovels etc. to dig the dry river valley for boreholes during water stress in search of water for irrigation. 92% reported that they use modernized pumping machines which presently replace the use of buckets for watering the sugarcane farms during the dry season.

To prevent the river banks from excessive landslides, 41% reported that they plant trees and cover crops along it while 55% reported that they shifts away from any area that is prone to flood and landslide each year. 94% of the respondents affirmed that they use chemical fertilizers. The chemical fertilizers were found to be very effective in making the sugarcane stick to grow bigger and taller ahead of the water level during the excessive flood. Also, 61% of the respondents were discovered to practice mulching which helps to prevent sugarcane roots from excessive water loss during the dry season period.

Sugar cane farmers' challenges to climate change adaptation

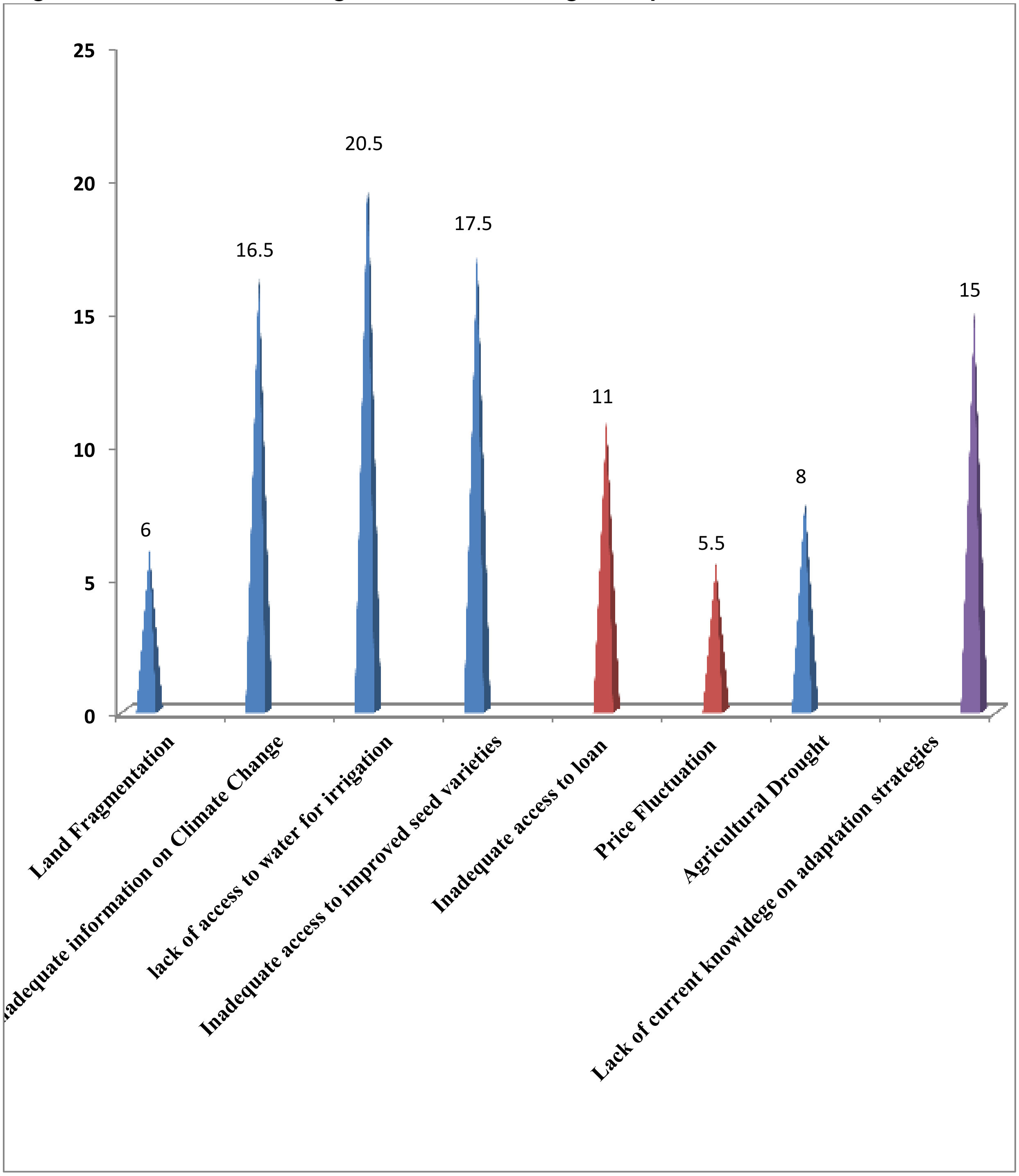


Fig. 4: Sugar Cane farmers' challenges to climate change
Source: Field work 2016

The analysis of the challenges encountered by the sugarcane farmers in the study area is shown in Fig. 4. The common challenges as analyzed are lack of access for irrigation, inadequate access to improved seed varieties, and inadequate information on weather related issues, lack of current knowledge on adaptation strategies, price fluctuation and agricultural drought.

Summary of the Findings

The study has evaluated the sugarcane farmers' perception, challenges and response to climate change in Kaduna state. The study has achieved to a large extent the objective of the study which is to find out the level of awareness on climate change, how sugarcane farmers respond to climate change and the challenges the farmers faced in cultivating sugar cane in the study area.

The study revealed that 58% of the farmers have perceived the continuous increase in temperature which has positively increased sugarcane growth during the dry season, although, such temperature increase has resulted in increased irrigation needs; temperature increase has led to the prevalence of weeds, diseases and insect pests of sugarcane; increase in rainfall amount in recent years has resulted to devastating floods which usually destroyed most of the sugarcane farms and sometimes washed away the entire farmlands along the floodplains; water stress is experienced during the dry season. While inadequate access to water for irrigation and information on weather forecasting and lack of knowledge on adaptation methods are some of the challenges farmers are faced with. The study revealed several adaptation measures adopted by the farmers to cope with the effects of climate change, among which are; introduction of new hybrid-black sugarcane; local boreholes and Planting of trees along river valleys to prevent landslide.

Recommendations:

Based on the findings made in the study, the following recommendations are made:

- **i.** There is need to raise more awareness on climate change in the area. Government agencies and NGOs can help to educate the Nigerian farmers and the general public on the reality and impacts of climate change on the environment, agriculture, human and animal health.
- **ii.** There is need for government's intervention in providing funds to the farmers to boost their sugarcane production. The funds can be in the form of loans, grants or subsidies.
- **iii.** Construction of standard dams with well-connected drainage channels across the farmlands is imperative in the area as this will enable the farmers to make use of the available water in the dams during water deficit in the area.
- **iv.** There is need to build artificial levees alongside most of the

streams in the area to prevent the destructive annual flood. This can be done by the Government, NGOs or the collaboration of both.

v. There is need for government, NGOs and the farmers to provide new farming technologies in the area. Tractors, giant pumping machines, standardized boreholes and fertilizers should be provided to farmers at subsidized rate.

vi. Government policies should therefore ensure that farmers have access to improved seed varieties, chemical fertilizer, water for irrigation and affordable credit as these increases the resilience of farmers to climate variability.

vii. Farmers' education development on new mitigation and adaptation to climate change should be ensured through extension agents in the area. The farmers should be educated on the importance of tree-planting and dangers of felling tree without replanting.

Reference:

Anselm, A. E. and Taofeeq A. A. (2010). Challenges of Agricultural Adaptation to Climate Change in Nigeria: a Synthesis from the literature. A conference paper held on 27th July 2010 at Enugu, Nigeria.

Apata T.G., Samuel K. D and Adeola A. O. (2009) Analysis of Climate Change Perception and Adaptation among Arable Food Crop Farmers in South Western Nigeria. A paper prepared for presentation at the International Association of Agricultural Economists' 2009 conference, Beijing, China.

Caviglia-Harris, J. (2002). Sustainable Agricultural Practices in Rondônia, Brazil: Do Local Farmer Organizations Impact Adoption Rates, Department of Economics and Finance, Salisbury University.

Deressa, T. T., Hassan, R. M., and Ringler, C. (2011). Perception of and Adaptation to Climate Change by Farmers in the Nile basin of Ethiopia, J. Agric. Sci., 149, 23-31, 2011.

Deressa, T., Hassan R., Poonyth, D. (2005). Measuring the Impact of Climate Change on South African Agriculture: The Case of Sugarcane Growing Regions. *Agrekon,* 44(4) pp 1 – 19.

FAO (2008). Hunger on the Rise. *Food and Agriculture Organisation.* Retrieved August 7, 2010 from *http://www.fao.org/newsroom/EN/news/*

Garba, A. (2006) Alleviating Poverty in Northern Nigeria. Being a Paper Presented at the Annual Convention of Zumunta Association at Minneapolis United State of America from July 28-29, 2006.

Gawander J. (2007). Impact of Climate Change on Sugar-cane Production in Fiji. WMO Bulletin 56(1).

Journal of Geography and regional Planning, 1(8):138-143.

Idowu, A. A., Ayoola, S. O. and Ikenweiwe A. I. (2011). Impact of Climate Change in Nigeria. *Iranica Journal of Energy and Environment,* 2(2) pp. 145 - 152

IFAD (2010) Rural Poverty in Nigeria: Agriculture in the Federal Republic of Nigeria. International Fund for Agricultural Development. Retrieved August 7, 2010 from http://www.ruralpovertyportal.org/web/guest.

Ikpe, E., Sawa B. A., Idoma K., Ejeh L. and Meshubi A. (2016). Shift in Crop Production as an Adaptation Strategies to Climate Change by Grain Farmers in Goronyo Local Government Area of Sokoto state, Nigeria. *International Journal of science for global sustainability*, 2(1). 106 - 113

IPCC (2007), Climate Change 2007, Synthesis Report Summary for Policy Makers. Available at: http://www.ipcc-wg1-report-htm.pp1-15

IPCC, (2001*). Climate Change 2001: The Scientific Basis. The contribution of working Group I to the Third Assessment Report of the International Panel on Climate Change IPCC Cambridge.* Cambridge University Press, Cambridge.

Ishaya, S. and Abaje, I. B. (2008). Indigenous Peoples' Perception on Climate Change and Adaptation Strategies in Jema'a Local Government Area of Kaduna State, Nigeria,

Medugu, N. I (2009) Nigeria: Climate Change - A Threat to the Country's Development. http://www.allafrica.com/nigeria/

Mertz, O., Mbow, C., Reenberg, A., and Diouf, A. (2009). Farmers' Perceptions of Climate Change and Agricultural Adaptation Strategies in Rural Sahel, Environ. Manage. 43, 804-816.

Mishek, C. (2013). Potential Impacts of Climate Change in Sugarcane and Mitigation Strategies in Zimbabwe. *African Journal of Agricultural Research*, 8(23) pp. 2814 - 2818

Mogues, T; Morris, M; Freinkman, L; Adubi, A; Ehui, S; Nwoko, C; Taiwo, O; Nege, C; Okonji, S.P; and Chete, L. (2008). Agricultural Public Spending in Nigeria. *International Food Policy Research Institute* Discussion Paper 00789.

National Population Commission, NPC. (2009). National Population Commission Census Report, Federal Republic of Nigeria.

Nze, E. C. and Ebo, O. R. (2011), Technological Challenges of Climate Change Adaptation in Nigeria: Insight from Enugu state. *African Technology policy network.* 52:1-5.

Nzeadibe, A. C., Cukwuome, N. A., Egbule, C. L. and Agu, C. L. E. (2011). Climate Change Awareness and Adaptation in the

Niger Delta Region of Nigeria, *African Technology network*, Pp.65-83.

Odjugo, P. A. (2010). Shift in Crops Production as a means of Adaptation to Climate Change in the Semi-Arid Region of Nigeria in *Journal of Meteorology and Climate Science* Vol. 8(1), 1-6.

Odjugo, P. A. (2011). Climate Change and Global Warming: The Nigerian Perspective In Journal Of "Sustainable Development And Evironmental Protection. Vol. 1 No. 1.

Odjugo, P. A. O. (2009). Global and Regional Analysis of the Causes and rate of Climate Change. Proceeding of the National Conference on Climate Change and Nigerian Environment held at the Department of Geography, University of Nsukka, Nsukka, Nigeria, 29th June — 2nd July, 2009.

Smit, B. and Skinner, M. W. (2002). Adaptation Options in Agriculture to Climate Change: A Typology. Mitigation and adaptation Strategies for Global Change. *African Journal of Agriculture and Resource Economics,* 3(5):78-82.

UNEP, (1998). Handbook on Methods for Climate Impact Assessment and Adaptation Strategies; 2 (Freenstra, J. I., Burton: Smith J. and Tol R. (EDS) United Nations Environment Programm, Institute for Environmental Studies, Amsterdam, The Netherlands, 359, pp

Weber, E. U. (2010). What Shapes Perceptions of Climate Change? *Wiley Interdisciplinary Reviews: Climate Change,* 1, 332-342.

Wikipedia (2014). Lere, Kaduna State, available at www.en.wikipedia.org/../Lere_Kaduna_State retrieved on 20/10/15

World Bank, (2006) 'Nigeria: Competitiveness and Growth', jointly prepared with DfID, Africa Region, 20 September 20

Kassam, A. H. and J.M. Kowal, 1975. Water use, energy balance and growth of gero-millet at Samaru, Northern Nigeria. Agric. Met. 15, 333 – 342.

Maduakor, H.O. 1991. Physical and Hydrolic properties of soils of the Suddanno – Sahilian region of Nigeria. IAHS Pub. no. 199

Oluwasemire, K.O., J.J. Owonubi, E.O. Oladipo, S,S,. Jagtab and C.J. Stigter, 1995. Microclimate improvement and soil protection aspects of inter cropping with leguminous (cover) crop. The TTMI – project and the Picnic model. Wageningen Agric. University, Netherlands.

Sivakumar, M.V.K. 2005. Impacts of natural disasters in Agriculture range land and forestry : an overview. Eds. Sivakumar, Motha, Das, Natural disasters and extreme events. Springer pub.

Comparing double ring and mini ring infiltrometer data for predicting infiltration characteristics of an Alfisol in northern Guinea savanna of Nigeria

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ABSTRACT

Water infiltration is one of the most important hydraulic properties of a soil in hydrological research, but presents practical difficulty in measurement. The commonly used double ring method requires significant amounts of water during field measurement. With climate change projections of less rain in the dry ecological zones and existing water scarcity in the semi-arid agroecological zone, the need to conduct simple, reliable yet water-saving method of determination with mini infiltrometer rings becomes crucial. This study was conducted on an Alfisol at the Institute for Agricultural Research (IAR) Farm, Samaru, Northern Guinea Savanna of Nigeria, using the conventional double ring infiltrometer with an outer ring diameter of 55cm and inner ring diameter of 30 cm, both 30cm in length, and with a mini single ring (diameter of 8 cm by 12 cm length) to measure soil infiltration. A total of 30 points were selected at a uniform sampling interval of 3.5m along the field for each measurement type. Parameters of three common infiltration (Horton, Kostiakov and Philip's) equations could be predicted from field measured data, and the best fitting equation identified. From each measurement, data was used to determine Infiltration parameters of the three equations by regression technique. Philip and Kostiakov's equations with regression coefficient (R^2) ≥0.99, adequately described the infiltration data from both measurements using linear and non-linear regression, respectively, and both equations performed better than the Horton's equation with R^2 value of 0.6449 for the double ring to as low as 0.2301 for mini ring. Mean R^2 from measured and predicted infiltration characteristics of 0.980, 0.975 and 0.781 from Kostiakov, Philip and Horton's equation respectively, with the lowest standard error of mean (SEM) observed from Kostiakov's equation with the double ring infiltrometer data. This study showed that the mini ring can be used in place of the double ring infiltrometer to predict the infiltration characteristics of Alfisols in northern Guinea savanna of Nigeria, to save water, cost and labour involved with the conventional double ring method. This will depend on the infiltration equation intended for a particular study or applications in other hydrological models or research.

Keywords: Infiltrometer, least sum of squares, regression, standard error of mean.

Introduction

Water infiltration is one of the most important hydraulic properties of a soil in hydrological research. Infiltration is one of the major components of the hydrologic cycle and constitutes the sole way by which water moves into the soil to sustain the growth of vegetation and replenishes the ground water supply to wells, springs and streams (Oram, 2005). However measurement of infiltration presents with practical difficulty. The commonly used double ring method requires significant amounts of water during field measurement. With climate change projections of less rain in the dry ecological zones and existing water scarcity in the semi-arid agroecological zone, the need to conduct simple, reliable yet water-saving method of determination with mini infiltrometer rings becomes crucial.

Soil infiltration measurement methods are often time consuming, expensive and laborious with the conventional double ring infiltrometer. Despite the fact that lateral flows are not controlled with single ring measurements, data from single rings infiltrometers were found to closely describe soil infiltration characteristics as the double ring (Abdulkadir et al., 2016).
Infiltration equations such as those by Kostiakov (1932), Horton (1940), Philip (1957) and many others have gained wide spread usage in infiltration studies the world over. These infiltration equations have been tested in different locations to determine compatibility with measured data and ranking the models' performance (Wuddivira *et al*., 2001; Shukla *et al*., 2003). Infiltration characteristics of the soil are quantified when field infiltration data are fitted mathematically into infiltration equations (Oku and Aiyelari, 2011). The objective of the study is to fit infiltration data from double ring and mini ring infiltrometers into Kostiakov, Philip and Horton's infiltration equations and to test the applicability of the three equations in predicting water infiltration into soils of the study site from the two measurements.

Materials and method

The study was carried out on a fallow plot at the Institute for Agricultural Research (IAR) farm, Samaru with coordinates N 11° 09. 943', E 007° 37. 958'. and 686m above the sea level. The area is situated In the Northern Guinea Savanna ecology of Nigeria. Soils are leached tropical Ferruginous classified as Typic Haplustalf according to USDA soil taxonomy. The area has a mono-modal rainfall pattern with long-term average annual rainfall of 1011± 161mm concentrated mostly in five months (May/June to September/October) and mean daily temperature of 24°C (IAR, 2016).

Infiltration experiments were conducted with two infiltrometers i.e the double ring and the single mini ring infiltrometer on a total of 30 points selected at a uniform sampling interval of 3.5 m. A double ring infiltrometer with outer ring dimension of 55cm in diameter by 30 cm in height, and inner ring dimension of 30cm by 30cm were installed into the soil by hammering with minimum disturbance to a depth of 10cm.The outer ring was first ponded with water to a constant depth which acts as the buffer zone before ponding the inner ring to the same depth as the outer ring. Depth of water infiltration was taken immediately with a graduated ruler at every 1min for 5 minutes, every 5 minutes for the next 30 minutes and every 30 minutes until 120 minutes. Data collected was used to calculate the cumulative infiltration and infiltration rate using the instantaneous values. Data were also fitted into the three infiltration equations as follows.

Infiltration equations

Horton's (1940) Equation

$$f = f_c + (f_o - f_c)e^{-\beta t} \quad (1)$$

where, f= infiltration rate at any time, T; f_c and f_o= final and initial infiltration rates; β= constant, t= time

Kostiakov's (1932) Equation

$$I = \beta t^n \quad (2)$$

Where I is cumulative infiltration (L)

t is time (T);

β and n are fitting parameters.

Philip's (1957) Equation

$$I = St^{1/2} + At \quad (3)$$

Where

I is cummulative infiltration rate(L); t is time, (T)

S is sorptivity, ($L/T^{0.5}$), A is a parameter depending upon the ability of the soil to transmit water (L/T).

Results and Discussion

Infiltration parameters from all measurement points and type were obtained from linear and non-linear regression for the three equations. Philip and Kostiakov's equations with regression coefficient (R^2) ≥0.99, adequately described the infiltration data from both measurements using linear and non-linear regression, respectively. Both equations performed better than the Horton's equation with R^2 value of 0.6449 for the double ring to as low as 0.2301 for mini ring. Mean R^2 from measured and predicted infiltration characteristics of 0.980, 0.975 and 0.781 from Kostiakov, Philip and Horton's equation respectively, with the lowest standard error of mean (SEM) observed from Kostiakov's equation with the double ring infiltrometer data (Table 1). For both measurements, R^2 values obtained were highest for Kostiakov's equation than Philip's and Horton's equation. Kostiakov's equation had the lowest SEM (Table 1) which is considered the best fitting with measured infiltration data. Across all the measurement points, R^2 values of measured and predicted infiltration characteristic from the three equations are presented in Figure 1. Data from both mini ring and double ring infiltrometer show a better fit of the Kostiakov's and Philip's model than the Horton's model. This is indicated in the boxplot with more variation and range of the R^2 values obtained with the Horton's model.

Several studies have been conducted to establish equations parameters, validate models or compare models efficiencies and applicability for different soil conditions. Igbadun and Idris (2007) investigated the capacity of Kostiakov's, Philip's, Kostiakov-Lewis' and modified Kostiakov infiltration equations to describe water infiltration into a hydromorphic soil of the flood plain in Zango village, Samaru, Zaria, Nigeria. They reported that although the four equations provided good overall agreement, Kostiakov's and modified Kostiakov's equations were found to provide best fit. Musa and Adeoye (2010) in their study to adapt infiltration equations to the soil of the

Table 1: Summary of Regression Coefficients (R^2) of measured and predicted infiltration characteristics from three different infiltration models from double ring infiltrometer data.

	Horton	Philip	Kostiakov
MEAN	0.781	0.975	0.980
SEM	0.033	0.01	0.007

- SEM= standard Error of Mean

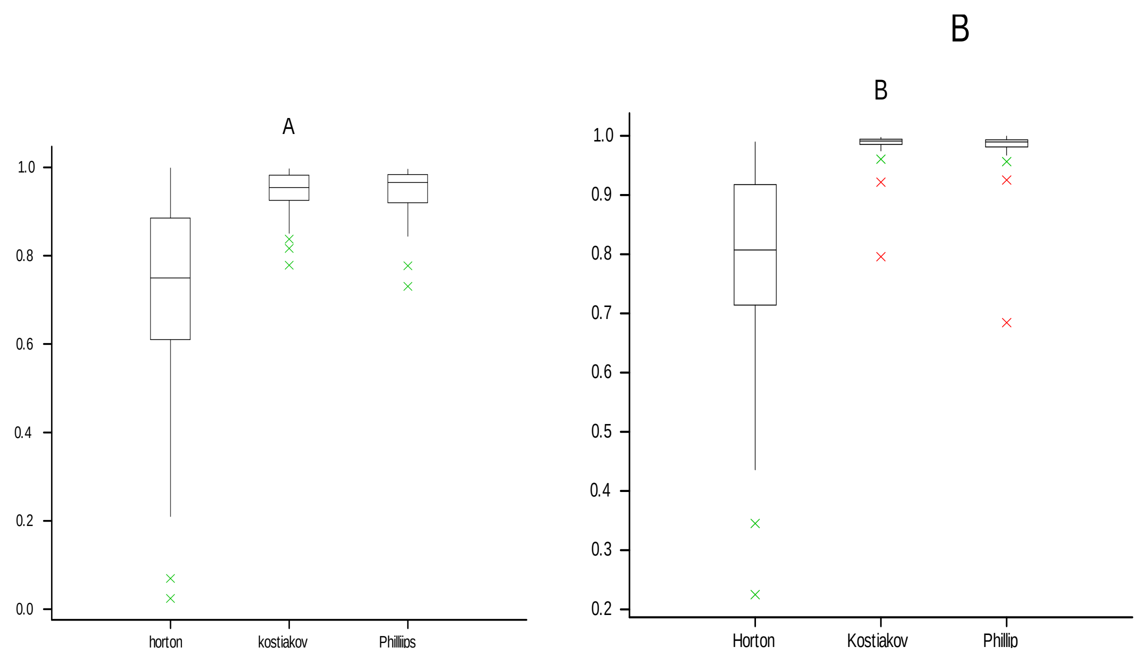

Figure 1: Box plot of regression coefficient (R^2) for the three infiltration equations from infiltration data measured with (A) mini ring and (B) double ring infiltrometer

permanent site farm of the Federal University of Technology, Minna, in the Guinea Savannah Zone of Nigeria stated that Kostiakov's model showed a better performance over those of Philip and Horton's models.

Oku and Aiyelari (2011) deduced that Philip's equation was more suitable than Kostiakov's from a study of the infiltration capacity of Inceptisols of the humid forest of southern Nigeria. Girei et al. (2014) conducted an experiment where the predicted infiltration characteristics of Samaru Alfisols using three infiltration equations namely Philips, Horton and Kostiakov and he reported applicability of all the models in predicting infiltration characteristics with Kostiakov's equation giving the best fit. All these studies used data from double ring infiltrometer measurement. Few or no study exists on fitting data from mini ring infiltrometer measurements in predicting soil's infiltration characteristics.

Conclusion

This study showed that data from the mini ring infiltrometer can be fitted in the three predictive infiltration equations. This indicates that mini ring infiltrometer can be used successfully to predict the infiltration characteristics of Alfisols in northern Guinea savanna of Nigeria and can to save water, cost and labour involved with the conventional double ring method. This will depend on the intended infiltration equation for a particular study or applications in other hydrological models or research as the Kostiakov and Philip's equation showed a better fit in data from the two measurements.

References

Abdulkadir, A., Wudivira, M. N., Abdu, N., and Mudiare, O.J. (2011). Use of Horton infiltration model in estimating infiltration characteristics of an alfisol in the northern Guinea savanna of Nigeria. *Journal of Agricultural Science and Technology*, 925-931.

Abdulkadir, A., Hyelatakiri, B., Ogunsola, O. E., Jibril, I. and Girei, A.H. (2016). Comparing infiltration characteristics of soils using single and double ring infiltrometer. A paper presented at the 40th Soil Science Society of Nigeria Annual conference, Calabar. 14th -18th March, 2016.

Girei, H.A. (2014). Hydraulic characteristics and temporal variability of soil Properties under a long-term trial in Samaru, northern Guinea savanna of Nigeria. (Unpublished master's thesis) Department of Soil Science, Ahmadu Bello University, Zaria.

Horton, R.E. (1940). An approach toward a physical interpretation of infiltration-capacity. *Soil Science Society of American Proceedings*. 5, 399-417.*Hydralogy. Division. ASCE* 96, 2535–2548.

Igbadun, H.E. and Idris, U.D. (2007). Performance evaluation of infiltration models in a hydromorphic soil. *Nigeria Journal of Soil and Environmental Research*, 7: 53 – 59.

Kostiakov, A. N. (1932). On the dynamics of the coefficient of water-percolation in soils and on the necessity of studying it from a dynamic point of view for purposes of amelioration. Trans. Com. *International Society of Soil Science*. Moscow, Part A, pp. 17-21.

Musa S.J. and Ayodele, E.A., (2010). Comparison of estimation methods of soil in five soils. R. Bras. Ci. Solo, 33:487-495

Oku, E. and Aiyelari, A. (2011). Predictability of Philip and Kostiakov infiltration model under inceptisols in the Humid Forest Zone, *Nigeria. Kasetsart Journal* , 45: 594 -602.

Oram, B. (2005). Hydrological Cycle. Watershed Assessment, Education, Training, Monitoring Resources in Northeastern Pennsylvania. Wilkes University. Environmental

Engineering and Earth Sciences Department. Wilkes-Barre, PA http://www.water-research.net/watershed/hydrologicalcycle.htm. Accessed 8/29/06.

Philip, J. R., (1957), "The Theory of Infiltration: 1. The Infiltration Equation and Its Solution," *Soil Science Society of America Journal*, 83(5): 345-357.

Shukla, M.K., Lal, R. and Unkefer, P. (2003): Experimental evaluation of infiltration models for different land use and soil management systems. *Soil Science,* 168: 178 - 191

Wuddivira, H.N., Abdulkadir, A. and Tanimu, J. (2001): Prediction of infiltration characteristics of an Alfisol in the Northern Guinea Savanna of Nigeria. *Nigerian*

Journal of Soil Research, 2: 1 – 5.

Spatio-Temporal Assessment of the Impact of Urban Sprawl on Urban Heat Island in a Derived Savannah

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Abstract:

The study investigated the impact of landuse change due to urbanization on urban heat island formation in the tropical region of Southwestern Nigeria using satellite data, spanning a period of 29 years starting from 1986 to 2015. The changes in the land cover pattern and its influence on land surface temperature (LST) and surface urban heat island (SUHI) was examined in this study. Landsat imageries of 1986 and 2015 covering Southwestern Nigeria were used to examine the dynamics of Landcover, LST and UHI. The results suggested that urban heat island effect of the city was best reflected by the pattern of landuse change and urban form. Over the years, the gradual transition of landuse from suburban to urban land in peri-urban districts around the highly urbanized Osogbo, Southwestern Nigeria, resulted in an increase of 11.12% in built-up areas. UHI was observed to be on the increase, especially in areas where the rate of landuse conversion through urbanization and population growth was highest. In 1986 the average temperatures of highly urbanized and peri-urban settlements were found to be (1 - 2) degree Celsius higher than that of the surrounding countryside. However, by 2015 after significant landuse conversion, the difference increased to between (3 to 4) degrees Celsius. The findings of this study also suggest that urban heat island formation in tropical region is sensitive to the feedback interaction between landuse change and climate.

Keywords: Urban Heat Island, Land use/land cover, Climate Change, Urbanization, Land Surface Temperature

2. Introduction:

The world is increasingly becoming urbanized and the rate at which city populations grow and countries urbanized is indicative of the pace of social and economic change (Donk, 2006). Before now, majority of the world population has lived primarily in rural areas, by 2030; roughly 60% of the world population is expected to reside in urban centres (UN, 2006). In comparison, the world's rural population is expected to decline thus nearly the entire future population growth is expected to be in towns and cities (UN, 2006).

Because of their built environment, cities create their own micro-climate, which generally enhances the effects of global climate change (Grimmond, 2007). There is growing appreciation that the populations, infrastructure and ecology of cities are at risk from the impacts of climate change. The impacts of different land uses for example in urban areas, can also lead to an increase in temperature at the city center compared to the surrounding country side, known as the UHI effect (Squires, 2002; Burchell, 2002). Thus the average temperatures of cities and towns become 2 – 6 degrees Celsius more than that of the surrounding countryside (Parker, 2010). Different factors contribute to the UHI such as roofs covering material, urban structure, existence of vegetation, street width, directions, etc. The UHI significantly affect the human health, living conditions, increase energy consumption and atmospheric pollution (Rizwan *et al*., 2008). Numerous studies have focused on the impact of the urban heat island on urban environment (Chen *et al*., 2006; Hart and Sailor, 2009; Zhi *et al*., 2014). Most of the known studies of the urban climatology of tropical cities focus mainly on the diurnal analysis based on data collected over a short period of time. Related examples abound in the investigation carried out by Nakamura (1967) in Nairobi, Kenya, where the urban minimum temperature was observed to be greater than that at the International Airport (suburban) by 1.3K. Oguntoyinbo (1984) also observed that the heat island in Ibadan was between 5.0 K and 7.5 K, in the month of March. Adebayo (1987) reported that the mean heat island, reflected by the night-time minimum temperature, is about 1.0 K during the dry season, and 0.5 K during the rainy season.

Remotely sensed data have a great importance to monitor impacts of different environmental Issues. Remote sensing data supply a practicable approach for the investigation of both phenomenon of landuse change (Weng, 2002) and LST (Weng *et al*., 2004) on wide spatial and temporal scales. Remote sensing techniques have been used for monitoring the spatio-temporal and dynamic changes in land use/land cover at regular intervals, using optical and near infrared bands of multi-temporal remote sensing satellite data such as Landsat TM images. The thermal band in Landsat satellite series i.e. (MSS, TM and ETM +) have also been proven to have a crucial role in estimating surface temperature. Different algorithms developed by different authors have been used to extract landuse/landcover change (Herold *et al*., 2005) and land surface temperature (LST) from remote sensing data for several decades. Geographic Information System provides the platform on which data on such images are stored, processed and analyzed for decision making (Maguire, 1991). Thermal infrared remotely sensed data in the bandwidth of 10.4-12.5 μm, acquired over urban areas during the day and at night available from Landsat-7 Thematic Mapper and Enhanced Thematic Mapper (TM and ETM+), which has 60 m resolution in thermal region have been used to monitor the heat island effect associated with urban areas (Cornelis *et al*.

1998, Rahman, 2007). Another example of urban heat island studies in the tropical area using satellite data is the work of Kandoum *et al.* (2014), who carried out an investigation of the effect of increase in impervious surface area due to urbanization on the temperature using thermal bands of the Landsat data observed that mean heat island in Ibadan increased by 7.485 kelvin over a period of 22 years from 1984 to 2006. It was in view of the remarkable rate of urbanization in Osogbo and surrounding districts within the last few decades and the need to carry out more studies on the urban climate of tropical cities that this study was conceived. The effect of urbanization on the urban heat island is therefore being examined in the study area.

3. Methodology

Study Area: The study area was Osogbo and the ten local districts that surrounds it, which is located in Osun State, in the South western region of Nigeria, located within latitude 7 ⁰ 46"N and 7 ⁰ 48" N and between longitude 4 ⁰ 31'E and 4 ⁰ 35'E. The area of study includes Osogbo, Ede North, Olorunda, Obokun, Egbedore, Ede South, Orolu, Ifelodun, Boripe, Atakumosa West and Ilesa West (Figure 1). The rapid pace of urbanization of Osogbo which can be dated back to 1991 when it became the capital city of the newly created Osun State (Abegunde, 2009), also affected the surrounding towns and settlements and many areas that were covered with vegetation, bare surfaces and water bodies in 1986 have drastically changed into built up. Not long after the state was created towns like Osogbo, Ede North, Olorunda and Ifelodun began to experience increase administrative and economic activities leading to rural-urban migration for people in search of greener pastures. At the same time the numbers of commercial and residential buildings continue to increase while the construction of roads, buildings, factories, and manufacturing plants became more rampant. The phenomenal growth in the population overtime is related to the introduction of modern technology and administration as Osogbo became a growth center that pulled population from its neighbouring settlements through its centripetal forces of railway station, Steel rolling mill, Machine tool industries and commercial activities. Road transport allowed dispersal of development in all direction from the traditional core. As the population keeps increasing, further development in housing and other related services occurs.

Osogbo has over the years become a capital with several core areas.

The climate of Osogbo is dominated by the influence of three major wind currents, namely; the maritime tropical (mT) air mass, the continental tropical (cT) air mass and the equatorial easterlies (Odekunle, 2004). The mT air mass originates from the southern high-pressure belt located off the coast of Namibia, and in its trajectory, pick up moisture from over the Atlantic Ocean, crosses the Equator and enters Southwest Nigeria (Omogbai, 2010). The cT air mass originates from the high-pressure belt north of the Tropic of Cancer. It picks up little moisture along its path and is thus dry. This influences the dry harmattan season. The harmattan season occurs in the middle of the dry season around December and extends till February and March where it clears off as rainy season approaches. The season is thus characterized by low insolation as a result of dusty wind from Sahara desert which brings about haze in the atmosphere (Adefolu, 1984).

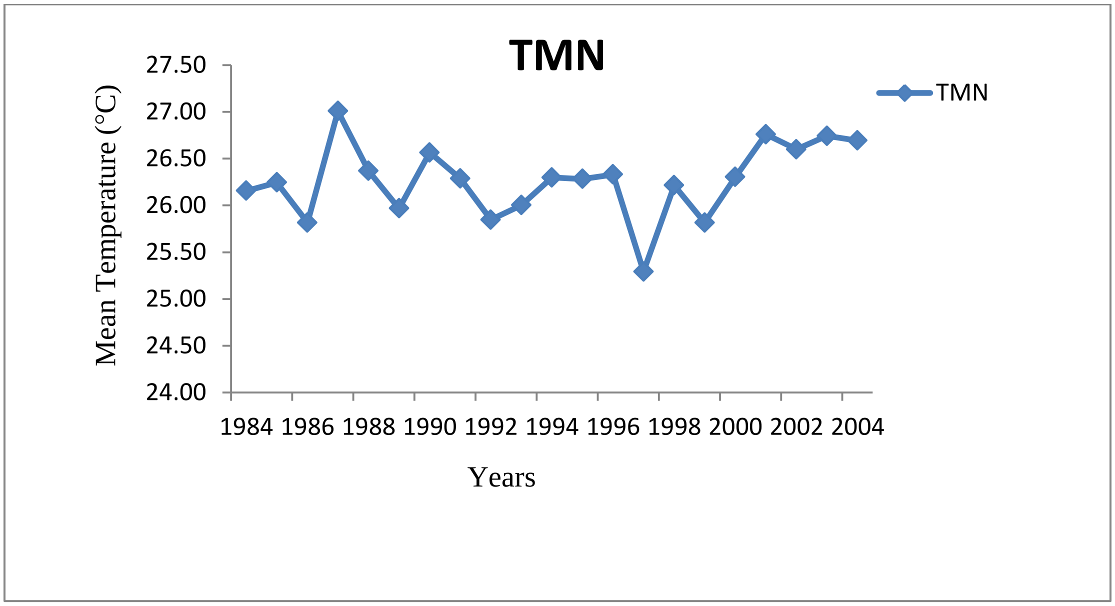

Figure 1: Trends of temperature parameters in Osogbo between 1984 and 2004

Data Acquisition: Two scenes of Landsat-5 Thematic mapper (TM) and Landsat-8 Operational Land Imager (OLI) of (190/55) acquired on 15 January 1986 and 2015 respectively were used in this research. The datasets were provided by the United State Geological Survey (USGS) websites.

Table 1: Details of satellite imageries used

Satellite (Sensor)	Path/Row	Date/Time of Acquisition	Sun Elevation	Cloud Cover	Image Quality
Landsat TM (1986)	190/55	15-01-1986 09:24:08	44.38	0.00	9
Landsat OLI/TIRS (2015)	190/55	15-01-2015 09:56:47	50.41	0.01	9

Image Preprocessing

Data Processing: The imageries were firstly pre-processed for geometric rectification. The image bands used for this study were geometrically rectified to Geographic Coordinate System; WGS_84_UTM Zone 31N. Atmospheric corrections, contrast stretching, histogram equalisation and spatial filtering were as well carried out in order to improve the spectral information of the bands combination, for land cover change assessment.

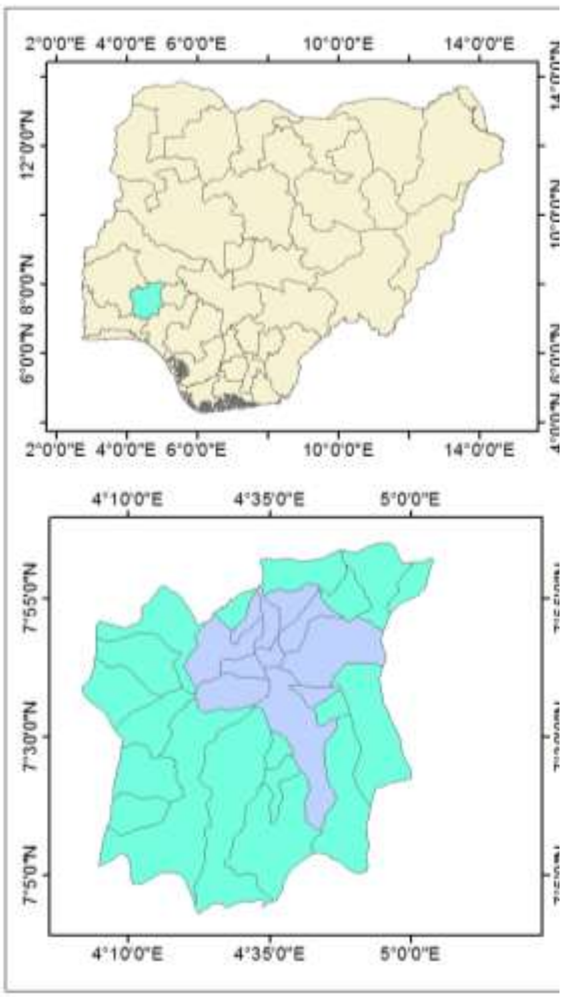

Figure 2: Map of Nigeria, with the study area

Image classification:

A land cover map with five classes; water bodies, degraded forest, cultivated land, bare surface and built up was generated by classifying a composite of the non-thermal bands (i.e., bands 1, 2, 3, 4, 5 and 7) using the maximum likelihood algorithm (Jensen, 2000). Training signatures were selected based on unsupervised classification and local knowledge of study area. Unsupervised classification was initially performed on the images for an idea of the spectral separability of the land use/land cover classes using band 2, 3 and 4 of Landsat TM and band 3, 4 and 5 of Landsat OLI. The land use / land cover types were therefore reclassified into water bodies, degraded forest, cultivated land, bare surfaces and built up. Due to the absence of reliable historical data, accuracy assessment data was generated from the visual interpretation and comparison of TM and ETM colour composites of the 1986 and 2015 imageries respectively.

The sub-scene of the area was extracted and overlaid on the respective images in order to assess the coverage. Bands 4, 3 and 2 were combined (in R G B) and the contrast enhanced using the linear contrast enhancement function of the software. This allows for better visual perception and interpretation of the land use and land cover types on the image.

Calculation of Land Surface Temperature

Land Surface Temperature was calculated using both the TM band 6 of 1986 and OLI/TIRS band 10 and 11 of 2015 (i.e., the low gain thermal band). The thermal band detectors record top of atmosphere brightness temperature (TOA) in the form of Digital Numbers (DNs). Therefore, by using the single channel algorithm (Sobrino *et al*., 2004; Yuan and Bauer, 2007) the TOA can be converted to surface temperatures. According to Yuan and Bauer (2007), surface temperatures obtained with this model are highly accurate. The errors are less than 2 Kelvin. The single window algorithm method makes corrections for the atmospheric and surface emmisivity effects with surface emmisivity as an input based on the differential absorption in a split window (Wan and Dozier, 1996).

i. <u>Conversion of Digital Number (DN) to AT-Spectral Radiance</u>

The DN of the thermal band were converted into radiance values for each of the investigated years using the following formula

$$Radiance = L_{MIN} + \left(\frac{(L_{MAX} - L_{MIN})}{Q_{CALMAX} - Q_{CALMIN}} \right) \times \left(Q_{CAL} - Q_{CALMIN} \right)$$

1

where, Radiance =(Watts / m2.ster.µm), L_{MIN} = minimum spectral radiance at, L_{MAX} =maximum spectral radiance at Q_{CAL} Q_{CALMAX} =255, Q_{CALMIN} =0, Q_{CAL} =Digital Number (DN)

ii. Conversion to AT Reflectance

$$R\lambda = \frac{\pi \times L\lambda \times d2}{ESun\lambda \times Sin(SE)}$$

2

Where, $R\lambda$ = At surface reflectance, $L\lambda$ =Spectral radiance, π = 3.142 (constant), $ESun\lambda$ =Sun elevation angle, $d2$ = earth-sun distance

iii. Conversion from Radiance to Brightness Temperature (in degree Celsius)

The thermal band radiance values were converted to brightness temperature value using the Plancks's function Equation as;

$$T = \frac{K2}{In\left(\frac{K1}{L_\lambda}+1\right)} - 272.3$$

3

Where; T= temperature [Celsius degree], K1=calibration constant 1 [W/(m2sr µm)], K2= calibration constant 2 [Kelvin], In =natural logarithm, L_λ =spectral radiance at the sensor's aperture [W/(m2sr µm)]

iv. Estimation of Land Surface Emissivity (LSE)

In estimating LSE, Normalized Differential Vegetative Index (NDVI) was utilized for emissivity correction,

LSE = $0.004Pv + 0.986$ 4 Pv = $\left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2$

5

$$NDVI = \left(\frac{NIR - RED}{NIR + RED}\right)$$

6

Where, Pv=proportion of vegetation, NIR= near InfraRed Band, Red=red Band, $NDVI_{min}$= minimum value of NDVI, $NDVI_{max}$=maximum value of NDVI

v. Estimating LST

$$LST = \frac{BT}{1+w} \times \frac{BT}{p} \times In(e)$$

7

Where, BT=At-sensor brightness temperature, w =wavelength of emitted radiance, p = $h \times \frac{c}{s}\left(1.438 \times 10^{-2} mK\right)$, h= Plank's constant $\left(6.626 \times 10^{-34} Js\right)$, s = Boltzmann constant $(1.38 \times 10^{-23} J/K)$, c =velocity of light $(2.998 \times 10^{8} m/s)$, e = Land Surface Emissivity

GIS Operations and Generation of Zonal Statistics

ArcGIS 10.3 was basically used for all GIS operations. The zonal statistic was generated from the classified images using the landuse image and the land surface temperature image. This function summarized the values of the raster within the zones of another data and the report of the results was presented as a table.

RESULTS AND DISCUSSION

The Spatiotemporal Pattern of Landuse/Landcover

The result of the maximum likelihood unsupervised classification carried out on Landsat 1986, and 2015 are given in Figures 3 and 4. Details of Land use classes and their corresponding areas/percentage are given below in Figure 3. Degraded forest (35.54%), cultivated land (31.84%) and bare surface (24.19%) covered the largest percentage of land area in 1986; while water bodies (2.70%) and built up (5.73%) occupied the least area in that period. In 2015, the land cover categories were distributed as degraded forest (35.84%), cultivated land (35.54%), built-up (15.44%), bare surface (12.63%) and water (0.55%). The comparison of the two periods (1986 and 2015) showed a variation in the pattern of land cover.

In 2015, the proportion covered by built up category increased by 9.71% and extended from the Centre towards the western part of the study area when compared to 1986. Another 3.70% increase was recorded for cultivated lands, while degraded forest also increased by a factor of 0.3%. On the other hand, bare surface reduced by 11.56%. This result suggests that a significant urban development has taken place in the study area over the years, occurring mostly in high density urban areas between 1986 and 2015 more at the expense of agricultural areas than forests. This pattern agrees with the result of a recent study by Aguda and Adegboyega (2013) who noted that with unprecedented rate of sprawling growth in Osogbo, the adjacent periurban settlements had been increasingly perforated by uncoordinated urban

expansion which in turn has paved the way for a corresponding urban encroachment on the inner more rural settlements and farmlands.

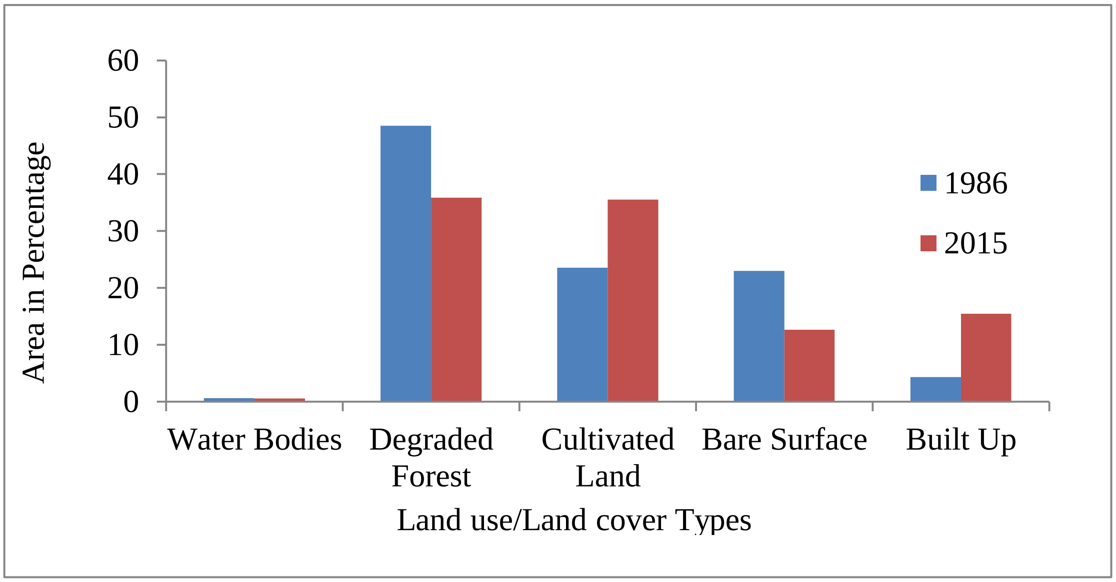

Figure 3: Percentage Distribution of Landuse/Landcover Categories in the Study Area

This is because, population growth exerts pressure on land and thus affects land use change significantly, particularly for the purpose of supplying new areas for development. The loss of these agricultural or vegetated areas means a more extensive cover by artificial surfaces and less natural services provided by vegetation such as infiltration, filtration and protection against erosion (Furberg *et al*., 2008). Increased urban development could in essence compromise (hinder or disrupt the natural processes that provide) ecological services such as protection of wildlife habitats, flood control and regulation and water quality preservation, to the region (Salzman *et al.,* 2001).

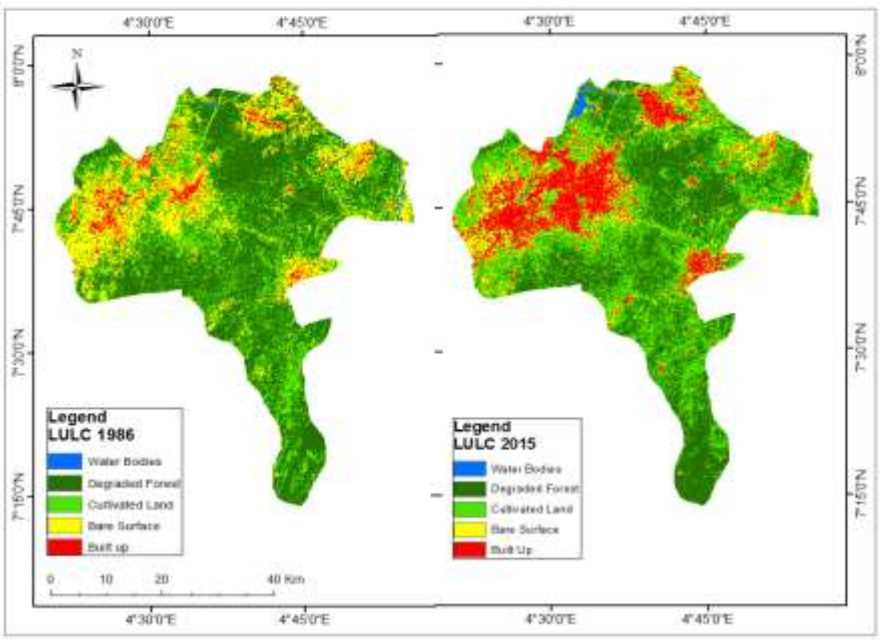

Figure 4: Comparison of 1986 and 2015 Landuse and Landcover Change

Spatiotemporal Pattern of Land Surface Temperature

The spatial and temporal distributions of land surface temperature (LST) are shown in Table 1 and figures 4.5-4.9 respectively. The LST which depicted the spatial variability of land surface temperature over study area ranges from 17.99°C to 46.17°C with a mean of 21.23°C, standard deviation of 1.44 in 1986 and from 20.51°C to 37.72°C with a mean of 25.85°C, and a standard deviation of 2.05 in 2015. The mean and standard deviation are observed to have increased from 21.23 to 25.85 and 1.44 to 2.05 by 4.62 degree Celsius and 0.6 S.D respectively over the years. These results suggest that overall, mean surface temperature and its variability generally increased in all the districts over the entire 29 years period.

Table 2: Temporal Distribution of Land Surface Temperature in Osogbo and its environs

Year	T_{min} (^{0}C)	T_{max} (^{0}C)	T_{mean} (^{0}C)	S.D
1986	17.99	46.17	21.23	1.44
2015	20.51	37.72	25.84	2.04

Relationship between Changes in Landuse/Landcover and LST

For the built-up category, which has spread in the eastern and western directions mean LST increased from 24.11°C to 29.13°C. The vegetated areas recorded an increase of average LST from 20.26°C to 24.33°C, and for cultivated areas, the LST mean ranged from 20.98°C to 25.39°C. The lowest temperature was recorded from the surface water bodies, 20.22°C – 21.82°C while the highest mean LST comes from bare surface category (including fallow lands, sands, rocks) which ranged between 22.42°C – 27.64°C during the study period (Table 3). One of the most important factors leading the UHI phenomena is the land cover land use. The bare surface areas in this study has a relatively higher temperature from the surrounding cover because of its diverse composition including fallow agricultural lands, rock surfaces, sands, and mined areas with very high albedo compared to the surrounding landcovers. A small area with bare soil can result in a rapid increase in the surface temperature from the surrounding cover (Abutaleb *et al*, 2015).

Table 4: Zonal Statistics for 1986 and 2015 using Landuse/Landcover Types

Landuse/ Landcover	Mean 1986 (^{0}C)	Mean 2015 (^{0}C)
Water Bodies	20.22	21.82
Degraded Forest	20.26	24.33
Cultivated Land	20.98	25.39
Bare Surface	22.42	27.64
Built Up	24.11	29.13

Relationship between urbanization and LST

It was observed that LST varies depending on the existing land use/

land cover change. The value of the UHI in some centers (including Osogbo, Olorunda, Ede North) ranged between 3°C to 4°C above the mean of some peripherals in 2015. In 1986, UHI only ranged between only 1°C to 2°C above the mean temperature of the districts peripheries. Data shown in Table 4 illustrate that those districts having a UHI of value ranged between 22.35°C to 28.72°C, such as Osogbo, 21.45°C to 28.114°C, Ede North, 20.76°C to 26.08°C, Olorunda, 22.06°C to 27.35°C and Ifelodun are the big industrial, administrative and commercial centers in the central part of the study area, meanwhile Orolu, Ede South, Atakumosa west and Obokun districts which has UHI of value (21.34°C to 25.13°C), (21.21°C to 25.25°C), (20.51°C to 24.79°C) and (20.96°C to 25.21°C) are characterized by the informal settlement dominated with vegetation, very narrow roads and minor economic activities.

The difference in mean surface temperature resulting in the more distinct urban heat island can be attributed to the gradual transition of landuse from suburban to urban land (Zhi *et al*., 2014). The highly urbanized Osogbo and Olorunda districts in this study, shows a more compacted urban form which gradually evolved during the study frame and led to UHI increase. However, most of the increase in land use conversion happened mostly in regions that borders the highly urbanized districts which include Ede North, Ilesa-west, and Ifelodun than in other districts Figure 4 and 5. As urbanization therefore spreads east and west of the highly urbanized districts, neighboring districts including Ilesa West, Ede North and Ifelodun gradually became warmer and this may explain why most of the increase in mean temperature has occurred in these districts (Akinbode *et al*., 2008). The higher urban heat island experienced in a district like Ifelodun on the Northeastern side of Osogbo may be further exacerbated by the presence of more of the bare soil category with associated mining and industrial activities. In other areas where the temperature has not increased significantly, the vegetation class still (degraded forests and cultivated lands) dominates the landscape in both 1986 and 2015.

Table 3: Percentage Change in Land Surface Temperature of the Local Government Areas

LGA	Mean 1986 (°C)	Mean 2015 (°C)	Difference	% Change in LST
OROLU	21.34	25.13	3.78	18
EGBEDORE	22.24	27.23	4.99	22
OSHOGBO	22.35	28.72	6.37	29

EDE NORTH	21.45	28.11	6.66	31
OLORUNDA	20.76	26.08	5.32	26
EDE SOUTH	21.21	25.25	4.04	19
ATAKUMOSA WEST	20.51	24.79	4.28	21
OBOKUN	20.96	25.21	4.24	20
ILESA WEST	21.89	26.88	4.99	23
IFELODUN	22.06	27.35	5.28	24
BORIPE	21.57	26.17	4.59	21

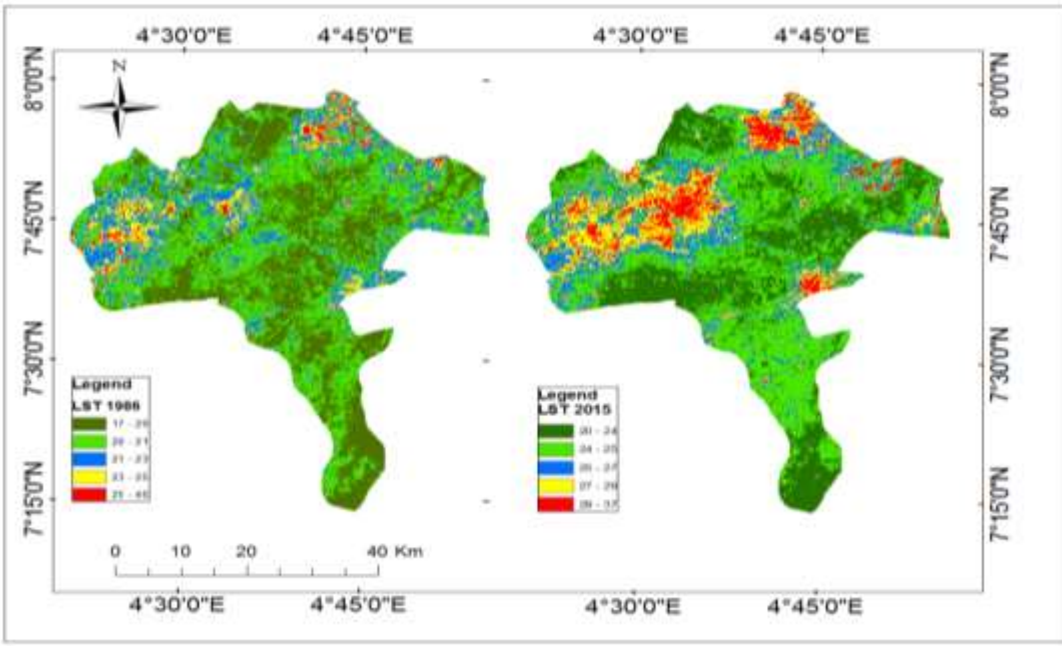

Figure 5: Comparison of 1986 and 2015 Land Surface Temperature Change

SUMMARY AND CONCLUSION

This study results suggests that LST varies depending on the existing land use/ land cover. In general, it is clear that temperature difference increases towards to the center of the urban area and decrease in the direction of the peripheries and this is defined as urban heat islands. The urban heat island effect of the city is best reflected by the pattern of landuse change and urban form which is higher in urbanized and peri-urban districts. Analysis of the relationship between landuse change due to urbanization and urban heat island gives a clear evidence of an increase in temperature with increase in urban sprawl east and west of the highly urbanised core between 1986 and 2015. UHI was observed to be on the increase, in the study area especially in Osogbo, Olorunda and Ede districts where the rate of landuse conversion through urbanization and population growth was highest. This further emphasis that there is an important role played by climate landuse interactions that control the magnitude of the urban heat island in this tropical region. As urbanization and population pressures induced land use change continues to reshape urban form the urban heat island effect will, on the one hand enhance climate change, lead to increased energy demand for cooling and on the other hand contribute to heat and air pollution (UNPF, 2007). The more impacts of UHI lead to more energy demand for conditioning and urban areas are more likely to experience more electricity cut off and increased use of generators which could also lead to more UHI phenomena and air pollution. In this backdrop, big changes are expected to happen in the coming years in these regions of the developing countries, which will not only affect global economic growth, but also environmental sustainability, including energy issues and increased impact of climate change.

REFERENCES

Abegunde, A. A. (2009). The Role of community based organisations in economic development in Nigeria: The case of Oshogbo, Osun state, Nigeria. *International NGO Journal*, 4(5): 236-252.

Aguda, A. S. and Adegboyega, S. A. (2013). Evaluation of Spatio-Temporal Dynamics of Urban Sprawl in Osogbo, Nigeria Using Satellite Imagery and GIS Techniques. *International Journal of Multidisciplinary and Current Research*, 1-14pp.

Akinbode, O. M., Eludoyin, A. O. and Fasae, O. A. (2008). Temperature and Relative Humidity Distributions in a Medium-Size Administrative Town in Southwest Nigeria. *Journal of Environmental Management*, 87: 95-105.

Burchell, R. W., Lowenstein, G., Dolphin, W. R., Galley, C. C., Downs, A., Seskin, S. and Moore, T. (2002). Costs of Sprawl.

Chen, X. L., Zhao, H. M., Li, P. X. and Yin, Z. Y. (2006). Remote Sensing Image – Based Analysis of the Relationship between Urban Heat Island and Land Use/Cover Changes. *Remote Sensing of Environment*, 104(2): 133–146.

Cohen, W. B., Fiorella, M., Gray, J., Helmer, E. and Anderson, K. (1998). "An Efficient and Accurate Method for

Mapping Forest Clear-Cuts In the Pacific Northwest Using Landsat Imagery," *Photogrammetry Engineering and Remote Sensing*, 64(4): 293-300.

Donk, V. M. (2006). Positive Urban Futures in Sub-Saharan African: HIV/AIDS and the Need for a Broader Conceptualisation (ABC). *Environment and Urbanisation*, 18(1): 155-177.

Furberg, D., and Ban, Y. (2008). Satellite monitoring of urban sprawl and assessing the impact of land cover changes in the Greater Toronto Area. In The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, ISPRS Congress Beijing, 131-136pp.

Grimmond, S. (2007). Urbanization and Global Environmental Change: Local Effects of Urban Warming. *The Geographical Journal*, 173(1): 83-88.

Hart, M. A., and Sailor, D. J. (2009). Quantifying the Influence of Land-Use and Surface Characteristics on Spatial Variability in the Urban Heat Island. *Theoretical and Applied Climatology*, 95(3-4): 397-406.

Herold, M., Couclelis, H., and Clarke, K. C. (2005). The role of spatial metrics in the analysis and modeling of urban land use change. Computers, environment and urban systems, 29(4): 369-399.

Jensen, J. R. (2000). Remote Sensing Of the Environment: An Earth Resource Perspective. Prentice-Hall, New Jersey. 181-243, 333-529pp.

Maguire, D. J. (1991). An overview and definition of GIS. Geographic Information Systems: Principles and applications, 1: 9-20.

Milesi Christina (2003). "Assessing the impact of Urban Development on Net Primary Productivity in The Southeastern United States". *Remote Sensing of the Environment Journal*, 86: 401-410.

Omogbai, B. E. (2010). An empirical prediction of seasonal rainfall in Nigeria. *Journal of human Ecology*, 32(1): 23-27.

Odekunle, T. O. (2004). Rainfall and the length of the growing season in Nigeria. International *Journal of Climatology*, 24(4): 467-479.

Parker, D. E. (2010). Urban heat island effects on estimates of observed climate change. Wiley Interdisciplinary Reviews: Climate Change, 1 (1): 123-133.

Rizwan, A. M., Dennis, L. Y. C. and Liu, C. (2008). "A Review on the Generation, Determination and Mitigation of Urban Heat Island," *Journal of Environmental Sciences*, 20(1): 120– 128.

Salzman, J., Thompson Jr, B. H., and Daily, G. C. (2001). Protecting ecosystem services: Science, economics, and law. *Standard Environmental Law Journal*, 20: 300-309.

Squires, G. D. (2002). Urban Sprawl: Causes, Consequences, and Policy Responses. The Urban Institute, 12pp.

United Nations Centre for Human Settlements (UN- Habitat) (2006). Cities-Magnets of Hope. World Habitat Day Celebration Release, Nairobi.

Weng, Q. (2002). Land use change analysis in the Zhujiang Delta of China using satellite remote sensing, GIS and stochastic modelling. *Journal of environmental management*, 64(3): 273-284.

Weng, Q., Lu, D., amd Schubring, J. (2004). Estimation of land surface temperature-vegetation abundance relationship for urban heat island studies. *Remote sensing of environment*, 88(4): 467-483.

Zhi, Q., Guangjin, T., Lixiao, Z. and Xinliang X. (2014). Influences of Urban Expansion on Urban heat Island in Beijing during 198-2010, 1-12pp.

CONTAMINATION ASSESSMENT AND WATER QUALITY EVALUATION OF SELECTED GROUND WATER SUPPLY SYSTEMS IN AYETORO, OGUN STATE, NIGERIA

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ABSTRACT

The dependence on groundwater as a source of freshwater, increased anthropogenic activities and the resulting threat to the availability of potable groundwater necessitated this study. Fifteen groundwater supply sources (11 hand – dug wells and 4 boreholes labelled S1 – S15) were randomly selected using the multistage sampling method. Water samples were collected and analysed for the presence of physical, chemical parameters and heavy metals using standard procedures by Bartram and Ballance (1996). The results of water quality analysis were compared with SON (2007) and WHO (2011) drinking water quality standard. The result of water quality analysis was used in determining the pollution rate and saturation index using the Contamination factor (C_f), Degree of contamination (C_{deg}), Enrichment factor (EF) and Geo – accumulation Index (I_{geo}) and Langelier Saturation Index (LSI). All physical and chemical parameters analysed were within the allowable limits except for pH which was acidic for all sampled locations and alkalinity which was much higher than the 100 mg/L allowable limit. The C_f values for all the metals indicated that the water had low contamination with the exception of Cd whose highest value was 7.3000 indicating very high contamination. All I_{geo} values of the metals were negative indicating 'uncontamination', except for the result of Fe at location S9 which was positive signifying moderate contamination. The LSI result indicated that the water is undersaturated with respect to calcium carbonate and has the tendency of removing the existing calcium carbonate which protects the coatings in pipelines and equipment; hence the treatment of the water is recommended in other to protect pipes and other equipment used. This study recommended the need for routine ground water quality analysis for the study area, household water treatment and proper waste disposal practises. The use of multiple pollution rate assessment tools is advised as it provides a platform isolate metals that should be paid more attention to which may not be detected should the research is simply based on comparing the result of water quality assessment to existing drinking water quality standards alone. Also attention of farmers should be drawn to the use of inorganic fertilizers as against organic fertilizers.

Keywords: groundwater, pollution rate, saturation index, water quality, contamination

INTRODUCTION

Availability and uneven distribution of fresh water resources has been the top priority of key global water and sanitation initiatives for decades. Groundwater, in the absence of fresh surface water is exploited to meet the increasing fresh water demand (Annapoorna and Janardhana, 2015). Groundwater occurs below the ground surface in pore spaces between particles of rock or soil, or in the crevices and cracks in rocks, usually within 100 meters of the surface of the Earth (Adesuyi *et al.,* 2015). Groundwater motion along its flow paths below the ground surface increases the concentration of the chemical species (Domenico and Schwartz, 1990; Kortatsi, 2007; Aghazadeh and Mogadam, 2010). Spatial variation in groundwater quality with respect to local geologic structure and anthropogenic influences warrants the assessment of the quality of groundwater for any purposes including human consumption (Annapoorna and Janardhana, 2015).

Groundwater chemistry can provide vital information on aquifer geological history; factors, such as general geology, degree of chemical weathering of the various rock types, quality of recharge water and inputs from sources other than water rock interface to a large extent determines groundwater chemistry; the interactions that result in a complex groundwater quality (Domenico and Schwartz, 1990; Guler and Thyne, 2004; Vazquez Sunne *et al.,* 2005; Aghazadeh and Mogadam, 2010). The quality of groundwater is dependent on the composition of the recharge water, interactions between water and the soil, soil gas, and rocks with which it comes in contact with in the unsaturated zone, and the residence time and reactions that take place within the aquifer (Meybeck *et al.,* 1996). Although groundwater has provided inexpensive drinking water for millennia, alteration of natural groundwater chemistry through increased anthropogenic activities (Hem, 1989; Alloway and Ayres, 1997; and Clark, 2006) and has been a threat to this gift from nature. Groundwater quality degradation is linked primarily to the land use: industrial, agricultural or other commercial activities such as markets, hospitals or mechanic villages.

The study area is located in Ogun State, known for her industrial, agricultural and various commercial activities due to the proximity of the state to Lagos State known as Nigeria's commercial nerve centre. Ayetoro, the study area which equally boasts of substantial commercial activities lies about 35km northwest of Abeokuta the Ogun State capital. Ayetoro is the administrative seat of Yewa North Local Government Area (formerly called Egbado North Local Government Area) and lies on Latitude $3^{0}03'$E and Longitude $7^{0}12'$N. The town is located on a deciduous derived savannah zone of Ogun State with a sub – humid climate recording an average annual rainfall of about 1,900mm. Ayetoro lies between 90 – 120mm above the mean sea – level and drained by Rori and Ayinbo rivers. The study area boasts of a heavy dependence on groundwater for her water supply needs. Known for agricultural activities amongst other human activities, the major crops grown Ayetoro include maize, cowpea cassava; with 'fufu' (a cassava derivative) production being the trademark of the town.

The continued dependence on groundwater as a source of freshwater, increased anthropogenic activities and the resulting threat to the availability of potable groundwater necessitated this study. The study seeks to assess the groundwater chemistry of Ayetoro with the aid of selected physical chemical and heavy metal parameters.

METHODOLOGY

Groundwater supply sources (11 hand – dug wells and 4 boreholes and labelled S1 – S15) were randomly selected using the multistage sampling method. Water samples were collected from the selected groundwater sources and analysed for the presence of physical and chemical parameters using standard techniques (Bartram and Ballance, 1996). The samples were tested for pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), sodium (Na), calcium (Ca), magnesium (Mg), chloride (Cl), nitrate (NO_3), sulphate (SO_4), and bicarbonate (HCO_3). Others include turbidity, alkalinity and hardness. The water samples were also analysed for the following heavy metals: zinc (Zn), copper (Cu), chromium (Cr), cadmium (Cd), arsenic (As), Iron (Fe) and Nickel (Ni).

The results of water quality analysis were interpreted and compared with the Nigeria Standard for Drinking water quality published by the Standard Organisation of Nigeria (SON, 2007) and World Health Organisation Drinking Water Quality Standard (WHO, 2011). The rate of pollution in the area was estimated using Contamination factor (C_f), Degree of contamination (C_{deg}), Enrichment factor (EF) and Geo – accumulation Index (I_{geo}). The corrosivity potential of the groundwater samples were equally determined using the Langelier Saturation Index, LSI (Langelier, 1936).

Pollution rate

The rate of pollution of the groundwater was assessed using quantitative contamination indices (contamination factors (C_f), geo – accumulation index (I_{geo}), enrichment factor (EF) and degree of contamination (C_{deg}) to illustrate the concentration trend of the measured heavy metals (Omotoso and Ojo, 2015; Likuku *et al*., 2013). In determining the factors that are composed in pollution rate, it is common to use the concentrations of the metals analysed from sediments with a study area as background values. However, since determination of metal concentration in sediments is not covered by this study, average shale values (Turekian and Wedepohl, 1961) for the analysed metals were used as background values (Moore *et al.,* 2009; Sarala Thambavani and Uma Mageswari, 2013)

i. Contamination factor

The Hakanson (1980) model was adopted for determining contamination factor (C_f). The model determines C_f for each heavy metal using the formula:

$$C_f = \frac{C_{sample}}{C_{background}}$$ .... **Equation 1**

Where:

C_{sample} = is the concentration of heavy metal in the analysed sample

$C_{background}$ = is the average shale value of the metal

ii. Degree of contamination

Degree of contamination refers to the sum total of all contamination factors in the sample. It is determined using the formula (Aksu et al., 1998):

$$C_{deg} = \sum \left(C_{sample} / C_{background} \right)$$

……………………………………………
Equation 4

Four categories have been defined for the degree of contamination which includes:

Table 1: Contamination factors and degree of contamination categories and terminologies

C_f	Terminologies	C_{deg}
C_f**<1**	Low C_f indicating low contamination / low C_{deg}	C_{deg}<8
1 $\leq C_f <$ **3**	Moderate C_f and C_{deg}	$8 \leq C_{deg} < 16$
3 $\leq C_f$ <**6**	Considerable C_f and C_{deg}	$16 \leq C_{deg} < 32$
C_f ≥**6**	Very high C_f and C_{deg}	$C_{deg} \geq 32$

Source: Likuku *et al*. (2013)

iii. Geo – accumulation Index

Index of Geo-accumulation (Igeo) commonly used to assess the degree of metal contamination or pollution in terrestrial, aquatic and marine environment (Tijani et al., 2009; Fagbote and Olanipekun, 2010). The Igeo of a metal in

sediment is determined using the formula (Asaah and Abimbola, 2005; Mediola et. al, 2008; Fagbote and Olanipekun, 2010):

$$I_{geo} = Log_2 \left(\frac{C_{metal}}{1.5\ C_{metal\ (background)}} \right)$$

……………………………………………
Equation 2

Where C_{metal} is the concentration of the heavy metal in the analysed sample and

$C_{metal\ (background)}$ is the average shale value of the metal

Table 2: Geo – accumulation Index categories and terminologies

Value	Class	Description
I_{geo} **> 5**	6	Extremely contaminated

4 < $\square_{\square\square\square}$ ≤ 5	5	Strongly to extremely contaminated
3 < $\square_{\square\square\square}$ ≤ 4	4	Strongly contaminated
2 < $\square_{\square\square\square}$ ≤ 3	3	Moderately to strongly contaminated
1 < $\square_{\square\square\square}$ ≤ 2	2	Moderately contaminated
0 < $\square_{\square\square\square}$ ≤ 1	1	Uncontaminated to moderately contaminated
$\square_{\square\square\square}$ = 0		Uncontaminated

Source: Müller (1969)

Enrichment factor

Enrichment factor (EF) can be used to differentiate between the metals originating from anthropogenic activities and those from natural procedure, and to assess the degree of anthropogenic influence. Enrichment factor is determined by the formula:

$$\boldsymbol{E}\square = \frac{\left(\square_{\square}/\square_{\square\square}\right)_{\square\square\square\square\square\square}}{\left(\square_{\square}/\square_{\square\square}\right)_{\square\square\square\square\square\square\square\square\square\square}}$$

……………………………………………

Equation 3

Where:

$\left(\square_{\square}/\square_{\square\square}\right)_{\square\square\square\square\square\square}$ refers to the ratio of metal and Fe concentrations of the sample and

$\left(\square_{\square}/\square_{\square\square}\right)_{\square\square\square\square\square\square\square\square\square\square}$ refers to the ratio of metal and Fe concentrations in the average shale value

The results of Enrichment factor were interpreted using Table 2.

Table 3: Enrichment factor model for heavy metals contamination

Enrichment factor (EF) values	Degree of contamination
EF ≤1	No enrichment
EF≤ 3	Minor enrichment
EF 3 – 5	Moderate enrichment
EF 5 – 10	Moderately severe enrichment
EF 10 – 25	Severe enrichment
EF 25 – 50	Very severe enrichment
EF > 50	Extremely severe enrichment

Source: Birch (2003)

Saturation index

Saturation indices are used to evaluate the degree of equilibrium between water and minerals or otherwise as an indicator of water balance. Langelier Saturation Index (LSI) was the first potential corrosivity indicator for water (Langelier, 1936; Larson *et al.,* 1942; Belitz *et al.,* 2016) making it possible to predict the tendency of calcium carbonate either to precipitate or to dissolve under varying conditions (Alsaqqar *et al*., 2014). LSI is among the most commonly used saturation index and determines whether water has tendency to precipitate or dissolve $CaCO_3$ (Gupta *et al.,* 2011). LSI is determined as the difference between the measured pH of the water and the pH at calcite saturation (pHs) (Langelier, 1936; Gupta *et al.,* 2011; Belitz *et al.,* 2016):

$$LSI = pH - pH_s$$ ……………………………**Equation 5**

Where pH = the measured groundwater pH and

pHs = is the pH at saturation in calcite or calcium carbonate

$$pH_s = (9.3 + A + B) - (C + D)$$ ………………………………**Equation 6**

Where:

$$A = (log_{10}[TDS] - 1)/10$$

$$B = -13.13 \times log_{10}(°C + 273) + 34.55$$

$$C = log_{10}[CaH\ as\ CaCO_3] - 0.4$$

$$D = log_{10}[Total\ Alkalinity\ as\ CaCO_3]$$

The results of LSI calculations were interpreted using Tables 3 and 4.

Table 4: Description of the Langelier Saturation Index values

LSI	Indication
LSI<0	Water is undersaturated with respect to calcium carbonate. Undersaturated water has a tendency to remove existing calcium carbonate protective coatings in pipelines and equipment.
LSI=0	Water is considered to be neutral. Neither scale-forming nor scale removing.
LSI>0	Water is supersaturated with respect to calcium carbonate ($CaCO_3$) and scale forming may occur.

Source: Tchobanoglous *et al.* (2003)

Table 5: Interpretation of the Langelier Saturation Index values

LSI (Carrier)	Indication
-2.0<-0.5	Serious corrosion
-0.5<0	Slightly corrosion but non-scale forming
LSI = 0.0	Balanced but pitting corrosion possible
0.0<0.5	Slightly scale forming and corrosive
0.5<2	Scale forming but non corrosive

Source: Carrier Air Conditioning Company (1965)

RESULTS AND DISCUSSIONS

Physical and chemical analysis

The statistical summary of the result of physical and chemical analysis is presented in Table 6. The mean and range values of pH, EC and temperature were 4.75, 258 µS/cm and 30.23 ^{0}C; 3.75 – 6.04; 40 – 620 µS/cm and 28.3 – 33.3 ^{0}C respectively. The result showed that the pH values of the analysed samples were acidic and below the acceptable limit set by WHO (2011) and SON (2007). This occurrence could be attributed to anthropogenic influences on the quality of water. The pH value of water may be influenced by domestic sewage and industrial wastes as attributed by Bhattacharya (1988) and Napacho and Manyele (2010). However, pH has no direct impact on consumers (WHO, 2011). The results of EC were below the acceptable limit of 1000 µS/cm (WHO, 2011 and SON, 2007), indicating acceptability. EC which is temperature dependent generally indicates the high degree of anthropogenic activities such as waste disposal and agricultural effluents; hence the water in study area is considerably ionized and has the higher level of ionic concentration activity due to dissolve solids (Mohsin *et al.,* 2013).

TDS, Na and Mg mean and range values were 126.67 mg/ L, 10.74 mg/ L, and 0.13 mg/ L and 20 – 310 mg/ L, 3.46 – 14.23 mg/ L and 0.03 – 02 mg/ L respectively. The values of TDS, Na and Mg in comparison with the water standards were within the acceptable limits. Total Dissolved Solids comprise inorganic salts (mostly Ca, Mg, K, Na, HCO_3, Cl and SO_4) and small amounts of organic matter that are dissolved in water (WHO, 2011). The results of TDS can be used to check the accuracy of analyses when relatively complete analyses have been made on water (Ballance, 1996). Sodium, a silver white metallic element is generally agreed to be essential to human life, there is no however no agreement on the minimum daily requirement; although it has been estimated that a total daily intake of 120–400 mg will meet the daily needs of growing infants and young children, and 500 mg those of adults (Mohsin *et al.,* 2013; National Research Council, 1989; WHO, 1996).

Table 6: Statistical Summary of Analysed Parameters in Comparison with WHO (2011) and SON (2007) Drinking Water Quality Standards

Parameters	Mean	Range	WHO (2011) Standard	SON (2007) Standard
pH	4.75	3.75 – 6.04	6.5 – 8.5	6.5 – 8.5
EC	258	40 – 620	1000 µS/cm	1000 µS/cm
Temperature	30.23	28.3 - 33.3	-	-
TDS	126.67	20 – 310	-	500 mg/ L
Na	10.74	3.46 - 14.23	200 mg/L	200 mg/ L
Mg	0.13	0.03 - 0.2	-	0.20 mg/ L
Ca	15.77	5.36 - 25.6	50 mg/ L	-
NO_3	6.04	2.43 - 8.74	50 mg/ L	50 mg/L
SO_4	67.87	45 – 87	500 mg/ L	100 mg/ L
Cl	24.07	4.5 – 49	-	250 mg/ L
HCO_3	48.09	16.35 - 78.08	-	-
Turbidity	0.03	0 - 0.19	-	5 NTU
Alkalinity	454.87	105 -841	100 mg/ L	-
Hardness	60.53	12 – 118	-	150 mg/ L
Zn	0.0506	0.0219 - 0.132	3 mg/ L	3 mg/ L
Cu	0.0103	0.0051 - 0.0221	2 mg/ L	1 mg/ L
Cr	0.0051	0.0001 - 0.013	0.05 mg/ L	0.05 mg/ L
Cd	0.0096	0.0032 - 0.0219	0.003 mg/ L	0.003 mg/ L
As	0.0023	0.0001 - 0.0043	0.01 mg/ L	0.01 mg/ L
Fe	0.1089	0.024 - 0.7342	0.3 mg/ L	0.3 mg/ L
Ni	0.0303	0.0102 - 0.0481	0.07 mg/ L	0.02 mg/ L

Magnesium is the fourth most abundant cation in the body. Low magnesium levels are associated with endothelial dysfunction, increased vascular reactions, elevated circulating levels of C – reactive protein and decreased insulin sensitivity, possibly leading to hypertension, coronary heart disease, type 2 diabetes mellitus and metabolic syndrome (Cotruvo and Bartram 2009).

Calcium (Ca), NO_3, SO_4 and Cl each recorded mean values of 15.77 mg/L, 6.04 mg/L, 67.87 mg/L and 24.07 mg/L respectively; range of values of 5.36 – 25.6 mg/L, 2.43 – 8.74 mg/L, 45 – 87 mg/L and 4.5 – 49 mg/L respectively. Ca, NO_3, SO_4 and Cl all fell with the permissible limit set by WHO (2011) and SON (2007). More than 99% of total body calcium is found in bones and teeth, Inadequate intakes of which have been linked with increased risks of diseases such as osteoporosis, nephrolithiasis (kidney stones), colorectal cancer, hypertension and stroke, to mention a few (Cotruvo and Bartram 2009). Nitrate is the most common chemical contaminant in the world's groundwater aquifers (Spalding and Exner, 1993). Nitrate ingestion could lead to a blood disorder called "methaemoglobinaemia" also known as "blue baby syndrome" (Tahir and Rasheed, 2008), Children are susceptible to goitre and respiratory tract infections when exposed to high levels of nitrate (Gupta et al., 2000; Weyer et al., 2001). Sulphate concentrations in drinking-water could result in noticeable taste and thereby contributing to the corrosion of distribution systems (WHO, 2011). Pollution sources such of domestic wastewater and septic tanks can result in higher concentrations of chloride in the groundwater (Akoteyon and Soladoye, 2011). However, while chloride ions are non-cumulative toxins, if taken over a period of time in excessive amount can constitute a health hazard (Dallas and Day, 1993; Adetunde *et al*., 2011).

The mean and range values of HCO_3, turbidity, alkalinity and hardness were 48.09 mg/L, 0.03 mg/L, 454.87 mg/L and 60.53 mg/L respectively; 16.35 – 78.08 mg/L, 0 – 0.19 mg/L, 105 – 841 mg/L and 12 – 118 mg/L respectively. WHO (2011) and SON (2007) had no recommended limits for HCO_3. SON (2007) recommends 5 NTU as the acceptable limit for turbidity. The results for alkalinity were quite higher than the 100 mg/L limit set by WHO (2011). The values obtained for hardness were within the acceptable limits set by SON (2007). Hardness is caused by the dissolved calcium and magnesium in water and can also be influenced by pH and alkalinity (WHO, 2011). WHO (2011) proposed no health-based guideline value for hardness; however a 200mg/L could result in scale deposition in distribution systems.

The result of heavy metals showed that Zn, Cu, Cr and Cd recorded mean values of 0.0506 mg/L, 0.0103 mg/L, 0.0051 mg/L and 0.0096 mg/L respectively and range of values of 0.0219 – 0.132 mg/L, 0.0051 – 0.0221 mg/L, 0.0001 – 0.013 mg/L and 0.0032 – 0.0219 mg/L respectively. As, Fe and Ni each recorded mean values of 0.0023 mg/L, 0.1089 mg/L and 0.0303 mg/L respectively and range of values of 0.0001 – 0.0043 mg/L, 0.024 – 0.7342 mg/L and 0.0102 – 0.0481 mg/L. The results of heavy metals all fell within the minimum acceptable limits set by WHO (2011) and SON (2007). The order of concentration of the metals is Fe>Zn>Ni>Cu>Cd>Cr>As. Anthropogenic activities are the major causes of elevated metal concentrations in water (Adekunle *et al.,* 2007; Adepelumi, *et al.,* 2001; Domagalski, *et al.,* 2001), although weathering of soil materials could be another factor (Likuku *et al*., 2013).

Pollution rate

Contamination factor and Degree of contamination

Contamination factor and degree of contamination results are presented in Table 7. C_f value range as follows: Zn (0.0231 – 0.1389), Cu (0.0487 – 0.2933), Cr (0.0001 – 0.0144), Cd (1.0667 – 7.3000), As (0.0008 – 0.0331), Fe (0.001– 0.1556), Ni (0.015 – 0.0707), while their mean C_f values were 0.0532, 0.1124, 0.0056, 3.2089, 0.0179, 0.0210 and 0.0445. The C_f values for all the metals indicated that the water had low contamination with the exception of Cd whose highest value was 7.3000 indicating very high contamination. The high contamination of Cd could be attributed to the interaction of groundwater with sediments in the ground as sediments have been described as a sink or reservoir for pollutants in water (Samir *et al*., 2006). Cadmium an important factor in aquatic monitoring studies has been implicated in endocrine disrupting activities which could pose serious health problems (Awofulu *et al*., 2005; Addo *et al*., 2011). Other sources include runoff from agricultural fields (Hutton *et al*., 1987; Addo *et al*., 2011); agriculture being a prevalent occupation in the study area. The order of contamination of the sampling sites with respect to the result of C_{deg} are as follows: S9>S11>S4>S15>S1>S10>S8>S5>S3>S6>S14> S7>S2>S13>S12. However, all sampling sites recorded C_{deg} values less than 8, indicating low contamination.

Table 7: Contamination factor and degree of contamination values

Sample	C_f							C_{deg}
	Zn	**Cu**	**Cr**	**Cd**	**As**	**Fe**	**Ni**	
S1	0.0282	0.0596	0.0144	3.6333	0.0154	0.0025	0.0599	3.8133
S2	0.0432	0.0911	0.0016	1.7667	0.0192	0.0006	0.0372	1.9596
S3	0.0231	0.0487	0.0011	2.7000	0.0323	0.0030	0.0396	2.8478
S4	0.0466	0.0984	0.0122	5.5333	0.0008	0.0007	0.0638	5.7558
S5	0.0607	0.1282	0.0022	2.7000	0.0169	0.0022	0.0599	2.9701
S6	0.0400	0.0844	0.0111	2.1000	0.0331	0.0015	0.0559	2.3260
S7	0.0255	0.0538	0.0013	1.9000	0.0123	0.0008	0.0497	2.0434
S8	0.0575	0.1213	0.0056	2.9667	0.0092	0.0011	0.0459	3.2073
S9	0.0672	0.1418	0.0114	7.3000	0.02	0.0156	0.0525	7.6085
S10	0.0389	0.0822	0.0001	3.3000	0.0192	0.0010	0.0316	3.4730
S11	0.1247	0.2633	0.0037	5.5000	0.0131	0.0014	0.0216	5.9280
S12	0.1389	0.2933	0.0029	1.0667	0.0131	0.0011	0.0200	1.5360
S13	0.0537	0.1133	0.0127	1.3333	0.0162	0.0005	0.0150	1.5447

S14	0.0266	0.0562	0.0004	2.1333	0.0238	0.0010	0.0446	2.2859
S15	0.0236	0.0498	0.0033	4.2000	0.0238	0.0017	0.0707	4.3729
ASV	95	45	90	0.3	13	4.72	68	-
Mean	0.0532	0.1124	0.0056	3.2089	0.0179	0.0210	0.0445	3.4448
Min	0.0231	0.0487	0.0001	1.0667	0.0008	0.0010	0.0150	1.5360
Max	0.1389	0.2933	0.0144	7.3000	0.0331	0.1556	0.0707	7.6085

ASV: Average Shale Value

Geo – accumulation index

The result of $\mathbf{I_{geo}}$ is presented in Table 8. All $\mathbf{I_{geo}}$ values of the metals were negative indicating 'uncontamination', except for the result of Fe at S9 which was positive signifying moderate contamination. Fe is a metallic element common in the earth's crust and is dissolved as water percolates through soil and rock carrying it into groundwater, however, Fe contamination in water is anthropogenic activities related (Foster 1985; Moyosore *et al.*, 2014). Although Iron is very essential for most living things as it is a component of haemoglobin (Mayouf, 2012), nevertheless, ingestion of large quantity of iron can lead to Haemochromatosis-ineffective operation of normal regulatory mechanisms resulting tissue damage (ATSDR, 2008b; USEPA, 2004; WHO, 2004).

Enrichment factor

Table 9 shows the result of EF for all metals except for Fe. Computing EF is vital in geochemical studies, and used generally to differentiate between the metals originating from crustal and non – crustal (anthropogenic and geogenic) sources, and in assessing degree of metal contamination (Selvaraj *et al.,* 2004; Olivares-Rieumont *et al.,* 2005; Yongming *et al.,* 2006; Moore *et al.,* 2009; Hallı *et al*., 2014). Normalization of heavy metal concentrations are generally carried out using conservative elements, such as Al, Fe, Li, and Sc (Hallı *et al*., 2014), however with respect to this study Fe was chosen as the element of normalization because natural sources (1.5%) vastly dominate its input (Tippie, 1984). Deely and Fergusson (1994) proposed Fe as an acceptable normalization element since Fe distribution in soils is not related to the distribution of other heavy metals.

Table 8: Geo – accumulation index values

Sample	I_{geo}						
	Zn	**Cu**	**Cr**	**Cd**	**As**	**Fe**	**Ni**
S1	-5.8806	-8.8954	-7.0023	-15.4853	-12.4942	-1.4196	-5.7602
S2	-5.2672	-9.0474	-10.2173	-16.5256	-12.1722	-3.6115	-6.4461
S3	-6.1719	-8.9803	-10.7027	-15.9136	-11.4238	-1.1755	-6.3576

S4	-5.1556	-7.2368	-7.2433	-14.8785	-16.8161	-3.2896	-5.6675
S5	-4.7742	-8.3665	-9.7028	-15.9136	-12.3567	-1.6088	-5.7602
S6	-5.3768	-8.3104	-7.3808	-16.2762	-11.3898	-2.1847	-5.8592
S7	-6.0278	-8.2433	-10.4397	-16.4206	-12.8161	-3.0266	-6.0282
S8	-4.8539	-8.5011	-8.3808	-15.7778	-13.2311	-2.6538	-6.1437
S9	-4.6293	-7.7028	-7.3382	-14.4787	-12.1157	**1.2081**	-5.9493
S10	-5.4153	-8.6496	-14.0247	-15.6241	-12.1722	-2.7574	-6.6809
S11	-3.7360	-8.1058	-8.9372	-14.8872	-12.7286	-2.2459	-7.2294
S12	-3.5804	-8.6496	-9.3242	-17.2535	-12.7286	-2.6115	-7.3416
S13	-4.9523	-8.5328	-7.1918	-16.9316	-12.4238	-3.7270	-7.7566
S14	-5.9637	-8.0023	-12.0247	-16.2535	-11.8619	-2.7759	-6.1859
S15	-6.1393	-9.3523	-9.1178	-15.2762	-11.8619	-1.9597	-5.5192
Mean	-5.1950	-8.4384	-9.2686	-15.8597	-12.5728	-2.2560	-6.3124
Min	-6.1719	-9.3523	-14.0247	-17.2535	-16.8161	-3.7270	-7.7566
Max	-3.5804	-7.2368	-7.0023	-14.4787	-11.3898	1.2081	-5.5192

Table 9: Enrichment factor values

Sample	EF					
	Zn	**Cu**	**Cr**	**Cd**	**As**	**Ni**
S1	0.1121	0.0618	0.0574	14.4355	0.0611	0.2378
S2	0.7835	0.2542	0.0282	32.0715	0.3491	0.6754
S3	0.0773	0.0492	0.0037	9.0575	0.1084	0.1327
S4	0.6772	0.7132	0.1775	80.3602	0.0112	0.9269
S5	0.2751	0.1017	0.0101	12.2302	0.0767	0.2711

S6	0.2701	0.1576	0.0750	14.1801	0.2234	0.3773
S7	0.3083	0.2958	0.0161	22.9946	0.1490	0.6016
S8	0.5372	0.1911	0.0519	27.7278	0.0863	0.4288
S9	0.0432	0.0229	0.0074	4.6929	0.0129	0.0336
S10	0.3911	0.1852	0.0011	33.1401	0.1931	0.3175
S11	0.8787	0.1894	0.0266	38.7459	0.0921	0.1523
S12	1.2612	0.1674	0.0262	9.6819	0.1187	0.1815
S13	1.0558	0.3933	0.2491	26.2219	0.3177	0.2950
S14	0.2709	0.2939	0.0045	21.7009	0.2426	0.4534
S15	0.1362	0.0655	0.0193	24.2641	0.1378	0.4087
Mean	0.4719	0.2095	0.0503	24.7670	0.1453	0.3663
Min	0.0432	0.0229	0.0011	4.6929	0.0112	0.0336
Max	1.2612	0.7132	0.2491	80.3602	0.3491	0.9269

The distribution of the heavy metals in relation to the EF result was Cd>Ni>As>Zn>Cu>Cr. EF values that are close to 1 indicates that metal contamination are from anthropogenic or crustal sources while values greater than 1 indicate geogenic or non – crustal/natural sources (Sarala Thambavani and Uma Mageswari, 2013). Except for Zn and Cd, all other metals recorded EF values less than 1. Four (4) locations (S2, S4, S8 and S11) recorded Zn EF values close to 1 thereby indicating contamination from anthropogenic sources while 2 locations (S12 and S13) recorded values greater than 1 indicating contamination from geogenic sources. EF values for Cd were all greater than 1 indicating contamination from geogenic sources. Cd contamination has been highlighted by the result of $\mathbf{C_f}$ and could be attributed to leaching of contaminants from fertilizer washed from agricultural lands or sewage sludge (ATSDR, 2008a). Usually, geogenic contamination results from long residence times and mineralogy of an aquifer without direct or indirect anthropogenic influence (Grützmacher *et al*., 2013)

Saturation index

Table 10 shows the results for LSI. The result ranged between – 5.3 and – 2.7 indicating that the water is undersaturated with respect to calcium carbonate and has a tendency to remove existing calcium carbonate protective coatings in pipelines and equipment. LSI refers to the quality of water in terms of salts saturation and their ability to prevent corrosion (Alhameid and Al – Naeem, 2014). The order of possible corrosion in the in the study are in relation to the sampling sites is: S15> S2> S14> S1> S10> S3> S4> S12> S8> S11> S7> S13> S9> S6> S5. Treatment of the water is recommended in other to protect pipes and equipment.

Table 10: Langelier Saturation Index values

Sample	LSI	Indication	Description	Remarks
S1	-3.2			
S2	-2.8			
S3	-3.5			
S4	-3.9			
S5	-5.3	Water is undersaturated with respect to calcium carbonate. Undersaturated water has a tendency to remove existing calcium carbonate protective coatings in pipelines and equipment.	Serious corrosion	Treatment Recommended
S6	-4.8			
S7	-4.3			
S8	-4.1			
S9	-4.7			
S10	-3.2			
S11	-4.1			
S12	-3.9			
S13	-4.6			
S14	-3.1			
S15	-2.7			

Langelier Saturation Index – pH – Alkalinity relationship

Figure 1 shows the relationship between LSI – pH – alkalinity. The results of LSI were verified using the results of pH and alkalinity. The LSI – pH – Alkalinity relationship was used to highlight the levels of interdependence involved in LSI, pH and alkalinity. It should be recalled that the result of water quality analysis showed that pH result was acidic for the sampling sites and the result of alkalinity was much higher than the maximum allowable limit.

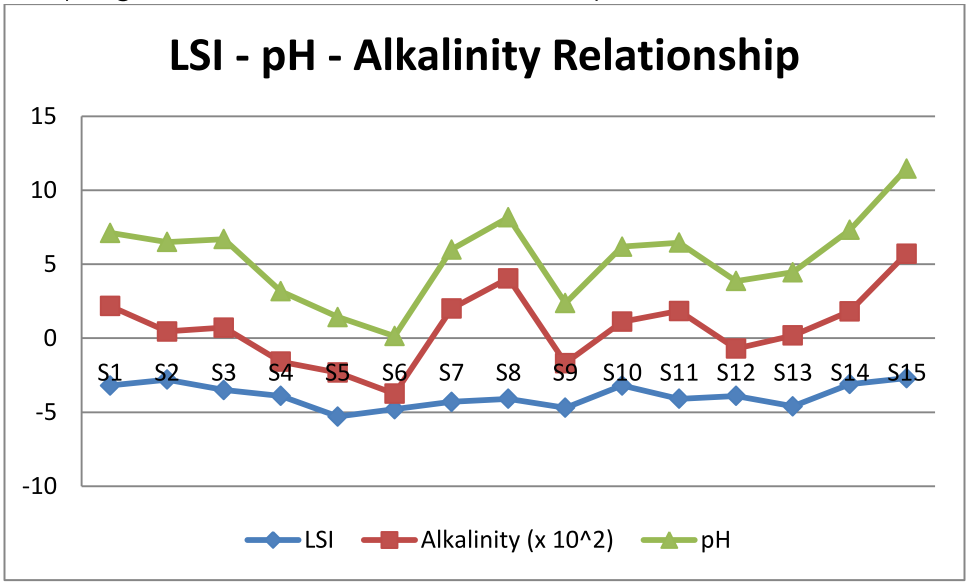

Figure 1: Graph showing the LSI – pH – Alkalinity relationship

Figure 1 gives an indication of the trends occurring in the 3 water quality indicators. LSI – pH – alkalinity relationship could represent a vital tool in establishing the degree of corrosivity of water.

CONCLUSION

Acidic pH values and increased alkalinity values has highlighted the implications of anthropogenic activities on groundwater quality in the study area. Water treatment at household levels should be encouraged as much as possible and awareness of proper waste disposal practices as well as the consequences of indiscriminate refuse dumping must be stressed. Though geogenic contamination besides anthropogenic activities could also influence the concentrations of water quality parameters within the aquifer; thereby affecting the quality of the groundwater.

Although the concentrations of heavy metals in relation to WHO (2011) and SON (2007) water standards showed that the metal concentrations are within the allowable range, additional analysis of the data using pollution rate tools proved necessary to further evaluate the extent of the metal concentrations. Multiple pollution rate assessment tools provides a platform isolate metals that should be paid more attention to; a development that may not be detected should the research is simply based on comparing the result of water quality assessment to existing drinking water quality standards. For instance with respect to this study, Cd was found to be a metal that should be of research priority; an issue that was only detected using contamination factor pollution rate detection tool. Attention of farmers should be drawn to the effects of the use of inorganic fertilizers due to the fact that inorganic fertilizer is a possible source of Cd contamination. Organic fertilizer use as alternatives can be encouraged. Further attention needs to be paid to Fe concentration as well as indicated by the result of I_{geo}.

Increased population growth translates to increased anthropogenic influences on the components of the environment resulting in continuous increase in pollutants in the environment, as highlighted in the result of LSI result. The LSI results indicates the tendency of the water to remove existing calcium carbonate protective coatings in pipelines and equipment; hence the treatment of the water is recommended in other to protect pipes and other equipment used and the need for routine monitoring cannot be overstressed.

REFERENCES

Addo, M.A., Okley, G.M., Affum, H.A., Acquah, S., Gbadago, J.K., Senu, J.K. and Botwe, B.O. (2011) Water Quality and Level of Some Heavy Metals in Water and Sediments of Kpeshie Lagoon, La-Accra, Ghana, Research Journal of Environmental and Earth Sciences Vol 3, No 5, pp 487-497, ISSN: 2041-0492

Adekunle, I. M., Adetunji, M. T., Gbadebo, A. M. and Banjoko, O. B. (2007) Assessment of Groundwater Quality in a Typical Rural Settlement in Southwest Nigeria, International Journal of Environmental Research and Public Health, Vol 4, No 4, pp 307-318 ISSN 1661-7827

Adepelumi, A.; Ako, B. and Ajayi, I. T. (2001) Groundwater contamination in basement –complex area of Ile-Ife, Southwestern Nigeria: A case study using the electrical-resistivity of geographical method, Hydrogeology Journal, Vol 9, No 6, pp 611 -622.

Adesuyi, A. A., Nnodu, V. C., Akinola, M. O., Njoku, K.L., and Jolaoso, A. O. (2015) Groundwater Quality Assessment in Eliozu Community, Port Harcourt, Niger Delta, Nigeria, International Journal of Scientific & Technology Research, Vol 4(12) ISSN 2277-8616149 Available at www.ijstr.org

Adetunde, L.A., Glover, R.L.K. and Oguntola G.O. (2011) Assessment of the Ground Water Quality in Ogbomosho Township of Oyo State of Nigeria, Vol 8, No 1, pp 115 – 122

Aghazadeh, N. and Mogadam, A. A. (2010) Assessment of Groundwater Quality and its Suitability for Drinking and Agricultural Uses in the Oshnavieh Area, Northwest of Iran, Journal of Environmental Protection, Vol 1, pp 30-40 doi:10.4236/jep.2010.11005

Akoteyon, I. S. and Soladoye, O. (2011) Groundwater Quality Assessment in Eti-Osa, Lagos-Nigeria using Multivariate Analysis, J. Appl. Sci. Environ. Manage. Vol 15, No 1, pp 121 – 125 Available Online at www.bioline.org.br/ja

Aksu, A.E., Yaşar, D. and Uslu, O. (1998) Assessment of marine pollution in Izmir Bay: Heavy metal and organic compound concentrations in surficial sediments. Translations and Journal of Engineering and Environmental Science, Vol 22, pp 387-415.

Alsaqqar, A.S., Khudair, B.H. and Ali, S.K. (2014) Evaluating Water Stability Indices from Water Treatment Plants in Baghdad City, Journal of Water Resource and Protection, Vol 6, pp 1344-1351

Alhameid, A. H. and Al – Naeem, A. A. (2014) Spatial Pattern of Groundwater Quality and its Impact on Pipes and Wells Equipment Corrosion in Al – Hassa Oasis Kingdom of Saudi Arabia, Trends in Applied Sciences Research, Vol 9, No 9, pp 545 – 556 DOI: 10.3923/tasr.2014.545.556

Alloway, B. J. and Ayres, D. C. (1997) Chemical principles of environmental pollution, In Wastes and their disposal, (2 Ed), Blackie A-cad Professional London, UK, pp 353-357

Annapoorna, H. and Janardhana, M.R. (2015) Assessment of Groundwater Quality for Drinking Purpose in Rural Areas Surrounding a Defunct Copper Mine, Paper presented at International Conference on Water Resources, Coastal And Ocean Engineering (ICWRCOE 2015), Aquatic Procedia Vol 4, pp 685 – 692 doi: 10.1016/j.aqpro.2015.02.088

Asaah A. V. and Abimbola, A. F. (2005) Heavy metal concentrations and distribution in surface soils of the Bassa Industrial Zone 1, Doula, Cameroon, The Journal for Science and Engineering Vol 31, No 2A, pp 147 - 158

ATSDR (2008a) Cadmium Toxicity: Case Studies in Environmental Medicine (CSEM), Available online at https://www.atsdr.cdc.gov

ATSDR, (2008b) Toxicological profile for Manganese; Agency for Toxic substances and Disease Registry, Available online at www.**atsdr**.cdc.gov

Awofulu, O.R., Mbolekwa, Z., Mtshemia, V. and Fatoki, O.S. (2005) Levels of trace metals and sediment from Tyume River and its effects on an irrigated farmland. Water SA., Vol 31, No 1, pp 87-94.

Bartram, J. and Ballance, R. (1996) (Ed.) Water Quality Monitoring: A Practical Guide to the Design of Freshwater Quality Studies and Monitoring Programme, Published on behalf of UNDP & WHO Chapman & Hall, London 383 pp.

Ballance, R. (1996) Physical and Chemical Analyses In Bartram, J. and Ballance, R. (Eds.), A Practical Guide to the Design of Freshwater Quality Studies and Monitoring Programme, Published on behalf of UNDP & WHO ISBN 0 419 22320 7 383pp

Belitz, K. Jurgens, B.C., and Johnson, T.D., 2016, Potential Corrosivity of untreated groundwater in the United States: U.S. Geological Survey Scientific Investigations Report 2016–5092, 16 p., http://dx.doi.org/10.3133/sir20165092 ISSN 2328-0328 (online)

Bhattacharya S. K. (1988) Urban Domestic Water Supply in Developing Countries, New Delhi, India

Birch, G. (2003) Coastal GIS, Wollongong University Papers Centre of Maritime Policy, Australia p. 14

Carrier Air Conditioning Company (1965). Handbook of Air Conditioning System Design, New York, McGraw-Hill Books

Clark, J. 2006. Rivers and their catchments: impact of landfill on water quality, Earth Sciences. Branch, Scottish Natural Heritage 2

Cotruvo, J. and Bartram, J. (2009) Calcium and Magnesium in Drinking-water: Public health significance, eds. World Health Organization, Geneva ISBN 978 92 4 156355 0

Dallas H.F. and Day J.A. (1993) The effect of water Quality Variables on River and ecosystem. Water Research Commission Report No TT61/93

Deely, J.M., and Fergusson, J.E. (1994) Heavy metal and organic matter concentrations and distributions in dated sediments of a small estuary adjacent to a small urban area. The Science of the Total Environment, 153(2): 97–111

Domagalski, J. K., Chao, L. and Xinquan, Z. (2001) Comparative assessment of groundwater quality in the Tangshan region of the People's Republic of China and similar areas in the U.S. Scientific World Journal, Vol 10, No 1, pp 415 –422.

Domenico, P. A. and Schwartz, F. W. (1990) Physical and chemical hydrogeology, John Wiley and Sons, New York, pp. 824

Fagbote, E. O. and Olanipekun, E. O. (2010) Evaluation of the Status of Heavy Metal Pollution of Sediment of Agbabu Bitumen Deposit Area, Nigeria, European Journal of Scientific Research, Vol.41 No.3, pp.373-382 ISSN 1450-216X Available at http://www.eurojournals.com/ejsr.htm

Guler, C. and Thyne, G. D. (2004) Hydrologic and geologic factors controlling surface and groundwater chemistry in Indian Wells-Owens Valley area, Southeastern California, USA, Journal of Hydrology, Vol. 285, pp. 177–198

Grützmacher, G., Kumar, P.J.S., Rustler, M., Hannappel, S. and Sauer, U. (2013) Geogenic groundwater contamination – definition, occurrence and relevance for drinking water production, Zbl. Geol. Paläont. Teil I Available online at www.schweizerbart.de Vol 1, pp 69 – 75

Gupta, S. K., Gupta, R. C., Gupta, A. B., Seth, A. K., Bassin, J. K. and Alk, G. (2000) Recurrent acute respiratory tract infections in areas with high nitrate concentrations in drinking water. Environ. Health Perspectives Vol 108, pp 363-366

Gupta, N., Nafees, S. A., Jain, M. K. and Kalpana, S. (2011) Assessment of Groundwater Quality of Outskirts Kota City with Reference to its Potential of Scale Formation and Corrosivity, E – Journal of Chemistry Vol 8, No 3, pp 1330 – 1338 ISSN: 0973 -4945

Hakanson, L. (1980) Ecological risk index for aquatic pollution control, a sedimentological approach, Water Resource Journal Vol 14, pp 975–1001

Hallı, M., Sarı, E. and Kurt, M. A. (2014) Assessment of Arsenic and Heavy Metal Pollution in Surface Sediments of the Ergene River, Turkey, Pol. J. Environ. Stud. Vol 23, No 5, pp 1581-1590

Hem, J. D. (1989) Study and interpretation of the chemical characteristics of natural water, US Geological Surveys, Water-Supply Paper, 2254

Hutton, M., Chaney, R.L., Krishna, C.R., Murti, M., Olade, A. and Page, A.L. (1987) Group Report, In: Hutchson, T.C. and K.M. Meena, (Eds.), Lead, Mercury, Cadmium and Arsenic in the Environment, John Wiley, New York, pp 35-41

Kortatsi, B. K. (2007) Hydrochemical framework of groundwater in the Ankobra Basin, Ghana, Aquatic Geochemistry, Vol. 13, No. 1, pp. 41–74

Langelier, W.F. (1936) The Analytical Control of Anticorrosion Water Treatment, Journal of American Water Works Association, Vol 28, pp 1500

Larson, T.E., Buswell, A.M., Ludwig, H.F., and Langelier, W.F., 1942, Calcium carbonate saturation index and alkalinity interpretations [with discussion]: Journal of the American Water Works Association, v. 34, no. 11, p. 1667–1684.

Likuku, A. S., Mmolawa, K. B. and Gaboutloeloe, G. K. (2013) Assessment of Heavy Metal Enrichment and Degree of Contamination Around the Copper-Nickel Mine in the Selebi Phikwe Region, Eastern

Botswana Environment and Ecology Research 1(2): 32-40, DOI: 10.13189/eer.2013.010202 Available online at http://www.hrpub.org

Mayouf, J. A. (2012) Determination of Iron, Copper, Lead and Cadmium Concentrations in Rain Water Tanks in Misurata, Libya, ARPN Journal of Science and Technology, Vol. 2, No 8, pp 676 – 680 ISSN 2225-7217 Available online at http://www.ejournalofscience

Moyosore, J.O., Coker, A.O., Sridhar, M.K.C. and Mumuni, A. (2014) Iron and Manganese Levels of Groundwater in Selected Areas in Ibadan and Feasible Engineering Solutions, European Scientific Journal Vol 10, No 11, pp 137 – 153 ISSN: 1857- 7431

Mediolla, L. L., Domingues, M. C. D. and Sandoval M. R. G. (2008) Environmental Assessment of and Active Tailings Pile in the State of Mexico (Central Mexico), Research Journal of Environmental sciences Vol 2, No 3, pp 197 – 208

Meybeck, M., Kuusisto, E., Mäkelä, A. and Mälkki, E. (1996) Water Quality In Bartram, J. and Balance, R. (Eds.), Water Quality Monitoring: A Practical Guide to the Design of Freshwater Quality Studies and Monitoring Programme, Published on behalf of UNDP & WHO Chapman & Hall, London 383 pp.

ISBN 0 419 22320 7

Mohsin, M., Safdar, S., Asghar, F. and Jamal, F. (2013) Assessment of Drinking Water Quality and its Impact on Residents Health in Bahawalpur City, International Journal of Humanities and Social Science Vol. 3 No. 15 pp 114 - 128

Moore, F., Forghani, G. and Qishlaqi, A. (2009) Assessment of Heavy Metal Contamination In Water And Surface Sediments Of The Maharlu Saline Lake, South West Iran, Iranian Journal of Science & Technology, Vol. 33, No.1, pp 43-55

Müller, G. (1969) Index of geoaccumulation in sediments of the Rhine River, Geojournal No.2, pp 108–118

Napacho, Z. A. and Manyele, S. V. (2010) Quality assessment of drinking water in Temeke District (part II): Characterization of chemical parameters, African Journal of Environmental Science and Technology 4(11), pp. 775-789 Available online at http://www.academicjournals.org/AJEST ISSN 1991-637X

National Research Council (1989) Recommended dietary allowances, 10th ed. Washington, DC, National Academy Press

Olivares-Rieumont, S., Rosa, D. D. L, Lima, L., Graham, D. W., Alessandro, K. D., Borroto, J., Martinez, F. and Sanchez, J. (2005) Assessment of heavy metal levels in Almendared River sediments-Havana City, Cuba. Water Res, Vol 39, pp 3945-3953

Omotoso, O. A. and Ojo, O. J. (2015) Assessment of some heavy metals contamination in the soil of river Niger floodplain at Jebba, central Nigeria, Water Utility Journal Vol 6, pp 71 – 80

Samir, M.N., Mohamed, A.O. and Shaif, M.K. (2006) Environmental assessment of heavy metal pollution in bottom sediments of Aden Port, Yemen, Int. J. Ocean Oceanogr., Vol 1, No 1, pp 99-109

Sarala Thambavani D. and Uma Mageswari T.S.R. (2013) Metal Pollution Assessment in Ground Water, Bull. Env.Pharmacol. Life Sci., Vol 2, No 12, pp 122-129

Selvaraj, K., Moha, V. R. and Szefer, P. (2004) Evaluation of metal contamination in coastal sediments of the Bay of Bengal, India: geochemical and statistical approaches. Mar. Pollut. Bull, Vol 49, pp 174-185

SON (2007) Nigerian Standard for Drinking Water Quality NIS 554: 2007

Tahir, M. A. and Rasheed, H. (2008) Distribution of nitrate in the water resources of Pakistan, African Journal of Environmental Science and Technology Vol. 2 (11). pp. 397-403, Available online at http://www.academicjournals.org/AJest ISSN 1996-0786

Tchobanoglous, G., Burton, F. L. and Stensel, H. D. (2003) Wastewater Engineering, Treatment, and Reuse, 4th edition McGraw – Hill, New York 823p

Tijani, M. N. and Onodera, S. (2009) Hydrogeochemical Assessment of metals contamination in an urban drainage system: A case study of Osogbo Township, SW-Nigeria. J. Water Resource and Protection Vol 3, pp 164-173

Tippie, V. (1984) An Environmental Characterization of Chesa- peak Bay and a Framework for Action, In: Kennedy, V. Ed., *The Estuary as a Filter*, Academic Press, New York, pp. 467-487

Turekian, K. K. and Wedepohl, K. H. (1961) Distribution of the elements in some major units of the earth's crust, Bulletin of Geological Society of America, Vol 72, pp 175–92.

USEPA, (2004) Drinking Water Health Advisory for Manganese, US Environmental Protection Agency. Available online at http://www.epa.gov/safewater

Vazquez Sunne, E., Sanchez Vila, X. and Carrera, J. (2005) "Introductory review of specific factors influencing urban groundwater, an emerging branch of hydrogeology, with reference to Barcelona, Spain," Hydrogeology Journal, Vol. 13, pp. 522–533,

Weyer, P. J., Cerhan, J. R., Kross, B. C., Hallberg, G. R., Kantamneni, J., Breuer, G., Jones, M. P., Zheng, W. and Lynch, C. F. (2001) Municipal drinking water nitrate level and cancer risk in older women: the Iowa Women's Health Study. Epidemiol. Vol 11, No 3, pp 327-338

WHO (1996) Guidelines for drinking-water quality, 2nd ed. Vol. 2, Health criteria and other supporting information, World Health Organization, Geneva

WHO, (2004) Manganese in Drinking water, Background document of WHO Guidelines for Drinking water quality, Available online at www.who.int/**water**_sanitation_health

WHO (2011) Guidelines for Drinking Water Quality, 4th Edition, Geneva, Switzerland ISBN 978 92 4 154815 1 564pp

Yongming, H., Peixuan, D., Junji, C. and Posmentier, E. S. (2006) Multivariate analysis of heavy metal contamination in urban dusts of Xi'an, Central China. Sci. Total Environ, Vol 355, pp 176-186

AN ANALYSIS OF SOME WATER BALANCE INDICES IN NIGERIA OVER TWO YEARS WITH CONTRASTING MOISTURE CONDITION

ABSTRACT

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A routine study of water balance indices is a veritable tool in monitoring the amount of water that will be available in the soil of any particular place at a particular time for optimal crop production and other uses. The semi-arid region of Africa and Nigeria in particular, is constantly bedeviled with the problem of inadequate water for efficient crop production. Hence, the needs for adequate information on soil water balance for efficient water management to boost crop production. However, this study makes analysis of some water balance indices in Nigeria over two years with contrasting moisture condition. The year 1983 has been described as a dry year while the year 2003 on the other hand as a wet year. This study used mean monthly air temperature and monthly rainfall data. The data were sourced from the archives of the Nigerian Meteorological Agency NIMET with respect to twenty-seven synoptic weather stations across Nigeria. The entire mean monthly air temperature and monthly rainfall data for 1983 and 2003 were subjected to Thornwaite's method to estimate water balance indices such as potential evapotranpiration, actual evapotranspiration, and water deficit. Paired sample test revealed that there is a significance difference between the water balance indices of a dry year and a wet year and across the weather stations in Nigeria [p=.000]. This study concluded that there is no uniformity in the pattern of water balance indices across Nigeria and over the two years. The study thus suggests that government should provide alternative sources of water inform of irrigation to those locations where water deficit is higher in order to boost their crop production. On the other hand, places with high moisture surplus and runoff should be properly managed to forestall greater danger of soil erosion and flood.

Keywords: water balance, indices, actual evapotranpiration, potential evapotranspitraion, water deficit, water surplus and runoff.

INTRODUCTION

There are reports of an increasing trend in aridity in the arid and semi-arid region of Nigeria [1]. As a result, Irrigation agriculture can be 2 to 3 times more productive than rain-fed agriculture in Sudao-Sahelian zone of Africa. The development of irrigation potential in this region is based on the availability of reliable information on the water resources.

Long term and routine records of scientifically documented facts about the water balance are a necessary pre-requisite to sustainable developments of water resources. It is against this backdrop that this study focuses on the analysis of some water balance indices in

Nigeria over two years with contrasting moisture condition. The year 1983 and 2003 has been described as a dry and a wet year [2]. The objectives of this study are: to estimate the potential evapotranspiration for each of the weather stations selected in Nigeria for the year 1983 and 2003, to compute water balance sheet for each of the weather stations in Nigeria for 1983 and 2003, to determine the spatial, temporal and latitudinal variations of the water balance indices in Nigeria and to find out whether there is any significance difference between the water balance indices of a dry year and a wet year in Nigeria.

Water balance is an accounting of the inputs and outputs of water on the earth's surface. The water balance of any place, whether it is an agricultural field, watershed, or continent, can be determine by calculating the input, output and storage changes of water at the earth's surface. The major input is from precipitation and output is evapotranspiration [3]. [4] Stresses that inadequate water supply is the most important factor affecting agricultural production in Sudano-Sahelian region of Africa and a better understanding of the magnitude and dynamics of the different components of the soil water balance is very crucial to development of technological options for sustainable management of soil and water resources.

Materials and methods

The study area is Nigeria. It is located between latitude 4°N and 14°N of the equator and longitude 3°E and 15°E of the Greenwich Meridian. The materials used for this study include the Excel template used to estimate the PE, the Thornwaite,s Monograph containing the soil water holding capacity used for computing the water balance indices, Journals and other publications used as literature. The data used for this study are the mean monthly air temperature and monthly precipitation for only two years with contrasting moisture condition. The data were sourced from the archives of the Nigerian Meteorological Agency [NIMET] with respect to twenty seven [27] selected weather stations well spread across Nigeria. The air temperature data collected were subjected to Thornwaite's method to estimate the monthly potential evapotranspiration [PE] for each of the stations for the selected wet and dry year. The estimated monthly PE values in conjunction with the monthly rainfall data and Thornwaite's soil water holding capacity of 250mm serve as the input data to compute other water balance indices. The water balance indices analyzed in this study are: Potential evapotranspiration, precipitation, actual evapotranspiration and soil water deficit. The results of the annual water balance indices for the two years were presented in a table. Spatial maps were produced using Arc GIS to show the spatial pattern of the annual water balance indices in Nigeria. The monthly and latitudinal variations of the water balance indices were presented on charts for better understanding.

Figure1 Map of Nigeria showing the distribution of selected synoptic meteorological stations Source: [2].

Result and discussion

Spatial, latitudinal and monthly variations of Potential evapotranspiration in Nigeria

Result from table1 indicates that the rate of PE varies across Nigeria in both dry year [1983] and wet year [2003]. It could be observed from figure 3 that most of the stations located north of latitude 7°N experiences higher rate of potential evapotranspiration of above 2000mm in both the year 1983 and 2003 when compare to those stations south of latitude 7°N. Gusau recorded the highest PE of 2205mm in 2003 while Yelwa recorded the highest PE of 2199mm in 1983. On the contrary, Jos recorded the least amount of PE in both years. Critical examination of table 1 show that the amount of PE recorded in 2003 is significantly higher than that of 1983. See figure 2a & 2b for the spatial pattern of PE in Nigeria. The spatial variation of PE is being influenced by factors such as the amount of available water, energy from solar radiation, topography, vegetation cover, and time [season] of the year etc. The manifestations of these factors give Jos a distinct record of low PE among her counterpart in the north.

Result from figure 4 revealed that the rate of PE is higher during the month of February, March, April, May, June, October and November both in 1983 and 2003. The highest PE was recorded during the month of April and March in 1983 and 2003 respectively. The lowest PE on the other hand was recorded in January in 1983 and August in 2003.

Spatial, Latitudinal and Monthly variations of Rainfall in Nigeria

Result from table 1 shows that the amount of rainfall varies across Nigeria both in the year 1983 and 2003. It could be inferred from table 1 that rainfall is significantly higher in most of the stations located south of latitude 6°N where, most of the stations recorded annual rainfall above 2000mm compare to those located north of latitude 6°N of the equator. Warri recorded the highest annual rainfall of 2523mm in 1983 while Calabar recorded the highest rainfall of 2440mm in 2003. On the contrary, Nguru in the extreme north east recorded the least rainfall in both years. See detail in table 1. See figure 5a &5b for spatial pattern of rainfall in Nigeria and figure 6 for the latitudinal variation as well. Result shows that the amount of rainfall varies from January to December across Nigeria in both 1983 and 2003. A visual observation of figure 7 unfolds that the amount of rainfall is low from January to around May in both years. The months with the higher records of rainfall are June, July, August, and September

Spatial, Latitudinal and Monthly variation of Actual evapotranspiration in Nigeria

Actual evapotranspiration is the actual "amount of water use" that is, water that is actually evaporating into the atmosphere based on the environmental condition of that particular location [3]. However, result from table 1 shows that the rate of AE varies across Nigeria and over the dry and the wet years. It is also evidence from figure 8a &8b that the rate of annual AE increases from the north towards the south where there are higher amount of rainfall in both years. Most of the stations located south of latitude 6°N record higher AE of above 2000mm both 1983 and 2003. The highest AE of 1521mm was recorded in Ikom in 1983 while Calabar recorded the highest AE of 1771mm in 2003. Nguru recorded the least AE in both 1983 and 2003. A critical observation of table 1 shows that the rate of AE is significantly higher in the wet year compare to the dry year. See detail of latitudinal variation of Actual evapotranspiration in Nigeria over the two years in figure 9.

Result from figure 10 shows that the rate of AE varies from the month of January to December in 1983 and 2003. While the monthly AE is significantly low during the months of January, February, March, November and December, it is on the other hand higher during the months of May, June, July, August September and October across Nigeria in 1983 and 2003. The month with the highest AE in 1983 is June while the highest AE was recorded in the month of October in 2003. See figure 10.

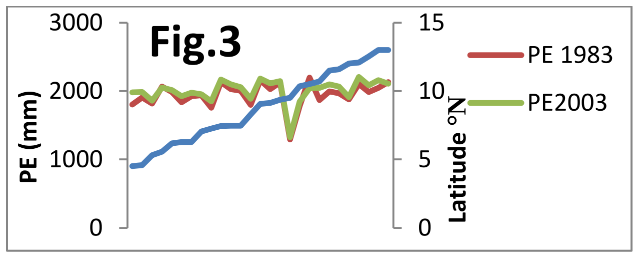
Spatial, Latitudinal and Monthly variation of Water Deficit in Nigeria

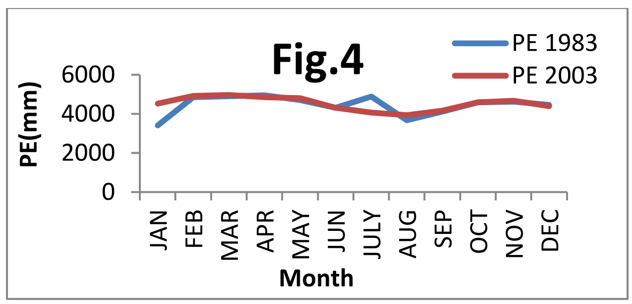
Moisture deficit occurs when the demand for water on the earth's surface exceeds what is actually available. In order words, deficit occurs when PE exceeds AE i.e. [PE>AE]. However, it could be observed from table 1 and figure11a &11b that the occurrence of moisture deficit is higher northwards in both years when compare to what is obtained in the southern stations. It could also be observed that stations located south of 6°N such as Calabar, Portharcourt, Warri, Benin, Enugu, Jos and Lagos recorded lower annual moisture deficit in both 1983 and 2003. See figure 12 for latitudinal variation. The spatial pattern of soil moisture deficit across Nigeria could also be related to the findings of [5].

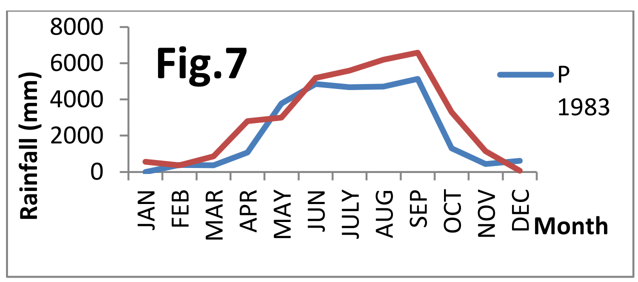
Result from figure13 reveals that stations such as Nguru, Katsina, Minna, Yelwa, Kano, Maiduguri, Sokoto, Bida, except Jos, Yola and Kaduna, experiences moisture deficit throughout the year while virtually all the stations in the south only experiences deficit for between four to five months in the years. Detail observation of figure13 shows that the amount of water deficit decreases from January across the stations during the years to around September in the north and to October in the south. It could also be observed that the amount of water deficit increases from the month of November to December in both the dry and the wet years. It is very clear from figure 14 that January recorded the highest water deficit while lowest water deficit on the other hand was recorded during the month of August in both 1983 and 2003.

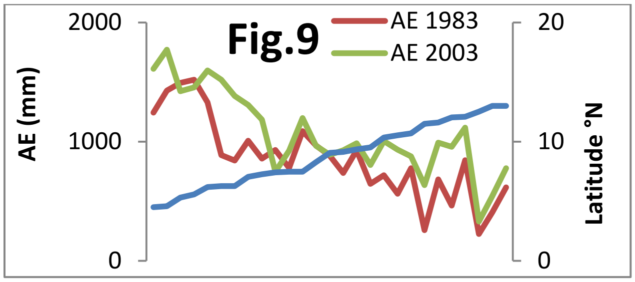
Conclusion and Recommendations

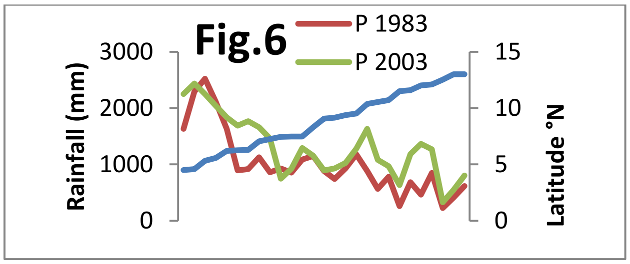
This study concludes that there is no uniformity in the spatial, latitudinal and temporal pattern of water balance indices in Nigeria. This study therefore recommends that Government should provide alternative source of water inform of irrigation scheme in those part of Nigeria where there are very low rainfall, high potential evapotranspitation and high water deficit to boost crop production. Places with high rainfall, water surpluses and runoff should be properly managed to forestall severe soil erosion and flooding.











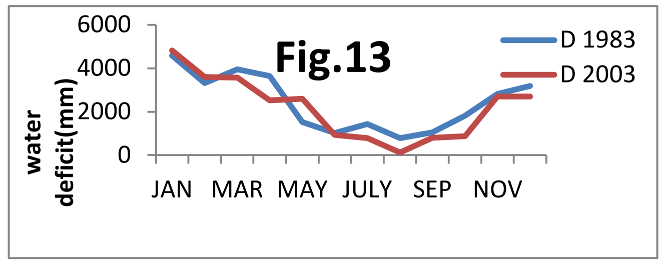
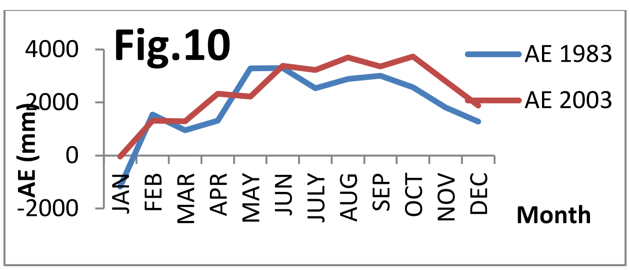


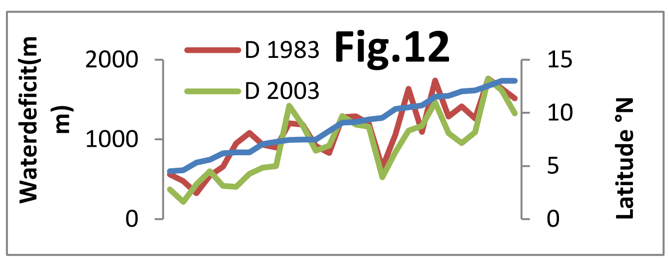
Table 2 summary of some annual water balance indices across twenty seven weather stations in Nigeria for the year 1983 and 2003 values [mm]

station	latit°N	long°E	PE1983	P1983	AE193	D1983	PE2003	P2003	AE2003	D203
Port/H	4.51	7.01	1805	1633	1244	561	1982	2248	1610	372
Calabar	4.58	8.21	1906	2298	1428	478	1987	2440	1771	216
Warri	5.31	5.44	1818	2523	1494	324	1861	2252	1424	437
Ikom	5.58	8.58	2065	2110	1521	544	2054	2041	1455	599
Benin	6.19	5.06	1989	1630	1331	658	2013	1833	1598	415
Lagos	6.27	3.24	1838	893	887	951	1925	1691	1521	404
Enugu	6.28	7.33	1924	918	843	1081	1977	1769	1382	568
Ondo	7.06	4.5	1941	1126	1008	933	1953	1660	1309	644
Ibadan	7.26	3.54	1755	858	858	897	1849	1460	1184	665
Makurdi	7.44	8.32	2132	930	930	1202	2170	749	749	1421
Lokoja	7.47	6.44	2029	854	780	1187	2101	924	924	1177
Oshogbo	7.47	4.29	2007	1089	1089	918	2056	1293	1198	858
Ilorin	8.29	4.29	1798	1152	969	829	1887	1157	965	922
Bida	9.06	6.01	2161	882	882	1279	2184	891	891	1293

Yola	9.14	12.28	2029	738	738	1291	2112	927	927	1185
Minna	9.37	6.32	2125	928	928	1197	2145	1024	986	1159
Jos	9.52	8.45	1293	1176	647	646	1328	1280	805	523
Kaduna	10.36	7.27	1780	885	720	1060	1848	1633	1005	843
Yelwa	10.53	4.45	2199	563	563	1636	2044	1080	933	1111
Bauchi	10.7	9.49	1871	779	779	1092	2046	967	878	1168
Maidug.	11.51	13.05	1996	257	257	1739	2101	635	635	1466
Zaria	11.6	7.41	1970	683	683	1287	2068	1183	991	1077
Kano	12.3	8.12	1880	464	464	1416	1911	1366	957	954
Gusau	12.1	6.42	2106	846	846	1260	2205	1266	1117	1088
Nguru	12.53	10.28	1989	227	227	1762	2087	329	330	1757
Katsina	13.01	7.41	2046	409	409	1637	2162	546	546	1616
Sokoto	13.01	5.15	2131	618	618	1513	2107	801	779	1328

Source: author's computation, 2016





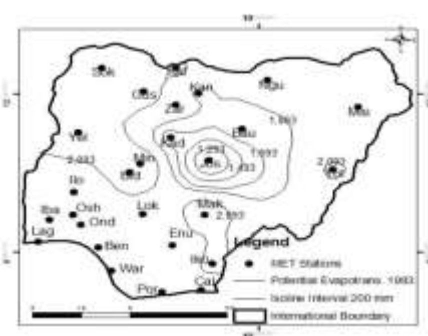
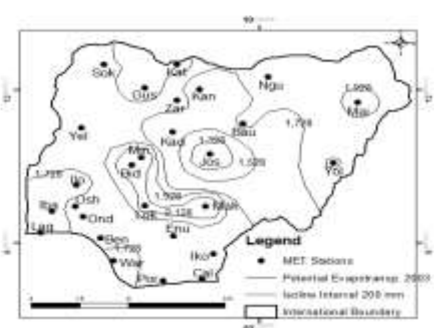


Fig.2 a



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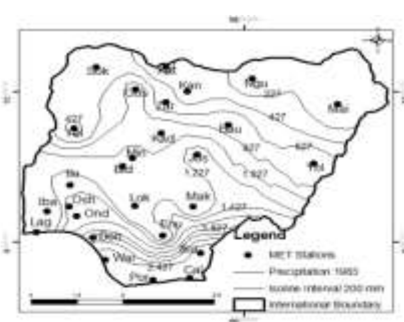

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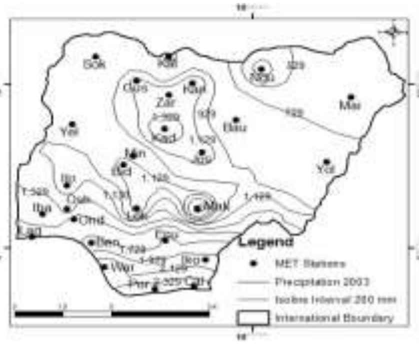
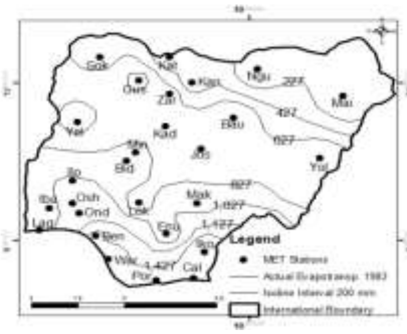




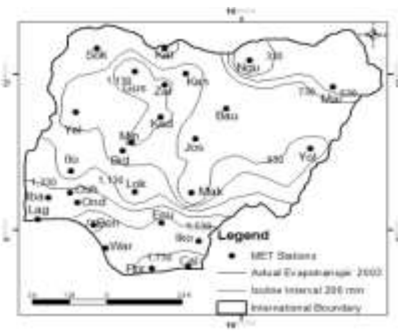
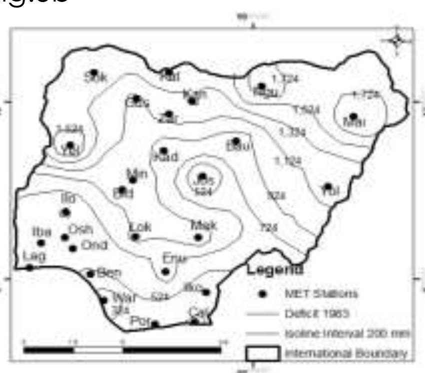


Fig.5b Fig.8a Fig.8b



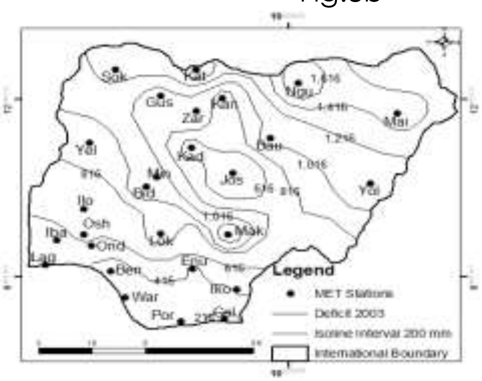


Fig.11a & 11b

References

1 Sawa, B. A, Ati, O. F, Jayeoba, I. A, Oladipo, E. O (2015) Trends in Aridity of the Arid and Semi-Arid Regions of Northern Nigeria: *Journal of Environment and Earth Sci.* 5 (10): 61-68.

2 Ritter, M. E. (2012) The Physical Environment: *An Introduction to Physical Geography.* Retrievedfromhttp//www.earthonlinemedia.com/ebooks/tpe-3e/tittle-page.html.2012.

3 Umar, A.T (2013) Frequency and Spatial Pattern of Droughts in Nigeria, *J. of Meteorolo. And Climate Science*, J. Met & Clim. Sci. 11(1):58-74.

4 Lal, R (1991) *Current Research on Crop Water Balance and Implication for the future*. Soil Water Balance in the Sudano-Sahelian Zone (Proceedings of the Niamey Workshop, February 1991). LAHS Publi. No 199, 1991. Page:31-32.

5 Nigerian Meterologica Agency (NIMET) (2013), *Quarterly Weather Review*, January, February, March and April. Pp 1-25.

FLOOD FREQUENCY ANALYSIS OF RIVER DONGA, AT DONGA, TARABA STATE, NIGERIA

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ABSTRACT
The aim of the study was to analyze the flood flows regimes of River Donga by modeling stream flow using Gumbel's probability distribution. Annual maximum discharge of the river for a period of 35 years (1955 to 1989) was modeled to predict floods for return periods (T) of 10, 25, 50 and 100 years. The predicted water level and flood flow magnitude obtained for respective return periods are as follows: 5.39 meter and 2,385.0 Cumecs, 5.72 meter and 2,631.2 Cumecs, 5.97 meter and 2,812.0 Cumecs, 6.2 meter and 2,980.4 Cumecs. The result revealed a gradual rise in both water level and magnitude with increase in return period (10, 25, 50 and 100 year flood). It was hypothesized that there is no significant difference between observed and predicted flood flow for river Donga. A goodness of fit test was conducted using regression analysis and non-parametric Chi square to find out if Donga flood flow fits the Gumbel distribution. From the trend line equation, R2 gives a value of 0.0105. This indicates that the flow data fits Gumbel distribution and hence, can be used to predict the frequency and magnitude of flood flow of river Donga catchment area. The plot also gives the relationship between the observed flow and corresponding year as: 2.9697 xs + 3916.9. The regression curve shows that there is no significant difference in the observed frequency of discharge (m^3/S) within the period 1955-1989 in the study area at a co-efficient of 1.05%. The outcome of the Gumbel's flood frequency analysis from this study provides relevant information that is useful for flood mitigation and management through engineering design of hydraulic structure (bridges, dams, culverts) for storm water, extreme river discharges and flood disaster early warning systems. This will minimize damages to lives, properties and even the environment associated to recent river Donga episodic floods.

Key words: Flood, flood-frequency, return-period, Gumbel's distribution, peak discharge.

INTRODUCTION

Flooding is one of the most common and widely distributed natural risks to life and property worldwide. Flood has been identified worldwide as highly destructive. It has a special place in natural hazards and accounts for approximately one third of all natural disasters in both developed and developing world (UNISDR 2012 cited in: Oyatayo, et al., 2016).

Floods are the leading cause of natural disaster worldwide and were responsible for 6.8million deaths in the 20th century. Asia is most flood-affected region, accounting for nearly 50% of flood related disaster leading to death, change in landform, and creation of flood plain in the 20th century. Flooding is the most common environmental hazard in Nigeria (Etuonovbe, 2011). Flood disaster is not a recent phenomenon in the country, and its destructive tendencies are sometimes enormous. Reports have it that serious flood disasters have occurred in Ibadan (1985, 1987 and 1990), Osogbo (1992, 1996, 2002), Yobe (2000) and Akure (1996, 2000, 2002, 2004 and 2006). The coastal cities of Lagos, Port Harcourt, Calabar, Uyo, and Warri among others have severally experienced incidences that have claimed many lives and properties worth millions of dollar.

Nwafor (2006) defined flood as a natural hazard like drought and desertification which occurs as an extreme hydrological (run off) event. Flood is a large volume of water which arrives at and occupies the stream channel and its flood plain in a time too short to prevent damage to economic activities including homes. Flood is a large amount of water covering an area that is usually dry. It is an overflowing of a great body of water over land not usually submerged (Abam, 2006).

Okereke (2007) observes the following as consequences of flooding: loss of human lives, flooding of houses, streets, inflow to soak away, municipal pollution, damage to properties, health hazards, cleanup costs, disruption of services, traffic problems, adverse effects on aesthetics, disturbances on wildlife habitats, economic loses and infrastructural damage.

Decision makers, planners and stakeholders need to know the frequency and magnitude of flooding. Utilization of flood stage or river gage levels in the land is essential for hazard zoning.

It is therefore necessary to use scientific methodology such as flood frequency analysis to provide a basis for concerted action-plan to be carried out in flood plain planning, flood structures or hazard mitigation, warning systems and rescue operations by either government or non-governmental agencies as applicable.

Flood frequency analysis is a viable method of flood flow estimation and provides reliable prediction in regions of relatively uniform climatic conditions from year to year and it is now an established method of determining critical design discharge for small to moderately sized hydraulic structures (Haktan, 1992). Flood frequency analysis is the universal method used for the estimation of recurrent interval of any hydrological event (Izinyon, 2011). Karmakar (2008) observes that flood estimation via flood frequency analysis provides a basic standard for flood risk evaluation especially in areas that are close to floodplains. More precisely, Izinyon (2011) affirms that return periods associated with annual maximum flood peaks are modeled using flood frequency analysis. This gives room for prediction of such extreme events (especially river runoff) since they are unpredictable and difficult to estimate spatiotemporally. Scientists and researchers find flood frequency analysis a useful tool for the estimation of the contribution of precipitation to stream flow and river runoff to flood occurrence. Hence, the need for this research. This is pivotally essential for the management of flood in Donga Town with respect to mitigation, design, planning and operations through the use of fundamental knowledge of flood characteristics in modeling.

4.0 Study Area

2.1 Location

The Donga River at Donga Town is located between latitude 7°43′00″N and longitude 10°03′00″E. The river arises from theMambilla Plateau in northeastern Nigeria. It forms part of the international border between Nigeria and Cameroon, and flows northwest to eventually merge with the Benue River in Nigeria. The Donga watershed is 20,000km^2 (7,700 sq mi) in area. At its peak near the Benue, it the river delivers 1,800 m^3 (64,000 cu ft) of water per second.

2.4 Climate

The mean annual rainfall of the study area is 1200mm. The area has two marked seasons, the dry and the rainy season. November to March, and April to October for dry and the rainy season respectively. The temperature is generally high with mean annual temperature at 32^{0}C recorded in April and minimum temperature as low as 10^{0}C experienced in December January, with the mean annual temperature at 22^{0}C (Enoch, 2014).

2.5 Geology and soil

Donga is underlain by sedimentary rock of post Cambrian land era, and consist mainly of gentle undulating land with plains. It's river and the basin constitutes one of the fertile arable lands of the region. The hilly undulating land stand at an altitude of 120-130 meters above sea level (Enoch, 2014). The soils by the river bank are not far from alluvial type according to the Food and Agriculture Organization (F.A.O) genetic classification. They are highly susceptible to annual flooding which takes place around the months of August and September with locally developed lithosols. Also the notable quality soil doesn't retain much water and is not highly forested. This makes it more manageable than soils found in the flood plains of the southern parts of the country.

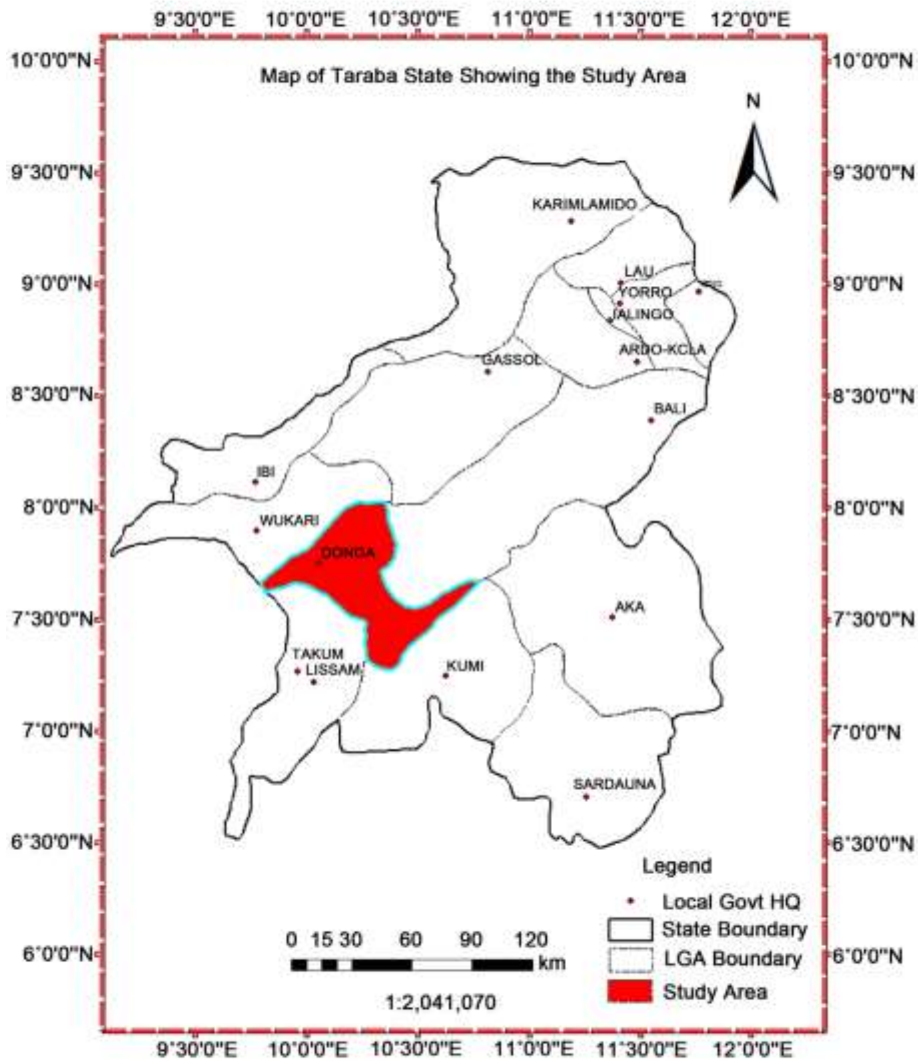

Figure 1: Location of Donga Local Government Area on Map of Taraba
Source: Ministry of Land and survey, Jalingo, Taraba State.

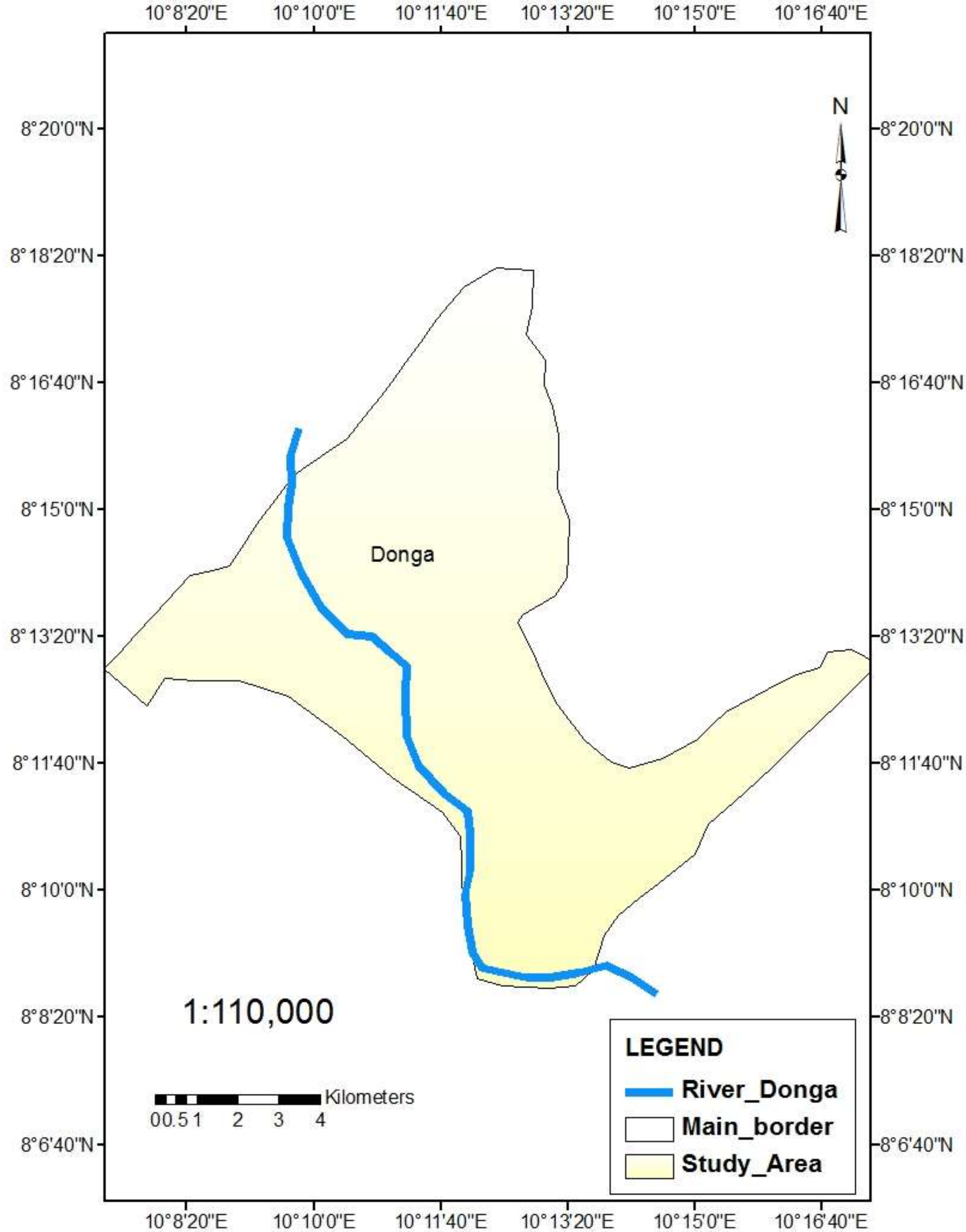

Figure 2: Map of Donga Local Government Area Showing River Donga
Source: Ministry of Land and Survey Jalingo, Taraba State.

2.4 Vegetation

Donga local government falls within the woodlands savannah zone a distinct type of vegetation, which is a transition between forest and savannah vegetation type. Thus there are both varieties of forest and savannah vegetation in which natural plant cover consist of trees, shrubs, and grasses, some of them loose there leaves for only short period in the year. A forest variety such as oil palm is formed scattered all over the area, (Enoch, 2014)

5.0 MATERIALS AND METHOD

3.1 Materials and Data:

The materials and data used for this study are as follows:

Hardware:

Computer, Printer, Scanner

Software:

MS Excel, SPSS.

Sources of Data

The following are the primary and secondary sources of data used:

Primary source

The primary data is the annual maximum gage height data of River Donga at Donga from 1955 to 1989 obtained from the measurements carried out by the National Inland Water Authority (NIWA), Lokoja, Kogi State, Nigeria.

Secondary source of data

The secondary source of data includes official and unofficial statistics from both national and international publication including newspapers, articles, journals, thesis, dissertations and websites.

3.2 METHOD OF DATA ANALYSIS

Flood Flow Modeling

The Gumbel statistical distribution methodology as defined by Sharma and Sharma (2003) was adopted in this research. According to Gumbel, the annual maximum flow data are the extreme values in observed data of various years and hence should follow the extreme value distribution law. In this study, Gumbel distribution has been applied for flood frequency analysis because:

(a) Peak flow data are homogeneous and independent hence lack long-term trends;

(b) The river is lessregulated, hence is not significantly affected by reservoir operations, diversions or urbanization; and

(c) Flowdata cover a relatively long record (more than 10 years) and is of good quality.

Based on this, annual maximum gage height data for thirty five (35) years was used for the analysis. The Gumbel's Extreme Value Statistical Distribution equation is given by:

T = $\bar{X}$ + k * SDV

Where

T = Value of variate with a return period 'T'

$\bar{X}$= Mean of the variate

SDV = Standard deviation of the sample

k = Frequency factor expressed as:

$$K=\sqrt{\frac{6}{n}}[\ 0.57721 + Ln^*\ (Ln_{T-1}^{T})]$$

3.3 Goodness of fit test

To determine whether Donga flood flow fits Gumbel distribution, the following hypothesis was postulated:

H0: There is significant difference between recorded and predicted flood flow of River Donga at Donga.
H1: There is no significant difference between observed and predicted flood flow of River Donga a Donga
Chi square and regression analysis with the aid of the statistical package for social science (SPSS) was used to test the stated hypothesis.

4 RESULTS AND DISCUSSION

4.1 Introduction

This section presents the result of the flood frequency analysis conducted using the Gumbel extreme value distribution for different flood return periods. Also presented, are the results of the Chi-square ($\chi 2$) and regression analysis conducted to test the stated hypothesis.

4.2 Annual maximum discharge of River Donga from 1955 to 1989

Annual maximum discharge values for River Donga at Donga were derived from annual maximum gage height data of the river obtained for a period of 35 years. The maximum instantaneous flow and water level of 2,172 Cumecs and 5.69 meter were recorded in 1985, while the lowest values of 548 Cumecs and 2.99 meter were recorded in 1976. The 35-year mean instantaneous flood flow and water level is 1,939 Cumecs and 479.1 meter respectively.

4.3 Water level and flood flow prediction (magnitude)

Table 2: Modeled water level and magnitude

Return Period (year)	Water level (Meters)	Magnitude (Cumecs)
100	6.20	2980.4
50	5.97	2812.0
25	5.72	2631.2
10	5.39	2385.0

Table 1 shows the results of modeled water level and magnitude values of 100, 50, 25 and 10 year flood of river Donga at Donga town. The water level and magnitude for 100 year flood is 6.2 meter and 2,980.4 Cumecs, 50 year flood is 5.97 meter and 2,812.0 Cumecs, 25 year flood is 5.72 meter and 2,631.2 Cumecs and 10 year flood is 5.39 meter and 2,385.0 Cumecs respectively. The result shows a gradual rise in water level and magnitude with increase in return period (10, 25, 50 and 100 year flood). This confirms the works of Mujere (2011), Shakirudeen and Saheed (2014) and Okoroafor et al.,(2015). Flood frequency of this nature is a multi-dimensional tool used in the assessment of water resource potential as well as a measure of both hydrologic and hydraulic measure that must be integrated in the engineering construction of structures that concern a defined water body. In addition, this measure is a tool of necessity to ascertain the extent of inundation based on available hydrologic data. It provides the data frame for inundation area mapping as well as for the assessment of flood hazard and risk within an area (Shakirudeen and Saheed, 2014).

4.4 Test of Goodness of fit

Table 2: Statistical analysis

Return period (year)	**Magnitude (Cumecs) (O)**	**Expected (E)**	**(O-E)**	**(O-E)2**	**(O-E)2/E**
100	2980.4	2702.2	278.3	77423.1	28.7
50	2812	2702.2	109.9	12067.0	4.5
25	2631.2	2702.2	-70.9	5033.9	1.9
10	2385	2702.2	-317.2	100584.1	37.2
Total	**10808.6**	**10808.6**		**Chis. Value Cal.**	**72.2**
Expected	**2702.15**	**2702.15**			

Chi-squares calculated value= 72.2

Chi squares Tabulated value:

Chi-square (3) at degree of freedom (df) =4-1=3

Right-tail probability = 0.05

Complementary probability = 0.95

Critical value = 7.81473

Decision Rule

- If the $\chi^2_{cal} < \chi^2_{tab}$, accept Ho Otherwise,
- $\chi^2_{cal} > \chi^2_{tab}$, accept H1.

From the empirical result of $\chi^2_{cal}(72.2) > \chi^2_{tab}(7.81)$, this indicates that there is enough evidence to reject H0 in favour of H1 and therefore there is no significant difference between observed and expected flow data in the study area. The χ2 test revealed a satisfactory fit between observed and estimated flood flow values. This indicates that the flow data fit Gumbel distribution and hence, can be used to predict frequency of floods of river Donga at Donga. This confirms the findings of Mujere (2011) who conducted a research on flood frequency analysis using Gumbel distribution and presented a result of measured and predicted flood flows showing no significant (p=1.000) differences hence, a goodness of fit of the Gumbel distribution.

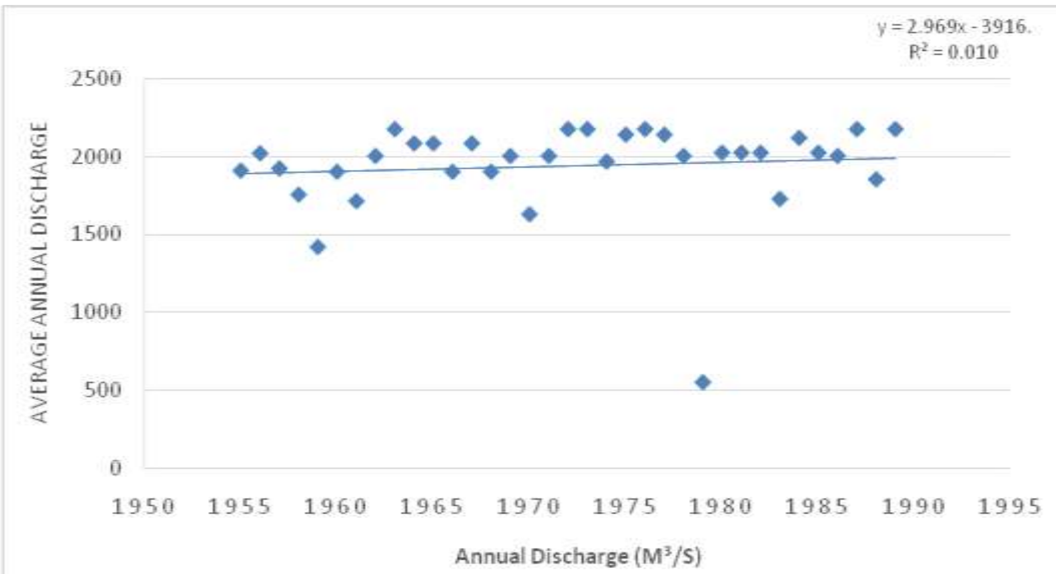

Figure1: Plot of River Donga at Donga Discharge

Figure 1 shows a plot of the flow of the river using the observed data. From the trend line equation, R2 gives a value of 0.0105. This shows that the pattern of the scatter is narrow and that Gumbel's distribution is suitable for predicting expected flow in the river. The plot also gives the relationship between the observed flow and corresponding year as: 2.9697xs + 3916.9. The regression curve shows that there is no significant difference in the observe frequency of discharge (m^3/S) within the peroid 1955-1989 in the study area with the co-efficient of 1.05%.From here, other values not shown in chart can be extrapolated. These and other values obtained will be useful in the area of flood mitigation and management and also in the engineering design of hydraulic structure such as storm water drains, culverts with a view to protecting lives and properties at the downstream of the river. This corroborate the findings of Okonofua and Ogbeifun (2013) whose trend line equation (R2) gives a value of 0.954which shows that Gumbel's distribution is suitable for predicting expected flow in riverOsse.

5 CONCLUSION AND RECOMMENDATION.

5.1 CONCLUSION

The conclusion from the research is that river Donga flow data fit Gumbel distribution and hence, can be used to predict flood flow in the study area.

The conclusion also from the study is that modeled water level and magnitude values of 100, 50, 25 and 10 year flood of river Donga at Donga include: 6.2 meter and 2,980.4 Cumecs, 5.97 meter and 2,812.0 Cumecs, 5.72 meter and 2,631.2 Cumecs and 5.39 meter and 2,385.0 Cumecs respectively. The result shows a gradual rise in water level and magnitude with increase in return period (10, 25, 50 and 100 year flood). These values will be useful in the area of flood protection and management, in engineering design of hydraulic structure such as storm water drains, culverts and with a view to protecting lives and properties at the downstream of the river.

5.2 RECOMMENDATIONS

Probability of flooding can be reduced but never eliminated. Flood flow studies can be used as a guide in determining the capacity of a structure. Reliable flood frequency estimate are vital for floodplain management: to protect the public, minimize flood related cost to government and private enterprises and assessing hazard related to the development of floodplain. Flood risk can be reduced by reducing the flood hazard or flood mitigation. The finding provides the following recommendation:

- Flood control structures should be constructed and early warning system put in place.
- Due to high discharge flood flow the land use/ land cover system in the study area needs to be checked, as more research on land use and land cover will help in harnessing the potential of the study area.

APPENDIX

Table of DISCHARGE (Q)

YEAR	ANNUAL MAXIMUM Gage height	DISCHARGE (Q) in M^3	$Q-\bar{Q}$	$(Q-\bar{Q})^2$
1955	471	1906	-33.4	1115.6
1956	483	2017	77.4	5990.8
1957	472	1920	-19.4	376.4
1958	454	1752	-187.4	35118.8
1959	418	1416	-523.4	273947.6
1960	475	1899	-40.4	1632.6

1961	456	1710	-229.4	52624.4
1962	483	2000	60.6	3672.4
1963	500	2172	232.6	54102.8
1964	497	2081	141.6	20050.6
1965	498	2081	141.6	20050.6
1966	474	1899	-40.4	1632.6
1967	494	2081	141.6	20050.6
1968	475	1899	-40.4	1632.6
1969	488	2000	60.6	3672.4
1970	440	1626	-313.4	98219.6
1971	482	2000	60.6	3672.4
1972	514	2172	232.6	54102.8
1973	514	2172	232.6	54102.8
1974	479	1964	24.6	605.2
1975	499	2137	197.6	39045.8
1976	569	2172	232.6	54102.8
1977	495	2137	197.6	39045.8
1978	482	2000	60.6	3672.4
1979	299	548	-1391.4	1935994.0
1980	484	2021	81.6	6658.6
1981	486	2021	81.6	6658.6
1982	489	2021	81.6	6658.6
1983	450	1724	-215.4	46397.2
1984	494	2116	176.6	31187.6
1985	487	2021	81.6	6658.6
1986	481	2000	60.6	3672.4
1987	519	2172	232.6	54102.8

1988	467	1850	-89.4	7992.4
1989	500	2172	232.6	54102.8
		$\sum Q$=67879/35 Q=1939.4cumecs		$\sum(Q-\bar{Q})^2$ =3002324

Source: Research calculation 2016

Standard deviation= $\frac{\sqrt{\sum(Q-\bar{Q})2}}{N}$

= $\frac{\sqrt{\sum 3002324}}{35}$ =$\sqrt{85780.7}$

SD= 292.9

X = RETURN PERIOD 100, 50 ,25 and 10 years

$(\bar{Q})$= 1939.4 cumecs

K= Frequency Factor

SD= 292.9

X=$\bar{X}$+KS

X 100= 1939.4 + (3.554 x 292.9)

=1939.4+1040.96

=2980.4 cumecs

X 50= 1939.4 + (2.979 x 292.9)

=1939.4 + 872.5

=2812.0 cumecs

X 25= 1939.4 + (2.354 x 293.9)

=1939.4 + 691.8

=2631.2 cumecs

X 10= 1939.4 + (1.516 x 293.9)

=1939.4 + 445.6

=2385 cumecs

TABLE OF ANNUAL GAUGE HEIGHT (cm) (X)

×	$\times -\bar{X}$	$(\times -\bar{X})^2$
471	-8.1	65.6
483	3.9	15.2
472	-7.1	50.4
454	-25.1	630.0
418	-61.1	3733.2
475	-4.1	16.8

456	-23.1	533.6
483	3.9	15.2
500	20.9	436.8
497	17.9	320.4
498	18.9	357.2
474	-5.1	26.0
494	14.9	222.0
475	-4.1	16.8
488	8.9	79.2
440	-39.1	1528.8
482	2.9	8.4
514	34.9	1218.8
514	34.9	1218.8
479	-0.1	0.01
499	19.9	396.0
569	89.9	8082.0
495	15.9	252.8
482	2.9	8.4
299	-180.1	32436.0
484	4.9	24.0
486	6.9	47.6
489	9.9	98.0
450	-29.1	846.8
494	14.9	222.0
487	7.9	62.4
481	1.9	3.6
519	39.9	1592.0

467	-12.1	146.4
500	20.9	436.8
$\sum X$= 16768 $\frac{\sum X}{n}$= 16768/35 $\bar{X}$= 479.1		$\sum(\times - \bar{X})^2$= 55148

Standard deviation $\frac{\sqrt{\sum(\times-\bar{X})2}}{N}$

$=\frac{\sqrt{55148}}{35}=\sqrt{1575.7}$= 39.69

SD= 39.7

X=$\bar{X}$+KS

X=Return Period

$\bar{X}$= Mean

K= Frequency Factor

S= Standard Deviation

X 100= 479.1 + (3.554 x 39.7)

=479.1 + 141.09

=620.19

Cm to M= 620.19/100

X_{100} =6.20M

X 50= 479.1 + (2.979 x 39.7)

=479.1 + 118.26

=597.36

Cm to M= 597.36/100

X_{50} =5.97m

X 25= 479.1 + (2.354 x 39.7)

=479.1 + 93.45

=572.55

Cm to M=572.55/100

X_{25} =5.72m

X 10= 479.1 + (1.516 x 39.7)

=479.1 + 60.18

=539.28

Cm to M= 539.28/100

X_{10} =5.39m

REFERENCES

Abam T.K.S. (2006): The Application of Kruskal-Wallis technique for flood prediction in the Niger Delta, Nigeria, Management of Environmental Quality;

An International Journal, Vol17 Iss: 3, pp 275-288.
Enoch, B. (2001) History of Donga Local Government. Donga Educational Books, Donga, 1-
End.
Etuonovbe, A K (2011),"The devastating effect of flooding in Nigeria", FIG Working Week 2011, Bridging the Gap between Cultures, Marrakech, Morocco, available at
http://www.fig.net/pub/fig2011/papers/ts06j/ts06j_etuonovbe_5002.pdf, accessed November 11, 2013.
Haktan Y.T (1992): Comparison of Various flood frequency distribution using annual flood
Peaks data of rivers in Anatolis. 136; 1-31

Mujere, N. (201). Flood Frequency Analysis Using theGumbel Distribution. *International*

*Journal on Computer Science and Engineering.*Vol.3 (7)

Nwafor A. N, (2004): Flood Extent Mapping in Bayelsa State, Nigeria. *Journal of Geography*,
Vol 8 (33),pp 18-22
Izinyon, O.C., Ihimekpen, N. andIgbinoba, G.E. (2011). Flood Frequency Analysis of Ikpoba River
Catchment at Benin City Using Log Pearson Type III Distribution. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS), 2 (1): pp. 50 – 55.
Okereke, C. (2007): The politics of the environmental: A Survey: Europe politics of Series. Taylor & Francis, London, pp 136-157. ISBN9781857433418
Okonofua and Ogbeifun (2013). Flood Frequency Analysis of Osse River Using Gumbel's
Distribution .*Civil and Environmental Research*, Vol.3, No.10.

Okoroafor, O.O., Egwuonu, C.C., Chikwue M.I., Okafor, V.C. and Nzediegwu. C. (2015).
Flood Frequency Analysis of Otamiri River Catchment Area Using Gumbels Distribution
Method. *International Journal of Emerging Technology and Advanced Engineering*.
Volume 5, Issue 10.
Oyatayo,K.T., Songu, G.A., Adi, T., Jidauna, G.G., Ndabula, C. (2016). Assessment of People's

Awareness andPerception of Flooding in Donga Town,Taraba State, Nigeria. *Journal*

*of Geoscience and Environment Protection,*2016, 4, 54-62

Karmakar, S. and Simonovic, S.P. (2008). Bivariate flood frequency analysis using copula with parametric and non-parametric marginal. Paper Presented at the Fourth ISFD Conference
Toronto Canada, 22
Shakirudeen, O. andSaheed, A. R. (2014). Flood Frequency Analysis and Inundation Mapping.

Journal of Water Resource and Hydraulic Engineering. Vol. 3 Iss. 3, PP. 48-59

Sharma, R. K and Sharma, T. K. (2000). A Textbook of Hydrology and Water resources

Engineering. DhanpatRai Publications (P) Ltd, New Delhi. Fifth Edition

UNISDR (2012): United Nations International Strategy for Disaster reduction, available at: http://www.unisdr.org (last access: 31 March 2012), 2012.

CLİMATE CHANGE MİTİGATİON IN SUB-SAHARAN AFRİCA: THE GREEN CİTY CONCEPT

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Abstract.

This paper reports the current mitigation challenges faced in Sub-Saharan Africa as climate change continues to be a state of concern to many developing and underdeveloped countries. While taking a look at the climate change scenarios, there is a need to assess the critical role of cities in advancing green growth and combating climate change effects. This can be lead to debates and formulation of eco-friendly policies that will enhance a clean environment.

This paper therefore looks at the socio-economic challenges involved in advancing an urban green city concept. It also considers how the government and its citizens can play key roles in advancing this cause, which is basically by proper measurements and monitoring, thereby providing the enabling environment and finance to make this a reality.

It therefore concludes by suggesting suggestions for future research based on various scenarios, to achieve better results and make our environment a better place.

Keywords: Climate change, Urbanization, Green Cities, Urban Sustainability, Mitigation

Introduction

The term mitigation refers to efforts to cut or prevent the emission of greenhouse gases - limiting the magnitude of future warming. It may also encompass attempts to remove greenhouse gases from the atmosphere. It differs from climate change adaptation, which refers to the actions taken to manage the unavoidable impacts of climate change. Mitigation may require the use of new technologies, clean energy sources, change people's behavior, or make older technology more energy efficient.

Switching to low-carbon energy sources such as wind power, solar, geothermal, hydroelectric or nuclear represents one of the major strategies for lowering the emissions of greenhouse gases in the atmosphere. Also greening urban areas can also make a difference. Cities are home to half the planet's population, and are responsible for three-quarters of energy consumption and 80% of carbon emissions. Retro-fitting buildings to make them more energy efficient and cutting the impact of transport emissions represent some of the strategies for doing this (*BBC*, 2014)

Clımate Change and Urbanızatıon

Climate change is defined as the change in the distribution of weather patterns when that changes lasts for an extended period of time (*Wikipedia*, 2016). Scientific evidence indicates that the Earth’s climate is changing and, without taking appropriate and early action, climate change will have potentially disastrous effects for many areas of the planet. Some factors that tend to climate change are, variations in solar radiation, variations in the Earth's orbit, variations in the albedo or reflectivity of the continents and oceans, mountain building and continental drift and changes in green house gas concentrations. These factors can either be "internal" or "external". The internal factors are natural processes within the climate system itself e.g. thermohaline circulation while the external factors can either be natural e.g. changes in solar output or anthropogenic e.g. increased emissions of greenhouse gases. Climate related risks are created by a range of hazards. Some are slow in their onset (such as changes in temperature and precipitation leading to droughts, or agricultural losses), while others happen more suddenly (such as tropical storms and floods).

Urbanization is the process in which the number of people living in cities increases compared with the number of people living in the rural areas. A country is said to be urbanized when over 50% of its population lives in urban places. For any city, the scale of the risk from these extreme weather events is much influenced by the quality of housing and infrastructure in that city, the extent to which urban planning and land-use management have successfully ensured risk reduction within urban construction and expansion, and the level of preparedness among the city's population and key emergency services. For small and large coastal settlements, the integrity of coastal ecosystems and in particular protective mangrove and salt marsh systems will also influence risk.

Urbanization and Climate Challenges in Africa

Though Africa has the lowest proportion of its population living in cities compared to other regions, this trend is quickly changing: According to a report by McKinsey, in 2010, Africa was nearly as urbanized as China and had as many cities with over one million people as Europe. Forecasts from the World Urbanization Prospects 2014 suggest that by 2050, Africa's urban population is projected to triple, making the continent the host of the world's second-largest urban population behind Asia. At the moment, according to a recent KPMG Africa report in 2012, three African cities—Lagos, Cairo, and Kinshasa—fall within the true definition of "megacities" (10 million people or more).This rapid growth of African cities will push at least another six cities—Johannesburg, Luanda, Nairobi, Addis Ababa, Casablanca, and Khartoum—into the "megacity" class within the next couple of decades.

Africa In Focus puts it that Increasing urban populations have been driving up energy demands and pollution levels—as anyone who has been stuck in traffic congestion in Lagos already knows. Thus, this trend not only raises global warming concerns, but also, if these rising demands and greenhouse gas emissions are left unmonitored, they could potentially pose further challenges for urban planning needs. This outcome results from the fact that urbanization on the continent is not just driven by standard models of structural transformation that have been explored in economic literature. Many have argued that urbanization in Africa is also driven by factors such as climate change: In some areas the lengthened dry seasons and environmental shocks are forcing Africa's rural workforce to seek employment in the city. As they move into cities, a large proportion of rural migrants get stuck in low-productivity employment in the non-tradable sector—increasing demand for better urban planning for basic services, infrastructure, housing, waste management, human livelihoods, and health.

Some of the climatic challenges experienced are categorized as follows:

Emissions from the following subsectors:

5. Energy industries – combustion emissions from electricity generation, petroleum refining and the production and processing of briquettes and natural gas
6. Manufacturing industries and construction – emissions from on-site combustion of fossil fuels by the manufacturing and construction industries (not including emissions from industrial processes, which are accounted for separately)
7. Transportation – combustion emissions from motor vehicles, rail, civil aviation, shipping and recreational vehicles
8. Fugitive emissions – the unintended release of emissions (such as carbon dioxide and methane) that may result from exploration, extraction, processing and distribution of oil, natural gas and coal. Emissions result from leakage, evaporation and storage losses, and venting and flaring activities

The Concept of Green Cities

Green cities are seen as cities that are environmentally friendly. A green city designed with consideration of environmental impact, inhabited by people dedicated to minimization of required inputs of energy, water and food, and waste output of heat, air pollution - CO_2, methane, and water pollution (*Wikipedia,* 2016). The term "Greening" refers to gardening. The purpose of "Greening" is to improve the phenomenon of cement-filling, and change it into an environment which relaxes people. "Greening" could be conducted at the roof, on the streets, on the slopes or on the ground. The benefits of "Greening" include: improving the appearance of the city, offering a space of resting, reducing the urban heat island effect, improving the quality of air, blocking some graceless scenery as well as messy or destroyed environment, reducing noises, reducing the influence of dazzling sunshine, resisting desertification and reducing the death rate between poverty gaps.

Green Buıdıng and Envıroment

"Sustainable Development" is a necessary condition for continuation of the earth; "Healthy and Comfortable"is a necessary condition for the continuation of life. Additionally, we are facing serious energy and naturalresource shortage, where global climate change is the problem cannot be ignored (Hsieh et al., 2011).

Green buildings afford a high level of environmental, economic, and engineering performance. These include energy efficiency and conservation, improved indoor air quality, resource and material efficiency, and occupant'shealth and productivity. The impact of climate change on buildings is deeply intertwined with consequences for the building occupants and key processes that take place in those buildings. As buildings have different functions, climate change impactassessment studies must be tailored towards the specific needs and requirements at hand. Complex interactionsexist for instance between the comfort as experienced byoccupants, control settings in the building, and energyconsumption of heating and cooling systems (Nicol and Humphreys, 2002). . The economic analysis showed that both zero carbon plants are feasible, and that the air-to-air heat pumps yield a shorter payback time. The exergy analysis confirmed the feasibility of both plants, and showed that the ground coupled heat pumps yield a higher energy saving.

Green Transportation

Transport-related pollution, noise and vibration can pose serious threats to human health and wellbeing. Local air pollution is caused by exhaust emissions produced by traffic, mostly in the form of Sulphur Oxides (SOx), Nitrogen Oxides (NOx), Carbon Monoxide (CO), Hydro Carbon (HC), Volatile Organic Compounds (VOC), Toxic Metals (TM), Lead Particles7 and Particulate Matter (PM) – including Black Carbon. These emissions represent a large proportion of pollutants, especially in developing cities.

Congestion is caused when the volume of traffic reaches the capacity of infrastructure. It is particularly common in urban areas. To achieve a green transportation, provision for Infrastructure such as tracks for buses and rail, pavements and bicycles, routes for public transport vehicles, low emission vehicles, park-and-ride facilities should be put in place so that not all citizen will be on the road with a personal car at the same time causing traffic congestions, noise and air pollution. Telecommunication technology to substitute conventional transport, e.g. telework/ teleconferencing and technologies to enact green transport, e.g. GPS systems, Intelligent Transport Systems, green logistics etc. As a result of these investments, carbon emissions are reduced radically, by 8.4 Gt of CO_2, or 68 per cent relative to BAU_2 in 2050.

Generating Green Energy

Over decades, fossil fuels were and are still being used as the major energysource for households, industries and service providers. However, due to the limited amount offossil fuels, energy is becoming more and more expensive, and the consequence of theirconsumption is having an impact on our environment and climate.

Solar Energy

This is a method of using the sun to generate electricity using a solar panel. A solar panel is a set of solar photovoltaic modules electrically connected and mounted on a supporting structure. A photovoltaic module is a packaged, connected assemblyof solar cells. The solar panel can be used as a component of a larger photovoltaic system togenerate and supply electricity in commercial and residential applications. A photovoltaicsystem typically includes a panel or an array of solar modules, an inverter, and sometimes abattery and/or solar tracker and interconnection wiring. Depending on construction,photovoltaic modules can produce electricity from a range of frequencies of light, but usuallycannot cover the entire solar range (specifically, ultraviolet, infrared and low or diffused light).Hence much of the incident sunlight energy is wasted by solar modules, and they can give farhigher efficiencies of illuminated with monochromatic light. Therefore, another design conceptis to split the lightinto different wavelength ranges and direct the beams onto different cellstuned to those ranges. This has been projected to be capable of raising efficiency by 50%.

Solar panels can be installed on roofs or on the ground. Additional trackers sense the directionof the sun and tilt the modules as needed for maximum exposure to the light. There are twomain types of catching solar energy easily, one which absorbs the direct sunlight andtransforms it into energy, and the other method is by using the sun's heat as an energy source. The invention of affordable solar stoves has been used since few years in Madagascar. Households use the sunlight for cooking and are even able to store energy in a battery for later use.

Wınd Energy

Countries rich on wind often refer back to the installation of windmills on wide and open fields. Around 90 countries are supporting the consumption of electricity through windmills since a few years, and more and more countries are following this new boom of eco-friendly technology. Windmills can be also installed off shore, in areas using the sea and ocean wind for generating electricity. However, whether on-or-off shore, the windmills cannot be working properly when the amount of wind is either too low or too strong. Windmills are always installed in certain fields and areas, mostly far from cities and villages due to the noise pollution and the need for open fields with wind. Municipalities therefore obtain regional planning on fields away from farms and even protected areas, since windmills can become a threat to wild birds. While fans use electricity to generate wind, the windmill does exactly the opposite. The blades of a windmill rotate once wind is present, which have a shaft connected to the generator to create electricity.

Hydro Energy

Water energy can come in different forms and variations. One type of renewable energy source is the building of dams. This relies on the potential energy difference in the levels of water reservoirs, dams and lakes and their discharge tail water levels downstream. The hydro power potential of Nigeria, for example, is very high and currently accounts for about 29% of the total electrical power supply. The first hydro power supply station in Nigeria is the Kainji dam on the River Niger where the installed capacity is 836mw with provisions for expansion to 1156mw. The second hydro power station on the Niger at Jebba with an installed capacity of 540mw.

Even though the majority of dams are immense in size, their process to generate electricity is however simple. "The water in the reservoir is considered stored energy. When the gates open, the water flowing through the penstock becomes kinetic energy because it's in motion". Thefaster and stronger the flow of the water, the more energy is generated.

Greenıng the Envıronment

A lot of damage is being through deforestation, which is contributing immensely to desertification. This occurs in the form of tree felling for energy, bush burning and overgrazing by herdsmen. It is very amazing that even though there exist wide range of disparity between human and trees, they still cannot survive independently. Man needs oxygen which tend to be produced as the waste product of trees, on the other hand, trees also needs carbon dioxide which is also a waste from humans, in order to survive. The importance of trees and its usefulness according to scientific proven illustration has it that trees could be very resourceful as the first defensive measure against global warming because they absorb the carbon-dioxide in the atmosphere, and replenish the air with oxygen and also contribute immensely to aesthetic of the environment. Trees also prevent erosion and stem the tide of windstorm by serving as wind breakers. They are also brilliant cleansers; they remove other pollutants through the stomates on the leaf surface. Trees acts as what some call a carbon sink, storing the gas in the branches, trunk, leaves, etc, instead of leaving the gas to become free floating and further polluting the atmosphere. Trees directly reduces the growth of the green house effect and counteract global warming. It provides natural habitat for small and large creatures , and reduce the temperature by providing shades. In times of heavy rain, trees roots help solidify the soil. Trees are not just beautiful creatures standing amongst the many phenomenal picturesque setting of this world, it is a powerful and vital tool that directly ensures our survival.

Park ecosystems often offer significant amounts of open space that allow for relatively high densities of trees, shrubs, grasses, and other vegetated surfaces. Other vegetation types such as shrubs and grasses will have similar effects to trees, but often to a lesser degree due to their smaller stature.For example, healthy shrubs and grass will remove air pollution to a lesser degree than trees.However, their effects are not always similar. For example, shrubs and grass will not have the same effect as trees in reducing ultraviolet radiation loads on humans because they often do not reach the height necessary to block solar radiation reaching humans.

Some Examples of Governments Adopting Green Growth Strategies

5. Chile launched the National Green Growth Strategy in December 2013 outlining a set of actions over the short, medium, and long term (2014-2022). Actions include implementing environmental management instruments, promoting the market for environmental goods and services, and monitoring and measuring progress (Government of Chile, 2013).
6. China has committed to green growth in its 12th Five Year Plan. Actions include investing in natural resource management, with the aim of creating one million new forestry jobs and reducing rural poverty (OECD, 2013).

7. Mozambique launched the Green Economy Roadmap at the Rio+20 Conference on Sustainable Development, setting out its vision to become an inclusive, middle income county by 2030. In October 2013 the government approved the Plan of Action for 2013/2014 laying out the actions over the period of one year on the road to a green economy and is in process of linking the Roadmap to the long-term National Development Strategy 2015-2035 (WWF, 2013).
8. Rwanda released the Green Growth and Climate Resilience National Strategy for Climate Change and Low Carbon Development in October 2011. It aims to be a developed climate-resilient, low carbon economy by 2050, through the achievement of three key strategic objectives: energy security and a low carbon energy supply; sustainable land use and water resource management; and social protection and disaster risk reduction (Republic of Rwanda, 2011).

Summary

Human and societal well-being depends on nature. According to Lehrer (2001), to work towards creation of sustainable development, one must understand theenvironmental impacts of buildings and their relative importance. The most and best understood impact is causedby energy used in building operations. The primary energy loads in buildings are created by lighting, space heating, cooling equipments and domestic hot water. The production and consumption of this energy contributes to air pollution, acid rain and global climate change. Conventional buildings have a significant impact on the environment including wetland depletion and deforestation (Otegbulu 2006). However, estimates indicate that climate – sensitive design with the use of appropriate and available technologies could cut heating and cooling energy consumption by 60 percent. Heating is however not important in tropical climate regions like that of Africa where cooling is mostly required. The design of the building must reflect consideration directed towards reduction in energy cost. Microclimatic temperature is affected byradiation, convection and evaporative cooling. Trees affect microclimate through their effect on these processes.

Trees abound in Sub-Saharan Africa but most often, building sites are cleared of all vegetation (trees) and covered with asphalt orconcrete which often have adverse environmental consequences. Energy could also be saved through provisionof natural ventilation and lighting in building design.

Recommendations

The following are the recommendations associated with increasing green concept in our environment which will result into a friendly and comfortable environment:

- Increase the number of healthy trees (increases pollution removal).
- Maximize use of traditional practices that have been proved to be environmentally beneficial for housing in various African cities, given the fact that urban

population is rapidly increasing in growth.

- Designing buildings taking into account climatic conditions on the continent and by so doing making use of naturally available energies that can be harnessed profitably.
- Reduce fossil fuel use in maintaining vegetation (reduces pollutant emissions).
- Plant trees in energy conserving locations (reduces pollutant emissions from power plants).
- Plant trees to shade parked cars (reduces vehicular VOC emissions).
- Utilize evergreen trees for particulate matter reduction (year-round removal of particles).

In general, in terms of vegetation designs for trees, the more tree cover the better, as the trees can reduce air temperatures and directly remove pollution. Tree cover that is aggregated together in forest stands can reduce pollutant concentrations toward the center of the stands. However, species composition can also affect pollution effects.

Actions at all governance levels, involving the participation of all relevant stakeholders, are needed for a successful transition to a green economy.

Green growth can improve quality of life and, if designed and implemented well, can address social equity issues. By reducing environmental degradation and conserving vital natural resources, governments can enhance the quality of life for citizens, especially the poor who are particularly vulnerable to natural resource limits and environmental damage. It also an established truth that green buildings have many benefits for our environment, not only can they save energy, but also they reduce the damage to the environment. It is believed that, with the continuing development of Green Buildings, people may have a greater chance to live in a natural and healthful environment in the near future.

References

Africa in Focus (2015). Mobilizing Africa's Rapid Urbanization For Sustainable Climate change.

BBC (2014). *What is climate change mitigation?* http://www.bbc.com/news/science-environment-26980837

Hsieh, T.-T., C.M. Chiang, M.C. Ho, and L.P. Lai. (2011). *The application of green building materials to sustainable building for environmental protection in Taiwan*. Proceedings of the International Conference on Materials for Environmental Protection and Energy Application, 27-28 September, Kuala Lumpur, Malaysia.

KPMG (2012). *The role of cities in Africa's rise*. www.kpmgafrica.com

Nicol, J.F., and M.A. Humphreys. 2002. Adaptive thermal comfort and sustainable thermal standards for buildings. Energy and Buildings, 34(6):563–72.

Otegbulu A.C. (2006). An Assessment of User Demand Preferences of Urban Infrastructure in Lagos Metropolis Using Contingent Valuation Model: PhD Thesis Submitted to The Faculty of Environmental Science, Enugu State University of Science and technology Enugu, Nigeria

Republic of Rwanda. (2011). Green Growth and Climate Resilience: National Strategy for Climate Change and Low Carbon Development. Kigali: Republic of Rwanda.

WWF. (2013). Mozambique Government approves 2013-2014 action plan for Green Economy. 21 October 2013. WWF News

The Ministry of Environment and the Ministry of Finance. Government of Chile. (2013). *National Green Growth Strategy*.

Wikipedia (2016). *Climate change*. https://en.wikipedia.org/wiki/Climate_change

Access and utilization of Seasonal rainfall prediction (SRP) information in Warakai Village, Goronyo Local Government Area, Sokoto State

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The need to have a reliable forecast about rainfall is very essential for agricultural production. This paper investigates the access and utilization of NIMET Seasonal Rainfall Prediction (SRP) in Warakai village, Goronyo Local Government area of Sokoto State. A total of 42 farmers were randomly selected and interviewed with open and closed schedule. The questions ranged from awareness, sources, types of information, and comment on information they received from SRP. The results revealed that 81% are aware of the, SRP; majority (55%) received it through radio while 38% from Agricultural officers. The results showed that 73% receive only the Seasonal Rainfall Prediction while 10% received monthly information on rainfall. Some 33% rated the SRP as excellence while 44% rated it as good and reliable. Majority of respondents agreed that for the last ten years rainfall was at the increase. The study recommended that SRP information should be timely presented and translated in to the local Language because the farmers are readily to utilize it.
Key Word Warrankai Village, SRP Information, Utilization.

1.0 Introduction

Agriculture is perhaps the most weather-sensitive of all man's economic activities (Ayoade,1993). The major determinants of successful agricultural practices both in rainfed and irrigation farming is directly link with rainfall amount and its distribution at a particular season. Thus, reliable information about climate and weather of a place is very crucial since all stages of agricultural production from land clearing, sowing seed, tilling, management, harvesting and marketing of agricultural products are subject having good knowledge of the local climate. Generally all crops have their climate requirements for optimal growth, therefore the timely dissemination of climate information to farmers and other rural end-users might lead good harvest. According to Iloeje (1979), an understanding of the characteristics of rainfall distribution in different ecological zones with regard to the physiological phases of crops varieties and soil conditions is a pre-requisite for successful crop production in Nigeria. Generally while some people considered climate change from the scientific approach others looked at it as religious phenomena and resorted to superstitions in explaining this natural event, thus climate change has varied explanation (Francis et al, 2011). This situation also exist in Nigeria as Idoma and Mamman (2015) highlighted that several contextual factors including social, cultural content - related and technological barriers as explanation of climate change. According Iloeje (1979), sustainable agriculture is embedded in the relationship between humans and climate, especially in attitudes towards climate change.

2.0 Material and Method

2.1 Study Area

The study area (Warankai Village) located at the downstream section of the Goronyo Dam, the second largest man made in Nigeria on the Rima River. It located on the Latitude $13^{0}.59058$N and Longitude $005^{0}.65529$E. Emphatically the village is quite vulnerable to flooding because of its location. However, People have chosen to reside there to practice both rainfed and irrigation farm on the account of fertile soil around See (Figure 1) NIMET (2016) predicted that Goronyo will receive the rainfall amount of 808mm, while onset starts on 22nd June and cessation dates to be around Oct 2nd.

2.1 Methodology

To reiterates the study was conducted in Warankai village, some six kilometers away from Goronyo the Local Government headquarters. The rationale behind choosing this village was one of the major cash crops producing areas in the local government both in rainy and dry season such as onion, pepper and rice. Another crucial reason is that the area is very vulnerable to flood disasters based on its location along the downstream of Goronyo Dam. Some 42 farmers were randomly selected in Warankai village and interviewed on their farm using both open and closed-end interview schedules. The data collected were processed using computer software and the descriptive statistics that resulted are hereby reported.

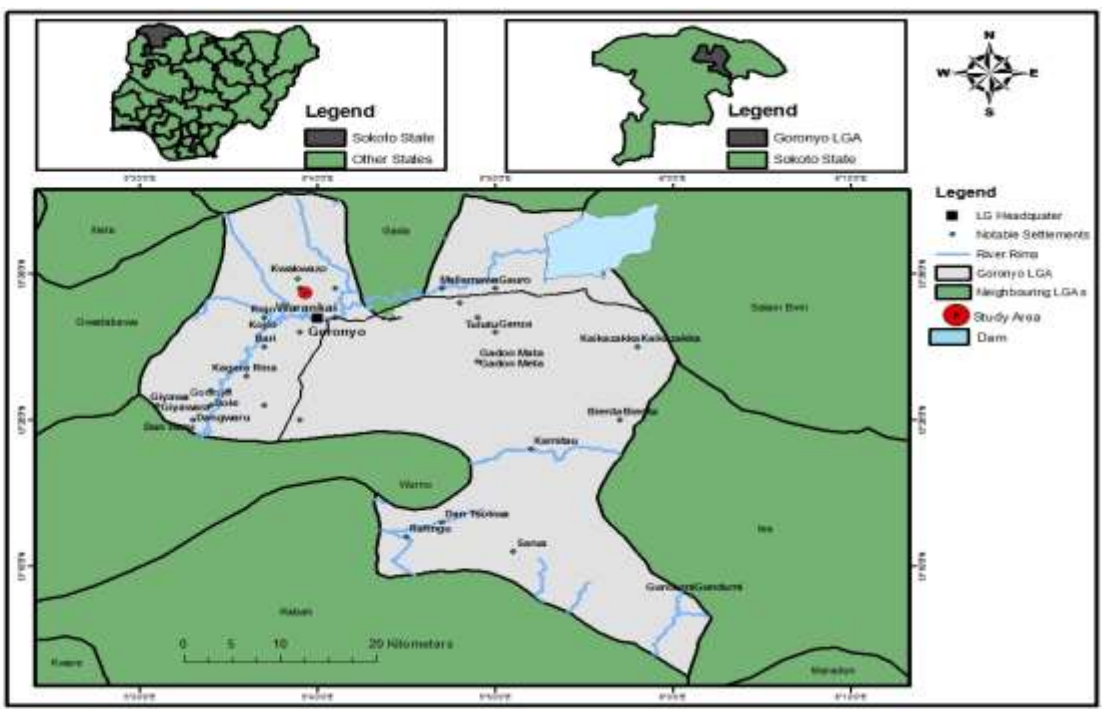

Figure 1.1 Study Area

2.2 Results and Discussion

The result presented in Table 1 showed that majority of the respondents are within active working age are between 26-40 years, while 17% are above 56 years. Some 76% of the respondents are of the opinion that for last decade, rainfall had been increasing while 24% did not agree to this view. The findings further reveal that 81% were aware of the NIMET Seasonal Rainfall Prediction particularly on rainfall, while 17% were not aware of it. The results presented in Table1also showed that 55% of the interviewees do receive their SRP through radio broadcast while 38% get it from the local agricultural officer. The result further reveals that majority (71%) of the respondents only receive Seasonal Rainfall Prediction; while 17% got information on weekly basis mostly from the staff managing the Goronyo Dam. It must be highlighted that the farmers interviewed rated the SRP as excellent (33%), good (43%) while 7% did not even believe it.

It is very clear that 76% of the farmers interviewed believe that NIMET SRP was quite useful. However, there was also credible evidence that some farmers were yet accept the conventional forecast of (SRP). The result presented in Table 2 indicated that 52% of the farmers accepted and were ready to start a new conventional forecast if they are made available to them. Some 29% said they do not use SRP because of their religion and cultural beliefs. Others (19%) do not have confidence in SRP. Further analysis in Table2 revealed that majority of the respondents (62%) have never received any technical advice from their Local Government while others (17%) do frequently receive advice. The analysis showed that 60% of the respondents relied on their indigenous methods of prediction to predict drought, flood and other disasters while 40% of the respondents do not plan for any hydro-meteorological disasters.

Table 1 Age,Perception and Sources of SRP Information

Age	**Percentage (%)**
10 - 25	17
26 - 40	36
41 - 55	31
56 - Above	17
Rainfall for the Last Decade	
Increases	76
Decreases	24
Awareness of SRP information	
Yes	81
No	17
Sources Of Information	
Radio/TV	55
From Agric Officer	38
From Farmers Association	04
Other	04
Types of Information	

Seasonal Rainfall	71
Monthly Rainfal	12
Weekly	17
Comment on The information	
Excellent	33
Good	43
Don't Know	17
Unacceptable	07

Source: Field work 2016

Table 2 Utilization & Advice received from

Utilization of SRP information if available	
Definetily Yes	52
No	29
May be	19
Yes frequently	17
Yes not Frequently	17
Hadly at all	07
Never	62
Existing Plann when Drought/flood Occurs	
Yes	60
No	40

Source: Field work 2016

2.3 Discussion of the Findings

The Study revealed that farmers in the study area Warankai do received NIMET Seasonal Rainfall Prediction (SRP) as have been asserted by Idom and Mamman study (2015). Radio broadcast in particular, is the major method of receiving SRP followed by the local agric extension officer. Thus, the role of agricultural officers should not be underestimated in the dissemination of climate information to farmers as many scholars has pointed out (Idom and Mamman, (2015). The findings also revealed that some of the farmers in Warankai village received SRP and are willing to adopt all scientific approaches in disseminating climate information but others because of their religion and cultural beliefs consider climate change as natural phenomena as earlier highlighted (Francis *et al* 2011). The study further revealed that indigenous knowledge of climate still plays a significant role in taking livelihood decisions, as many people heavily relied on its.

2.4 Conclusion

It is clear from the foregoing discussion that climate, whether directly or indirectly, affects agricultural production. Therefore, knowledge about climate must be taken into consideration in the planning of all agricultural operations and in the planning of agricultural development in general. The study recommends that the good timing of weather and climate information should be communicated to farmers and interpreted in their local dialects, regular updates through agricultural officers in view of the erratic nature of climate should also be done.

References

Ayoade, J.O. (1993) *Applied Climatology*. Ibadan: University of Ibadan.

Francis K., Ernest D, Ato B.P. ,and Nicholas K. B (2011). *Farmers' Perception Of Climate Change In The Ejura-Sekyedumase District Of Ghana* ARPN Journal of Agricultural and Biological Science

Idoma Kim and Mamman Moses(2015) Access and Utilization of Climate Change Information and Support Services Among Vulnerable Communities in Agatu LGA Benue State, Nigeria. Paper Presented at 2015 International Conference & 29th Annual General Meeting of the Nigeria Meteorological Society On the 23rd -26 November 2015, Sokoto Nigeria

NIMET (2016) Seasonal Rainfall Prediction by Nigerian meteorological Agency

Iloeje, N.P. (1979) A Geography of Nigeria. (Marrison and Gibb Limited, London and Edinburgh

EFFECTS OF CLIMATE CHANGE ON HYDRO-CLIMATIC VARIABLES IN NIGERIA DURING EPISODES OF SEA SURFACE TEMPERATURE ANOMALIES IN THE GULF OF GUINEA

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ABSTRACT

Sea surface temperature anomaly (SSTA) is critical to climate monitoring at the local, regional and hemispheric scales. It is well established that sea surface temperature (SST) plays a significant role in the hydrologic cycle in which precipitation is the most important part. The hydro-climatic variables vis-a-vis Dates of Onset of Rains (DOR), Dates of Cessation of Rain (DCR) Duration of Rains (DR) and Frequency of Occurrence of Rain Day (FORD) were determined. Characteristics (Early, normal and late) of hydro-climatic variables in Nigeria at various Agro-ecological zones were then examined. SSTA data obtained from International Research Institute center for climate prediction at selected longitudes (10 °W, 8 °W, 6 °W, 4 °W, 2 °W, 0°, 2 °E, 4 °E, 6 °E, and 8 °E) along latitudes 5 °N, 4 °N, 2 °N and 0° (equator) respectively and continental climatic data (moisture, thermal and aerodynamic parameters) obtained from the archives of Nigerian Meteorological Agency at selected locations were used for the analysis. Both descriptive and inferential statistical analyses were employed to establish the relationship. It is observed that higher frequency of occurrences of the different characteristics of hydro-climatic variables was during warm episodes of SSTA. Furthermore SSTA over GOG had significant ($p<0.05$) correlation with DOR, DCR, DR, FORD and RR in Nigeria. It was confirmed in this study that warm SSTA over GOG has significant impacts on the hydro-climate variables in Nigeria.

1.0 Introduction

The pattern of global and hemispheric temperatures has shown a threatening trend since the early 19th century. According to World Meteorological Organization report (WMO, 1998), global air temperature fluctuated below the norm until the early 19th century. Since then remarkable positive anomalies have persisted in the global and hemispheric scales.

Sea Surface Temperature (SST) have been playing an important role in the annual cycle of precipitation over the globe with layers of warmer water temperatures ranging from 20 - 30^{o}C found all the year round in different parts of tropical Atlantic region including that of the Gulf of Guinea (GOG). This region has been observed to be the main source of moisture for the West African Monsoon (WAM). Temperature *anomalies* in the region are likely to influence hydro-climatic parameters (rainfall incidence and cessation, duration of rainfall, frequency of rain days) over West African countries including Nigeria. Climatology and variability of hydro-climatic parameters are valuable information for scientists, engineers, planners and managers working in water-related sectors (agriculture, ecology, and hydrology and water resources).

Since the late 20th century, SST anomaly field has been a key driver of decadal climate variability (Folland et al. 1986; Palmer 1986; Rowell et al. 1995; Mohino et al, 2011). Several studies that have shown relationship between the SST anomalies and climate of West Africa sub regions includes Salahu, Edafienene and Afesiemama (1996); Gbuyiro *et.al* (2002); Okumura and xie (2004); Wang *et al* (2004); Okeke (2006); Odekunle and Eludoyin (2008) and Omogbai, 2010). Studies conducted by (Lamb, 1978, Fontaine *et al*, 2000, Folland *et al*.,1986) have linked rainfall variability to occurrences of Atlantic and/or global SST dipole patterns. Several attempts have been made to study the characteristics of hydro-climatic variable in order to provide an explanation for the patterns of rainfall incidence, cessation, length of growing period and water availability for agricultural purposes in Nigeria. Notable examples include Oguntoyinbo (1981),Olaniran and Sumner (1990) and Bello (1996a).

Understanding the hydro-climatic features during episodes of SST anomalies is essential for effective agricultural and hydrological operations. On the face of global climate change where food security is becoming threatened, affecting food systems in several ways ranging from direct effects on crop production, changes in rainfall pattern leading to drought or flooding, warmer or cooler temperature which leads to changes in the length of season, pattern of incidence and cessation of rain etc., background and scenario projections of the problem assumed greater importance; therefore attempts have been made in recent decades world-wide to understand the problem on regional/local scales. This comprehensive study of the characteristics of hydro-climatic variables across agro-ecological zones in Nigeria during different episodes of SSTA in GOG is undertaken with the following objectives in mind. To examine the trend of Sea Surface Temperature Anomalies in the Gulf of Guinea region in order to establish its variability over time and determination of hydro-climatic variables (onset, cessation and duration of rains as well as rain-days and rainfall amount) in the various agro-ecological zones in Nigeria also to examine the influence of SSTA on them. In order to combat the risk such as famine, incidence of failure of annual crops, replanting and low ultimate yield etc pose by unpredictable climate pattern, there is need for proper monitoring and preparedness. We hypothesized that there is no significant influence of Sea Surface Temperature Anomalies in the Gulf of Guinea on the hydro-climatic variables in the different Agro-ecological zones in Nigeria.

2.0 Study area

Figure 1 is the map of the study area showing the GOG region and the different agro- ecological zones in Nigeria with the data collection points. The GOG is situated along the West Africa Ocean. In West Africa, it extends from the equator (0^0) to approximately latitude 5^0 N (0^0 - 5^0 N) and longitudes 15^0 W to 8^0 E. Along the Nigerian coast, it extends from latitude 0^0 to 5^0 N and longitude 2° 2'E to 8^0 20'E. Nigeria is bordered to the west by Benin, to the northwest and north by Niger, to the northeast by Chad and to the east by Cameroon, while the Atlantic Ocean forms the southern limits of the country's territory.

Climate of both the GOG and Nigeria are influenced by two major wind currents namely, the tropical maritime (mT) air mass and the tropical continental (cT) air mass. The (cT) air mass originates over Sahara, while the warm and humid (mT) air mass originates from the Atlantic Ocean. Separating the two air masses is a zone which is generally referred to as the Inter Tropical Convergence Zone (ITCZ) over the Ocean. And it is a region of atmospheric instability at the convergence of the northern and southern trade winds.

3.0 Methodology

3.1 Type and timescale of data

Two types of data utilized for this study were the continental climatic data and oceanic climatic data. The continental climatic data used are: daily rainfall (mm), mean air temperature (^{0}C) (Maximum and Minimum) Relative humidity (%), wind speed (m/s) at elevation of 2 metres, shortwave radiation (MJ/M^2/day), albedo over the selected meteorological stations in the different agro ecological regions in Nigeria. The oceanic climatic data utilized are the remotely sensed monthly Sea Surface Temperature (^{0}C) anomalies over the GOG region. Hydro-climatic and sea surface temperature anomalies data for a period of 20 years (1991-2010) were utilized.

3.2 Data processing and analysis

The data were processed and analyzed statistically using Climate predictability tools (CPT) (version 13.4.2) and INSTAT$^+$ software.

To determine the trend of Sea surface temperature Anomalies (SSTA) in the GOG region, SSTA data on a spatial resolution of 2˚ by 2˚ (latitude and longitude) grid were extracted from latitudes (4^0N, 2^0 and 0^0) and longitudes (8^0E, 6^0E, 4^0E, 2^0E, 0, 2^0W, 4^0W, 6^0W, 8^0W and 10^0W). Linear regression analysis method was employed to determine the overall-trend in a time series analysis. For a given time series, the trend equation is of the form:

$$y= a + bx \qquad (1)$$

where 'a' is the base intercept of the line on the y-axis, 'b' is the regression coefficient or slope of the line, **x** is the independent variable, here time in year was used, where each year is represented by a numerical value e.g 1991=1, 1992=2 etc and the dependent variable **y** is the SSTA values obtained over each latitude considered in the GOG region.

The regression coefficient (b) and the correlation coefficient (r) between y and x were later related by the equation:

$$b = r\frac{\delta y}{\delta x} \dots\dots\dots\dots\dots\dots\dots . . (2)$$

where δy and δx are the standard deviation of y and x respectively. This was used to study the relationship between the SSTA and the hydro-climatic attributes considered in the different agro ecological zones in Nigeria.

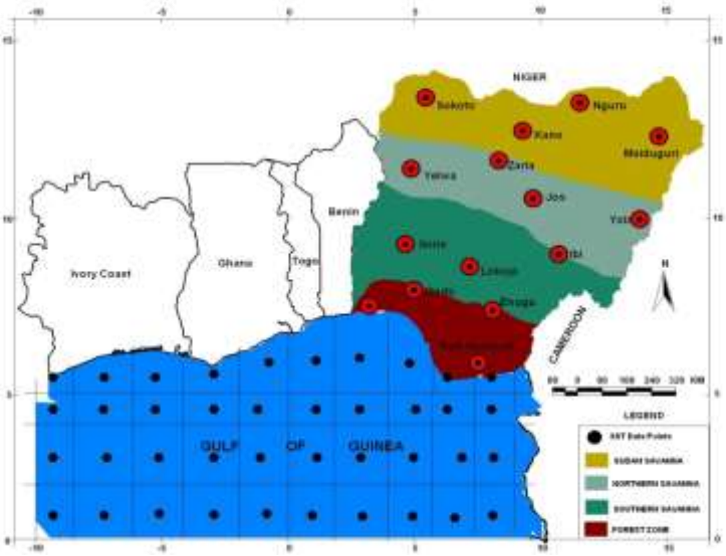

Figure 1: Map of study area showing data collection points

The hydro-climatic characteristics considered are:

(i) Dates of onset and cessation of rain
(ii) Duration of rain
(iii) Rain days

Dates of onset and cessation of the rains was determined using rainfall-potential evapotranspiration model. According to Bello (1996), the date of onset was marked by the time when the accumulated difference between rainfall and half the PE exceed zero, provided that it is not followed by a dry spell of 5 days or more in the week of the date. The cessation date of rains was also taken but in this case the accumulation was done in the reverse order from December of the same year. This was in line with the modification made by Bello (1989) and Olaniran and Summer (1989).

$$\sum(P - 0.5PE) > 0 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (3)$$

P is the rainfall amount and PE is the potential evapotranspiration.

Duration of rains was taken as the difference between the cessation and onset days of rain. In determination of rainy days, 0.85mm was found appropriate for Agricultural purposes in West Africa (Garbutt et al. (1981)). This implies that, all values below this threshold value are considered as zero. Based on this, the frequency of occurrences of rain day (FORD) was obtained.

Characteristics of hydro-climatic variables was determined by adopting Bello (2000) methods in which early, normal and late onset/cessation of rains were obtained by calculating the deviation of each year mean date from the norm at each station. This was obtainable if its deviates from the norm date below, equal and more than 5 days respectively. Based on this method, early, normal and late onset and cessation of the rains was determined. Shorter, normal and longer duration of rains was also determined if it deviates from the norm below, equal and above respectively. Rain days were considered to have below, normal and above if it deviates from the norm. Thereafter, their frequency of occurrences during normal, warm and cold SSTA were also determined.

4.0 Result

The trend of annual mean SST is shown in figure 2. It shows that positive sea surface temperature anomalies (SSTA) are generally high at the equator (0^0) over the gulf of guinea, but it decreases from here northwards to latitude 5^0N, while negative SSTA are lower at the equator (0^0) but increases northwards. Positive SSTA were observed in all the latitudes from 1998 to 2010, except in the year 2000 when negative SSTA was experienced at all the latitudes, 2004 and 2008 also experienced negative SSTA only at the equator (0^0). A remarkable high positive and negative SST anomaly was observed in 2001 and 1995 respectively.

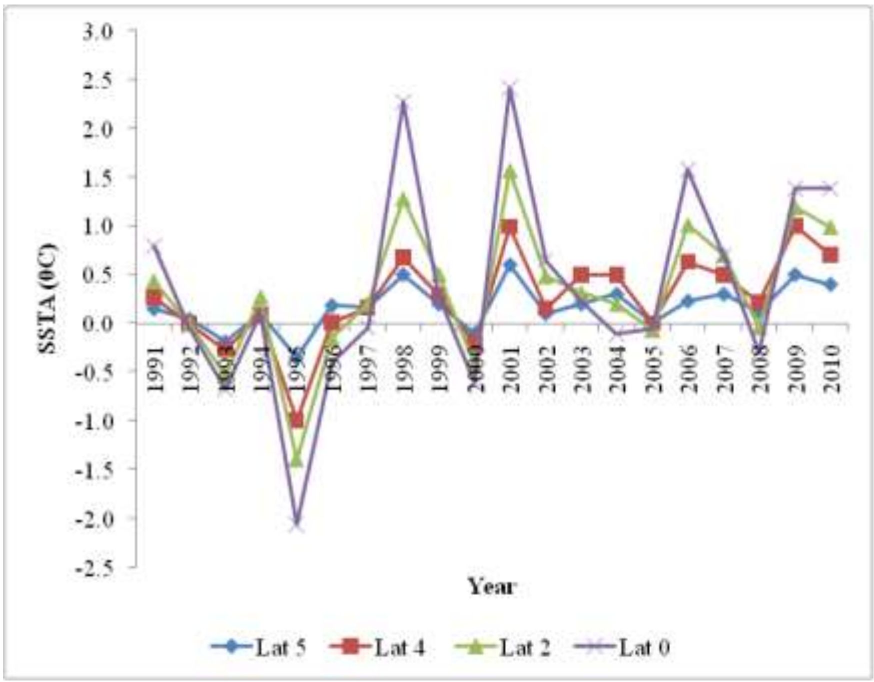

Fig 2: Annual Sea Surface Temperature Anomalies of Latitude 5^0N, 4^0N, 2^0N and Equator (0^0) in the Gulf of Guinea region.

Table 1 shows the result of the linear trend line equation of SSTA over Latitude 5^0N to the equator (0^0). It revealed that the GOG region from the equator up to latitude 5^0N experience upward trend in sea surface temperature and the highest trend observed over latitude 4^0 N with a coefficient of determination (R^2) of 36%, while the lowest temperature trend was observed over latitude 2^0 N with a coefficient of determination (R^2) of 19%. . The result has revealed that the SST observed positive trend during the study period.

Table 2 shows the episodes of Cold and Warm SSTA and normal years in the GOG region. It revealed that generally warm episodes of SSTA occurred most often followed by normal years and lastly the cold SSTA episode during the period of study. The result on the average SSTA of all the latitudes considered in the GOG, showed that 11 out of the 20 years of observation have warm SSTA episode, 6 out the years experienced normal condition while only 3 out of the 20 years of observation experienced cold SSTA episode. The result of the analysis of the frequency of occurrence of onset of rains during different SSTA episodes is presented in Table 3. The dates of onset revealed that late onset dates is more associated with warm SSTA in the entire zone.

Table 4 result revealed that late cessation dates was observed specifically over Forest zone during warm SSTA when 6(55%), 8(72%), 7(64%) and 5(46%) out of the 11 warm years over Lagos, Port Harcourt, Ondo and Enugu respectively. For the Northern Savanna zone, late cessation dates occurred during the warm SSTA years with Yola observing the highest no of late cessation occurring in 7(64%) out of 11 years. The result of Southern Savanna shows that only Ilorin recorded late cessation dates for 7(64%) out of the 11 warm years of SSTA. For Sudan savanna zone, all the station observed high late cessation dates during the normal episodes. Frequency of occurrence of duration of rains during different episodes of SSTA in the GOG region is presented in Table 5. It reveals that during warm SSTA shorter duration of rain occurred more frequently over the forest and southern savanna zones except over Ibi while longer during of rain was more prominent over the northern and sudan savanna zones. Over the Northern savanna zone, normal SSTA episodes are conspicuous in all the stations. For cold SSTA episodes, longer duration of rains dominates over the Forest and Southern guinea savanna zones while shorter duration of rains dominated the Northern guinea and Sudan savanna zones. Table 6 shows the result of frequency of occurrences of rainy days (FORD) during the different SSTA episodes in the GOG region. The result revealed that in the forest and southern savanna zones, above normal rain days was more frequent during the warm SSTA years. Northern guinea savanna zone experienced above normal rainy days only in Yelwa with 7 (64%) out of the 11 warm years, the remaining stations observed below normal rain days observed during the warm SSTA years. Result of Sudan savanna zone also revealed higher frequency of below normal rainy days during the period of study. For the normal episode, Forest and Southern guinea savanna zone observed that below normal rainy days dominates while above normal rainy days dominates over Northern guinea and Sudan savanna zones. Except in Lagos, Ibi, Zaria, Yelwa and Nguru where the trend differs, during cold SSTA years, only Zaria and Maiduguri showed association with all the cold SSTA years when 3(100%) out of the 3 cold years have below normal rainy days in the two stations.

The result of the correlation coefficient analysis to assess the significant impact of the SSTA at each of the selected locations in the GOG on the hydro-climatic variables is presented on Tables 9-12. It revealed that there is a relationship between the SSTA in the GOG and hydro-climatic variable in the various agro-ecological zones selected with the highest positive significance ($P<0.05$) obtained over the forest zone.

SSTA Location	Regression coefficient (b)	Regression equation (Y)	Coefficient of Determination (R^2)	Standard Error of slope (SE)
Lat 5⁰N	0.0182	-0.0178 + 0.0182 *X	0.28	0.0082
Lat 4⁰N	0.0253	-0.1775 + 0.0253 * X	0.36	0.0078
Lat 2⁰N	0.0074	-0.0136 + 0.0074 * X	0.19	0.017
Equator 0⁰	0.0131	-0.0865 + 0.0131 * X	0.21	0.012

Table 1: Trend line equation of SSTA over Latitude 5⁰ N to the equator 0⁰

Table 2: Frequency of occurrences of deviation in onset dates during cold, normal and warm episodes of SSTA in the GOG.

EO-Early Onset, N-Normal, LO-Late Onset

Agro–ecological zones	Stations	Cold SSTA			Normal			Warm SSTA		
		EO	N	LO	EO	N	LO	EO	N	LO
Forest zone	Lagos	2	-	1	1	1	4	4	1	**6**
	Port Harcourt	1	1	1	3	1	2	4	-	**7**
	Ondo	2	-	1	4	1	1	2	2	**7**
	Enugu	2	1	-	1	3	2	-	5	**6**
	Mean	2	1	1	3	2	2	3	3	**7**
Southern Savanna zone	Ilorin	1	1	1	3	1	2	3	1	**7**
	Lokoja	2	1	-	4	1	1	3	3	**5**
	Ibi	2	1	-	1	1	4	3	2	**6**
	Mean	2	1	1	3	1	2	3	2	**6**
Northern Savanna zone	Yelwa	1	1	1	3	1	2	4	-	**7**
	Jos	2	-	1	4	1	1	5	3	**3**
	Zaria	1	-	2	2	1	3	4	2	**5**
	Yola	-	2	1	1	3	2	2	4	**5**
	Mean	1	1	1	3	2	2	4	3	**5**
Sudan Savanna zone	Kano	1	1	1	2	1	3	3	2	**6**
	Nguru	-	1	2	-	3	3	2	1	**8**
	Sokoto	-	1	2	-	4	2	2	3	**6**
	Maiduguri	1	1	1	2	1	3	2	2	**7**
	Mean	1	1	1	2	2	3	2	2	**7**

Table 3: Frequency of occurrences of deviation in cessation dates during cold, normal and warm episodes of SSTA in the GOG.

Agro–ecological zones		**Cold SSTA**			**normal**			**Warm SSTA**		
	Stations	EC	N	LC	EC	NC	LC	EC	N	LC
Forest zone	Lagos	1	1	1	3	-	6	2	3	6
	Port Harcourt	2	-	1	4	2	2	2	-	8
	Ondo	2	-	1	2	2	5	1	-	7
	Enugu	1	2	-	2	3	4	1	2	5
	Mean	2	1	1	3	2	4	1	2	7
Southern savanna zone	Ilorin	1	-	2	2	-	5	2	-	6
	Lokoja	1	-	2	7	-	2	4	3	1
	Ibi	2	-	1	6	1	2	4	2	2
	Mean	1	-	2	5	1	3	3	2	3
Northern savanna zone	Yelwa	2	1	-	3	1	5	2	3	3
	Jos	2	1	-	4	1	4	3	1	4
	Zaria	1	1	1	3	1	5	3	4	1
	Yola	1	-	2	1	-	5	5	-	6
	Mean	2	1	1	4	1	5	4	3	4
Sudan savanna zone	Kano	2	1	-	1	2	6	4	1	3
	Nguru	1	-	2	3	1	5	2	1	5
	Sokoto	1	1	1	2	2	5	3	2	3
	Maiduguri	2	1	-	3	-	5	3	2	3
	Mean	2	1	1	3	2	5	4	2	4

EC-Early Cessation, N-normal, LC-Late Cessation

Table 4 : Frequency of occurrences of deviation in duration of rains during cold, normal and warm episodes of SSTA in the GOG.

Agro–ecological zones	Stations	Cold SSTA			Normal			Warm SSTA		
		S	N	L	S	N	L	S	N	L
Forest zone	Lagos	1	-	2	4	2	-	2	4	5
	Port Harcourt	2	-	1	1	3	2	4	1	6
	Ondo	1	-	2	1	2	3	4	6	1
	Enugu	-	1	2	1	2	3	3	2	6
	Mean	1	1	2	2	2	3	3	3	5
Southern guinea savanna zone	Ilorin	1	-	2	3	1	2	8	-	3
	Lokoja	1	-	2	4	2	-	6	1	4
	Ibi	1	-	2	3	1	2	4	1	6
	Mean	1	-	2	3	1	2	6	1	4
Northern guinea savanna zone	Yelwa	2	1	-	2	1	3	3	6	2
	Jos	-	2	1	2	2	2	2	5	4
	Zaria	2	-	1	1	2	3	4	5	2
	Yola	1	1	1	1	1	4	3	6	2
	Mean	2	1	1	1	1	3	3	6	3
Sudan savanna zone	Kano	2	-	1	3	1	2	5	1	5
	Nguru	2	1	-	2	-	4	5	3	3
	Sokoto	1	1	1	2	1	3	4	3	4
	Maiduguri	1	2	-	3	-	3	6	2	3
	Mean	2	1	1	3	1	3	5	2	4

S-Short, N-normal, L-Long

Table 5: Frequency of occurrences of deviation in rainy days during cold, normal and warm episodes of SSTA in the GOG.

Agro–	Stations	Cold SSTA	Normal	Warm SSTA

ecological zones										
		BN	N	AN	BN	N	AN	BN	N	AN
Forest zone	Lagos	-	2	1	3	-	3	2	4	5
	Port Harcourt	1	1	1	3	1	2	4	2	5
	Ondo	2	-	1	3	1	2	3	3	5
	Enugu	1	-	2	2	3	1	3	3	5
	Mean	1	1	2	3	2	2	3	3	5
Southern Savanna zone	Ilorin	1	-	2	4	-	2	4	1	6
	Lokoja	2	-	1	3	1	2	4	2	5
	Ibi	1	-	2	2	1	3	3	3	5
	Mean	1	-	2	3	1	2	4	2	5
Northern savanna zone	Yelwa	1	1	1	-	4	2	4	-	7
	Jos	1	2	-	1	-	5	5	2	4
	Zaria	3	-	-	3	-	3	5	2	4
	Yola	-	1	2	2	1	3	4	5	2
	Mean	2	1	1	2	2	3	5	3	4
Sudan savanna zone	Kano	-	2	1	2	1	3	6	-	5
	Nguru	2	1	-	2	3	1	2	4	5
	Sokoto	2	1	-	1	2	3	2	7	2
	Maiduguri	3	-	-	-	3	3	4	3	4
	Mran	2	1	1	2	3	3	4	4	4

BN-Below normal, N-normal, AN-above normal

Table 6: Correlation analysis between SSTA and DOR at various agro-ecological zones in Nigeria

Agro-ecological zones	SSTA_Lat 5^{0} r (R^2)	SSTA_Lat 4^{0}N r (R^2)	SSTA_Lat 2^{0}N r (R^2)	SSTA_Lat 0^{0}N r (R^2)
Forest zone	0.4790*(0.2	0.3231*(0.10)	0.4673*(0.22)	**0.6339* (0.40)**
Southern guinea savanna	0.6081* (0.37)	0.4931*(0.24)	0.5771*(0.33)	0.5726*(0.33)
Northern guinea savanna	0.451* (0.2	0.3021*(0.09)	-0.014 ^{ns}(0.002	0.0621 ^{ns}(0.004)
Sudan savanna	0.055 ^{ns}(0.003)	0.0103 ^{ns}(0.001	0.2837* (0.08)	-0.1924*(0.04)

Table 7: Correlation analysis between SSTA and DCR at various agro-ecological zones in Nigeria

Agro-ecological zone	SSTA_Lat 5^{0}N r (R^2)	SSTA_Lat 4^{0}N r (R^2)	SSTA_Lat 2^{0}N r (R^2)	SSTA_Lat 0^{0}N r (R^2)
Forest zone	0.5224*(0.28)	0.4833*(0.23)	0.596*(0.36)	0.3295*(0.11)
Southern guinea savanna	0.2281*(0.05)	0.0076^{ns}(0.006)	0.0751^{ns} (0.006)	0.441*(0.19)
Northern guinea savanna	0.4203*(0.18)	0.164 ^{ns}(0.003)	-0.228*(0.05)	-0.0331^{ns} (0.001)
Sudan savanna	0.0831^{ns}(0.006)	-0.3575*(0.13)	-0.0746^{ns} (0.006)	-0.2481*(0.06)

*** significant ($P<0.05$), ns- not significant. r-correlation coefficient, R^2- coefficient of determination**

Table 8: Correlation analysis between SSTA and DR at different agro-ecological zones in Nigeria

Agro-ecological zone	SSTA_Lat 5⁰N r (R^2)	SSTA_Lat 4⁰N r (R^2)	SSTA_Lat 2⁰N r (R^2)	SSTA_Lat 0⁰N r (R^2)
Forest zone	0.3137*(0.10)	0.1253^{ns} (0.002)	-0.1753*(0.03)	-0.289*(0.08)
Southern guinea savanna	-0.45*(0.20)	-0.4499*(0.20)	-0.4887*(0.24)	-0.527*(0.28)
Northern guinea savanna	-0.0571^{ns} (0.004)	-0.2174*(0.05)	-0.2463*(0.06)	-0.1951*(0.04)
Sudan savanna	0.0506^{ns} (0.003)	-0.0424^{ns} (0.002)	-0.1892*(0.04)	-0.1234*(0.02)

Table 9: Correlation analysis between SSTA and FORD at different agro-ecological zones in Nigeria

Agro-ecological zone	SSTA_Lat 5⁰N r (R^2)	SSTA_Lat 4⁰N r (R^2)	SSTA_Lat 2⁰N r (R^2)	SSTA_Lat 0⁰N r (R^2)
Forest zone	0.1966*(0.04)	-0.1571*(0.02)	0.1911*(0.04)	0.1448*(0.02)
Southern guinea savanna	0.2755*(0.08)	-0.2224*(0.05)	-0.0449^{ns} (0.002)	-0.2546*(0.06)
Northern guinea savanna	0.0427^{ns} (0.002)	-0.1294*(0.02)	-0.0187^{ns} (0.003)	-0.1881*(0.04)
Sudan savanna	0.0158^{ns} (0.002)	-0.2057*(0.04)	0.1733*(0.03)	0.1236*(0.02)

significant ($P<0.05$), ns- not significant. r-correlation coefficient, R^2-coefficient of determination

5.0 Discussion

Result showed that the occurrence of positive temperature anomaly (warming trend) was highest (55% of the time) in the GOG. Negative anomaly (cooling) occurred just for 15% of the time while the norm was 30% of the time. On the average there is generally a warming trend over GOG. While association of late DOR and DCR, above normal DR and FORD with positive SSTA over GOG is probably evidence of the global climatic warming causing climate deterioration in Nigeria this had been reported by some authors (Olaniran, 1983b, Bello, 1996). This could invariably affect reliable agricultural practices in the various agro-ecological zones. As observed by Bello (2000) that incidence of failure of annual crops, replanting and low ultimate yield have become an annual occurrences. Furthermore SSTA over GOG had significant ($P<0.05$) impacts on DOR, DCR, DR and FORD in Nigeria. Furthermore SSTA over GOG had significant ($P<0.05$) impacts on DOR, DCR, DR and FORD in Nigeria.

Though the results have shown that the frequency of occurrences of hydro-climatic attributes as related to SSTA indicated that positive anomalies in SST and normal SST resulted in late occurrences of all the attributes which could invariably affect reliable agricultural practices in the various agro-ecological zones while negative anomalies in SST and normal SST resulted in early occurrences of all the attributes especially over Northern and Sudan Savanna zone with the highest weight over the Sudan Savanna zone. It is therefore pertinent to note that information on the occurrence of normal, early and late onset and cessation of the rains may be of practical value to the planning of agricultural activities in Nigeria. The result has shown clearly that reliability of hydro-climatic attributes for optimum agricultural activities cannot be achieve without contributing SSTA over the Gulf of Guinea.

6.0 Conclusion /Recommendation

This study has examined the SST anomalies in the GOG and discussed their association with the characteristics of hydro-climatic variable over the agro - ecological zones in Nigeria. For this period of study the SSTA over GOG indicated that it has undergone some warming over time and positive SSTA are significantly related with hydro-climatic variables in Nigeria.

Therefore SSTA should be seen as one of the factors responsible for climatic deteriorations in Nigeria such as flood, drought, acid rain, heat waves etc.

The study concluded that, the SST anomalies over GOG have impacts on the hydro-climatic variable in Nigeria.

Sea surface temperature should be seen as one of the forecasting tool in determining the various climatic attributes that is essential for optimal agricultural practices. This can be achieved with the use of reliable climate predictability tools. To enhance optimal schedule of farm operations for farmers, proper adaptation and mitigation practices should be put in place.

References

Adejuwon, J.O. and Odekunle, T.O. 2006. Variability and the severity of the "Little Dry Season" in Southwestern Nigeria. *Journal of Climate* 19: 483–493.

Afiesimama, E. A. 1996 : On the variability of the mean sea surface temperature and its influence on the rainfall pattern over a coastal station in West Africa. Proc. of the 4th Inter. Conference on School and Popular Met. and Oceanographic Edu. R. *Met. Soc. Publication* p321.

Bello, N.J. (1989) On the reliability of the methods of predicting the onset and cessation of the rains in a tropical wet and dry climate: ondo as a case study.

Bello, N.J. (1997) Investigating the spatial pattern of the characteristics of the onset and cessation of the rains in Nigeria. *Geojournal* 43 : 113-123.

Bello, N.J. 2000 : Application of rainfall potential evapotranspiration model for determining optimum planting date of maize (Zea mays) in a tropical Wet and Dry Climate. The Indian *Journal of Agricultural Sciences* Vol. 70 (6) 437-440.

Edafienene, at al, (1997): Sea surface temperature analysis from institu data at East Mole, Lagos Nigerian Meteorological Society proceedings of the 12th and 13th Department Symposia. Pp 35

Gbuyiro SO, Lamin MT, Ojo O. 2002. Observed characteristics of rainfall over Nigeria during ENSO years. *Journal of Nigerian Meteorological Society (NMS)* 3: 1 - 17.

Folland C. K., Palmer, T. N., and Parker, D. E, 1986: Sahel rainfall and worldwide sea temperatures. *Nature,* 320, 602-607.

Losada, T., B. Rodriguez-Fonseca, S. Janicot, S. Gervois, F. Chauvin, and P. Ruti, 2010a: A multimodel approach to the Atlantic ecuatorial mode. Impact on the West African monsoon. *Clim. Dyn.*, Doi: 10.1007/s00382-009- 0625-5.

Mohino, E., B. Rodríguez-Fonseca, C.R. Mechoso, S. Gervois, P. Ruti, and F. Chauvin, 2011a: Impacts of the Tropical Pacific/Indian Oceans on the Seasonal Cycle of the West African Monsoon. *Journal of Climatology.,* Doi: 10.1175/2011JCLI3988.1

Odekunle, T.O, and Eludoyin A.O, 2008: Sea surface temperature patterns in the Gulf of Guinea: their implications for the spatio-temporal variability of precipitation West Africa, *international. Journal of. climatology.*

Okeke F.N,; Marengo J.A., Nobre, C. (2006), Investigation of El Nino and La Nino effects and the impact of Atlantic Sea Surface Temperatures (SSTs), on precipitation in Nigeria from 1950 to 1992. *Surveys in Geophysics* Volume 27, Number 5, 545 - 555.

Okumura, Y. and Xie, S. 2004. Interaction of the Atlantic equatorial cold tongue and the African Monsoon. *Journal of Climate* 17: 3589 - 3602.

Olaniran, O. J. and Summer, GN. (1990). Long-term variations of annual and growing season rainfalls in Nigeria. *Theoretical. and Applied Climatology*., 41:41 – 53

Omogbai B.E. 2010. Rain Days and Their Predictability in South-western Region of Nigeria. *Journal of Human Ecology*, 31(3): 185-195

Omotosho JB, Balogun AA, Ogunjobi K. 2000. "Predicting monthly and seasonal rainfall, onset and cessation of the rainy season in West Africa, using only surface data". *International Journal of Climatology* **20**: 865–880.

Wang, C., S.P. Xie and J. A. Carton. 2004 A global survey of ocean-atmosphere interaction and climate variability, Geophysical Monograph.

EFFECT OF GREENHOUSE MICRO-CLIMATE AND PLANTING MEDIA ON THE PERFORMANCE OF TOMATO (*LycopersiconesculentumMill*) NURSERIES IN OFADA, SOUTH WESTERN NIGERIA

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ABSTRACT

Greenhouse as part of integrated pest management strategies provides an ideal environment for the protection of crops and raising their nurseries. Despite the fact that tomato grows in diverse growing media, there seems to be potentials limitation of some media use to some specific environment for the production of tomato seedlings in order to produce a minimal desired percentage of emergence and vigour that makes it suitable for transplanting into the main field.Traditional production of seedlings amongst Nigerian farmers is continually threatened with pest, poor emergence, damping off and rain wash. Greenhouse in this regards presents itself to provide a secured option to farmers.This study was conducted to evaluate the effect of controlled (greenhouse without crops), semi-controlled (greenhouse with crops), and uncontrolled (open field) microclimates simultaneously with the effect of planting media on the performance of tomato nurseries.Two greenhouse varieties (Eva and Nemonetta) using four different growing media (Locally sourced Peat Moss, cocopeat mixed with perlite, Compost Dresser, and Organic Soil). The experiment was conducted at the demonstration site of Dizengoff West Africa in the premises of Q6 (Villa Farms), Limited, Ofada, Obafemi-Owode LGA, Ogun State, Nigeria. The experiment was carried out at the onset of the two seasons, the dry harmarttern (December, 2014) and the Rain season (April, 2015).Three growing environment were used, the first is a small 15m by 8m greenhouse dedicated solely to seedling raising(NURSERY GREENHOUSE), the second is another acre sized, 80m by 48m greenhouse, generally used in growing crops to full maturity (GENERAL GREENHOUSE), and the third is the uncontrolled environ (OPEN FIELD). All three locations for the experiments involved the use of the same varieties planted in trays with grooves.The experimental design adopted in all three environ was a Split-plot fitted into a Randomized Complete Block Design, where variety were assigned to the main plots and the media subplots.The parameters measured included emergence, vegetative variants, that is, plant height and number of leaves; meteorological indices of each micro-climates taken were minimum and maximum temperatures, and humidity. Fertigation parameters were; pH, total dissolved solids, and electro-conductivity.The result from the study showed that EVA variety facilitated the highest percentage of emergence and survivability, with the tallest seedling and having the most number of leaves across all the growing micro climates with the use of all the growing media.The results also showed that the nursery greenhouse micro climate had significantly the most emerging seedling across the 3 weeks of experiment using *local peat moss* as 91.7%, 88.5% and 55.2% at($p \leq 0.05$).The result also showed that the general greenhouse micro climate had significantly the tallest emerging seedlings using the mix of *cocopeat and perlite* at 2.39cm, 4.76cm and 8.10cm respectively with the 3weeks period.Again the result revalidated that general greenhouse micro-climate allowed for that the seedlings with most number of leaves across the 3 weeks using *cocopeat and perlite* mix at 2, 4 and 6 leaves respectively.The uncontrolled open field microclimate although seemingly ranking third in each vegetative indicator; facilitated the best and most successful use as in the Nursery greenhouse of a locally sourced growing media- the *Local Peat moss* for raising seedlings with the most emergence, height and number of leaves simultaneously.

Keywords: Micro-climate, greenhouse, growing media and fertigation.

INTRODUCTION

Tomato belongs to species most frequently referred to as *Lycopersicon esculentum*. It is a native to the Andes region of South America. Tomato as one of the vegetable crops and fruits are very important in human nutrition (Abubakar, 1999).Tomato growing on a garden basis has been practiced in Nigeria for a long period of time mainly for domestic consumption such as soup, stew and vegetables salads (Poysa, 2000). This crop is now being grown in form of paste, purée, ketchups and as fruit drinks.In Nigeria alone, annual total area of one million hectares is reportedly used for its cultivation (Anon, 1989; Bodunde *et al*, 1993). Tomato may be eaten fresh as salad or they may be pressed into pastes or purees, which are used for cooking in soups or stews and producing fruit drinks.Vegetable productivity is influenced by properly grown transplants. Transplants quality is highly dependent on various factors such as temperature, Carbondioxide, air humidity, water supply, fertilization, substrate, cultivation methods, vegetable species or varieties [Atherton and Rudich 1986, Weston 1988, Ciardi et al. 1998, Vavrina 1998, Damato and Trotta 2000, Głowacka 2002, Paul and Metzger 2005, Brazaitytė *et al*. 2009, 2010, Juknys *et al*. 2011].

Greenhouses are used in order to create a more favourable environment that is essential for plant growth and productivity, especially in extremely hot and humid region of Nigeria. A greenhouse permit plants to grow during any season of the year by controlling temperature, carbon dioxide, air humidity and light intensity levels. The greenhouses are usually covered with a material (i.e., glass or plastic) that has the ability to transmit light to provide essential energy for plant growth and production. Conditions of light intensity, duration, and spectral distribution greatly affect plant physiological responses. Light intensity varies greatly according to the climatic zone, season of the year, cloud cover, and anthropogenic factors, e.g. the cleanness and thickness of windows in a greenhouse or the type of film covering the greenhouse. As observed by Pirog (1993), reducing the light intensity by 1% might result in 1% decrease in yield of plants.

Phenological development governs the plant growth and productivity (Awal and Ikeda, 2003b). Days to flowering, fruiting and maturity of crop are the important phenological events which determine the productivity of a crop. Temperature plays a major role in phenological development and productivity of crop plants. High temperature influences crops to mature earlier (Awal *et al*., 2003). Tomato plant grown under polyhouse was observed to be earlier in flowering and fruit setting by about 3 and 8 days, respectively when compared to the crop raised under open condition (Ganesan, 2002b). The early and higher yield of different vegetable crops inside the polyhouse was mainly because of better microclimate such as higher temperature (4-9°C than the nearby open field) observed during winter months (Cheema *et al*., 2004).Tomato is amongst the wide ranges of vegetable crops that have to be raised in nurseries for success; other commonly nursery grown vegetables are- cabbage cauliflower broccoli brussels sprouts. Lettuce, chilli leeks, brinjal, onion, celery e.t.c.

Increasingly, nursery stock is produced in containers due to market demands and numerous production advantages including greater production per surface unit, faster plant growth, higher plant quality, and lack of dependence on arable land. Nursery potting media usually contain substantial amounts of peat moss (*Sphagnum* spp.) since it provides adequate aeration, moisture retention and support for the seedlings (Raviv *et al.*, 1986). However the use of peat involves the exploitation of non-renewable resources and the degradation of highly valuable ecosystems like peatlands (Robertson, 1993). In many countries several restrictions have been established for the use of this material due to environmental concerns and, as a consequence, peat has become a rather scarce and expensive potting Substrate. Therefore, in order to reduce costs and adopt more environmentally-friendly practices, research on alternative substrates is of great interest, and several alternatives have been proposed. The parallel increasing concern in waste recycling has lead to the proposal of some organic materials such as compost-like substrates (Ostos *et al*., 2008), as partial substitutes of peat. Compost, as a product of thermophilic processes of organic waste degradation, and vermicompost, as a mesophilic biodegradation product resulting from interactions between earthworms and microorganisms are humus-like materials which could act as suitable substitutes of peat.

In spite that several studies have addressed the effect of different types of compost (García-Gómez *et al.*, 2002; Grigatti *et al.*, 2007; Herrera *et al.*, 2008) and/or vermicompost

(Edwards *et al.*, 2004; Hashemimajd *et al.*, 2004; Tognetti *et al.*, 2005) as potting or soil amendments on plant growth and yield, there are no studies concerning the effects of these two substrates in plant morphology when they are incorporated as potting substrates, hence this study.

Objectives of the study

The research aimed at determining the effect of greenhouse on the performance of tomato nursery in order to develop a comprehensive "Standard of Procedures" for greenhouse tomato nursery.

Specifically, the study's objective:

1. examined the effect of environment and media on the emergence and growth performance of tomato seedlings.
2. determined the relationship between micro-climatic elements and growth performance of tomato seedlings.

METHODOLOGY

The research was conducted at the DIZENCOMBI Greenhouse Demonstration Site, near Ofada, Obafemi-Owode LGA, Ogunstate. The demo farm is located near Ofada town about 12 kilometers from the state capital- Abeokuta, Ogunstate. The state is located between latitude 6.2^{0}N and 7.8^{0}N, and longitude 3.0^{0}E and 5.0^{0}E. The climate of the state follows a tropical pattern with the raining season between March and November, and the dry season between December and February. The mean annual rainfall varies from 1280mm in the south, to 1050mm in the northern part of the state. The average monthly temperature ranges from 23 ^{0}C in July to 32^{0}C in February.

Daily data on percentage emergence (%) plant height (cm), and number of leaves, were averaged into weekly readings. Weekly reading of temperature, humidity (%), Fertigationvolume(mL), pH of fertigation solution, electro conductivity (mS/cm) of fertigation solution, and the total dissolved solids(ppm) of the fertigation solution; was also collated side by side.

Data Analysis

The effect of controlled and non-controlled environment on the emergence and vigor of tomato seedlings was determined using Person Product Moment correlation.

The most suitable media mixture for a typical micro-climatic condition was thus identified using two-way Analysis of Variance while means of the significant values were separated at 5% level using Least Significant Difference.

RESULTS

Table 1 shows that the effect of environment singly on the emergence of tomato seedlings were not significant ($\rho \geq 0.05$). On the overall view there was a decline in the emergence and count over the three weeks of the dry season experiment in the entire three mirco-climate environment. The nursery greenhouse recorded a higher emergence count of 7.16, 7.03 and 5.78 in the first second and third weeks respectively, followed by the general green house with 7.16, 6.59 and 5.09 in the first second and third weeks respectively. While the open filed control experiment recorded, 5.59, 5.22, and 3.97 in the first second and third weeks respectively.

Furthermore, table 2 also shows that the effect of environment singly on the height of tomato seedlings were not significant ($\rho \leq 0.05$) all through the period of the dry season experiment. On the overall view there was a steady increase in the plant height over the three weeks of the experiment in the entire three micro-climate environment. The general greenhouse recorded the tallest emerging seedlings of 2.17, 4.24 and 7.42 in the first, second and third weeks respectively, followed by the general green house with 1.73, 3.39 and 5.98 in the first second and third weeks respectively. While the open filed control experiment recorded the shortest emerging seedlings emerging seedlings, 1.63, 3.57, and 5.67 in the first second and third weeks respectively.

Table 1 also shows that the effect of environment singly on the number of leaves of tomato seedlings were not significant ($\rho \geq 0.05$) all through the period of the dry season experiment. On the overall view there was a steady increase in the number of leaves over the three weeks of the experiment in the entire three micro-climate environment. The general greenhouse recorded the most number of leaves of 1.69, 3.34 and 4.25 in the first, second and third weeks respectively, followed by the nursery greenhouse with 1.56, 2.81 and 4.16 in the first second and third weeks respectively. While the open filed control experiment recorded the shortest emerging seedlings emerging seedlings, 1.25, 1.97, and 2.78 in the first second and third weeks respectively.

Table 2 shows that the effect of media on the emergence of tomato seedlings were significant ($p \leq 0.05$) all through the period of the dry season experiment. Local peatmoss had the most emergence of 8.08 followed closely by compost dresser at 7.62 while cocopeat plus pertile mix had the least perfomance in the first week. However in the second week organic soil recorded the most emergence and count of 8.17 followed closely by cocopeat plus perlite mix at 7.25, but local peatmoss had the least emergence and count at 4.23. At the point of transplant in the third week Local peapmoss still sustained the most emergence and count at 6.75, followed by compost dresser at 5.75 while the organic soil had the lowest emergence and count at 2.88.

Furthermore, table 2 also shows that the effect of media on the height of tomato seedlings were not significant ($\rho \leq 0.05$)all through the period of experiment. However an increasing trend was recorded over the three weeks of experiment. Although compost dresser medium facilitated the tallest seedlings in the first week, it increased moderately to a height of 4.14cm and 6.78cm in the second and third weeks respectively. The local peatmoss started with a height of 1.88 cm in the first week and had a remarkable increase to being the tallest at transplant of 4.22cm and 7.45cm in the second and third weeks respectively.

Again, table 2 also shows that the effect of media on the number of leaves of tomato seedlings were significant at weeks 1 and 2 but was not significant ($\rho \geq 0.05$) at week 3 of the period of experiment. However an increasing trend was recorded over the three weeks of experiment. Local peat and compost dresser facilitated the same performance with the most number of leaves at 1.67 and 4.29 in the first and third weeks respectively. While organic soil and the mix of cocopeat plus perlite facilitate the same performance but with a lower number of leaves at 1.33 in the first week and also ended up with the least number of leaves at 3.67 and 2.67 respectively.

Table 3 shows the correlation between meteorological parameters and agronomic characteristics of tomatoes seedlings for the first experiment done during the dry season. Mean temperature, temperature depression, volume of fertigation, electro conductivity, pH and Total dissolved Solid show low correlation with agronomic characteristics considered for the three micro climate used. Temperature depression correlated significantly and positively with percentage emergence ($r = 0.644$), plant height($r = 0.500$) and number of leaves($r = 0.563$), of tomato seedlings in the entire three micro climate during the dry season. While fertigation volume correlated significantly and positively with the ambient mean temperature ($r = 0.535$), just as the total dissolved solids of the fertigation solution correlated very significantly and positively with its electro conductivity($r = 0.992$).

Table 3:Pearson correlation of coefficients Between Growth parameters and Atmospheric Indices

	PE	PH	NL	T_{mean}	$T_{depr.}$	HUM.	Fert.Vol.	EC	pH	TDS
PE	1									
PH	0.914**	1								
NL	0.933**	0.977**	1							
T_{mean}	-0.041	0.172	0.138	1						

$T_{depr.}$	0.644*	0.500*	0.563*	0.347	1					
HUM.	-0.735*	-0.425	-0.591**	-0.129	-0.861**	1				
Fert.Vol.	-0.150	-0.196	-0.291	0.535*	-0.098	0.052	1			
EC	-0.085	0.329	0.195	0.348	0.015	-0.104	0.187	1		
Ph	-0.121	0.003	0.036	-0.729*	-0.314	0.280	0.195	-0.434	1	
TDS	-0.013	0.339	0.238	0.276	0.016	-0.142	0.235	0.992**	-0.367	1

PE= Percentage Emergence, PH=Plant Height, NL=Number of Leaves,T_{mean} = Mean temperature $T_{depr.}$.= Temperature Depression, HUM.= Humidity, Fert.Vol.= Volume of Fertigation pH= level of Alkaninity/Acidity, EC=Electro conductivity, TDS=Total Dissolved Solid*values significant at $P \leq 0.05$ **values significant at $P \leq 0.01$

Discussion of finding

The effect of greenhouse controlled and open field uncontrolled environment was glaringly not significant during the two seasons under experiment. The implication thus is farmers with or without greenhouse can raise seedlings successfully.However it was observed during the dry season experiment that the nursery greenhouse; which is solely meant for raising seedlings facilitated the most emergence and surviving seedlings during the three weeks of experiment, followed by the general greenhouse; which has other crops in it and the then the open field. While the general greenhouse encouraged the tallest emerging seedlings, followed by the nursery greenhouse and then the open field. On the other hand general greenhouse also had in it seedlings with the most number of leaves, followed by the nursery greenhouse and then the open field. It is noteworthy that in the wet season experiment all three micro-climate environment had close to uniform performance.

This is in accordance with the work of Arnold O. W. (2015), who in a similar vein concluded that, considering the temperature and relative humidity variables and the direct effect of solar rays in the shade house coupled with plant height parameter, shade house is an appropriate structure for cucurbit production in a tropical climate. We thus can conclude that greenhouse had an overall positive effect on the emergence, height, number of leaves, vigour and survivability of tomato seedlings.On the overall local peat moss was identified to be most suitable in all three micro climatein both seasons of the experiment.

Although preference is given to the use of coco peat and perlite mix in the general greenhouse simply for it property of having less bulk density; porosity and aeration which on the over-all disallow damping off at points of over irrigation.

The *general greenhouse* also presents itself as an ideal environ for the regulation of extreme dry season temperature -a key pointer of seedling elongation as a result of the presence of existing crops.

In a nutshell the farmer need not procure an extra greenhouse to carry on with production of tomato nursery for the next season. The mortality owing to transfer of infection and infestation of pest from older crops was not pronounced in the seedling counts during each experiment, as long as the routine agronomic preventive sprays gave the same desired effects also on the seedlings as it does the older crops.

The locally sourced peat moss was most excellent in the *open field* facilitating the most surviving and tallest seedlings with the most number of leaves simultaneously. This was similar to the findings of Zabiholah Rahimi *et al*. 2013, his results showed that produced seedlings had better conditions in peat moss media and they were in the highest values. In addition, peat moss and coco-peat as pure form or mixed with sand, had better results than other media and cultivation in soil and coco-peat (palmpeat) media were not suitable for tomato transplantproduction.

The *open field* is obviously an ideal environment for maximum air flow without hindrances of the greenhouse netting, thus helping to facilitate more evapotranspiration, nutrient uptake and consequently seedling's quick elongation within the shortest number of days. This is not to say that the *open field* does not have its own down sides, the major limitation been the restriction of raising seedling majorly in the dry season, as seedling are prone to wash off during rainfall.

Conversely, farmers who can afford a separate greenhouse for the purpose of raising tomato seedlings stand a chance of having seedling that are sterile and least infested. There is also less worries of the chances of wash-off by rain.

From the findings of this research work the *local peat moss* is the best option for raising seedlings with the highest chance of emergence and survivability but farmers may have to incur additional cost in procuring *compost dresser* to achieve good folia and height. This is so as a result of the caking-off effect *local peat moss* tends to have when temperature reaches its peak in the nursery in the absence of any cushioning effect.

On the other hand, humidity complications can result during raining season within both the nursery greenhouse and the general greenhouse, a major side effect is the damping off syndrome on tomato seedling, this by many literature is said to have been caused by lesser influx of dry air and minimal gaseous exchange thus inhibiting the much needed transpiration pull for seedling elongation and leaving behind previous moisture in the growing medium and thus preventing further nutrition at the next scheduled fertigation.(Bussell, Mckennier, 2004).

Before presenting the recommendations of this research work, it is pertinent to highlights at this juncture the concept of "*growing media amendment*", this although it is not in the main scope of this study, this research presents an opportunity that suggests that growing media could be mixed in varying percentages to achieve the desired results.

Conclusion and Recommendations

This research has helped to establish the fact that farmers who eventually are unable able to secure or procure a separate greenhouse facility to raise seedlings could as well go ahead and raise seedling in the same greenhouse along with existing crops as the latter helped to give the most needed cushioning effect all through the dry season.

This study indicated that the variety Eva grown with locally source *peat moss* (from the husk of long fallen palm tree and bee combs) offers suitable alternate for tomato seedling production in south west Nigeria. The importance of this research hence is that: since performance of tomato seedlings was significantly higher with local peat moss in two of the major growing micro-climate environment, it was therefore not economically justifiable or necessary as a country to be importing an expensive media such as the compost dresser, cocopeat and perlite for tomato nursery production even with other horticultural crops when its performance was not superior to our locally sourced peat moss.

Following the performance rank of the growing media; *local peat moss* been first, *compost dresser* second and the mix of cocopeat and perlite third; we could propose a varying mix with the understanding of the environment they are intended to be used. For example based on availability in the market and prevalent season one could mix 50% *local peat moss with* 20% saw dust or 30% wood shavings in the place of coco peat and perlite.While compost dresser could be used in mix with *local peat moss* in the nursery in raining season at 50:50 ratios and so on and so forth.

Also greenhouse was mostly ideal for the purpose of raising sterile seedling and not necessarily a factor to achieving a suitable or ideal seedling for transplant. Thus if the right choice of medium is been made i.e. local peat moss*:* as this research recommends, farmers can successfully raise their seedlings in shorter number of days even in the open field. It is noteworthy that there is room for further research into the least number of days seedlings can be raise in all other parts of the country across all seasons; with and without controlled environ. It is thus recommended that the government should look into funding further research work on local sourced peat moss, and most importantly set up indigenous industry for the refining, pre-treating and amendment of *local peat moss* from long dead decaying fallen palm trees and similarly fallen trees that host bee cavities. This will create an ideal alternative to the importation of expensive growing media for the use of Nigerian farmers in growing tomato seedling.

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REFERENCES

Abubakar U (1999). Studies on the nematodes of cowpea (*Vignaunguiculata*) of the savannah region of northern Nigeria and control of*Meloidogyne incognita* using selected plant extracts and animalmanures.Unpublished PhD. Thesis UsmanDanfadiyosokoto, p. 108.

Atherton, J.G. and Harris, G.P. (1986): Flowering In: Atherton, J.G. and Rudich, J. (eds) The Tomato Crop.A scientific Basis for Improvement. Chapman and Hall, London, pp. 165-200.

Awal, M.A. and T. Ikeda (2003a).Effect of elevated soil temperature on radiation-use efficiency in peanut stands. Agricultural and Forest Meteorology, 118 (1-2), pp: 63-74.

Awal, M.A. and T. Ikeda (2003b).Controlling canopy formation, flowering, and yield in field-grown stands of peanut (*ArachishypogaeaL.*) with ambient and regulated soil temperature. Field Crops Research, 81 (2-3), pp: 121-132.

Baille, A., Gutierrez Colomer, R. P., & Gonzalez-Real, M. M. (2006). Analysis of intercepted radiation and dry matter accumulation in rose flower shoots. Agricultural and Forest Meteorology, 137, 68e80.

Bussell W. T., Mckennie S.2004. Rockwool in horticulture, and its importance and sustainable use in New Zealand. *Journal of Crop and Horticultural Science*.,vol. 32, Issue 1, p. 29–37

Cheema, D.S., Kaur,P. and Kaur, S. (2004).Off-season cultivation of tomato under net house conditions. ActaHorticulturae (ISHS), 659, pp: 177-181.

Donnan, R. 1998.Hydroponics around the world Practical Hydroponics and Greenhouses.vol. 41, p. 18–25

Edwards C.A., Domínguez J., Arancon N.Q., 2004.The influence of vermicompost on plant growth and pest incidence. pp. 396-419.

Ganesan, M. (2002b). Effect of poly-greenhouse models on plant growth and yield of tomato (*Lycopersiconesculentum*). Indian Journal of Agricultural Sciences, 72 (10), pp: 586-588.

Ganesan, M. (2002c). Effect of poly-greenhouse on plant micro climate and fruit yield of tomato.*Karnataka Journal of Agricultural Sciences*, 15 (4), pp: 750-752.

García-Gómez A., BERNAL, M.P., ROIG, A., 2002.Ornamental plants growth in substrates using composts from agroindustrial wastes.Bioresource Technology 83, 81-87.

Grigatti M., Giorgonni,M.E., Ciavatta C., 2007. Compost-based growing media: influence on growth and nutrient use of bedding plants. Bioresource Technology 98, 3526-3534.

Hashemimajd K., Kalbasi M., Golchin A., Shariatmadari H., 2004. Comparison of vermicompost and composts as potting media for growth of tomatoes.*Journal Plant Nutrition* 27, 1107-1123.

Herrera,F., Castillo,J.E., Chica,A.F., López,B.L., 2008.Use of municipal solid waste compost (MSWC) as a growing medium in the nursery production of tomato plants. Bioresource Technology 99, 287-296.

Ostos, J.C., López-Garrido,R., Murillo,J.M., López,R., 2008. Substitution of peat for municipal solid waste- and sewage sludge-based composts in nursery growing media: effects on growth and nutrition of the native shrub *Pistacialentiscus*L. BioresourceTechnol 99, 1793-1800.

Piróg, J. 1993. Czynnikiklimatyczne pod oslonami. In: 'Uprawawarzyw pod oslonam' T. Pudelski (ed.), PWRiL, Warszawa

Poysa V (2000). Rate of firut development, leaf growth and earliness in determined tomatoes. Can. J. Plant Science 71: 1211-1218.

Raviv,M., Chen,Y., Inbar,Y., 1986.The use of peat and composts as growth media for container-grown plants. In: The role of organic matter in modern agriculture (Chen Y., Avnimelech Y., eds). MartinusNijhoff Publishing, Dordrecht. pp. 257-287.

Robertson,R.A., 1993.Peat, horticulture and environment.Biodiversity Conservation 2, 541-547.

Tognetti, C., Laos, F., Mazzarino, M.J., and Hernandez, M. T. (2005).Composting vs. vermicomposting: Acomparison of end product quality.*Compost Science and Utilization, 13*, 6-13.

Tognetti,C., Laos F., Mazzarino M.J., andHernández M.T., 2005.Composting vs. vermicomposting: a comparison of end product quality. Compost SciUtil 13, 6-13.

Vavrina, C.S., 1998. Transplant age in vegetable crops. Horticultural Technology

8(4):550–555.

YIELD PERFORMANCE OF PRO-VITAMIN A CASSAVA IN THREE CONTRASTING AGRO-CLIMATIC BELTS OF NIGERIA

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ABSTRACT

Yield performance of pro vitamin A cassava was studied in three contrasting agro-climatic belts of Nigeria namely Tropical rainforest, Guinea savanna and Sudan savanna). Secondary data on rainfall, atmospheric temperature, soil temperature, relative humility and sunshine hours of the study locations in each belt from 1983 to 2015 were collected from Nigerian Meteorological Agency (NIMET), Oshodi, Lagos and those on pro vitamin A cassava yield of 2011 to 2015 were obtained from National Root Crop Research Institute documentaries. The data were analyzed using mean, regression, correlation and analysis of variance (ANOVA). Result obtained showed that Pro vitamin A cassava had the highest yield performance of 49.60 metric tons at Otobi followed by Umuahia with 46.20 metric tons and Kano with the least, 26.00 metric tons. Relating this to the climatic parameters, rainfall totals and soil temperature gave the most significant relationship than others studied. The R^2 value 0.9097 indicated that 90.97% variability in yield is explained by the combined effects of all the climatic parameters. From the results, it could be concluded that climatic variables have a greater influence in the yield performance of pro vitamin A cassava in the three agro-climatic belts, most especially rainfall and soil temperature.

Key words: Yield Performance, Pro-Vitamin A Cassava, Climate Variability, Agro-Climatic Belts, Nigeria

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SUB THEME: Climate Variability and Change Impacts on Agriculture

Introduction

Cassava (*Manihot esculenta Crantz*) originated from South America and was believed to be introduced into Africa in the 16th and 17th Century (CPG, 2010). Since its introduction, Nigeria's Cassava production is by far the largest in the world accounting for more than a third of the production in Brazil and more than double that Indonesia and Thailand (FAO, 2014). Similarly, in Africa, Nigeria's cassava output of 45million metric tons is greater than combined productions from Democratic Republic of Congo, Ghana, Madagascar, Mozambique, Tanzania, and Uganda (FAO, 2005, NAERLS, 2010). Even in Nigeria Cassava production ranks first among other crops produced in the country. For example, in 2002, 45million tons of cassava produced was followed by 27million tons of yam, 7million tons of sorghum, 6million tons of millet and 5million tons of rice, (Agwu, Nwachukwu, and Anyanwu (2012).

The root of cassava is a stable food for many people since the late 19th century and equally 20th century. In Nigeria, for example, 80% of the people eat cassava meal at least once a day while some large households take cassava meal daily throughout the year (Nweke, Spencer, and Lyam 2002 and Njoku and Muoneke 2008). Indeed, cassava plays a major role in the country's food security hence it is regarded as a crop with a high poverty reduction potential for Nigeria most especially as the cost of production is low (Nweke, 2004, FAO 2005). Moreover, cassava has major advantages over other carbohydrate/starch crops because of the variety of uses to which it can be put. It is available all the year round, making it preferable to other more seasonal crops such as grains, peas and beans and other crops of food security (Akoroda and Teri 2004). Each component of the crop is valuable as the leaves maybe consumed as a vegetable, or cooked as soup ingredient or dried and feed to livestock as a protein feed supplement. The stem is used for plant propagation and grafting, while the roots can be eaten directly either raw or boiled and can be processed into several products which can easily and safely be consumed or stored for human and industrial consumption (IITA, 2005). In addition to being a feed source, cassava is also used in the production of yeast, alcohol and starch for various industrial purposes in the textile, plywood, paper and pharmaceutical industries (Akinpelu, Amamgbo, Olojede, and Oyekale, 2011). As a cash crop, cassava generates cash income for the largest number of households in comparison with other staples. Planting depth of cassava is between 5 and 20cm (IITA, 2014). It roots or tubers sometimes radiate from the stem just below the surface of the ground through the feeder roots penetrate the soil to a depth of 50 to 100cm (FAO, 1977), cassava yield and productivity are influenced, among other factors, by climate. Environmental factors such as soil temperature, moisture and nutrients affect root respiration (Sahney, Benton and Falcon-Lang, 2010). From the time of planting cassava stems to the stage of tuberization, pertinent climatic parameters have one role or the other to play in the crops growth. Cassava grows best when the soil temperature is about 30_ and stops growing when it is below 10 (IFAD/FAO, 2001).

Despite the fact that cassava is a cheap carbohydrate source capable of supplying adequate calories to human and livestock, it is poor nutritionally in terms of micronutrients, protein, vitamin and lacks the sulphur containing amino-acids such as methoionine, lysine and cysteine rendering the crop inferior to wheat and maize (Nagib, *et al.,*2010). It is on account of this and in the bid to add value to cassava as a major food crop that a variety known as pro-vitamin A cassava was introduce. The pro-vitamins A cassava variety is yellow in colour and naturally rich in pro vitamin A. Its variety with B-carotene concentration through natural plant-breeding techniques was introduce into Africa by international institute of tropical Agriculture (IITA) in collaboration with National Root Crop Research Institute Umudike (NRCRI) in Nigeria.

Though cassava is a hardy crop which grows with as little as 500mm annual rainfall and can survive dry periods of 5-6 months (Aina, Dixon and Akinrinde, 2007), yet successful cultivation depends on climate which varies in time and space. This is because climate forms the major part of the physical environment in which agriculture thrives as it determines what choice of crop to be cultivate, when and how to cultivate it and yield of crop. Climate affects the various aspects of plant growth and yield. The effect of climatic elements and their extremes include the significant alteration of crop production. This is because crop yield is the product of both growth and development. Rainfall, Temperature, soil temperature, Relative humidity, and Sunshine hours provide major constraint on primary productivity, which in turn determines secondary productivity. For instance, cassava growth failure can result if rain does not fall at all under rain-fed agriculture, or if it does not fall at the right time, or if it falls little. Having noted that Nigeria is the highest producer of cassava, it shows different growth behavior and yield in different years as a result of differences in the annual weather conditions (Eke-Okoro *et al.,* 1999). This study therefore examined the extent to which climate influence the yield performance of pro vitamin A cassava in three contrasting Agro-climatic belts of Nigeria.

Study Area

Nigeria is located between latitudes 4^0N and 14^0N and longitudes 3^0E and 15^0E and bounded in the north by Niger Republic, northeast by Chad, east by Republic of Cameroun, west by Benin

Republic, and south by the Atlantic Ocean (Figure 1). It has a total landmass of approximately 925,768km^2 (African Development Bank, 2010, FGN, 1999). The climate of Nigeria is characterized by high temperatures and with two marked seasons - dry and wet. The regions under any of the seasons are determined by the location of the Inter-Tropical Discontinuity (ITD). Nigeria's climate is humid in the south with annual rainfall over 2000mm and semi-arid in the north with annual rainfall less than 600mm (Ojo, 1977). Rainfall commences in approximately March/April in the southern coastal zones, spreads through the middle zone in May/June, and reaches the northern zone in June/July, reaching its peak over middle and northern zones between July and September. The rainfall retreat period follows a reverse of this progression (Ojo, 1977). The temperature distribution varies spatially and temporarily across the nation and is characterized by high temperature throughout the year, usually over 18°C. The temperature range increases from the southern fringes to the northern fringe (Ojo, 1977).

Due to the fairly uniform temperature across the country, rainfall amount and intensity basically define the climate and vegetation zones of the Nigeria, and hence the agro-climatic zones namely Swamp forest, Tropical rain Forest, Guinea savanna, Sudan savanna, and Sahel savanna (NIMET, 2012). The distribution of vegetation in Nigeria closely follows that of rainfall. The reason for this is quite apparent going from the fact that the main defining factor of climate in the country is rainfall (moisture availability). This is because temperature is generally high all over the country. The two major vegetation belts across the nation are; the Forest and the Savannah belts. A third type is the one peculiar to the mountainous areas known as the montane vegetation.

In 2006, Nigeria had a population of 140.004 million people (NPC, 2007). The agricultural practices of the tropics especially in the developing countries are still rain-fed. Dates of the onset of the rainy season determine the beginning of farm operation while the cessation of the rainy season signifies harvesting period for most crops.

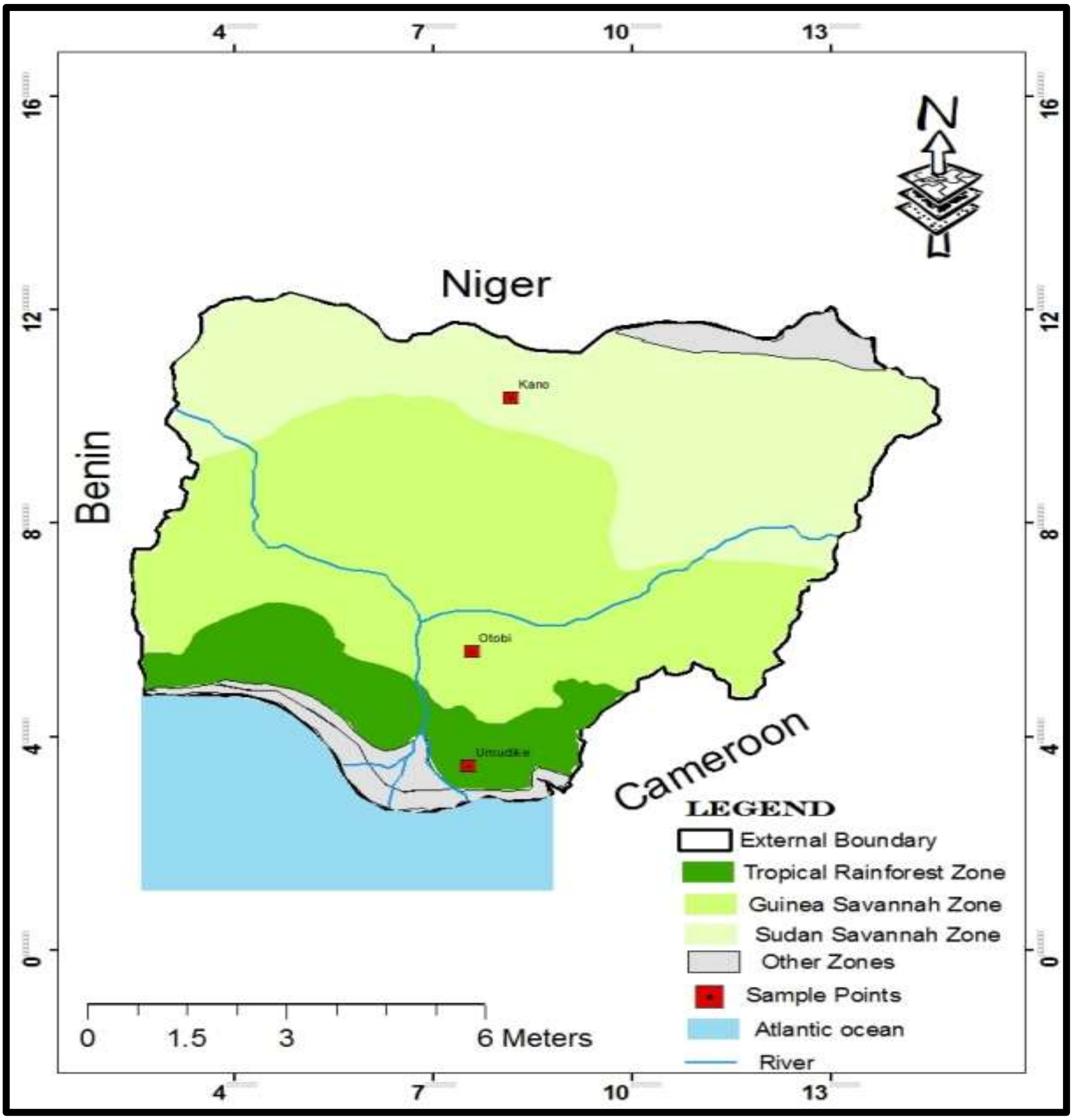

Figure 1: Map of Nigeria showing the three agro-climatic zones and the sample points

Materials and Methods

The data used in this work are basically secondary data. The authors were involved, where necessary, in homogenizing of the records as a quality control. The daily maximum and minimum temperatures covering 33 years for each of the agro-climatic belts used of this study namely the Tropical Rainforest, the Guinea Savanna and Sudan Savanna, were collected and transformed for this study. The daily maximum and minimum temperature data were transformed to mean monthly temperatures and furthermore to annual means. As for rainfall data, monthly totals were transformed to mean annual total and so with the other parameters. The data on tonnage of pro vitamin A cassava yield tons per hectare from the experimental farms of national root crops research institute, Umudike in the three contrasting agro-climatic belts under study were obtained from National Root Crops Research Institute, Umudike documentaries. The climatic data covers a period of 33years from (1983 to 2015) whereas yield data covers the period of four (5) years (2011-2015). In case of missing values (i.e. a year without and /or incomplete data) linear regression quantitative technique was used to determine the unknown values from the known values

(Hammond and McCullagh, 1978). The data are from the three locations under study and their location characteristics are presented in table 1.

Table 1: The location characteristics of the three belts used

S/NO	AGRO CLIMATE BELT	LAT.(ON)	LONG.(OE)	ALTITUDE (M)	DATA RECORD
1	Umuahia	05^0 29'N	7^{0}33'E	205m	1983-2015
2	Otobi	07^{0}10'N	08^{0}39'E	105.1m	1983-2015
3	Kano	11^{0}30'N	8^{0}30'E	488m	1983-2015

Source: Nigerian Department of Meteorological Services. Oshodi, Lagos (1996).

The statistical techniques chosen for this study were mainly for the analysis of the climate data to help discover patterns in them. In the preliminary treatment of the data, the authors were involved in the basic statistical techniques like the computation of the sums and mean for each of the agro-climatic belt under study. Techniques used for the data analyses include descriptive statistics, correlation, regression, mean and ANOVA.

Results and Discussion

In table 2, 2012 recorded the highest yield of 53 metric tons per hectare for Umuahia followed by 2011 with 51 metric tons, 2013 with yield of 48metric tons/h and 2015 recorded yield of 41metric tons/h, while 2014 with the yield of 38 metric tons recorded the lowest. In Otobi four of the years, that is 2011, 2012, 2013, and 2015 recorded high yield ranging from 51metric tons/h, to 53 metric tons/h in 2011 and 2013 whereas the year 2014 recorded a yield of 39 metric tons/h which was the lowest for the station. On the other hand, Kano station with yields as low as 20, 23, and 25 tons/h where recorded in the years 2014, 2012, and 2015 respectively, whereas the highest yield for 33 and 29 metric tons/h occurred in 2011 and 2013 respectively.

Comparatively, Otobi station recorded the highest in all the years and among all the stations under study. However, it was only in the years 2011 and 2012 that the yields in Umuahia matched that of Otobi in the years under study. Kano yield performance for the five years of is lower when compared with those of Otobi and Umuahia.

Table 2: Yield performance of Pro-vitamin A cassava (in tons per hectare) in the three belts for five years, from 2011 to 2015

		Tons Per Hectare Per Year				
S/N	**Belt**	2011	2012	2013	2014	2015
1	Umuahia (Tropical Rainforest)	51	53	48	38	41
2	Otobi (Guinea Savnna)	53	51	53	39	52
3	Kano (Sudan Savanna)	33	23	29	20	25

Table 3 shows the relationship between climatic parameters used in this study and Pro-vitamin A cassava yield. Yield (dependent) was regressed against seven climatic variables (independent variables) of maximum temperature, minimum temperature, mean temperature, rainfall total, sunshine Hours, Relative humidity and soil temperature using the multiple linear regression models.

The findings showed that significant variations exist in the yield performance of pro vitamin A cassava across the three belts. Otobi yield performance appears highest when compared with that of Umuahia and Otobi. Though each of the belts registered significant fluctuations within the study period, Otobi has a consistent high yield all through the five years except for 2014 when the yield dropped but not as low as any of the yield registered in Kano. Umuahia had high yield in 2011 and 2012 before the yield dropped whereas Kano yield performance throughout the five years is low and still fluctuated.

The fluctuations of the yield performance may not be unconnected with the variations of the climatic parameters since climate is the most important factor that influences agricultural production (Efe, 2009). Each of these belts is in different agro-climatic belts and each agro-climatic belt possesses different characteristics, it then shows that climatic variability among others affect yield performance considerably, hence the observed fluctuations of the yield of pro vitamin A cassava across the three belts. Finding is consistent with the works of Eke-Okoro *et al.* (1999). They confirmed that cassava shows different growth and yield behavior in different years as a result of differences in the annual weather conditions. Also Hansen and Jones (2000); Hu and Buyanousky (2003); Kumar *et al.* (2004) where it was observed that crop yield varies from one season to another owing to variations to climate during the growing season.

Table 3: Regression Estimate of the effect of climatic parameters on the yield of Pro-vitamin A cassava in the three belts.

Variable	Coefficient	Std Error	T value	P value
Constant	458.741	217.269	2.11*	0.0792
Max temp	-82.084	73.235	-1.12	0.3052
Min temp	-50.534	67.036	-0.89	0.4087
Mean temp	121.878	136.695	0.92	0.3938
Rainfall	-0.022	0.0059	-3.81	0.0089**
Sunshine Hrs	-4.7885	4.1769	-1.15	0.2953
Relative Humidity	-0.0166	0.2976	-0.06	0.9573
Soil temp	10.3724	4.7133	2.20	0.0700*
R^2	0.9097			
R^2 Adjusted	0.8043			
F value	8.63**			

Source: computed from STATA 2005

*and ** is significant at 10% and 5% level respectively

At 95% level of significant, the test statistics for the combined effect of the independent variables on crop yield is $R^2 = 0.9097$. The coefficient of determination therefore is 90.97% ($R^2 \times 100\%$). This in essence means that any unit change in the yield of the crop is accounted for by 90.9 increases in the climatic variables identified. The other 9.1% will be explained by other variables that were not captured in the model as stochastic variables.

Accordingly, rainfall totals and soil temperature show the most significant relationship with crop yield at specified level of significance (5% and 10% respectively). This is clear with 0.0089 for rainfall total and 0.0700 for soil temperature, whereas sunshine hours, temperature and relative humidity have no significant relationship with crop yield with values of 0.2953, 0.3052, o.4067, 0.3958 and 0.9573 respectively (see table 3).

Since Rainfall total and soil temperature are playing critical role in affecting the yield of Pro vitamin A cassava across the agro climatic belts under study than the other climatic parameters and these climatic parameters vary from belt to belt the yield of crop should equally be affected.

Result of the present work shows that rainfall and soil temperature have influenced the yield performance of Pro vitamin A cassava significantly within the years studied. This means that increase in rainfall could lead to decrease in yield because excessive rainfall leads to water logging. This was proved in the work of IPCC 2000 and Ogbuene (2010) who maintained that excessive rainfall results to flooding. While increase in soil temperature could increase yield of Pro vitamin A cassava conversely decrease in soil temperature could as well bring about decrease in Pro vitamin A cassava for germination. Odjugo 2008 and Ujuanbi (2002), observed that soil temperature is a predictor variable, which determines cassava emergence, growth and yield. The result in table 4 shows the regressive table of effect of climatic parameters on yield. The R^2 value 0.9097 indicates that 90.97% variability in yield is explained by the climatic parameters.

Yield (dependent) was regressed against seven climatic variables (independent variables) of maximum temperature, minimum temperature, mean temperature, rainfall total, sunshine Hours, Relative humidity and soil temperature using the multiple linear regression models. At 95% level of significant, the test statistics for the combined effect of the independent variables on crop yield is r = 0.8043. R^2 value on the other gave value of 90.97%. This in essence means that any unit change in the yield of the crop is accounted for by 90.7 increase in the climatic variables identified the other 9.3% will be explained by other variable than climate such as soil and agronomic practices that were not captured in the model as stochastic variables.

However, for the purpose of specific, rainfall totals and soil temperature show the most significant relationship with crop yield at specified level of significance. This is clear with 0.0089 for rainfall total and 0.0700 for soil temperature, whereas sunshine hours, temperature and relative humidity have no statistic significant relationship with crop yield with values of 0.2953, 0.3052, o.4067, 0.3958 and 0.9573 respectively (see table 4). This implies that rainfall is very important variable which pro vitamin A cassava cannot do without except water is specially supplemented with irrigation. Similarly, soil temperature is also statistically significant which could also be as a result of moderating effect of rainfall.

Accordingly, Rainfall total and soil temperature are playing critical role in yield performance of Pro vitamin A cassava across the agro climatic belts than the other climatic parameters. As these climatic parameters vary from belt to belt the yield of the crop is equally affected. This agrees with the finding of Lobell, *et al*. (2013). They maintained that the productivity of wheat and other crop species fall markedly at high temperatures.

Result of the present work shows that rainfall and soil temperature has influence on the yield performance of Pro vitamin A cassava significantly. Increased rainfall without flooding may be beneficial in very dry areas and allow limited crop growth. Conversely Increase in rainfall could cause decrease in yield because excessive rainfall leads to flooding. This was proved in the work of IPCC (2000) and Ogbuene (2010) who maintained that excessive rainfall results to flooding and eroding of farm land and waterlogged soils cause plant roots to rot and heavy rainfall damages tender young plants. In a related study, Rosenzweig, Tubiello, Mills and Bloomfield (2002) opined that recent flooding and precipitation events in USA and worldwide have caused great damage to crop production. Their study emphasized that if the frequency of these weather extremes were to increase in the near future, the cost of crop losses in the coming decades could rise dramatically.

Increase in soil temperature will increase yield of Pro vitamin A cassava but decrease in soil temperature could bring about decrease in Pro vitamin A cassava for germination, Odjugo 2008 and Ujuanbi (2002) However, soil conditions after planting are also critical. Odjugo (2008) and Ujuanbi (2002), working in Nigeria, found that soil temperature was a predictor variable, which determines cassava emergence, growth and yield.

Table 4: Average yield performance of Pro-vitamin A cassava in the three agro-climatic belts

Location	Mean
Umuahia	46.200
Otobi	49.400
Kano	26.000
LSD	3.306
F	22.15**

Source: computed from SAS 2003
** = significant at 0.003
Mean with the same letter are not significant different

The result shows the average yield performance of Pro-Vitamin A cassava. The yield performance of Umuahia and Otobi is relatively the same but statistically different from the yield in Kano. As shown in table 3, the years 2011 and 2012, Umuahia and Otobi had the highest yield of 51 and 53metric tons respectively whereas the highest yield for Kano was 33metric tons in 2011 and 23 metric tons for 2012.

In 2013 and 2014, the highest yield was from Otobi which was 53m/t, Umuahia had 48m/t while the highest for Kano was 29m/t in 2013. In 2015, Otobi still maintained the highest with 52m/t, Umuahia followed with 41m/t then lastly Kano had 25m/t which is better than 2012 and 2014 years. The statistical simple mean was applied and Otobi recorded the highest with 49.60m/t for the five years studied, Umuahia recorded 46.20m/t whereas 26.00m/t was gotten from Kano yield.

Basically, this has confirmed that there are annual significant variations in the yield of pro vitamin A cassava across the three belts just as we noticed variations in rainfall and soil temperature pattern. This is related to Odofin *et al.* (2003), whose work linked up reduced agricultural productivity and low income to the Nigerian farmers with fluctuations in moisture pattern. The study also relate to the finding of Hoogenboom, (2000), who emphasized that as much as the 80% of the variability of agricultural production is due to the variations in climatic conditions.

Table 5: Average yield performance of Pro-vitamin A cassava in the three agro-climatic belts

Location	Mean	Std Dev	Min	Max
Umuahia	46.20	6.45	38.00	53.00
Otobi	49.40	6.42	38.00	53.00
Kano	26.00	5.00	20.00	33.00

Source: *Computed from STATA 2005*

The result in table 2 above shows the ANOVA procedure for comparison of yield difference in the 3 belts. The F value of 22.15 was highly significant at 1% level indicating the presence of yield difference in the study.

The mean separation was also done to indicate where the yield differences were coming from. The result shows that the yield of Pro-Vitamin A cassava in Umuahia and Otobi were the same but statistically significant different from the yield in Kano.

Conclusion

This study provides valuable insight on the yield performance of pro vitamin A cassava in the three contrasting agro-climatic belts of Nigeria. Results from this study revealed that Pro-vitamin A cassava shows different yield behavior in different years as a result of differences in the annual climatic conditions (Eke-Okoro *et al.,* 1999). Otobi in Guinea Savanna agro-climatic belt performed highest followed by Umuahia in Tropical rainforest. The least is Kano in Sudan savanna. The study also revealed that climatic parameters play a central role in the yield of pro vitamin A cassava as yield followed closely with the variations and trends of the climatic parameters examined. Out of the seven major climatic parameters examined, rainfall and soil temperature had greater effect on yield performance of Pro-vitamin A cassava more than the other parameters.

Recommendations

Based on the conclusion of this study, it is recommended that the use of irrigation to grow Pro-vitamin A cassava profitably where rainfall is inadequate should be encouraged especially in the face of dare need to improve the in-take of vitamin A in Nigeria. With irrigation, most areas in the country will be able to cultivate the crop more than once in a year which will add to no small measure to the well-being of the citizens.

Since variability in climate parameters affects Pro-vitamin cassava, the construction of new, more intensive, functional and well-manned weather stations in all local government areas of the federation is recommended. And by extension Nigerian Meteorological Agency and Federal Bureau of statistic should develop a framework that will make climatic data and crop yield data available to researchers

References

Agwu N. M, Nwachukwu I. N, and Anyanwu C. I. (2012). Climate variability: relative effect on Nigeria's cassava productive capacity report and opinion 4(12).

Akinpelu, A. O., Amamgbo, L. E. F., Olojede, A. O. and Oyekale, A. S. (2011). Health implications of cassava production and consumption. Journal od Agriculture and Social Research (JASR). Vol. 11, No.1, 2011.

Akoroda, M.O. and Teri J.M. (2004); Food Security and Diversification in SADC Countries. Approach "A case study of Western Nigeria Cassava. Farmers" *Indian Journal of Agricultural Economics* 27 (2) 56-66.

Aina, O. O, Dixon, A.G.O and Akinrinde, E. A (2007). Effect of soil moisture stress on growth and yield of cassava in Nigeria. *Pakistan Journal of Biological Sciences,* 10:3085-3090

Efe, S. I. (2009). Climate change and food security in Africa: Delta state, Nigeria Experience. In Anyadike,, R.N.C, Madu, I.A., and Ajero, C. K. (2010). Conference proceedings on climate change and the Nigerian Environment held at UNN.

Eke-Okoro ON, Okereke OU, Okeke JE (1999). Effects of weather change and planting sett on growth and productivity of cassava in South-eastern Nigeria. Afr. J. Root Tuber Crops 3 (2): 34-38.

Federal Government of Nigeria (FGN) (1999) "Federal Republic of Nigeria Official Gazette". No 24 Vol.94.

Food and Agriculture Organization (FAO), 1977. Report on the Agro-ecological Zones project Vol.1 Methodology and Results for Africa. World Soil Resources Report no 48. 158pp.

Food and Agriculture Organisation (2005). *Climate Variability and Change: A Challenge for Sustainable*ₜ *Agricultural Production.*Committee on Agriculture.

FAO, (2014). *Save and Grow, Cassava: A Guide to Sustainable Production Intensification.* Rome: Food and Agriculture Organization of the United Nations

Hammond, R. and McCullagh, P. (1978). Quantitative techniques in Geography: An introduction. John wiley, London.

Hansen, J. W. & Jones, J. W. (2000). Scaling-up crop models for climatic variability applications. *Agricultural Systems* 65: 43 – 72.

Hoogenboom, G., (2000). Contribution of agrometeorology to the simulation of crop production and its applications. *Agricultural and Forest Meteorology* 103(1-2), 137-157.

Hu, Q. & Buyanovsky, G., (2003).Climate Effects on Corn Yield in Missouri. *Journal of Applied Meteorology* 42: 1626 - 1635.

IFAD and FAO. 2005. A Review of Cassava in Africa with Country Case Studies on Nigeria, Ghana, the United Republic of Tanzania, Uganda and Benin.

Intergovermental Panel on Climate Change (IPCC). (2001). Climate change 2001: impacts, adaptation, and vulnerability Cambridge, United Kingdom: Cambridge University.

Kumar, K.K., Kumar, K.R., Ashrit, R.G., Deshpande, N.R. & Hansen, J.W., 2004.Climate impacts on Indian agriculture. *International Journal of Climatology* 24: 1375-1393.

Lobell, D.B. and Burke, M.B., 2008. Why are agricultural impacts of climate change so uncertain? The importance of temperature relative to precipitation. Environ- mental Research Letters 3 (3), 034007.

Lobell, D. B., U. L. C. Baldos and T. W. Hertel, (2013): Climate adaptation as mitigation: the case of agricultural investments. Environmental Research Letters, 8. doi10.1088/1748-9326/8/1/015012.

.

Nagib, N. and Rodomiro O. (2010). Breeding cassava to feed the poor. www.scientificAmerican.com

National Population Commission. (2007). Census Figures: Nigeria Population Figure. National Population Commission, Abuja.

NAERLS (National Agricultural Extension and Research Liaison Services) (2010).Agricultural Performance Survey of 2010 Wet Season in Nigeria. Zaria, Nigeria, 182 pp.

Nweke, F.I., Spencer, D.S.C. and Lyam, J.K. (2002). The Cassava Transformation, Africa's best-kept secret. Michigan State University Press.

Nweke, F. (2004). *New challenges in the cassava transformation in Nigeria and Ghana*. EPTD discussion paper No.118. Washington, DC, IFPRI.

Odofin, J.J. et al, (2003). Socio-economic Implication of Change on Agriculture Production, A paper presented at the NMS regional conference on climate change and food sustainability in the 21st century held at Oshodi Lagos

Ogbuene, E. B. (2010). The Role of Tourism Potentials in the Development of Environmental Resources in Ugbo Towm, Awgu of Enugu State Nigeria ed. Journal of Geography and Development, Benue State University, Makurdi IITA research No.14/15NPC, 1996. National Population Census, pp: 21.

Ojeniyi, S.O., (1986). Effect of zero tillage and disc ploughing on soil water, soil temperature and growth and yield of maize (*Zea mays* L.). Soil and Tillage Research, 7: 173-182.

Ojo O (1977) The climates of West Africa. London, Ibadan, Nairobi, Lusaka: Heinemann

.

Rosenzweig, C. Tubiello, F. N., Goldberg, R. Mills, E. J. Bloomfield, J. (2002). Increased crop damage in the US from excess precipitation under climate change. Global Environ. Change, pp. 197–202

Sahney, S., Benton, M. J. and Falcon-lang, H. J. (2010): "Rainfall collapse triggered Pennsylvania tetra pod diversification in Euramerica". *Geology*, vol. 38, no. 12, pp. 1079 – 1082.

Ujuanbi, H.U. (2002). A comparative analysis in the growth and yield of cassava between zero and ridge tillage in Western Nigeria. *J. Environ.Knowledge*, 12(2): 20-28.

Effect of Temperature on Carbon Dioxide Production by Soil Microbial Respiration in Irrigated Soil in Jaba area, Kano State, Nigeria

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Abstract

The planet's soil releases about 60 billion tons of carbon into the atmosphere each year, which is far more than that released by burning fossil fuels. This enormous release of carbon is balanced by carbon coming into the soil system from falling leaves and other plant matter. The study aimed at evaluating the effect of soil temperature on carbon dioxide (CO_2) production through soil respiration. Ten samples were collected in dry and wet season from 0 – 25 cm depth using composite sampling method. The results shows that soil pH (7.65 ±0.57), organic carbon (1.82±0.21) and soil respiration (5.67±0.87) were found to be higher in wet season where the temperature is high (26^{0}C). However Cd (4.37±0.6), Cr (64.8±10.12) and Pb (43.61±3.77) were found to be higher in dry season where the pH and temperature is low. The results also revealed that soil pH and temperature have significant effect on rate of CO_2 production from soil by soil microbial activities because CO_2 production is higher in the wet season where pH and temperature is high. Soil temperature and pH significantly affect the soil respiration in the area and also increase of organic matter and avoid use of contaminated water for irrigation were recommended.

Key words: soil, microbes, respiration and temperature

INTRODUCTION

One of the major uncertainties in climate change prediction is the response of soil respiration to increased atmospheric temperature. Several studies show that increased soil temperature accelerates rate of microbial decomposition, thereby increasing carbon dioxide (CO_2) emitted by soil respiration and producing positive feedback to global warming (Allison *et al.*, 2010). The soil is the largest terrestrial carbon (C) pool, therefore stored soil C results from an imbalance between organic matter produced by plants and its decomposition back into the atmosphere as CO_2. The large pool of C in the soil is vulnerable to climatic warming and its potential loss may amplify further warming (Cox et al., 2000). Among the factors affecting soil microbial respiration are temperature, pH and pollutants are perhaps the most relevant. Regarding the temperature sensitivity of decomposition, kinetic theory predicts that temperature sensitivity of soil respiration should increase as the degree of substrate complexity and microbial activities increases. Changes in the belowground carbon pools can have a major impact on carbon storage in terrestrial ecosystems and change carbon flux to the atmosphere. CO_2 efflux from the litter surface originating as plant and microbial respiration reflects this large belowground activity. This study aimed as assessing the effect of soil temperature on soil respiration, while the objectives were to evaluate the CO_2 production through soil respiration and some chemical properties of soil and also determine the effect of temperature on the respiration activity in soil of the area.

MATERIALS AND METHODS

Study area

The study was carried out along the irrigated land of Jaba village located between latitude 12^0 10ˈ N to 12^o 21ˈN and longitude 8^o 46ˈE to 8^o 53ˈE and the area is situated in Ungogo local government area Kano state of Nigeria. The farmers in the area normally used water from River Getsi and Jakara, the crops grown in the area include cabbage, lettuce, onion, carrot, cucumber and tomatoes.

Materials and Method

The materials used in this study include soil auger for sampling the soil, global navigation system (GNS), pH meter for measuring soil pH. The study location was selected randomly whereby 10 samples were collected form 0 – 25cm using grid soil survey method. The samples collected were placed into polythene bags labelled appropriate, air dried, homogenized, sieve and then taken to the laboratory for further analyses. Soil pH was determine electrometrically by soil water ratio (1: 2.5) in KCl_2, organic carbon was determined as described by Walkley and Black (1934), heavy metals (Cd, Cr and Pb) were determined with Atomic Absorption Spectrophotometer (AAS) using wet digestion method described by Anderson (1974) and soil respiration was determined using incubation methods described by Khan and Joergensen 2006).

Results and discussion

The mean values of some selected physicochemical properties of soil Table 1(Appendix 1) shows that Cr, Cd, and Pb were found to be higher in dry season than that of wet season which is probably attributed to the effect of rainfall which facilitate the dilution of soil minerals, redox reaction, leaching and run off which are capable of removing heavy metals from subsurface soil. This is agreed by Delbari and Kulkarni (2011) who explained in their findings that high concentration of heavy metals in wet season is due to redox reaction, runoff and leaching which are facilitated by rainfall. This is contended by Lal (2006) who explained that seasonal variation of heavy metals in the soil influenced by runoff and leaching of dissolved heavy metals which is facilitated by rainfall

Table 1: Mean values of physicochemical properties of soil

	Physicochemical properties of soil						
Season	CO2 (µg NH4-N g-1)	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	pH (KCl_2)	Oc (%)	Temp (oC)
Dry	4.35	64.81	12.2	43.61	7.65	1.02	21.71
Wet	4.6	17.89	4.37	32.04	7.94	1.182	25.55

Source: Field work, 2015

The soil pH, organic carbon and soil temperature were found to be higher in wet season (table 1) which implies that Hydrogen (H^+) and Hydroxyl (OH^-) ions were freely released from the bound form thereby exchange complex of the soil in wet season is highly dominated by exchangeable cation and other base forming cation. This is explained By Brady and Weil (1999) who explained that at high pH Aluminium and Hydroxyl ions have been replaced by H^+ more in to the soil solution. The CO_2 production through soil respiration was found to be higher in wet season than dry season. High CO_2 production through soil respiration in wet season is probably attributed to the favorable condition for microbial population and activities due to rainfall, temperature and rapid mineralization rate in wet season (Mondell *et al.*, 2015). This indicates that soil respiration respond more to seasonal change and consequently can be used as an early and sensitive indicators of soil quality changes.

The correlation analyses shows that Cr (r = 0.55), Cd (r = 0.24) and Pb (r = 0.05) were positively correlated with soil respiration, this indicates that changes in soil respiration in the area is not significantly associated with Cr, Cd and Pb. The results is in line with the findings obtained by Smejkalova *et al* (2005) who reported positive correlation between soil respiration and some heavy metals. This is probably due to the high pH and temperature in the area which influence the soil microbes to resist the toxicity effect of heavy metals. The analyses also shows that Organic carbon (r = 0.81) and PH (r = 0.37) were positively correlated with soil respiration.

EFFECT OF TEMPERATURE ON SOIL RESPIRATION

Table 1 show that the mean values of CO_2 production through soil respiration was found to be higher in wet season where the temperature and pH were found to be higher and the heavy metals were found to be low, this indicates that CO_2 production through soil respiration is affected by temperature, pH and some heavy metals because respiration activities are characterized by the process of mineralization of organic matter in soil and other metabolic process in which CO_2 is released (Tobor-Kaplon *et al.,* 2005). High CO_2 production in wet season is probably attributed to the high temperature, pH and low heavy metals in the season this is because high temperature increases the rate of microbial activities and pH influence the availability, solubility and toxicity of heavy metals in the soil. This contented by Lenart-Boron and Piotr (2014) who reported that soil respiration increases with increase in temperature and pH.

CONCLUSION AND RECOMMENDATION

From the findings it was concluded that soil pH and temperature affect the microbial diversity and activities which influence the soil respiration in the area and also soil pollution management can mitigate the rate of carbon dioxide production from soil ecosystem. It was recommended that leaving crops biomass in soil, reduction of soil pollution through treating the waste before discharge will enhance the microbial activities which store more carbon in soil without release to the atmosphere.

REFERENCES

Alef, R. and Nannipieri, P. (1995). *Methods in Applied Soil Microbiology and Biochemistry.* London Academic Press Ltd, London. 350 – 351.

Allison SD (2005) Cheaters, diffusion and nutrients constrain decomposition by microbial enzymes in spatially structured environments. *Ecology Letters,* 8, 626–635.

Anderson, J. (1974). *Wet* Digestion *Versus Dry for the Analysis of Fish Tissue for Trace* metals; Afon Absorbtion Newsletter.

Brady, N. C. and Weil, R. R. (1999). *Nature and Properties of Soils;* Fourteenth Edition, Pearson Education Inc; Upper Saddle River New Jersey

Cox P.M., Betts R.A., Jones C.D., Spall S.A. and Totterdell I.J. 2000. Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. *Nature* 408: 184–187.

Delbari, S. A and Kulkarni, D. K. (2011). Seasonal Variation in Heavy Metals Concentration Agricultural Soils In Teheran, Iran. *Bioscience Discovery.* 2 (3): 333.

Khan, K. S. and Joergenesen, R. G. (2006). Decomposition of heavy metal contaminated Nettles (Urtica dioica L.) in soils subjected to heavy metal pollution by River sediments. *Chemosphere*. (65): 981-987.

Lal, R. (2006). *Encyclopedia of Soil Science (2nd Edition)*. The Ohio State University Colombus, Ohio, U.S.A. Newyork London. (1 and 2): 817 – 1813.Tailor and Francis group.

Lenart-Boron, A. and Piotr, B. (2014). The effect of industrial Heavy metals pollution on Microbial Abundance and Diversity in soil. *Open Sciencei: 760-783.* In Maria, C. and Sloriano, H (Eds) *Environmental Risk Assessment of Soils Contaminats.* In Tech Publishers.

Mondal, N. K., Pal, K.C., Dey, M., Ghosh, S., Das, C. and Datta, J., K. (2015). Seasonal Variation Variation of Soil Enzyes in Areas of Florida Strees in Birbhum District West Bengal, India. *Journal of Taibah University for Science.* (9): 133-142.

Smejkalova, M. Mikanova, O. and Boruvka, L. (2003). Effects of Heavy Metal Concentrations On Biological Activity Of Soil Micro-Organisms. Faculty of Biological Sciences, University of South Bohemia in Ceske Budejovice, Czech Republic: *J. of Research Institute of Crop Production, Prague, Czech Republic*. 49 (7): 321–326

Tobor-Kapłon M.A., Bloem J., Rőmkens P. F. A.M., Ruiter P. C. (2005). *Functional Stability of of Microbial Communities in Contaminated Soils. Oikos*, 119–129.

Walkley, A. and Black, C.A. (1934). An Examination of the Djetgareff Method for Determining Organic Matter and Proposed Modification of the Chromic Acid Titration Method. *Soil Sci*. (37): 29–38.

Appendix 1: Soil Respiration and some Physicochemical Properties of Soil

Dry season	Soil respiration	physicochemical properties of soil					
Sample ID	CO_2	Cr (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	pH (Kcl2)	OC (%)	Temp (oC)
SP1	3.407	74.07	9.56	46.67	7.2	0.07	22.5
SP2	4.3725	55.04	10.34	40.45	8.2	0.21	22
SP3	5.2725	67.05	10.2	43.62	7.6	0.76	22
SP4	3.37	72.11	10.02	37.34	8.2	1.3	22.1
SP5	5.605	81.65	13.21	42.71	7.6	1.03	22.3
SP6	3.675	58.52	16.28	50.45	7.4	1.1	22
SP7	4.795	73.34	10.09	40.53	8	1.56	21.4
SP8	4.49	56.56	12.03	43.65	7.18	0.92	23
SP9	4.185	51.53	20.31	47.18	8.15	2.06	20
SP10	4.39	58.23	10.04	43.54	7	1.23	19.87
Mean	4.3562	64.81	12.208	43.614	7.653	1.024	21.717
Wet Season							
SP1	3.6375	26.12	5.01	38.67	7.8	1.25	25.5
SP2	4.849	30.32	3.34	25.45	7.3	1.25	24.8
SP3	5.31	23.1	4.94	29.87	9.1	1.12	24.6
SP4	4.795	23.1	4.28	34.53	8	1.23	25.6
SP5	3.68	12.67	4.82	30.71	8.4	1.01	26
SP6	4.47	13.61	4.78	27.76	8.3	1.35	25
SP7	5.17	10.2	3.64	31.43	7.5	1.02	26
SP8	4.655	12.25	4.63	34.53	8.2	0.87	25
SP9	4.23	15.26	4.66	33.47	7.3	1.65	26
SP10	5.225	12.35	3.67	34.07	7.5	1.07	27
Mean	4.60215	17.898	4.377	32.049	7.94	1.182	25.55

Source. Field (2015)

CONSERVATION STATUS OF VEGETATION IN THE DRYLAND OF NORTHWESTERN NIGERIA

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ABSTRACT

Vegetation contributes to human and ecosystem existence is overwhelming. It provides food, raw materials and oxygen, as well as in exchange of water, energy, and nutrients. For this importance, the study of functional and structural attributes vegetation is so essential. Through researches it has been established that the present day vegetation is the manifestation of a long evolutionary process during which many species have become extinct and new species have arisen. This study determined the conservation status of fifty plant species which were encountered in nineteen study locations in the dryland of northwestern Nigeria. Quantitative data for the assessment was obtained through quadrat sampling. The sampling was done using 100 x 100m^2 quadrat in the nineteen locations identified on a line drawn diagonally along a north–south transect; which cover the major bioclimatic gradient of the study area. Relative densities of plants are used to categorise the fifty plants into five conservation statuses namely critically endangered, endangered, vulnerable, threatened and stable categories as found in IUCN Red lists version 3.1. Result show that the stable group (6%) consists of *Piliostigma reticulatum* (RD=21.02%), *Guiera senegalensis* (RD=12.40%) and *Azadirachta indica* (RD=10.32%) in order of decreasing relative densities. Vulnerable category (8%) consists of *Fadherbia albida* (RD=9.79%), *Ziziphus mauritania* (RD=8.16%), in decreasing order of relative densities. Threatened group (24%) consist of fourteen species. Notable species are *Balanite aegyptiaca* (RD=4.26%), *Adansonia digitata* (RD=2.47%), *Lannea acida* (RD=2.00%) and *Acacia seyal* (RD=1.60%) in decreasing order of relative density. Endangered group (44%) consist of twenty two species. Notable members are *Vitex doniana* (RD=0.14%), *Anogiessus leocarpus* (RD=0.19%), *Tamarindus indica* (0.38%) in order of decreasing relative density. Critically endangered group (18%) with nine plants comprises of *Albizia chivalieri* (RD=0.01%), *Butyresopermum parkii* (RD=0.09%), *Proposis africana* (RD=0.09%), and *Ficus iteophylla* (RD=0.09%) among others. Findings of this study concluded that a lot of species fall in vulnerable, endangered and threatened categories in the study area. It is therefore recommended that conservation status assessments and monitoring should be conducted regularly using local parameters so as to provide up to date information for the effective management of vegetation in the country and particularly the dryland of northern Nigeria.

Keywords: conservation status, vegetation, dryland, northwestern Nigeria

INTRODUCTION

Vegetation is an important component of the ecosystem that provides habitat for wildlife and maintains the functioning of the ecosystem. Vegetation plays a key role in earth's surface-atmosphere interaction, the alteration of which affects the biogeochemical cycles (Eric, 2003). Vegetation is not only a bond that links soil, climatic, hydrologic and other elements in the whole ecosystem (Sun *et al.*, 1998), but also an indicator of global climate change through carbon cycle (Li *et al.*, 2008).Vegetation forms the basis of our environment by releasing oxygen into the atmosphere and using sunlight, carbon dioxide and minerals to produce food. People and the rest of the living world depend upon this oxygen and food to survive (Briggs and Leigh, 1996). Linking soil, atmosphere, and moisture (Chuai, Huang, Wang, and Bao, 2013), vegetation plays an irreplaceable role in maintaining climate stability, regulating the carbon balance, and reducing global-scale greenhouse gases (Piao and Fang, 2013).Because of the unique importance of vegetation, countries throughout the world are actively trying to conserve the resources through policies and controls. Since Rio Earth Summit in 1992, significant conservation changes which involve the protection of many areas and control of poaching for resources were made in the Nigeria (Federal Government of Nigeria, FGN, 2006; David, 2008).

Despite its importance, vegetation still face intense pressures particularly from loss of genetic diversity and the threat, reduction, exclusion, or extinction of species in all ecosystems. Recent estimates show that 25% of all species could become extinct during the next 20 to 30 years (Singh, 2002). Two thirds of the world's plant species are in danger of extinction with pressure from the growing human population, habitat modification and deforestation, over-exploitation, spread of invasive alien species, pollution and the growing impacts of climate change (Secretariat of the Convention on Biological Diversity, CBD, 2009). In the past four decades, individual populations of many species have undergone declines and many habitats have suffered losses of original cover (Secretariat of the Convention on Biological Diversity, 2010). And these losses particularly of plant species could greatly limit the options of future generations and exacerbate great danger to marginal areas (Edward, 2008). This suggests that the dryland of Nigeria.

In recent years, discussions on priorities for species conservation have intensified. This gave rise to several approaches which are partly dominated by biogeographical information. A number of studies on conservation status of plants have been carried out in Nigeria (e.g Borokini, 2003). However, information on conservation status of Nigeria's plants is very limited although a lot of assessments are ongoing. Part of the challenges to lack of adequate information on status of plants is the neglect by researchers of the epicentre for diversity which is the dryland. This paper determines the conservation status of plants in the dryland of northwestern Nigeria using the International Union of Conservation of Nature (IUCN) categories in criteria version 3.1 (IUCN, 2012) with the hope that these findings may be used to manage the marginal environment and its vegetation resources. This categorisation does not indicate conservation actions are required for all species. Therefore, only plants that fall under threat, vulnerable and extinct categories require necessary and urgent conservation actions from relevant bodies and agencies.

There are inevitable gaps in this study as the focus is not to claim to have covered all of the criteria currently required to represent conservation status. However, by bringing the available information together, it is hoped that findings of this study on plants status will help agencies to decide where research efforts and policy focus is required so as to manage plants for their essential roles to human wellbeing and our planet.

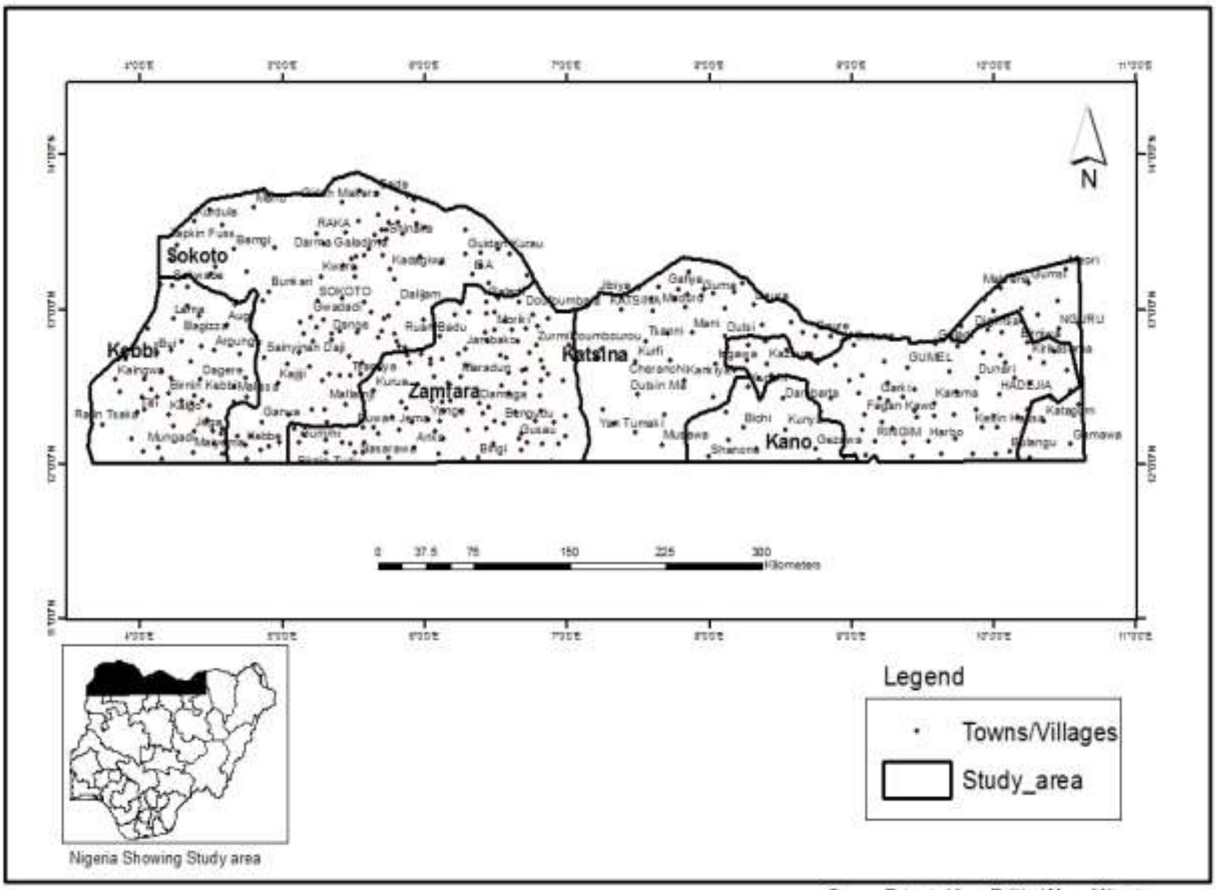
CONSERVATION STATUS

Conservation status of a species is an indicator of the likelihood of plant species continuing to survive either in the present day or the future. Conservation status indicates whether the group still exists and how likely it is to become extinct in the near future. Many factors are taken into account when assessing conservation status: not simply the number of individuals remaining but the overall increase or decrease in the population over time, breeding success rates and known threats.

Extinction occurs when the mortality (and emigration) rate is greater than the birth (and immigration) rate for a sufficiently long time that the population size reaches zero. When used in the context of the IUCN Red List, a taxon is classified as vulnerable when facing a high risk of extinction in the wild in the immediate future (IUCN, 2009). Endangerment is the exposure to risk. When it comes to living organisms, and used in the context of 'endangered species', it generally means the risk of the species becoming extinct (Miller, 2013). A species is threatened when it is believed to be in danger of extinction.

STUDY AREA

Northwestern Nigeria is composed of three distinct geographic entities: Sokoto-Rima Basin, the Kano Region and the North Central Highlands (Udo, 1970). Of the Nigeria's total area of 923,768 km^2, northwestern region occupies a total of 226, 662 km^2. The dryland of Nigeria constitute the Sudan and the Sahelian savanna with typical low rainfall and sparse vegetation. Mortimore and Adams (1999) noted that in Nigeria, the drylands are located north of latitude 12^{0}N.



Source: Extracted from Political Map of Nigeria

Figure 1: Dryland of northwestern Nigeria

The study area lies within latitudes 12^{0}N and 14^{0}N and longitude 3^{0}E and 10.35^{0}E. It covers six states namely: Jigawa, Kano, Katsina, Zamfara, Sokoto and Kebbi. This study only covers Jigawa, Katsina, Zamfara and Sokoto.

Climate of northwestern Nigeria is the tropical wet and dry type. It is coded as 'Aw' by Koppen in which distinctive wet and dry seasons are caused by the fluctuations of the ITCZ (Inter-tropical convergence zone) or the ITD south to north to bring rainy season and north to south to bring dry season. The ITCZ separates humid maritime (mT) air mass originating from the Atlantic Ocean and dry desert air mass (cT). The ITCZ follows the apparent movement of the sun, (northwards in April – July and southwards in September – October).

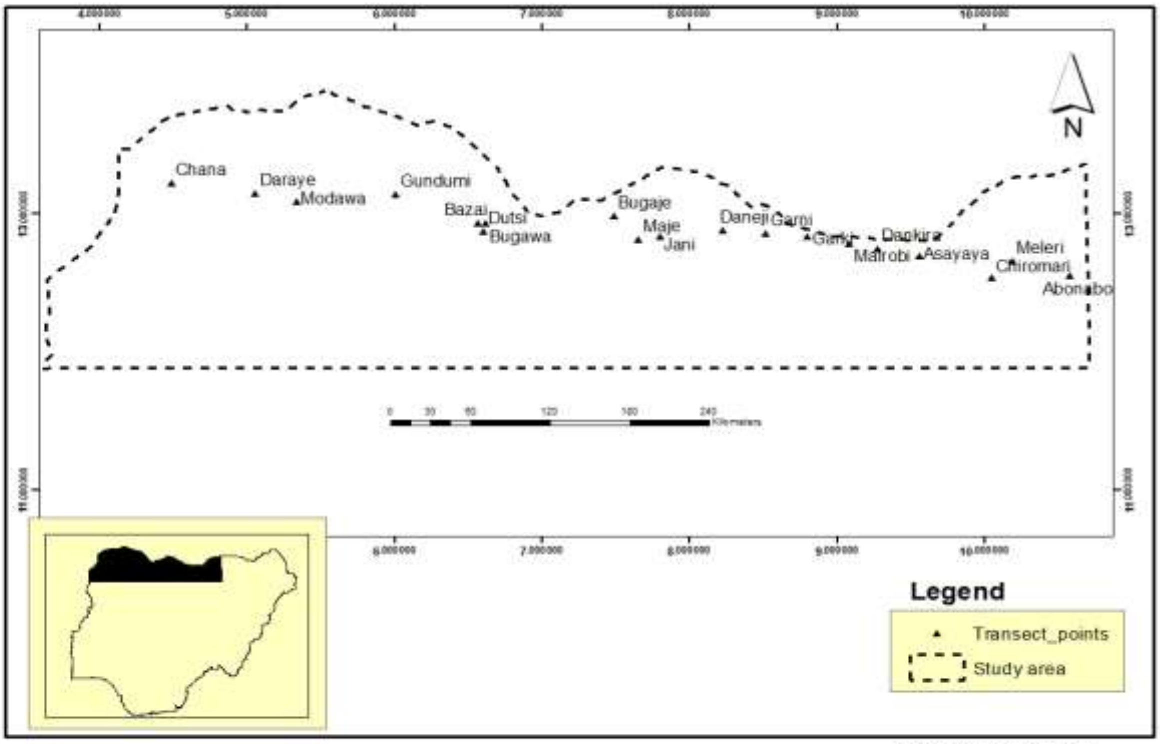
The vegetation type of northern Nigeria is of the West African type which follows the pattern of rainfall distribution. The northwestern Nigeria falls within Sudan Savanna zone of Nigeria, distinguished by large expanse of grasslands with widely spaced trees of varying heights and diversity. The Sudan savanna belt is found dominating the Sokoto Plains across to the Chad Basin, covering over a quarter of the country's land area. It is found in places with rainfall of about 600-1000 mm and 4 – 6 months of dry season. The vegetation is made up of grasses 1-2 m high and often stunted trees. Some of the most frequent trees in this environment are acacia, doum palm, and the baobab. Others include *Parkia biglobosa, Adansonia digitata, Khaya senegalensis, Fadherbia albida, Tamarindus indica*, and *Borassus aethiopum, Proposis africana, Balanite aegyptiaca, Acacia nilotica* and exotic species *Azadirachta indica, Eucalyptus camaldulensis and Cassia simmea*.

RESEARCH METHODS

This section consists of the following units: data types, sampling of study locations, procedures for data collection and data analysis.

Sampling of Study Locations in Northwestern Nigeria

Sampling of study villages was done using belt line transect method so as to capture the villages on either side of the line (Fewster, Laake, and Buckland, 2005). The line transect was plotted on a classified map of the study diagonally from the bottom right corner (latitude 12^{0}N and longitude 10.8^{0}E) to the top left corner (latitude 14^{0}N and longitude 4.5^{0}E) northwards. The locations extend from Chana in the West to Abonabo in the East. The nineteen locations selected for the study are: Abonabo, Chiromari, Meleri, Asayaya, Dankira and Mairobi (Jigawa State), Garki, Garni, Daneji, Jani, Maje, and Bugaje (Katsina State), Bugawa, Dutsi and Bazai (Zamfara), Gundumi, Modawa, Daraye and Chana (Sokoto State) (Figure 2).



Source: Data analysis (2016)

Figure 2: Study Locations in the Dryland of Northwestern Nigeria

Data Sources

Data for the study is sourced from quadrat sampling.

Procedures for Data Collection

Data for the study was obtained from sampling of vegetation in 100 x 100 m^2 quadrat. The choice of this size is based on suggestion that quadrat should be large enough for differences related to vegetation to become apparent (Kindt and Coe, 2005). A total of nineteen quadrats were laid across the dryland of northwestern Nigeria. Sampling involved: quadrat laying, inventorying, identification and recording of species. Samples of unknown were collected on pressers and transported to herbarium of Department of Biological Sciences of Bayero University Kano for identification. Local names of plants were also collected. Sample was conducted in January to March 2016.

Procedures of Data Analysis

Data was analysed in Microsoft Excel for density and relative density to determine the conservation status of vegetation in line with Onyekwelu, Mosandl and Stimm (2007).

$$\text{Density} = \frac{\text{Number of individuals of a species}}{\text{Size of quadrats studied}}$$

$$RD = \frac{\text{Number of individuals of a species}}{\text{Number of all individuals counted}} \times 100$$

Where RD= Relative Density

RESULT AND DISCUSSION

Conservation Status of Plants

Status assessment in conservation has its roots in the late 1890s when researchers began to use population monitoring as a means to determine how populations of different species change overtime (Stem *et al*., 2005). The International Union of Conservation of Nature (IUCN) Red List Categories and Criteria are widely used for its objective and authoritative system for assessing the global risk of extinction for species (Mace and Lande, 1991). The Red List, introduced in 1994, is a list of species which have been evaluated against quantitative criteria to identify the extinction risk of species (Staurt, Wilson, McNeely, Mittermier and Rodriguez, 2010). Currently, the IUCN Red lists categories and criteria version 3.1 are widely used (IUCN, 2012). The aim of conservation status assessments is to provide information and analyses on the status, trends and threats to species in order to inform and catalyse action for biodiversity conservation (Possingham and Andelman, 2002; Mace, Possingham and Leader-Williams, 2007). The criteria have five categories of statuses namely: extinction (EX), critically endangered (CR), endangered (EN), threatened (T) or vulnerable (VU).

According to Onyekalu, Mosandl and Stimm (2007) relative densities of species can be used to categorise plants into conservation statuses. In this study, fifty plants are categorised into critically endangered (CR), endangered (EN), threatened (T) or vulnerable (VU) in line with IUCN categories and stable (S) (Table 3). Extinction was not assessed due to limited data.

Stable category consists of *Piliostigma reticulatum* (RD=21.02%), *Guiera senegalensis* (RD=12.40%) and *Azadirachta indica* (RD=10.32%). Vulnerable category consists of *Fadherbia albida* (RD=9.79%), *Ziziphus mauritania* (RD=8.16%), *Acacia nilotica* (RD=4.40%) and *Balanite aegyptiaca* (RD=4.26).

Table 3: Conservation Status of Vegetation

Botanical Names	Life forms	RD (100%)	Status
Piliostigma reticulatum	Tree	21.02	Stable
Guiera senegalensis	Shrub	12.40	Stable
Azadirachta indica	Tree	10.32	Stable
Fadherbia albida	Tree	9.79	Vulnerable
Ziziphus mauritania	Shrub	8.16	Vulnerable
Acacia nilotica	Tree	4.40	Vulnerable
Balanite aegyptiaca	Tree	4.26	Vulnerable
Adansonia digitata	Tree	2.47	Threatened
Calatropis procera	Shrub	2.19	Threatened
Securinega virosa	Tree	2.10	Threatened

Cassia sieberiana	Tree	2.00	Threatened
Lannea acida	Tree	2.00	Threatened
Acacia seyal	Tree	1.60	Threatened
Annona senegalensis	Shrub	1.49	Threatened
Sesbania dalzielli	Shrub	1.23	Threatened
Sclerocarya birrea	Tree	1.15	Threatened
Combretum micranthum	Shrub	1.08	Threatened
Perguleria tomentosa	Herb	1.08	Threatened
Hyphaene thebaica	Tree	1.02	Threatened
Mitragyna inermis	Tree	0.94	Endangered
Parkia biglobosa	Tree	0.88	Endangered
Dichrostachys cinerea	Tree	0.80	Endangered
Terminalia avicennoioides	Shrub	0.75	Endangered
Alyscicarpus vaginalis	Tree	0.57	Endangered
Acacia macrostachya	Tree	0.57	Endangered
Waltheria indica	Shrub	0.57	Endangered
Ziziphus spina-christi	Tree	0.52	Endangered
Indigofera tictora	Shrub	0.52	Endangered
Diosphyros mespiliformis	Tree	0.42	Endangered
Tamarindus indica	Tree	0.38	Endangered
Rogeria adenophylla	Herb	0.38	Endangered
Commiphora africana	Tree	0.33	Endangered
Ficus thonningii	Tree	0.28	Endangered
Hyphaene thebaica	Tree	0.24	Endangered
Diospyros mespiliformis	Tree	0.24	Endangered
Bauhinia rufescens	Shrub	0.24	Endangered
Anogiessus leocarpus	Tree	0.19	Endangered
Bauhinia rufescens	Tree	0.19	Endangered
Combretum lamprocarpum	Tree	0.19	Endangered
Vitex doniana	Tree	0.14	Endangered
Ficus iteophylla	Tree	0.14	Endangered
Bauhinia rufescens	Tree	0.09	Critically Endangered
Lonchocarpus cyanescens	Tree	0.09	Critically Endangered
Proposis africana	Tree	0.09	Critically Endangered
Ficus spp.	Tree	0.09	Critically Endangered
Butyrospermum paradoxa	Tree	0.09	Critically Endangered
Cassia singuena	Shrub	0.09	Critically Endangered
Ficus sycomorus	Shrub	0.09	Critically Endangered
Feretia apodanthera	Shrub	0.09	Critically Endangered
Albizia chevalieri	Tree	0.01	Critically Endangered
		100%	

RD=relative density

Threatened category with fourteen species and notable plants are *Balanite aegyptiaca* (RD=4.26%), *Adansonia digitata* (RD=2.47%), *Lannea acida* (RD=2.00%) and *Acacia seyal* (RD=1.60%). Endangered category with twenty two species comprises of notable members like *Vitex doniana* (RD=0.14%), *Anogiessus leocarpus* (RD=0.19%), *Tamarindus indica* (0.38%). Critically endangered category with nine species comprises of *Albizia chivalieri* (RD=0.01%), *Butyresopermum parkii* (RD=0.09%), *Proposis africana* (RD=0.09%), *Ficus iteophylla* (RD=0.09%) among others (Table 3).

This study reveals great variations interms of species conservation status in the dryland of northwestern Nigeria. From its findings, *Piliostigma reticulatum and Azadirachta indica* are stable in the study area. The ornithophilic seed dispersal of *Azadirachta species* may be responsible for its stability in the study area as similar findings of Rajendran *et al.* (2001) suggested. In India, ornithophilic seed dispersal character which is known with *Azadirachta indica* is responsible for its stability. *Adansonia digitata* is threatened in this study. Guinko (1984) reported that the species is threatened in the whole Sahelian and sub-Sahelian zone. *Butyrespermum parkii* and *Anogeissus leiocarpus* are endangered according to findings of this study. These species were listed as endangered by Gbile, Ola-Adams, and Soladoye (1978). An important browse species *Bauhinia rufescens* (browse species) is also endangered in the study area. This was also reported by Lykke, Fog and Masden (1999) that the plant is endangered in Senegal because of gnarling by browse animals. *Albizia chevalieri* is highly critically endangered across the study locations.

Proportion of Plants in the Status Categories

Figure 2 show that highest percentage of plants is found in threatened and endangered conservation status categories. This is not surprising as it was reported that about 0.4 and 8.5% of 7895 plant species from 338 families and 2215 genera identified in Nigeria fall under threatened and endangered statuses (FGN, 2006). Borokini (2013) also reported that of 164 red list plants in Nigeria, 18 and 15 fall under 'endangered' and 'critically endangered' categories.

Implication of this is persistent decrease in overall plant productivity across the dryland of northwestern Nigeria which could exacerbate the vagaries of climate in the study area and may lead to agro-habitat degradation and unsustainable natural resource extraction.

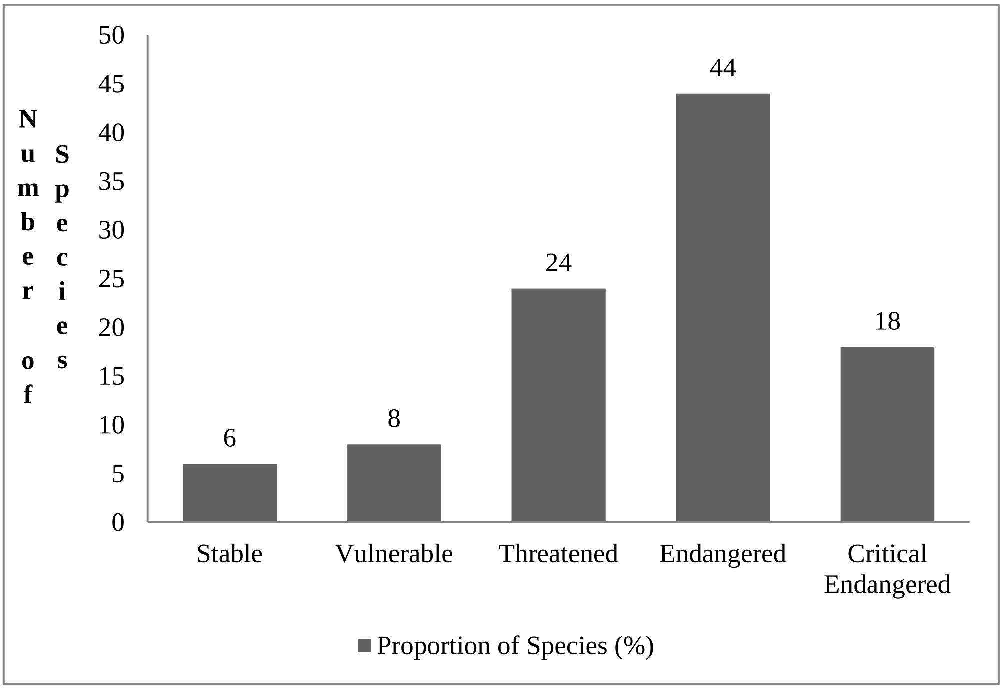


Figure 2: Proportions of Plants Conservation Statuses Categories

CONCLUSION

This study reveals that the greater numbers of species are found in threatened and endangered categories. This shows that most species that were encountered in the study locations are at risk of extinction. Therefore urgent conservation action is required to restore the widespread loss and degradation of native species. This categorisation does not indicate conservation actions are required for all plant species. Therefore, only plants that fall under threatened, vulnerable and endangered categories require necessary and urgent conservation actions from relevant bodies and agencies. However, different species have different degrees of resilience and tolerance to environmental perturbations of the area and therefore not every plant is worth protecting at a time. Relevance should be an integral part of the conservation actions to be taken.

RECOMMENDATIONS

1. Deeper understanding is needed of the drivers of vegetation change such as climate change, deforestation and agriculture and their implications for dryland biodiversity.

2. The task of assessing Nigeria’s flora is almost impossible without broader participation from local communities and natural resources planners. Therefore it is recommended that integrated assessments should be conducted to compile a list that distinguishes species conservation statuses for Nigeria without going through the formal process of applying the more detailed and time-consuming IUCN Red List criteria. Use of the IUCN Red List may require additional effort and may not be feasible for many taxa, given the financial constraints in the country.

3. Strengthening governance and rights over natural resources particularly land and trees are required through working with communities to formalise tenure arrangements where appropriate. This can be an entry point for building confidence between communities and the State and developing appropriate institutional relationships for effective conservation of resources.

APPENDIX

Table 1: Study Locations in Northwestern Nigeria

Villages	LGAs	State	Coordinates	
			Nothings	Eastings
Abonabo	Gurri	Jigawa	$12^{0}33^{I}25.3^{II}$	$010^{0}34^{I}45.8^{II}$
Chiromari	Malammadori	Jigawa	$12^{0}32^{I}31.8^{II}$	$010^{0}03^{I}15.5^{II}$
Meleri	Kirikasamma	Jigawa	$12^{0}39^{I}39.5^{II}$	$010^{0}11^{I}41.1^{II}$
Asayaya	Maigatari	Jigawa	$12^{0}42^{I}00.7^{II}$	$009^{0}33^{I}28.6^{II}$
Dankira	Sule tankarkar	Jigawa	$12^{0}44^{I}49.6^{II}$	$009^{0}16^{I}43.1^{II}$
Mairobi	Sule tankarkar	Jigawa	$12^{0}47^{I}00.0^{II}$	$009^{0}05^{I}01.1^{II}$

Garki	Baure	Katsina	$12^0 50^I 29.3^{II}$	$008^0 48^I 09.2^{II}$
Garni	Zango	Katsina	$12^0 51^I 48.4^{II}$	$008^0 31^I 20.4^{II}$
Daneji	Dutsi	Katsina	$12^0 52^I 50.3^{II}$	$008^0 13^I 41.2^{II}$
Jani	Mani	Katsina	$12^0 50^I 14.5^{II}$	$007^0 48^I 10.1^{II}$
Maje	Rimi	Katsina	$12^0 49^I 02.7^{II}$	$007^0 39^I 15.6^{II}$
Bugaje	Jibia	Katsina	$12^0 59^I 25.5^{II}$	$007^0 29^I 23.2^{II}$
Bazai	Shinkafi	Zamfara	$12^0 56^I 06.4^{II}$	$006^0 34^I 06.6^{II}$
Bugawa	Shinkafi	Zamfara	$12^0 56^I 06.5^{II}$	$006^0 37^I 07.1^{II}$
Dutsi	Zurmi	Zamfara	$12^0 52^I 35.0^{II}$	$006^0 36^I 26.4^{II}$
Gundumi	Goronyo	Sokoto	$13^0 08^I 31.8^{II}$	$006^0 00^I 38.4^{II}$
Modawa	Kware	Sokoto	$13^0 05^I 42.5^{II}$	$005^0 20^I 15.8^{II}$
Daraye	Wamakko	Sokoto	$13^0 08^I 55.3^{II}$	$005^0 03^I 32.8^{II}$
Chana	Gudu	Sokoto	$13^0 13^I 19.7^{II}$	$004^0 29^I 17.2^{II}$

REFERENCES

Borokini, T.I. (2013). A Systematic Compilation of IUCN Red-listed Threatened Plant Species in Nigeria. *International Journal of Environmental Sciences,* Vol. 3(3):104-133

Briggs, J. and Leigh, J. (1996). *Rare or Threatened Australian Plants*. CSIRO Publications, Melbourne.

Chuai, X.W., Huang, X.J., Wang, W.J. and Bao, G. (2013). NDVI, temperature and precipitation changes and their relationships with different vegetation types during 1998–2007 in Inner Mongolia, China," *International Journal of Climatology*, vol. 33(7):1696–1706.

David, M. (2008).*118/119 Biodiversity and Tropical Forest Assessment for Nigeria*. USDA Forest Service/International Forestry for USAID/Bureau for Africa. Washington, DC.

Edward, C.W. (1998). Threats to biodiversity. **In**: Brown, L.: *The elimination of species- rich tropical forests and other habitats is driving many plant and animal species to extinction*. Washington, DC.

Eric, F.L., Helmut J.G. and Erika L. (2003). Dynamics of land-use and land-cover Change in tropical regions. *Annu. Rev. Environ. Resour*., 28:205-41.

Federal Government of Nigeria (2006). *Approved National Forest Policy 2006*. Federal Ministry of Environment of Nigeria, Abuja

Fewster, R.M., Laake, J.L. and Buckland, S.T. (2005). Line transect sampling in small and large regions. *Biometrics,* 61:856-859.

Gbile, Z.O., Ola-Adams, B.A. and Soladoye, M.O. (1978). Endangered species of the Nigerian Flora. *Nigerian Journal of Forestry,* 8(1,2)

Guinko, S. (1984). *Vegetation de la Haute-Volta*. "Docteur en Science Naturelle" thesis, Université de Bordeaux

International Union for Conservation of Nature, IUCN (2012). *IUCN Red List Categories and Criteria: Version 3.1.* Second edition. Gland, Switzerland and Cambridge, IUCN, UK

Kindt, R. and Coe, R. (2005).*Tree Diversity Analysis. A manual and software for common statistical methods for ecological and biodiversity studies.* World Agroforestry Centre (ICRAF), Nairobi.

Li, X.H., Shi, Q.D., Chang, S.L., *et al*. (2008). Change of NDVI based on NOAA image in northwest arid area of China in 1981−2001. *Arid Land Geography*, 31(6): 940−945.

Lykke, A.N., Fog, B. and Madsen, J.E. (1999). Woody Vegetation changes in the Sahel of Burkina Faso assessed by means of local knowledge, aerial photos, and botanical investigations. *GeografiskTidsskrift, Danish Journal of Geography Special Issue,* 2: 57-68.

Mace, G.M. and Lande, R. (1991). Assessing Extinction Threats: Toward a Re-evaluation of IUCN Threatened Species Categories. *Conservation Biology,* 5:2

Mortimore, M. and Adams, W. (1999). *Working the Sahel: Environment and society in Northern Nigeria*. Routledge, London.

Onyekwelu, J.C., Mosandl, R. and Stimm, B. (2007). *Tree species diversity and soil status of two natural forest ecosystems in lowland humid tropical rainforest region of Nigeria.* Conference on International Agricultural Research for Development. University of Kassel-Witzenhausen and University of Göttingen, October 9-11, 2007

Piao, S. and Fang, J. (2013). Seasonal changes in vegetation activity in response to climate changes in China between 1982 and 1999. *Acta Geographica Sinica*, vol. 58(1);119–125.

Possingham, H. and Andelman, S. (2002). Limits to the use of threatened species lists. *Trends Ecol. Evol*., vol. 17:11:503–507.

Rajendran, P., Thirumurthi, S. and Kanna, S.U. (2001). Seed dispersal by Avian fauna in forest ecosystem. *Advances in Horticulture and Forestry,* 8:265-273.

Secretariat of the Convention on Biological Diversity (2009). *The Convention on Biological Diversity Plant Conservation Report: A Review of Progress in Implementing the Global Strategy of Plant Conservation (GSPC),* Montreal, Canada

Secretariat of the Convention on Biological Diversity (2010). *Global Biodiversity Outlook 3.* Convention on Biological Diversity, Montreal, Canada

Singh, J.S. (2002). The Biodiversity Crisis: A Multifaceted Review. *Current Science,* 82:638–647.

Stem, C., Margolius, R., Salafsky, N. and Brown, M. (2005). Monitoring and Evaluation in Conservation: a Review of Trends and Approaches. *Conservation Biology,* 19(2):295-309

Stuart, S.N., Wilson, E.O., McNeely, J.A., Mittermeier, R.A. and Rodriguez, J.P. (2010). The Barometer of Life. *Science*, vol. 328:80

Sun, H.Y., Wang, C.Y. and Niu, Z. *et al*. (1998). Analysis of the vegetation cover change and the relationship between NDVI and environmental factors by using NOAA time series data. *Journal of Remote Sensing*, 2(3): 204−210.

Udo, R.K. (1970).*Geographical Regions of Nigeria,* Heinemann, London.

IMPACT OF DAILY EXTREME TEMPERATURES ON MAXIMUM ALLOWABLE TAKE-OFF WEIGHT OF AN AIRCRAFT IN FLIGHT OPERATIONS

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Abstract

This study investigates the most recent impact of daily extreme temperatures on maximum allowable take-off weight of an aircraft in five airports in north central Nigeria, namely: Nnamdi Azikiwe International Airport, Abuja (ABV); Yakubu Gowon Airport, (JOS), Minna Airport (MXJ), Kaduna Airport (KAD) and Ilorin International Airport (ILR). Thirty years (1985-2014) historical daily maximum temperature observation was obtained from the Nigeria Meteorological Agency, National Weather Forecasting and Climate Research Centre, for the five airports. Historical weight restriction trends are examined during the period from 1985-2014 (30 yeas). Statistical methods of analysis was employed in the study from which daily maximum temperature distributions showed rough bell shaped component with leptokurtic distribution (i.e. kurtoses is greater than 0 in all the aerodromes). At each airport, Boeing 737-800 performance charts are used to calculate the temperature that will result in 1,000 lbs (454 kg) level of weight restriction. Thirty eight degrees Celsius (38^{0}C) was the threshold temperature obtained due to the relatively similar high elevation characteristics of the airports for the level of weight restriction considered. Five years moving average analysis of the days of weight restriction occurrence shows that Minna (MJX) had the highest restriction days between 2000 and 2004, at approximately 300 days while Ilorin International Airport (ILR) recorded the least with 50 days. Jos airport did not meet the 1000 lbs aircraft weight restriction temperature threshold at any day within the study period. All other commercial aircrafts will also experience the effect of increasing temperatures to varying degrees, making the results presented here highly relevant for current and future airline operations.

Key word: Impact, Daily extreme temperatures, Weight restriction days, Aircraft, airports Temperature distribution

Introduction

Nigeria, a country in West Africa, lies within the tropical zone and enjoys a truly tropical humid climate, which is dominated by West African monsoon system (McSweeney, 2010). Mean annual temperature averaged over Nigeria has increased by around 0.8 °C between 1960 and 2006, at an average rate of 0.18oC per decade. Also in their repots (McSweeney, 2010) daily temperature observations show statistically significant trends in the frequency of 'hot' and 'cold' nights. Trends in the frequency of 'hot 'and 'cold' days are statistically significant. The average number of 'hot' days per year in Nigeria has increased by 73 (an additional 20% of days) between 1960 and 2003. The rate of increase is seen most strongly in September-October-November.

However, the 2012 Nigeria Climate Review has shown very interesting features in the variability of the atmospheric elements compared to their long term averages. Most states in the North recorded above normal day time temperatures at early part of the year which increased the discomfort level. Temperatures across the country show an increasing trend from mid-20th century to date. The mean temperature anomaly showed clearly the prevalence of warming in the country. Temperatures have increased from 0.2 – 0.5□°C in the high ground areas of Jos, Yelwa and Ilorin in the north (NiMet, 2012).

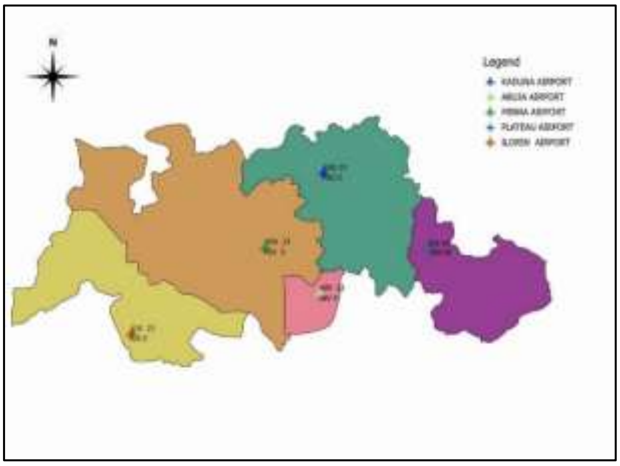
Weather extremes have tremendous influence on flight operations. From time immemorial, flight operations like any other human endeavors have been significantly affected, in terms of takeoff, landing and even in-flight by extreme weather (Christopher, 2014). Climate change may impact airplanes, airports and airstrips, affecting air travel and infrastructure. The resultant effect of these impacts range from flight delay [accounting for 70-80% in the US] (Coffel and Horton, 2014), cancellation, diversion, reschedule, poor air craft landing and taking off performance to ultimate economic loss [United States Environmental Protection Agency, 2016]. The loss of aircraft and engine performance, occasionally forcing a reduction in cargo or passenger carrying capability for the sake of safety, represents lost revenue for air transport operators. These factors should be carefully considered in the economic analysis of proposed equipment to be used on air routes in those parts of the world in which high temperatures and humidity may be expected as a matter of course. Thus far, to the best of our knowledge, no studies have been published on investigating the effects of climate variability and impact of warming weather on some aeronautic terminals across north central Nigeria. However, Christopher (2014) did study the effects of some weather parameters on flight operations in Kano and Abuja international airports, Nigeria. In this study, an attempt was made to quantify the impact of extreme temperatures on aircraft weight restrictions at the various aerodromes under study.

As air warms at constant pressure it becomes less dense, and an airplane wing traveling through this thinner air will produce less lift at a given speed than in cooler, thicker air. As a result, on warm summer days commercial airplanes have higher take off speeds. For each airport and aircraft type, there is a temperature threshold above which the airplane's minimum flying speed at its maximum take-off weight is too high to reach on the available runway, and the airplane must be weight restricted. Airlines respond by removing either passengers or cargo to decrease the aircraft's weight and thus lower its take-off speed (John, 1999). Finally, the number of days on which a Boeing 737-800 must be weight restricted as a result of climate change was investigated. The 737-800 has a slightly longer fuselage than the 737-400 and is fitted with the new wing, stabilizer, and tail sections. The 737-800 is 129ft 6in long and can carry up to 184 passengers in an all-economy configuration (Boeing, 2013). Studies by Ayoade (2004) have revealed that adverse weather conditions may cause delays, diversions, accidents and even outright cancellations of journeys, causing loss of time, revenue and even lives. According to Bisiriyu (2006), in aviation, weather has remained the important parameter in determining safety, regularity and efficiency of aviation operations. severe turbulence: thunderstorm, microburst (a small intense downdraft that descends to the ground resulting in a strong wind divergence, wind shear and poor visibility, contributes to the cause of approximately 70 percent of the delays in the National Airspace System (NAS).

Data and Methods

Daily maximum temperature data from five aerodromes in north central Nigeria were analysed. These airports were chosen because they are susceptible to increasing temperatures. The airports are Nnamdi Azikiwe International Airport, Abuja (ABV); Yakubu Gowon Airport, (JOS), Minna Airport (MXJ), Kaduna Airport (KAD) and Ilorin International Airport (ILR) as shown in Figure 1. These airports have shown frequent extremely high temperatures especially in the summer time (NiMet, 2012). Thirty years historical daily maximum temperature observation data from the Nigeria Meteorological Agency, National Weather Forecasting and Climate Research Centre were retrieved and analysed. Historical weight restriction trends are examined during the period from 1985-2014.

Figure 1: map showing five airports in north central Nigeria – Kaduna airport (KAD), Abuja airport



(ABV), Minna airport (MJX), Plateau airport (JOS), Ilorin airport (ILR)

The maximum runway lengths and elevations for these five airports are shown in Table 1. For this study, a level of weight restriction: 1,000 lbs (454 kg) was investigated. This level indicates how much the aircraft's maximum takeoff weight must be reduced as compared to a day with no restriction. At each airport, 737-800 performance charts from Boeing (2013) are used to calculate the threshold temperature that will result in any level of weight restriction. In this study, 38^0C was the threshold temperature obtained due to the relatively similar high elevation characteristics of the five aerodromes we considered.

Results and discussion

Aviation Weather Services (1995) revealed that weather parameters are of greater value when summarized in forms of aviation decision-aids. This may be through visualization, graphical representations, or recommendations that support the decision- processes. Daily maximum temperature distributions over the five airports are shown in Figure 2(a-e), shows a tri modal, asymmetrical and symmetrical temperature distribution patterns. The five stations have rough bell shaped component with leptokurtic distribution (i.e. kurtoses is greater than 0 in all the airports). The central locations at MJX (approximately at 29.5 °C, 35 °C and 38.5 °C), show higher temperature occurrences than at ABV (approximately 28.5 °C, 35 °C and 37 °C), KAD (approximately at 31 °C, 33.5 °C and 36 °C), ILR (29 °C, 34.5 °C and 36.0 °C) and JOS (24.5 °C, 28 °C and 31.5 °C) respectively. We define a weight restriction day as any day when the daily maximum temperature of matches or exceeds the weight restriction temperature thresholds (Coffel, 2015). Figure 3(a-e) shows the distribution and trend of the weight restriction days for MJX, JOS, ILR, KAD and ABV. Figure 3a shows a five year moving average for all the aerodromes. MJX had the highest number of 1k lbs restriction days of approximately 300 days between 200-2004. The least number of restriction days was recorded in ILR with approximately 50 days while Jos had no record of weight restriction day. However, Figure 3(b-e) shows yearly time series of weight restriction days. The patterns show a negative order in all the aerodromes on the average. However, the number of weight restriction days was highest in MJX with approximately 75 days, ABV, KAD, and ILR restriction days were 70,45 and 25 days respectively. JOS was not indicated in the graph because its maximum threshold temperature at any day within the study period did not meet the 1k lbs temperature threshold for a flight restriction day. The implications for this study is hereby presented as follows. The maximum takeoff weight of a 737-800 is 174.2k lbs. The empty weight (no payload or fuel) is 91.3k lbs, leaving 82.9k lbs available for both fuel and payload of passengers and cargo (Boeing, 2013). On a cross-country route, the aircraft will need nearly 100%

of its 46k lbs fuel capacity. In this situation, a 15k lbs weight restriction represents approximately 30% of the payload capacity of the aircraft. Thus, the weight restriction directly translates into less cargo or fewer passengers that can be carried. In practical application, a 737-800 in a typical two-class configuration seats 177 passengers, and in a high-density one-class configuration seats 189 passengers (Boeing, 2013). Using the current Federal Aviation Administration (2004) average summertime passenger weight of 190 lbs (including carry-on baggage), the 1k lbs, 10k lbs, and 15k lbs restrictions translate into 5, 52, and 79 passengers, respectively, that cannot be carried. The attendant effect could lead to passengers' restiveness due delay in baggage arrival to their destination.

Conclusion

The effect of extreme temperatures on aircraft weight restriction has been demonstrated in this study. Of course, changes in passenger behavior and weight, general economic conditions and technology will have large and unknown effects (Coffel and Horton, 2014) with no exception to some airports in Nigeria. The focus on rare events within the statistical reference distribution of particular weather elements at a particular place means that we do not only concentrate solely on the extremes that cause the largest socioeconomic losses and the greatest impacts as reported in the media (Albert et al; 2009). The effects of climate change on weight restriction are already detectable and are projected to become increasingly significant within the lifetime of aircrafts (Albert, et. al. 2009). All other commercial aircrafts will also experience the effect of increasing temperatures to varying degrees, making the results presented here highly relevant for current and future airline operations for which Nigerian airports are vulnerable. The attendant effect of passengers' restiveness due to weight restriction procedures (i.e. in terms of delay in baggage arrival to their destination) can be minimized in advance by coordinating adaptation strategies to climate impacts.

Acknowledgments

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References

Airport Characteristics, (2016). Retrieved from worldaerodata.com

Albert MG, Klein Tank, Francis W Zwiers and Xuebin Zhang, (2009). Guidelines on Analysis of extremes in a changing climate in support of informed decisions for adaptation. World Meteorological Organization. Retrieved From [http://lacad.ciifen.org/ES/documents/WCDMP_72_TD_1500_en_1.pdf

Aviation Weather Services, (1995). A call for Federal Leadership Action. The National Academic Press. Retrieved September 11, 2009 from hpp://books.nap.edu

Ayoade, J.O. (2004). Introduction to climatology for the tropics. Ibadan: Spectrum Books Ltd. Pg 45-66

Bisiriyu, R. (2006). Causes of Dereliction in the Nigerian Aviation Industry. Punch Newspaper, p. 41.

Boeing, (2013). 737 Airplane Characteristics for Airport Planning. Retrieved September 2013 from http://www.boeing.com/assets/pdf/commercial/airports/acaps/737.pdf.

Christopher Maikano Musa, (2014). Effects of some weather parameters on flight operations in Kano and Abuja International airports, Nigeria. Master's degree thesis in geography, department of geography, Ahmadu Bello University, Zaria, Nigeria.

Coffel, E., and R. Horton, (2015): Climate change and the impact of extreme temperatures on aviation. Weather Clim. Soc., 7, no. 1, 94-102, doi:10.1175/WCAS-D-14-00026.1.

Federal Aviation Administration advisory circular, (2004). Aircraft weight and balance control. August, 2004. Retrieved from

Gloria Kulesa, (2002). Weather and Aviation: How Does Weather Affect the Safety and Operations of Airports and Aviation, and How Does FAA Work to Manage Weather-related Effects? Retrieved from http://www.faa.gov/aua/awr/

John D Anderson, (2011). Introduction to flight. Published by Mcgraw-hill, March 2011. ISBN: 0073380245

McSweeney C, Lizcano G, New M, Lu X. (2010). The UNDP Climate Change Country Profiles, Nigeria. Bull. Amer. Meteor. Soc., 91, 157 166.

Nigeria Meteorological Agency-NiMet, (2012). Nigerian climate review. Retrieved from http://www.nimet.gov.ng/publication/annual-climate-review-bulletin-2012

United States Environmental Protection Agency (2016): climate impacts on air transportation. Retrieved from http://www3.epa.gov/

Table 1: Airport characteristics. Runway lengths are for the short and long runways at the airport - weather or other operating conditions may require any of the runways to be used for departures. Data obtained from WorldAeroData.com 2016

Figure 2: Daily maximum temperature distribution over MJX, ABV, KAD, ILR and JOS

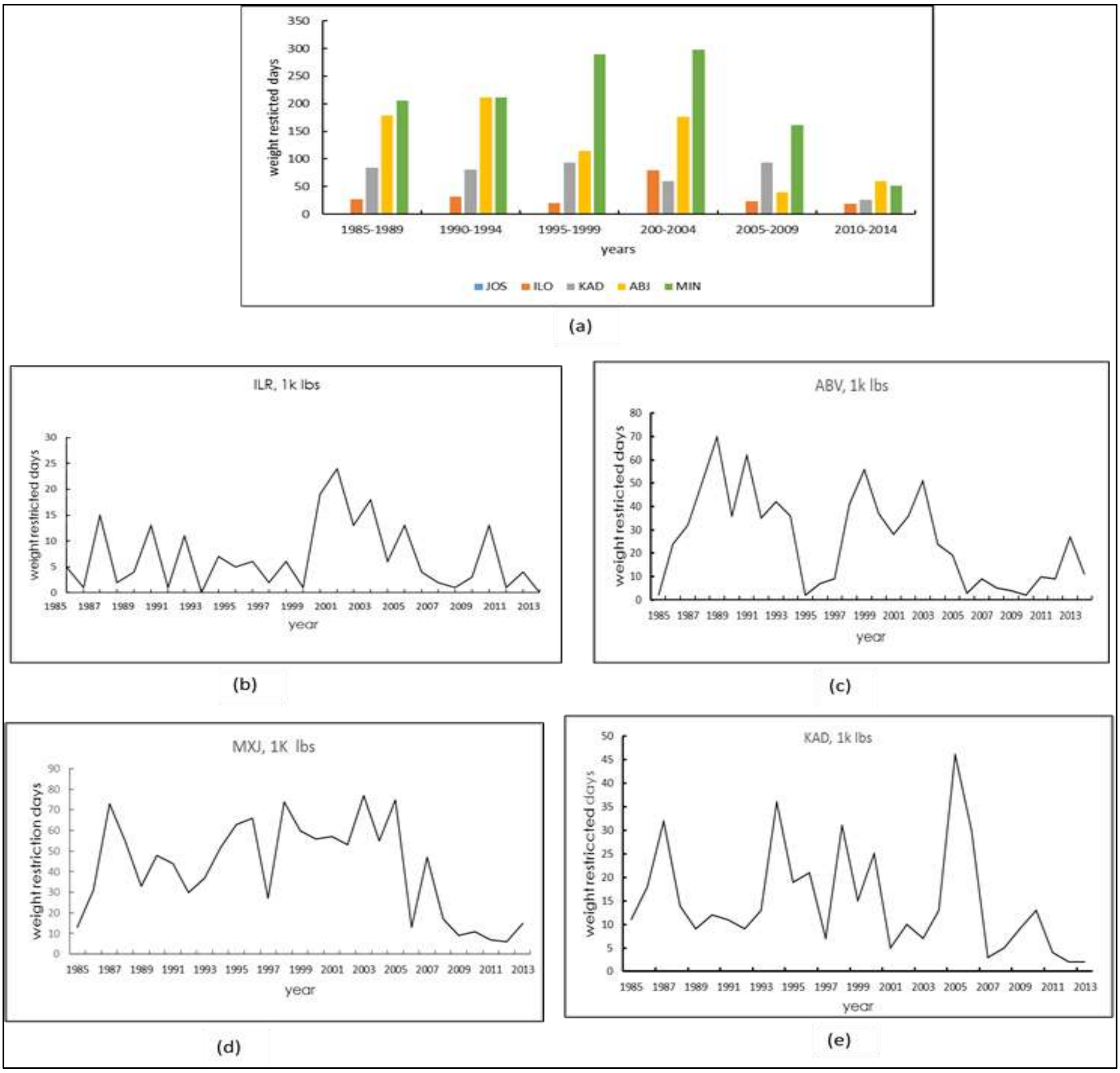

Figure 3: Number of weight restriction days per year (from analysis of historical temperature data, 1985-2014).

FLOOD SIGNATURE IN ILORIN FROM RAINFALL DATA

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Abstract

Flooding is becoming an increasingly signal and more frequent problems in Nigeria producing strong impact on both the urban and rural areas. Flood observation in Ilorin and environ experienced in 2015 led to strong propensity to examine in detail flooding sources. One of the factors considered strongly capable but leading to localised flooding is rainfall. Rainfall data acquired from the period 1980 to 2010 and those generated between 2014 and 2015 at Ilorin were analysed in this study. The rainfall intensity of years 2014 and 2015 had monthly average of 1.04mm/hr and 111.51mm/hr respectively. It also had percentage frequency of 0.3mm/hr at 22:00hr and 07:00hr on the average. 8% of the 2015 rainfall with intensity in excess of 3mm/hr while 4% occurred with intensity in excess of 30mm/hr. Daily average rainfall intensity for 2014 was 1.06mm/hr distributed annually while for year 2015, higher rainfall intensity was observed occurring mostly in April with highest daily value of 645.98mm/hr. Examination of the ratio of maximum to minimum annual amount falls between 75% and 100% of the mean in the 31 year period. The monthly mean is higher than the median with 16% of the month receiving zero rainfall. Actually, year 2001 received the lowest amount of rainfall of 697.1mm while 1998 received the highest within the period of time of 1595mm.

Keywords: Flood, Rainfall, Intensity, Annual, Daily

INTRODUCTION

Rain is a major component of the water cycle and is responsible for depositing most of the fresh water on the Earth. It provides suitable conditions for many types of ecosystems, such as water for hydroelectric power plants and crop irrigation. It is one of the principal controlling elements in agriculture in the tropics. Crop establishment and growth depend largely on the availability of adequate rainfall. The amount of rainfall that is received determines the type of agriculture that can be carried out and the crop that can be cultivated in a particular region. The total rainfall received in a given period at a location varies from one year to another. The variation depends on the type of climate and the length of the raining period. In general it can be stated that the drier the climate, the higher the variability of rainfall in time. Precipitation trend analyses on different spatial and temporal scales, have become important during the past century because of the attention given to global climate change. A small positive global trend, though large areas are characterized by negative trends (IPCC, 1996). Overflow of water that submerges land which is usually dry is referred to as Flood. It may occur due to an accumulation of rainwater on saturated ground in an area causing damage to homes and businesses situated in the natural flood plains of rivers. Urban flooding is a condition, characterized by its repetitive and systemic impacts on communities regardless of whether or not they are located within designated floodplains or near any body of water. The flood flow in urbanized areas constitutes hazard to both the population and infrastructure. Some recent catastrophes included the flooding of New Orleans (USA) in 2005, and the flooding in Rockhampton, Bundaberg, Brisbane during the 2010–2011 summer in Queensland (Australia), and the flood experienced in Nigeria cities such as Lokoja in recent years. Catastrophic riverine flooding is usually associated with major infrastructure failures such as loss of Agricultural produce, homes, properties, massive land slide, erosion and loss of lives in some cases. Most rainfall usually experienced in the tropics is light and of moderate intensity, less than 2.5mm/h to 10mm/h, while heavy, 10mm/h to 50mm/h, could occur once in a solar cycle and extreme rainfall, greater than 50mm/h, could occur once in century. It is possible, though improbable, to have multiple "1 in 100 Year Storms" in a single year (BIN; 2005, AMS; 2009). For agriculture, important aspects of rainfall include the days of start and end of the rainy season, and hence its duration. This includes the rainfall amounts and the risk of dry spells within the season, records of August rainfall in West Africa confirm oscillatory precipitation trends over the region, with different sub-climates showing rainfall increment or reduction during the last 35 years (Cannarozzo et al., 2006; Nyatuame et al., 2014;). A case study of Ilorin a city in Sub-Sahel West Africa. In this present study, data available consists of monthly precipitation time series from 1980 – 2010 and two years (2014 – 2015) five minutes interval average rainfall data generated at Ilorin site. These were analysed to detect flood signature, distribution, and average occurrence probability over annual return period.

MATERIAL AND METHODS

Site Description

Ilorin is situated in the Guinea Savannah zone of West Africa with Latitude 8° 19’ 12’’N, Longitude 4° 20’ 24’’E and 300m above sea level which is a transition zone between the Guinea coast and Sahelian West Africa. It is influenced by the dusty harmattan wind (Ginoux et al., 2010). It is shown in Plate 1 with dot. The climate is a transition between the equatorial rain forest in the south and the Sahel Savannah in the north. The hot dry season commences from late October to late March when the North-Easterly (NE) winds from the Sahel dominate the climate pattern. However during the wet season from late April to October, the climate is dominated by the South-Westerly winds from the Atlantic Ocean which is characterized with high relative humidity of values exceeding 80% (Akoshile et al. 2007). The type of rain usually experienced in Ilorin is convectional, where rising currents of warm air separated by more wide-spread areas of slowly sinking air follows the three steps of wind gathering; joining; and stacking, adduced to its closeness to the equator. This type of rain can be experienced all year round.

Plate 1: Map of Nigeria Showing Ilorin in dot

Instrumentation

The Rainfall Intensity data was taken with automated Rain Gauge with a digitised sensor coupled to a data logger (Pace XR5-SE) which was set to record and average the rainfall amount every five minutes. The data logger is a stand-alone recorder with eight (8) multi-range analogue inputs and three (3) pulse / frequency inputs, compatible with many sensors: of Temperature, Relative Humidity, Pressure, Acceleration, Current, Voltage, Light, Solar Radiation, Wind Speed, Rainfall and others. This sensor has only been put up for three years. On the other hand, the rainfall amount for the many years period were taken using manual Rain gauge that gives daily amount of rainfall during raining season and were obtained from Nigeria Meteorological Agency.

Data Acquisition

The rainfall Intensity data in mm/h obtained ate the University of Ilorin site from the data logger averaged into hourly, daily and monthly over the period of 2014-2015 to reveal both diurnal and seasonal variation. Monthly rainfall data in mm were obtained from the Nigeria Meteorological Agency (NiMet) Oshodi Lagos, Nigeria. The data over Ilorin obtained from NiMet cover the period of 1980 to 2010, was analysed for long term variability. According to World Meteorological Organization (WMO) standards for tropical region, it is necessary to acquire basic water resources data which could be used to study, analyse and advice on the optimum uses of water resources to better manage the rain fed agricultural activities.

Data Analysis

The short term (hourly, within a year) Rainfall data was analysed to characterise its intensity for possible local flood occurrence from the runoff generated and to determine the measure of central tendency, dispersion, duration and distributions. The long term Rainfall data (Monthly Rainfall Over 31 years) was analysed not to be able control flood or manage the irrigation water, but to be able to design Rainfall required during a crop season. Annual rainfall amount was derived from the monthly values and measure of central tendency and dispersion was conducted on both to give information on the normal amount of rainfall to be expected in the area which can be used to obtain the departure of the annual rainfall from normal. The Probability of Occurrence or exceedance of each annual total amount were calculated adopting Sevruk and Geiger, (1981) method of

$$P = \frac{(r-3/8)}{(n+1/4)} 100 \qquad \text{I}$$

where P is the probability in %, r is the the rank of the observation, and n is the total number of observations used (n = 10 to 100). The Return Period of the probability or rainfall amount is the reciprocal of the calculated probability in year. Distributions of Rainfall monthly and annual occurrence were performed using Normal distribution function with the Mann–Kendall analysis to identify the trend in the time series data for the regions.

Suppose (x_1, x_2, ..., x_n) is a time series data. The Mann–Kendall (M–K) test statistic is defined as

$$T = \sum_{i<j} sgn(x_j - x_i),\ \ where\ sgn(x) = \begin{pmatrix} 1\ if & x > & 0 \\ 0\ if & x = & 0 \\ -1\ if & x < & 0 \end{pmatrix} \quad II$$

Under the null hypothesis that there is no trend, *T* is distributed as a Normal random variable with mean zero and variance assuming no ties between (x1, x2, ..., x*n*) (Hirsch *et al*., 1982). The alternative used is no trend. All tests were at *a* = 0.05 level.

RESULTS AND DISCUSSION

Rainfall Intensity

Rainfall intensity is investigated by grouping it into four, consisting of light rainfall (*R* < 5 mm/h); moderate (5 ≤ *R* < 10 mm/h), heavy (10 ≤ *R* ≤ 50 mm/h), and extreme (*R* > 50 mm/h) according to the Boulder Area Sustainability Information Network (BIN). The Intensity data used is sectioned into two, 2014 and 2015 annual Rainfall. In 2014 (Figure 1), all the Rain experienced is in light and moderate rainfall categories since the intensity is less than 10mm/h on hourly average. The rain started early in the year beginning in January and ended in October of the same year (10 months of Rainy season). The long rainy season experienced stopped soil Infiltration due to soil saturation and as a result more runoff is generated which lead to Area flood that mostly affected the flat plane and local depression not connected to stream channel.

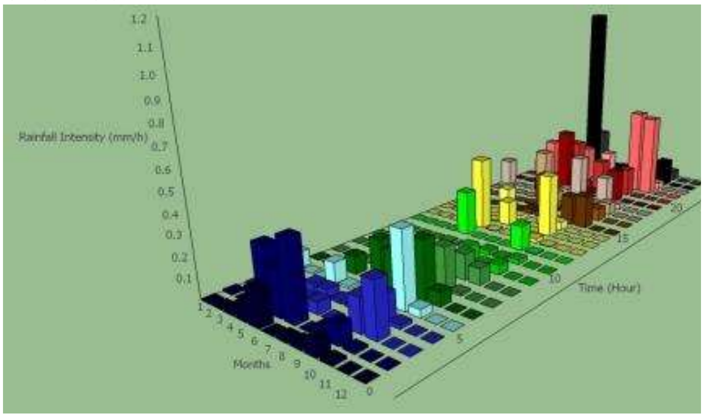


Figure 1: 2014 Seasonal and Diurnal rainfall Intensity

It was observed from Figure 1 that more intense rain clustered around the two ends of the day, first seven ours from 12:00am to 7:00am and last seven hours from to the 12:00am start of a new day with the low intensity rains scattered around the mid-day between 8:00am and 5:00pm nine hours. April experienced the highest intensity in the year with monthly average value of 1.04mm/h which falls between 11:00 – 12:00 hours, while September receives rainfall throughout the hours of the day. Usually August is a rainy break in Ilorin but 2014 experienced more rain in August than March which was the beginning of the rainy season.

In 2015, April to be specific experienced both heavy and extreme event cases of rainfall continuously for more than 20 hours in a day as shown in Figure 2. April 9, 2015 experienced 20 hours of rainfall consecutively with the maximum intensity of 1625.92mm/h about 07:00am hour and minimum of 212.92mm/h about 04:00pm hour. On the following day, April 10, 2015 12 hours of rainfall occurred with the maximum intensity of 1239.17mm/h and minimum of 121.67mm/h with only two hours break in between.

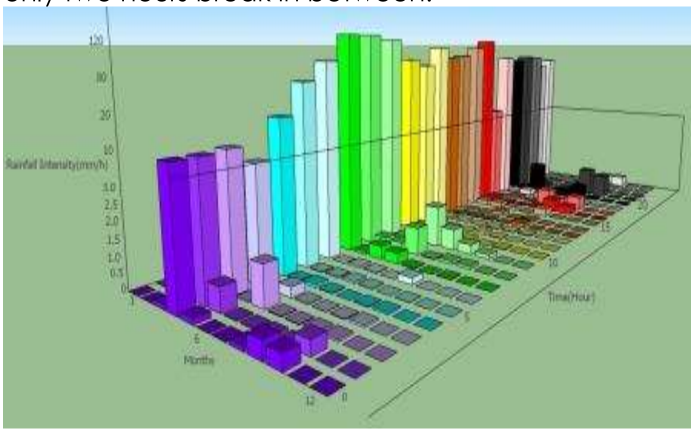


Figure 2: 2015 Seasonal and Diurnal rainfall Intensity

Another extreme rainfall event occurred on April 20, 2015 which lasted for about four hours starting 05:00 hour and ending about 08:00 hour with the maximum intensity of 1381.25mm/h and minimum of 290.08mm/h resulting in two extreme events within two weeks. This justifies the claim (BIN) that it improbable to have multiple rainfall. Event to occur in a single year. Figure 2 shows the monthly average highest intensity to be 111.51mm/h in April about 07:00 hour and in the same April, minimum intensity of 3.92mm/h. The annual rainfall of 2015 started in late February unlike the previous year that started in March. It could be inferred from the plot that the violent rainfall which occurred in April affected the amount of rain observed in the other months of the year with intensity falling in the light rainfall category.

Rainfall intensity measurements are valuable for the prediction of catastrophic events (Kwarteng et al. 2009) and the downpour of the violent rain in 2015 which its occurrence was predicted to be once in 100 years caused flash flood in the urban area of the Ilorin metropolis and riverine flood which affected the community both physically and economically. The physical effects included loss of life, damage of buildings and other structures including bridges, sewer system, road ways, canals, power transmission line damage and agricultural produce such as fish ponds near the rivers loss and crops to mention a few as documented by Kwara state fire service. Some of the economic hardships on the state are rebuilding costs, food shortage, decline in tourism etc. Though flood has some benefits such as recharging ground water, increasing soil fertility and nutrients in case of regular flood but the damages caused often surpass the benefits.

Table 1: Statistical summary of Monthly and Daily Rainfall Intensity for 2014 & 2015

		MONTHLY AVERAGE INTENSITY (mm/h)		DAILY AVERAGE INTENSITY (mm/h)	
S/N		2014	2015	2014	2015
1	MAXIMUM	1.0403(0.3%)	111.5081(0.3%)	1.0590(0.3%)	645.9861(0.3%)
2	MINIMUM	0.0000(50.7%)	0.0000(43.4%)	0.0000(72.6%)	0.0000(73.4%)
3	MEAN	0.4840	3.0949	0.4936	3.1538
4	MODE	0.0000	0.0000	0.00	0.00
5	STD DEV.	0.1015	13.1918	0.1316	39.6162
6	SKEWNESS	4.404	5.493	3.552	14.271
7	KURTOSIS	30.441	33.380	15.194	214.206
8	RANGE	1.0403	111.5081	1.0590	645.9861

From Table 1, 2015 has the highest daily and monthly average rainfall intensity of extreme cases that could cause flash flood within minutes of rainfall. It can be seen that over 70% of the hours in the daily average and over 40% of the day in the monthly average received zero rainfall in both years. Likewise, 2015 has higher standard deviation correlated with high range value. The standard deviation and range indicate the level of variability or spread of the rainfall intensity, meaning 2014 spread over small band of 0 to 1.1 compared to 2015 band of 0 to >600. To test the normal distribution of the intensity, the skewness and kurtosis were computed. Skewness is a measure of symmetry or lack of symmetry. The skewness for a normal distribution is zero, and any symmetric data should have skewness near zero while Kurtosis is a measure of data flatness relative to normal distribution. Hence 2015 rainfall intensity distribute more away from the normal than 2014 rainfall intensity, both in daily and monthly averages. Their values of skewness and kurtosis are positive and far away from zero. Figure 3 (a-d) shows the frequency distribution of the data and their various frequency percentages.

Annual Rainfall/Monthly Average Rainfall Variability

Rain over Ilorin is variable and irregular. It could best be described as oscillatory. From Figure 4a, year 1998 received the highest annual rainfall of 1595.5mm and 2001 received the lowest of the value 697.1mm with the mean value of 1197.23mm. The variability is less frequent from 1980 to 1987, more frequent from 1988 to 2003 (unpredictable) and stable from 2004 to 2006 before continue to rise through year 2008 and finally dropped in 2010. The standard deviation of the annual rainfall is 219.17mm and is 13.7% of the maximum annual rainfall which is within the range of 10 to 20% suggested by the pass literature for the temperate region. The ration of maximum to minimum annual amount is low showing high variability and in 19 years out of 31, annual amounts are between 75 and 110 percent of the mean.

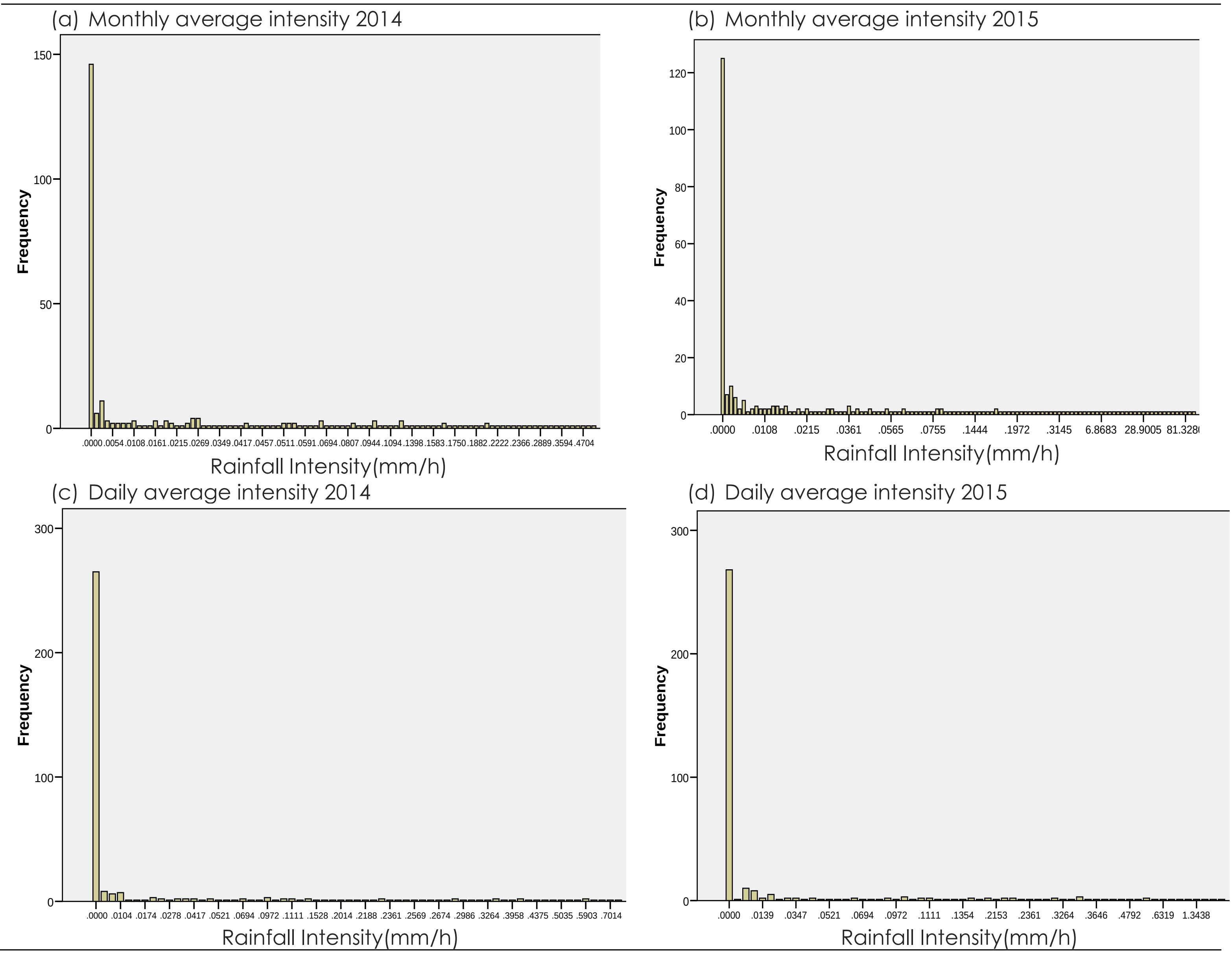


Figure 3: Frequency distribution of Rainfall Intensity

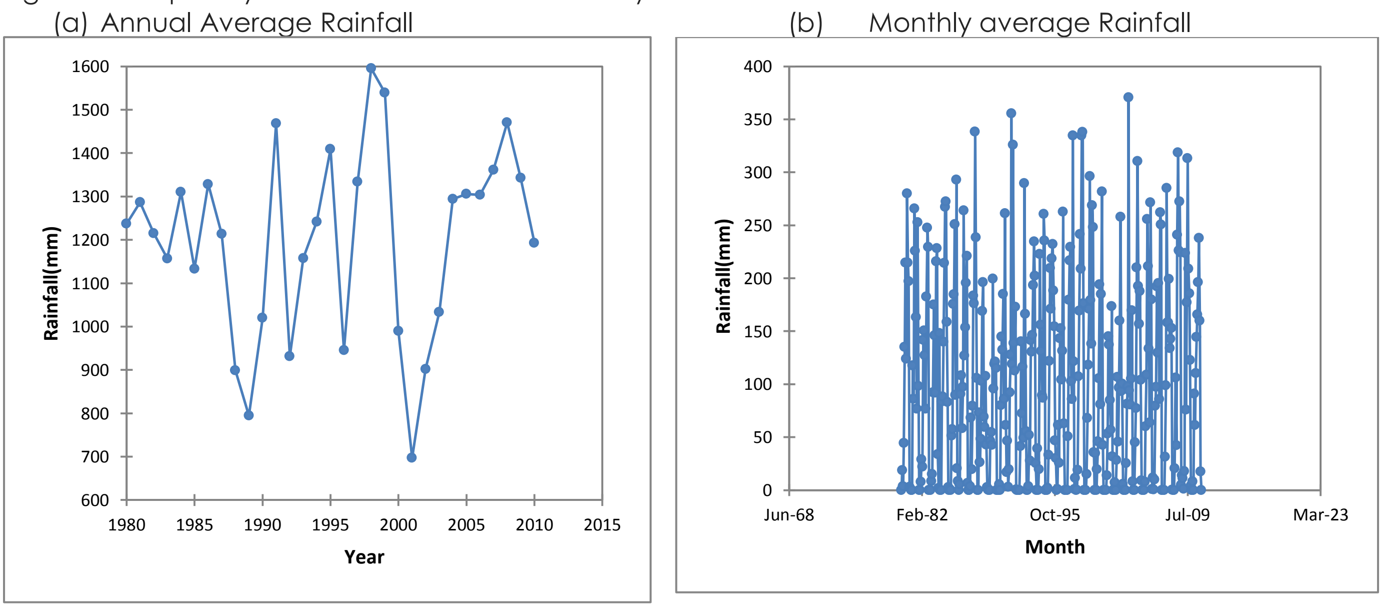
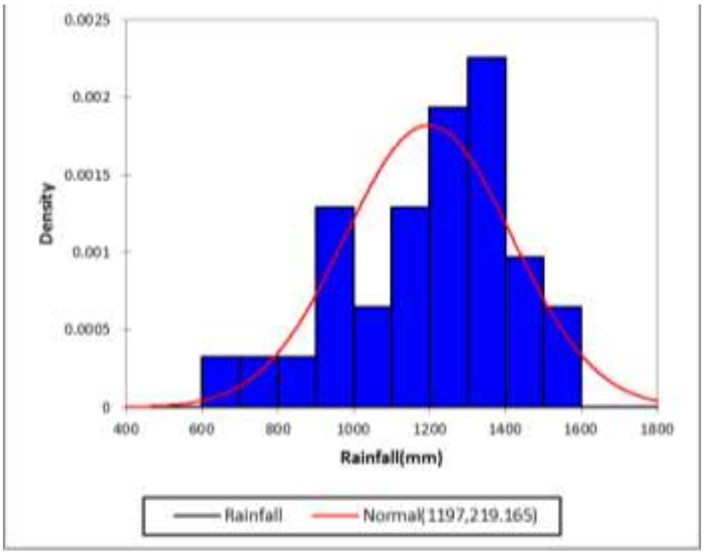


Figure 4: Plot of Annual amount and Monthly Average Rainfall

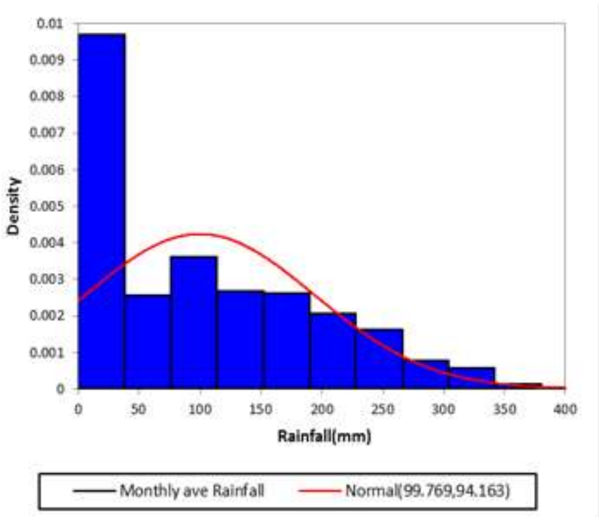
The monthly average rainfall plot shows high variability as shown in Figure 4b. The monthly plot indicates that the highest rainfall is mostly recorded in either May, June, August or September and accounted for 16.8% of the rainfall of the period considered. 16.5% of the months of the year considered received zero rainfall. The lowest monthly rainfall occurred in months of November, December, January and February which are in the harmattan season (Dry and Cool period) and these months collectively accounted for only 13% of the period considered. The low rainfall usually recorded in these months results in dryness in the atmosphere which brings the in-balance between evaporation and precipitation since the main source of rain in this locality is through convection. Approximately 69.3% of the total rainfall of the 31 year period occurred during the rainy season between April and October. In Table 2, it can be seen that the maximum monthly rainfall is 370.80mm with the mean value of 102.24mm. The annual rainfall data follow the normal distribution and monthly data are not normally distributed when tested for normalcy with the data set grouped into 10 classes of equal interval starting from 600 to 1600 for the annual and from 0 to 380 as it is shown in figure 5a & b for the monthly.

Table 2: Statistical summary of Annual Rainfall and Monthly Average Rainfall Time range

S/N		ANNUAL RAINFALL(mm)	MONTHLY AVERAGE RAINFALL(mm)
1	MAXIMUM	1595.50	370.80
2	MINIMUM	697.10	0.00
3	MEAN	1197.23	102.24
4	STD DEV.	219.17	93.98
5	SKEWNESS	-0.424	0.642
6	KURTOSIS	-0.304	-0.573
7	RANGE	898.40	370.80



(a) Annual Rainfall Distribution



(b) Monthly Rainfall Distribution

Figure 5: Normal distribution of the Rainfall data

The monthly and annual Rainfall data are having negative kurtosis indicating a flat peak distribution (Nyatuame et al. 2014) as shown in Figure 5. The trend analysis conducted using the Mann–Kendall statistic shows no trend since the T values computed (T_{Annual} = 0.295 and T_{month} = 0.667) for both annual rainfall and monthly average are greater than alpha value of 0.05.

Probability Analysis

The probability of exceedance (P_X) refers to the probability of the occurrence of a rainfall depth greater than some given values during a specific reference period such as hour, day, week, 10 day, month, or year. It is expressed as a percentage change with a scale ranging from 0 to 100 percent (Dirk, 2004). It is derived from the annual rainfall depth using Sevruk and Geiger, 1981 method. According to the computed probability, the probability of exceedance of the maximum annual rainfall is 2% while that of the minimum annual rainfall is 98% as can be seen in Table 3. The ranked annual observation was plotted against the corresponding probabilities using Excel software due to in-availability of probability paper. A polynomial fit was employed to represent the Ogive curve used in the manual plotting. The R^2 value of the fit is 0.96 and from the plot the Rainfall depth of any probability or vice-versa can be retrieved as shown in Figure 6. The probabilities are normally distributed based on the description by Dirk 2004.

Table 3: Probability and Return period Statistic Results for annual Rainfall Amount

YEAR	Annual amount(mm)	m-Rank	P-Prob. of excee.(%)	T-Return period(Yr)
1998	1595.5	1	2	50
1999	1539.3	2	5.2	19.23077
2008	1470.5	3	8.4	11.90476
1991	1468.4	4	11.6	8.62069
1995	1409.2	5	14.8	6.756757
2007	1361.4	6	18	5.555556
2009	1342.7	7	21.2	4.716981
1997	1334.4	8	24.4	4.098361
1986	1328.4	9	27.6	3.623188
1984	1310.5	10	30.8	3.246753
2005	1305.9	11	34	2.941176
2006	1303.8	12	37.2	2.688172
2004	1294	13	40.4	2.475248
1981	1286.9	14	43.6	2.293578
1994	1242	15	46.8	2.136752
1980	1237.1	16	50	2
1982	1215.1	17	53.2	1.879699
1987	1213.7	18	56.4	1.77305
2010	1193.1	19	59.6	1.677852
1993	1157.9	20	62.8	1.592357
1983	1157.2	21	66	1.515152
1985	1133.3	22	69.2	1.445087
2003	1033.5	23	72.4	1.381215
1990	1020.1	24	75.6	1.322751
2000	990.3	25	78.8	1.269036
1996	945.3	26	82	1.219512
1992	931.6	27	85.2	1.173709
2002	902.3	28	88.4	1.131222
1988	898.9	29	91.6	1.091703
1989	794.6	30	94.8	1.054852
2001	697.1	31	98	1.020408

Table 3 also shows the return period or recurrence interval (T) expressed in year in which the individual probability or rainfall depth is expected to return (Reining et al. 1989). Hence the return period of the maximum annual rainfall of 1595.50mm of 2% probability of exceedance is 50 years. This means on the average, once every 50 years the rainfall depth of such or more is expected. While the minimum rainfall depth of 697.10mm with the probability of 98% has the return period of 1.02 years meaning the storm of this amount or more is likely to reoccur in $1\frac{9}{10}$ years.

Such parameter like these are very useful in Rainfall designing for the cropping season at which the catchment area will provide sufficient runoff to satisfy the crop water requirement in order not to cause what is termed moisture stress in plants or surplus runoff which may result in damage to the structure.

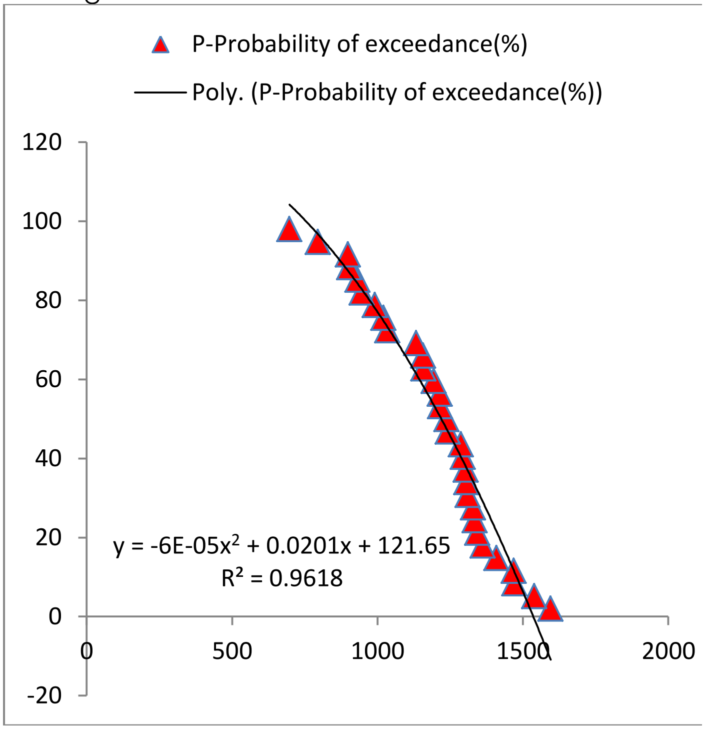


Figure 6: Probability of Exceedance plot

CONCLUSION

Rainfall is considered capable of leading to localized flooding. Analysed of the amount and intensity of rainfall measured at Ilorin. In the analysis, diurnal and seasonal variation of Rainfall Intensity and Rainfall amount were extracted. Rainfall in Ilorin is highly variable and is dominated with light and moderate rain. The result showed April, 2014 and 2015 experienced highest Intensity with monthly average of 1.0403mm/h and 111.508mm/h respectively and frequency percentage of 0.3% at 22:00 and 07:00 hour respectively. On the average, 8% of the 2015 rainfall occurred with Intensity in excess of 3mm/h and about 4% occurred with Intensity in excess of 30mm/h. Daily average of Rainfall Intensity in 2014 has highest value of 1.0590mm/h distributed evenly compared to 2015 which was characterized by higher Rainfall Intensities that mostly fell in April with daily highest value of 645.98mm/h. Annual total derived from monthly average rainfall over the period of 31years gave the ratio of maximum to minimum annual amount is low showing high level of variation and in 19 years out of 31, annual amounts are between 75 and 110 percent of the mean while the mean of monthly average rainfall is larger than the median where 16% of the months receiving zero rainfall. Year 2001 received the lowest amount of rainfall, 697.1mm, while 1998 received the highest in the period considered with the value of 1595mm. Yearly occurrence with such highly monthly rainfall occurrence like these could be predicted using the probability of exceedance curve generated from the annual rainfall values for the period considered. No trend was found in both the Intensity and Rainfall depth and the same has been reported by several researchers (Hulme, 1996; Gong *et al*., 2004).The return period or recurrence interval of each exceedance probability or annual amount in the curve was estimated.

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References

Ayoade J.O. (1983): *Introduction to climatology for the tropics*. John Wiley, London.

Babbitt, Harold E. & Doland, James J., *Water Supply Engineering*, McGraw-Hill Book Company, 1949

Boulder Area Sustainability Information Network (2005). What is a 100 year flood?. Boulder Community Network

Bradley, R. S., H. F. Diaz, J. K. Eischeid, P. D. Jones, P. M. Kelly, and C. M. Goodess, 1987: Precipitation fluctuations over Northern Hemisphere land areas since the mid-19th century. *Science,* **237,** 171–175.

Chen, C. L. 1983. Rainfall Intensity-Duration-Frequency Formulas, *Journal of Hydraulic Engineering*,**109**(12)1603-1621.

CHIA, L. S. 1968. An analysis of rainfall patterns in Selangor. *J. Trap. Geogr., Singapore,* 27: 1-18

Dirk RAES (2004): *Frequency Analysis of Rainfall Data*, ICTP- College on Soil Physics

Elisabeth M. Benders-Hyde (2003): World Climates. Blue Planet Biomes

Fredrick K.L. and Edward J.T. (1986): *The Atmosphere: An Introduction to Meteorology* (3rd

Edition). Prentice Hall, inc. Eaglewood Cliffs, New Jersey.

Geerts B. (2002): *Convective and stratiform rainfall in the tropics*. University of Wyoming

Glossary of Meteorology (June 2000): *Rain*. American Meteorological Society.

Gong D, Shi P, Wang J. 2004. Daily precipitation changes in the semiarid region over northern China. *Journal of Arid Environments* **59**: 771–784.

Hogg, R. V. and E. A. Tanis (1988). Probability and Statistical Inference, 3rd Edition, Macmillan Publishing Co., New York, NY.

Hulme M. 1996. Recent climatic change in the world's drylands. *Geophysical Research Letters* **23**: 61–64.

Hydrological Project of World Bank and Government of Netherlands (2002): *How to analyse rainfall data* training module, New Delhi India.

Jones, Myrtle (2000*)*. *Ground-water flooding in glacial terrain of southern Puget Sound, Washington*

Kwarteng A. Y., Atsu S. D. and Ganiga T. V. 2009 Analysis of a 27-year rainfall data (1977-2003) in the Sultanate of Oman. *Int. J. Climatol.* **29**: *605_617*

Met Office (2007). Fact Sheet No. 3: Water in the Atmosphere (PDF). Crown Copyright. p. 6. Paradox?". *Bulletin of the American Meteorological Society*. **78** (10): 21792196. Bibcode:1997BAMS...78.2179H. doi:10.1175/15200477(1997)078<2179:SPIROC>2.0.CO;2. ISSN 1520-0477

Mohamad Nooh Hassani and Roger D. Stern 1988 A Simple Method for Analysing Daily Rainfall Data- A Case Study for Kota Bharu. *Pertanika* **11**(1), 101-106

Paul E. Lydolph (1985): *The Climate of the Earth*. Rowman & Littlefield. p. 333.ISBN 978-0-86598-119-5

Reining et al**.** 1989 statistical analysis of rainfall data

Robert A. Houze Jr (1997); *Stratiform Precipitation in Regions of Convection: A Meteorological Paradox? (PDF)*. Bulletin of the *American Meteorological Society*, **78**(10):21792196. *Bibcode*:*1997BAMS...78.2179H*. *doi*:*10.1175/15200477(1997)078<2179:SPIROC>2.0.CO;2*. *ISSN* *1520-0477*

The Water Cycle, *Planetguide.net.*

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The Temporal Fluctuation of the Groundwater Level in the Basement Rocks Of Abeokuta, South-Western Nigeria

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Abstract

Water occurs in various locations and forms in the earth's atmosphere system. Groundwater level monitoring plays a key role in the environmental sustainability issue. This study examines the short term groundwater fluctuations in the basement rocks of Abeokuta, Southwestern Nigeria. Static water level of 23 randomly selected wells within Abeokuta metropolis were observed during the wet and dry seasons on weekly basis for nine months (January – October, 2008) using an hydrograph. Discharges of two major streams (Gangan and Ala) in the study area were also monitored. Water level hydrograph of the selected wells were then developed based on the static water level results as well as the discharge values of the two streams. The hydrograph revealed that Gangan stream in the study area could not dry up during the dry season as a result of the stream intersection of aquifers that contained abundant water in the wells near the stream. A comparism of the static water level and rainfall was done to determine the response of the wells to rainfall and a water table map was generated to indicate direction of groundwater flow. Evaporation data were compared with the static water levels of the wells to determine their relationship. The results indicated that rainfall was not the only factor that influenced groundwater level fluctuations: effluent streams and water withdrawn from the wells as abstraction by pumping were also contributing factors. The basement complex formation of the study area, lateritic over burden of varying thickness and permeability also contributed to the water level fluctuations.

Keywords: basement, hydrograph, static water level, discharge, water

INTRODUCTION

Groundwater includes all water found beneath the earth surface. It is the body of water derived from percolation and contained in permeable rock formation known as aquifer (Alagbe, 2002). The following factors influence groundwater level viz: difference between supply (recharge) and withdrawal (discharge) of groundwater, meteorological and tidal phenomena, urbanization, earthquake and external loads (Todd and Mays, 2005). The groundwater dynamics reflects the response of the groundwater system to external factors such as climate and human activities (Danyar et al., 2004, Yang et al., 2005).

The fluctuation in the groundwater level is also an important indicator of ecology and the hydrology of the region (Song et al., 2000). Fluctuation in groundwater levels reflects changes in ground water storage within aquifers. Two main groups of fluctuations have been identified: long term, due to seasonal changes in natural replenishment and persistent pumping, and short term as, due to the effects of brief period of intermittent pumping tidal and barometric changes (Gribovszki et al., 2010). If groundwater recharge exceeds groundwater discharge storage will increase, and if discharge is greater than recharge, storage will decrease.

The components of groundwater recharge are infiltration of precipitation at the ground surface, influent seepage from water bodies like rivers and lakes, groundwater leakage and inflow from adjacent aquifer and artificial sources such as irrigation recharge basins and wells among other sources (Chand et al., 2004). According to Gregoric et al. (2009), groundwater regime in any region is classified as climatic, hydrological and climatic-hydrological based on the correlation analysis of the dependence of groundwater level on precipitation. However, in the riparian belt, the formation of groundwater regime is primarily influenced by underground recharge and discharge, and where precipitation and evapotranspiration is neglectful, correlation between water level in the streams and groundwater level becomes crucial (Gregoric, et al., 2009).

Groundwater supplies 75% of water in dry season irrigation and almost all municipal water supplies. Thus, ground water is the major source of water that is used for municipal water supply and irrigation purposes (Rasel et al., 2013). Therefore it is very important to investigate the condition of ground water recharge in Abeokuta, as a sub-set of what obtains in the humid areas of Nigerian basement complex. It is very important to increase of ground water for agriculture, municipal and industrial needs. The main aim of this paper is to achieve the following specific objectives: Investigation of the fluctuation of ground water table as well as to evaluate the amount of recharge from the available rainfall data and find out the change in storage of ground water at the study region. Finally, the assessment of the environmental impact due to ground level fluctuation

Materials and Methods

Description of the Study Area

Abeokuta, the study area is situated in the south western region of Nigeria, about 70 km north of Lagos. The area lies between latitude 7° 06′ and 7° 13′ N and longitudes 3°15′ and 3°25′ E. It is located in a generally hummocky terrain, varying in altitude. The study area was selected from Abeokuta south local government which comprises of Olorunsogo, Ijaye, Lantoro, Oke Ejigbo and Iyana Mortuary as shown in Fig. 1.

Climate

The climate of the study area is tropical with distinct wet season (April-October) and dry season (November-March) which is controlled by the prevailing south-wind reaching the land from the limit of Guinea and the dry continental north east wind (Harmattan) originating from the Sahara desert. The wet season has two peak regimes which are separated by the August break.

Rainfall and Temperature

The average monthly rainfall for the peak regimes are about 190 mm (April-July) and 170 mm (September-October) and range annual rainfall is 130 mm. The latitudinal location of the state has given her an average higher temperature of 26.6 °C throughout the year with a mean minimum temperature 21 °C. The maximum temperature varies between 29 °C during the peak of the wet season and 34 °C at the onset of the dry season. The annual relative humidity is about 81%; this is attributable to the prevalence of moisture- laden tropical maritime winds over the state for about 9 months in the year combined with the fact that there is a high rate of temperature and dense vegetal cover in this region.

Soil and Vegetation

The area is underlain by the crystalline basement complex rocks of Precambrian origin. They are classified into three major groups: The migmatite-gneiss complex which consists of a crystalline complex of migmatites and gneisses, the schist belt which consists of the younger and the older granite which are pegmatite. The study area lies within the transition between the forest and savannah zones. This vegetation pattern is one which is defined as derived savannah zone. Thus, the derived savannah has come into existence as a result of the cultural practices of the people. Important tree species found in this vegetation type include *Lophira lanceolata*; *Daniellia olivern* and *Afzolia africana*. The most common grass species is the *Andropogon* spp.

The dominant hydrographic feature, the Ogun River, which runs in an approximate northeast-southwest direction with its main tributary, the Oyan River, joins it northwest of Abeokuta. The river Ogun acts as drainage basin of all the rivulets and streams in this area, these rivulets and streams are distributed on both sides of Ogun River. The streams in the study are Ala stream and Gangan stream (Figure 1).

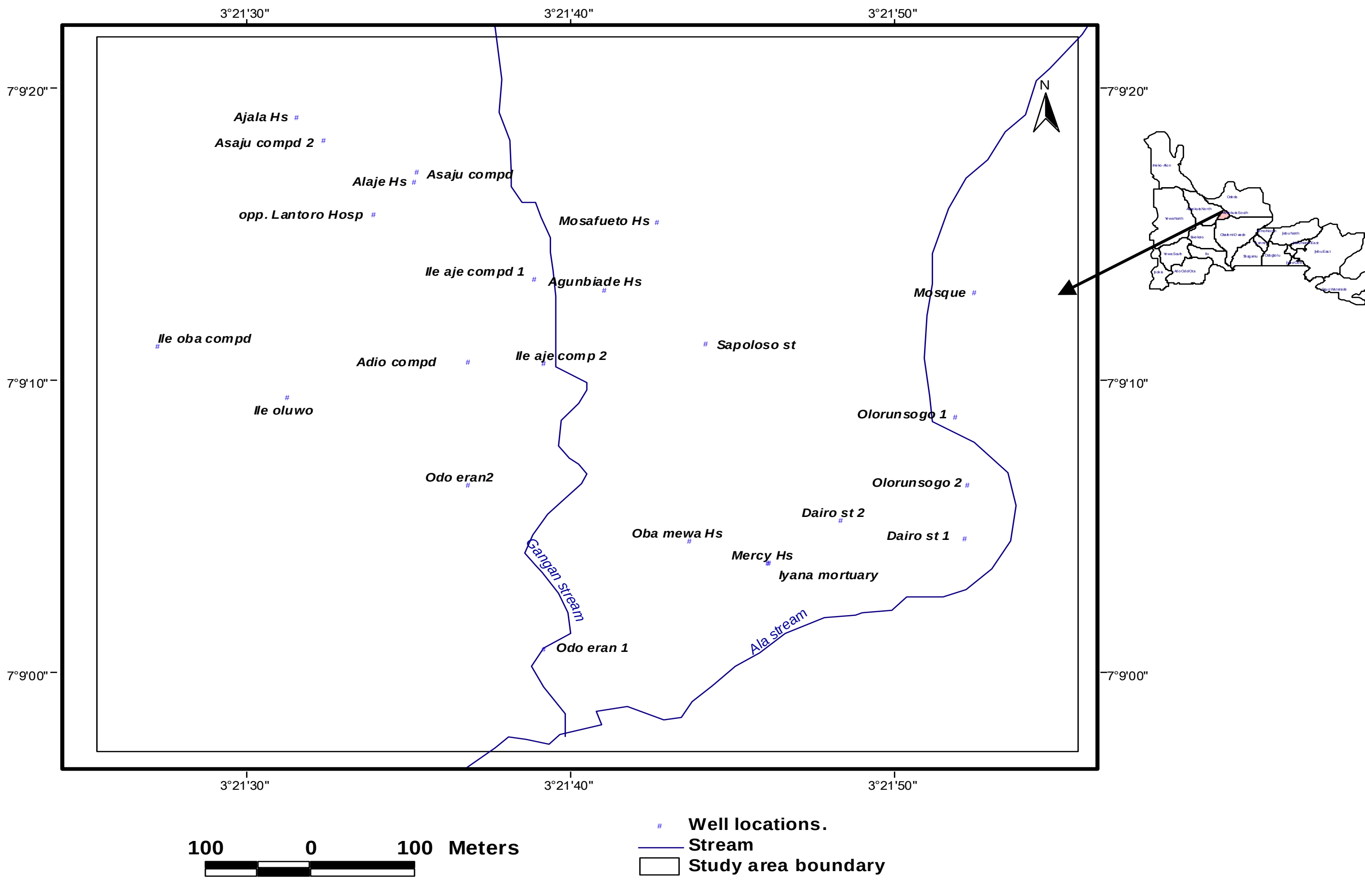

Figure 1: The map of the study area showing the selected streams and hand-dug wells

Data Collection

Measurement of Underground Water Level

The primary concern in this work is the dynamic change of the phreatic level; therefore the water level refers to the distance between the well head and the underground water table. The water level was measured by releasing a probe connected with a multimeter by dual-cable wire into the well. The multimeter was switched to the resistance shift. When the probe touched the water table, the cable was marked at the height of the well head, and the distance between the mark and the probe was measured after retrieval (Fan et al., 2008, Ayantobo et al., 2013).

In order to reflect the variation of water table in this period, the water table measurements of all observation hand-dug wells were made from January to October and weekly monitoring was done for the whole period. It takes 2-3 days each time to complete the measurements of all wells due to the dispersed locations of the wells. It is difficult to compare the water table data directly because the variation in the water table is small and the wells are very far from each other. Therefore, for each well, the subtraction of the nth observation H_n data from the initial observation data H_0 gave the relative water level at the nth observation ($H_0 - H_n$). The relative water level data were then statistically analyzed with the river discharge and hydrogeology data, and the variation of groundwater level was rationalized.

River Discharge Data

Real time data (discharges) of river was collected for a period of 10 months (January-October, 2008) covering the onset to the cessation of the rainy period. The discharges of the rivers were obtained by using surface float method (Adelana et al., 2006).

Hydrological Data

Daily rainfall data and evaporation data for the period of 22 years (1987-2008) for Abeokuta, Ibadan and Ikeja were obtained at Nigeria Meteorology Service Oshodi, Lagos, being the authorised Agency responsible for the weather services in Nigeria. The existing topographic map of the study area was obtained from the Abeokuta South local Government. The altitudes and the sample points coordinates (latituted & Longitude) were established using the Geographic position system.

Data Analysis

The analyses carried out include: Analysis of monthly fluctuation of groundwater level, derivation of normal graphs of maximum and minimum depth of water table from ground surface, discharge measurement using float method to determine the interaction between the stream and ground water, comparison of hydrographs of water level in the wells, rainfall graph, water table map and other factors affecting ground water fluctuations.

The static water level in the selected well was plotted against the duration of the research to show the fluctuation of the water. The hydrographs generated using the total discharge values were separated into two part, direct runoff and base flow. The base flow separation method was employed with the aim of estimating the groundwater recharge and to know whether the stream in the study area is losing or gaining stream. This method was chosen for this study because it has been reported to give reliable results by Adelana et al. (2006).

The hydrograph of the base flow may be represented by Eq. (1):

$$Qt = Qoe^{-\acute{a}t} \qquad (1)$$

Where Qo and Qt are the discharge at the beginning of the measurement period and at time t, respectively and á is the coefficient of recession or discharge coefficient.

Water table contour maps were produced. It is a map of the upper surface of the saturated zone and a graphic plot of the equilibrium relations between velocities, hydrologic properties of the water- bearing materials, and water-table slope of free water. A water table map was constructed from the static water level data; methods of construction include a topographic map of the study area, the measuring point for the well i.e. static water level of the well. This furnishes the data for a water table contour map for the period. A water map indicates the elevation of the water table by means of contours, in as much as flow in full an aquifer is almost horizontal a flow net can be constructed using the water table contours as equipotential line and drawing flow lines perpendicular to the contours. The flow net can then be used to find centre of recharge or discharge.

Results and Discussion

Descriptive Analysis of Rainfall

The average monthly variation of rainfall in the study area is presented in Figure 2. The monthly rainfall for the study area can be categorized into three seasons: two wet seasons ranging from April to October; and a dry season, which extends from November to March. The mid break, which is called the August-break was also observed. A mean annual rainfall value of 1625.9 ±167.12 mm was observed for the period of 22 years.

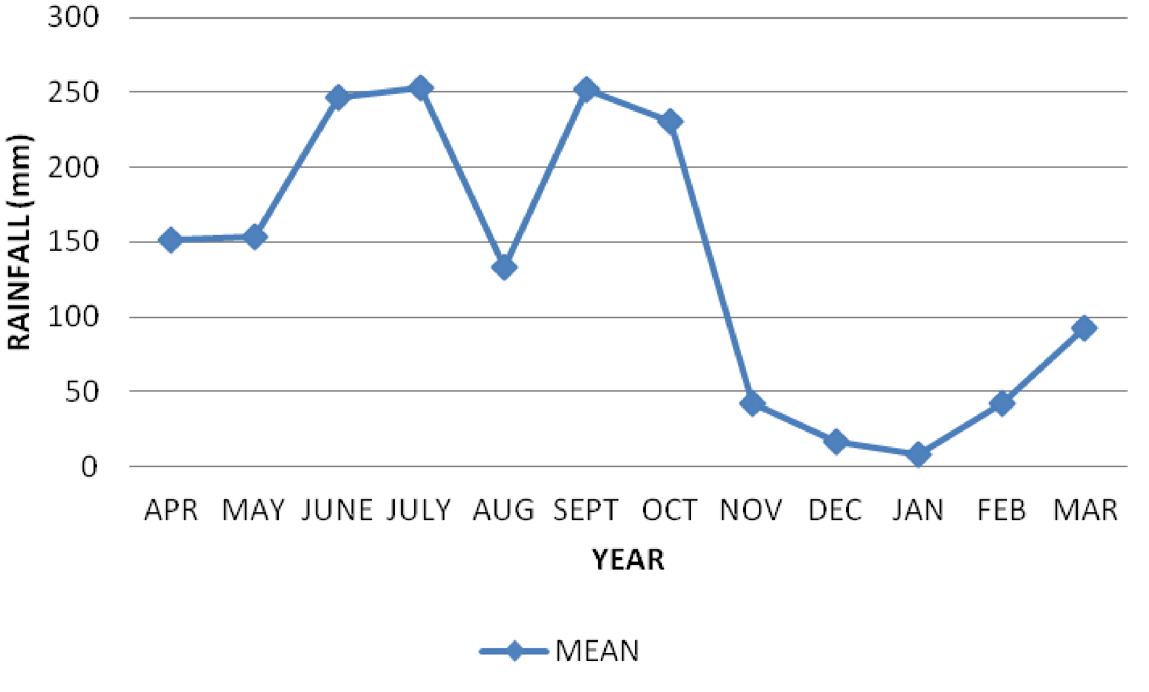

Figure 2: Trend of variation in mean monthly rainfall within the 22 years of study.

Discharge Measurement

The average monthly discharge values for the two streams from January to October, 2008 are presented in Table 1. Analysis carried out in this study includes those of stream discharge data, water level fluctuations, rainfall data, water table map and water quality data of the study area. High discharge values were observed in both streams between May and August due to wet season effects. However, Gangan stream showed higher discharge values than Ala stream which could probably be due to contributing effects from the neighbouring hand dug wells.

Table 1. The Average monthly discharge values for the two streams

Period	*Gangan stream* *Q (m^3/s)*	*Ala stream* *Q (m^3/s)*
Jan	0.08	0.02
Feb	0.13	0.13
Mar	0.04	0.08
Apr	0.03	0.10
May	0.31	0.20
Jun	0.50	0.30
Jul	0.55	0.34
Aug	0.30	0.10
Sep	0.10	0.33
Oct	0.20	0.30

Analysis of Groundwater Level Fluctuations

A groundwater level, whether water table of an unconfined aquifer or the pizeometric surface of confined aquifer, indicates the elevation of atmospheric pressure of the aquifer. Any phenomenon that can produce a change in pressure on the groundwater will cause the ground water level changing. The variation in groundwater table in any area in a year considering the maximum and minimum levels is referred to as fluctuation of the ground table in the study area (Rasel et al., 2013). The fluctuation of groundwater level is generally caused by change in groundwater storage, direct fluctuation of atmospheric pressure in contact with ground surface, deformation of aquifers, overdrawn of groundwater, natural causes such as earthquake flow to wind, secular and seasonal variation. The monthly variation of groundwater level in some selected wells is shown in the following Figure 3. Other static water level values are presented in Table 2. The result showed that the static water level rose during the wet season and declined during the dry season. Fluctuation of ground water level is different in magnitude depending on the extraction and recharge for different location. The water table fluctuation was basically controlled by varying thicknesses and permeability of basement rock. This might be due to abstractions from different consumers/populations.

Water table fluctuations tend to follow a fairly rhythmic seasonal pattern. High water levels occurred during the wet months and low levels during the dry months. The hydrograph of water level and rainfall of Dairo 1 clearly explained the response of the well during the wet season. The water rises during the wet season in response to rain infiltration (Figure 3). The reason for this may be due to recharge by rainfall. According to Loehnert (1981) who carried out an investigation into the groundwater system in the Akarabata district, the great fluctuation rate in his hydrographs was partly due to prompt water table response to Agbara river floods. This was proved by its isotope research. It was observed that between May and July the wells in the study area respond quickly to rainfall. The wells located at Odo Eran and Ile Oluwo increased by 2 m in the wet season compared to the dry season value.

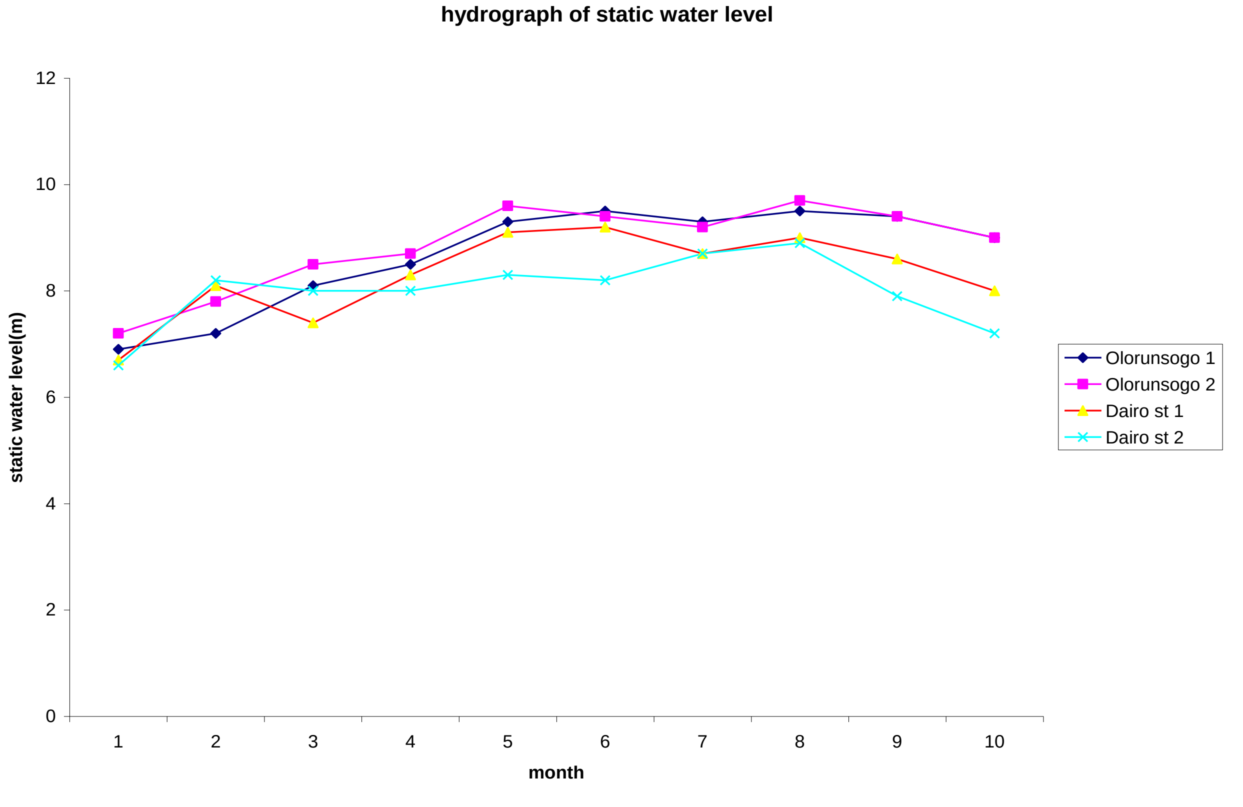

Figure 3: Hydrograph of static water level of selected wells in the study area

Table 2 Static water level of randomly selected hand-dug wells in meters, January-October, 2008

Wells	*Static Water Level (m)*									
Locations	***Jan***	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***
Odo Eran 1	8.1	7.2	6.7	7.7	9.0	9.2	8.9	9.0	8.6	8.4
Odo Eran 2	7.9	7.5	7.9	8.2	8.9	9.2	9.4	9.2	8.4	8.0
Ile Oba	8.0	7.7	6.9	7.4	8.4	9.0	9.2	9.3	8.2	8.7
Ile Oluwo	5.3	3.6	3.1	3.6	3.2	5.3	7.3	8.4	7.3	7.5

Asaju 1	9.3	8.6	8.6	9.0	8.4	8.7	8.8	9.1	8.9	8.0
Asaju 2	9.3	8.7	8.7	9.0	8.4	8.5	8.8	9.2	9.0	8.5
Ajala	8.0	8.4	6.9	7.3	8.4	9.1	9.2	9.3	8.2	7.5
Alaje	3.6	3.5	3.4	4.0	4.7	3.6	4.8	5.2	7.3	7.0
Mosafueto	4.0	4.4	4.6	5.2	5.4	6.8	7.2	8.6	4.4	4.0
Opp. Lantoro	4.0	3.3	3.0	3.1	3.0	4.1	5.1	5.2	9.1	7.0
Mosque	4.3	4.4	4.8	4.6	5.5	6.2	7.6	8.0	9.0	8.5
Agunbiade	8.2	8.3	7.4	8.7	9.2	9.0	9.5	9.5	8.3	7
Ile Aje	7.5	5.9	6	6.1	8.2	8.4	8.7	8.8	8.3	7.5
Ile Aje 2	7.0	7.1	7.1	6.9	7.7	7.9	8.3	8.6	7.7	7.0
Sapoloso	6.2	6.2	6.2	6.5	6.4	7.0	7.1	8.1	8.0	7.5
Adio	8.6	8.2	8.2	7.4	7.6	8.8	7.9	8.3	8.9	8.0
Iyana mortuary	8.7	8.6	8.6	9.0	9.0	9.5	9.3	9.2	8.0	7.0
Oba Mewa	5.0	8.5	8.5	5.5	7.6	8.0	8.2	8.7	8.8	8.0
Mercy	7.5	9.0	9.0	7.3	7.5	7.6	8.2	8.2	8	7.5

Water Level Map

Figure 4 shows the configuration of the water level map of the study area. A water table map indicates the elevation of the water table by means of contours. Flow directions appeared tortuous and dictated by surface topography while the flows are generally towards the stream channels in the study area. The water table map enables the identification of major areas of recharge. One occurs on a water divide that runs along Mosafueto also Agunnbiade and Ile Aje compound in the central part of the study areas, and also Adio compound as well as Odo – Eran 2 in the western part of the study area. Groundwater flows on the water divide towards River Ogun, this is evidenced by the occurrence of many streams and springs especially in the rainy season. It is also observed from the water table map that topography influences the flowing direction as water flows from higher elevation to lower elevation well in the mosque area of the study area (Department of Conservation, 2009).

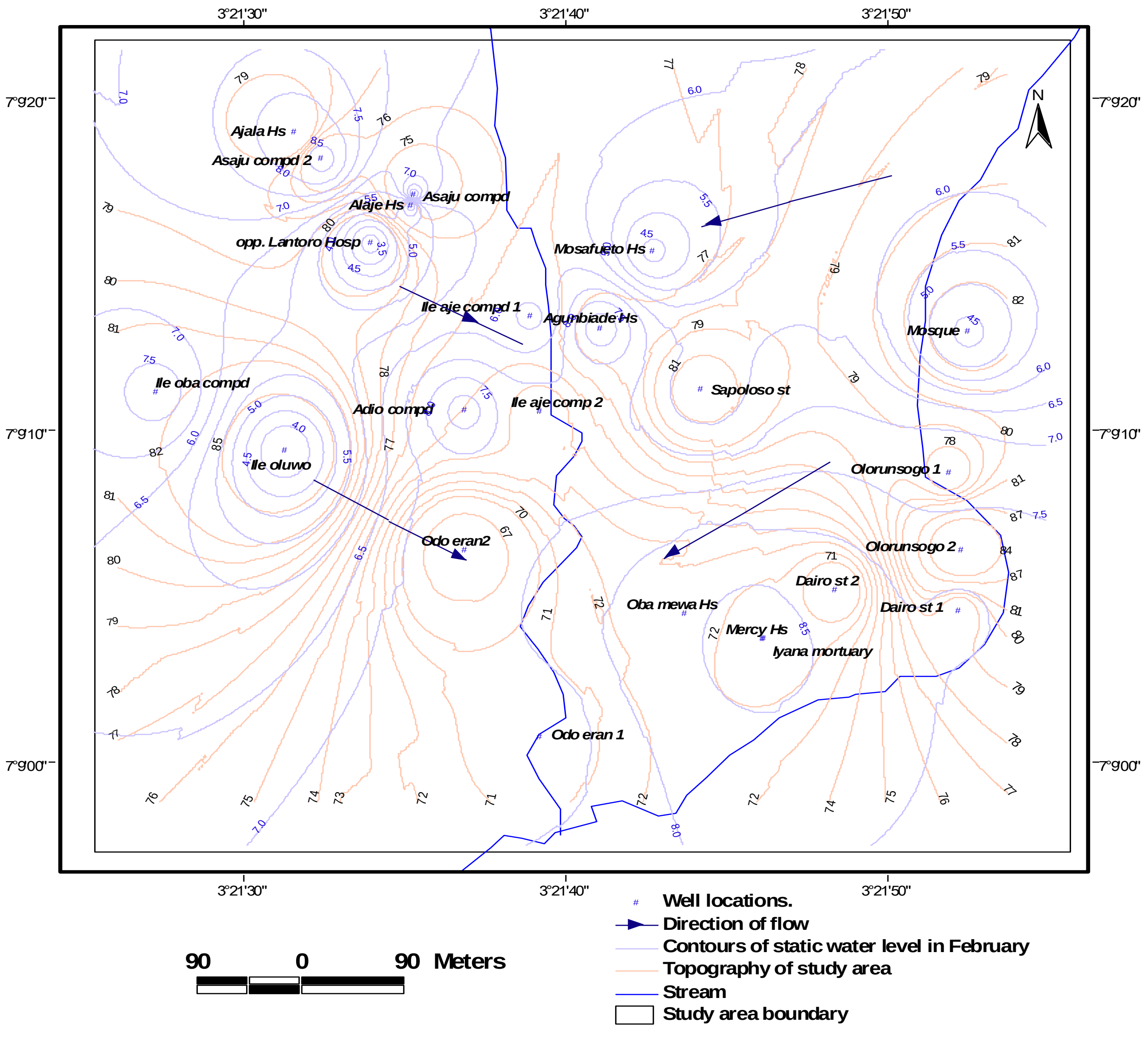

Figure 4: Contour Mapping of the water table of the study area

Effects of Effluent Stream on the Static Water Level

The influence of the effluent streams on the static water level (SWL) of wells was clearly observed for Agunbiade and Odo Eran wells which are located almost at equidistant points on both sides of a stream that survived the dry season as a base flow (Figure 5). The water declines in altitude towards the valley for the stream to maintain its perennial nature, it withdraws water from underground water reservoir thereby causing a gradual depletion in the groundwater level, from the stream hydrograph (Figure 5), and it was clearly shown that the well closer to the stream suffer much depletion than those farthest away from the stream. The common diastrophic features, through which groundwater or surface water percolates are jointed, fractured and sheared zones. These are the most abundant features in the area because it is a basement area. Groundwater occurs within the weathered zones or rather the weathered material serves as aquifers. Appreciable porosities and permeabilities are developed through fracturing and weathering of the rock. The depth of overburden had been found to vary from a few centimetres to twenty metres on the average. The crystalline nature of the rocks in Abeokuta area accounts for the low yields associated with the aquifers. Generally, it was observed that wells located in depressions or lowlands tend to be shallower than those on topographically higher ground (Asseez, 1972). Another factor that has significant influence on groundwater in the area is the degree and extent of fracturing and jointing of the rocks. Similar study conducted by Chand et al. (2004) has identified factors such as type of soil and degree of weathering/fracturing to influence groundwater recharge. In area where surrounding rocks are highly fractured or jointed, groundwater tends to occur at shallower depth than areas where the rock is less jointed and fractured. Since it is this diastrophic features that provides openings through which water infiltrate into the ground in the basement complex, the more fractured and jointed zones occurring in a rock, the more water that infiltrates into the ground through the rock.

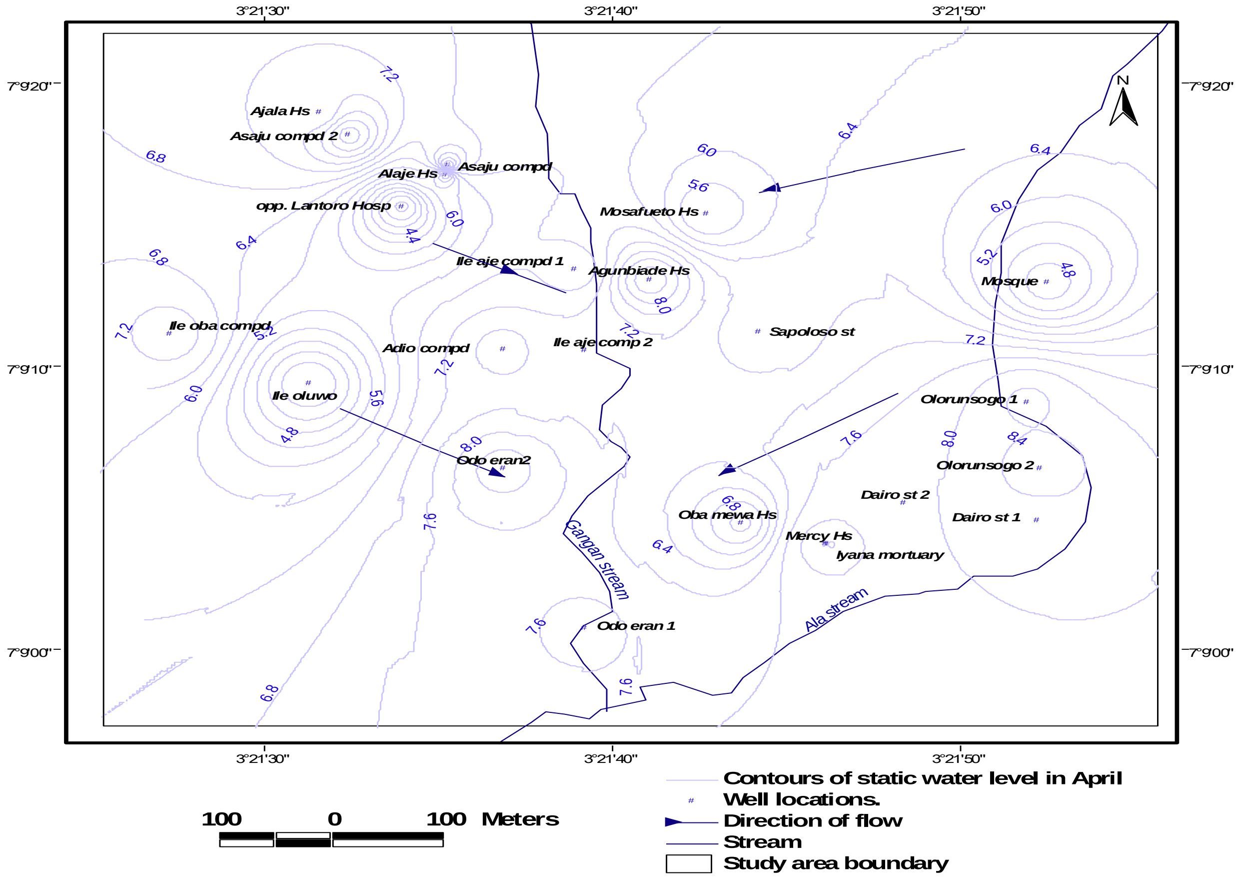

Figure 5: Effect of the efluent streams on static water level of the wells in the study area

Effects of Evaporation on the Static Water Level

Evaporation effect on the SWL of well samples is shown in Figure 6. It was observed that correlating the evaporation data of the study area with the SWL revealed little effect on fluctuations. Studies have shown that evapotranspiration had effect on fluctuation (Acharya et al., 2014). It is expected that the result would have effect on SWL if evapotranspiration data was used instead of evaporation data (Gribovszki et al., 2010).

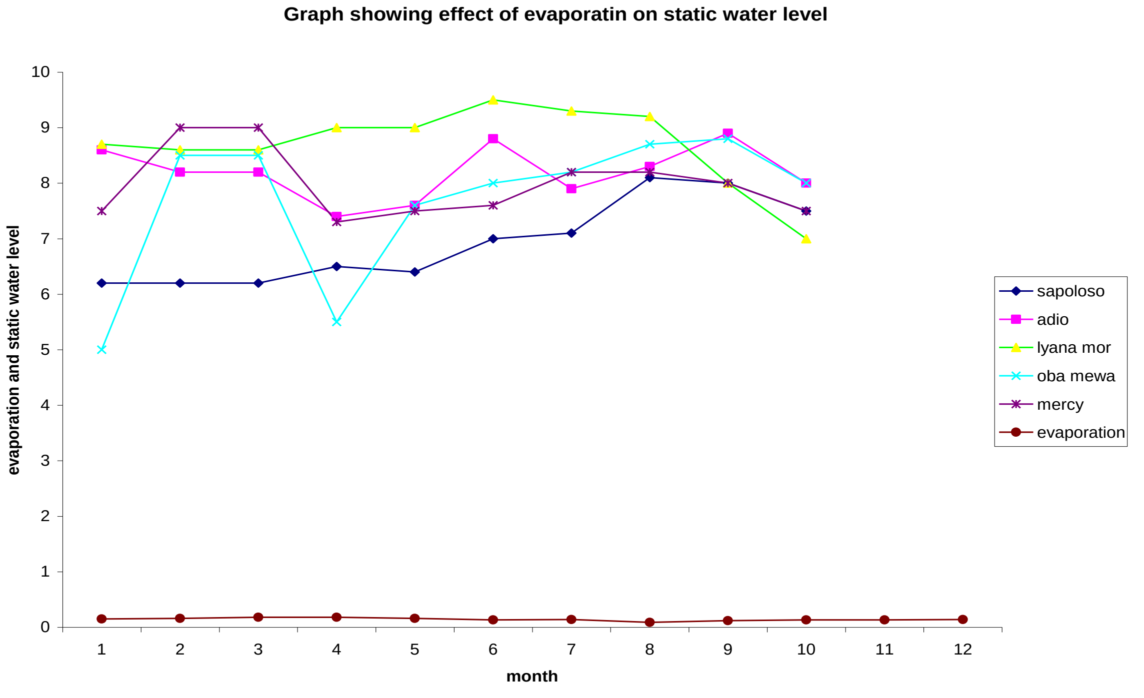

Figure 6: Effect of evaporation on static water level

Effects of Abstraction on the Static Water Level

Wells are strongly influenced by usage and pumping. A close observation of Ajala well on early morning shows the effect of abstraction (Figure 7), as SWL was 5.2 m and decline to 2.8 m in 4 hours later, as a result of abstraction of the well, the water level dropped by 2.4 m. Also, longer time of pumping cycle affects the surrounding well in the area, as it was observed in Sapoloso borehole during longer pumping period; the surrounding wells that are in the same direction of flow were greatly affected. Such lowering of water table by pumping affects stream flow crossing the area of influence if the stream is supplied from and therefore "supported" by the water table, and may perhaps change the stream from effluent to influent, thereby causing the stream to lose water. The influence of pumping discharges on groundwater fluctuation has also been reported by Rojas and Dassargues (2007).

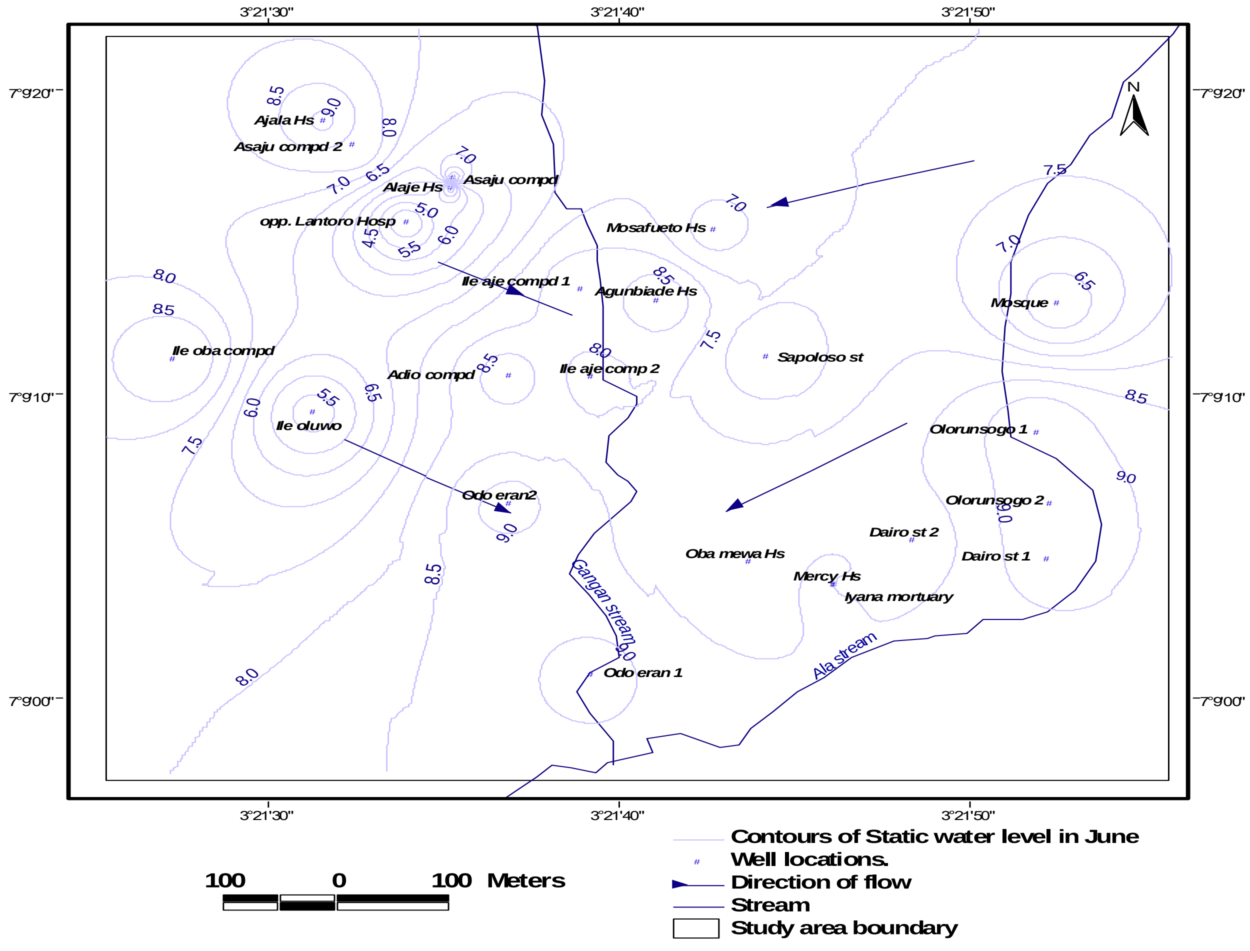

Figure 7: Effects of Abstraction on static water level of the wells

Conclusion

The ground water level in the study area rises and falls continuously with the advance of wet and dry seasons with peak value observed between May and September. This study showed that ground water level in the aquifers of the study area is basically controlled by the sources of recharge such as rainfall, stream and thickness of the lateritic overburden. Analysis of hydrographs has therefore helped to determine the interaction between groundwater and surface water (stream) in the study area, in which the stream was discovered to be effluent stream withdrawing water from underground reservoir in order to maintain flow. The water table map also indicates the response of ground water to rainfall. In summary, it has been discovered from this study that rainfall is not the only factor affecting ground water level fluctuations. Factors including stream flow, increase demand (abstraction) and growing population also contributed to the fluctuations. It is sincerely hoped that this present work will provide pressing information in the economic development and rational utilization of groundwater to the public benefit and economic growth of the nation. The case studies in the report identified the natural and human induced stresses on the aquifers and the relative and combined effects of each on groundwater levels. This illustrates the point of emphasis, that groundwater level fluctuations must be given a considerable attention for proper development, management and protection of the Nation's groundwater resources.

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References

Adelana, S.M.A., Olashehinde, P.I. and Vrbka, P. 2006. A quantitative estimation of groundwater recharge in part of the Sokoto Basin, Nigeria. J. Environ. Hydrol. 14, 1-16, http//hydroweb.com/jeh/jeh2006/adelana.pdf.

Alagbe, S.A. 2002. Groundwater resources of river Kan Gimi Basin, north-central, Nigeria, Environ. Geol. 42, 404-413, doi: 10.1007/s00254-002-0544-9.

Acharya, S., Mylavarapu, R. and Jawitz, J. 2014. Evapotranspiration Estimation from Diurnal Water Table Fluctuations: Implementing Drainable and Fillable Porosity in the White Method. Vadose Z. J. 13(9).

Asseez, L.O. 1972. Rural water supply in the basement complex of Western State, Nigeria. Hydrol. Sci. J. 17(1), 97-110.

Ayantobo, O.O., Oluwasanya, G.O., Idowu, O.A. and Eruola, A.O. 2013. Water Quality Evaluation of Hand-Dug Wells in Ibadan, Oyo State, Nigeria. Glob. J. Sci. Front. Res. Agric. Veter. 13(10), 56-64.

Chand, R., Chandra, S., Rao, V.A., Singh, V.S. and Jain, S.C. 2004. Estimation of natural recharge and its dependency on sub-surface geoelectric parameters. J. Hydrogeol. 299, 67-83, doi:10.1016/j.jhydrol.2004.04.001.

Danyar, S., Song, Y. D. and Jumakeld, M. 2004. Influence of groundwater level change on vegetation coverage and their spatial variation in arid regions. J. Geogr. Sci. 14(3), 323 - 329.

Department of Conservation. 2009. An introduction to ground water hydrology, Maine Geological Survey Handbook. On line at: http://www.maine.gov/doc/nrimc/mgs/explore/water/hand book/refs.htm.

Fan, J.L., Xu, X.W., Lei, J.Q., Zhao, J.F., Li, S.Y., Wang, H.F., Zhang, J.G. and Zhou, H.W. 2008. The temporal and spatial fluctuation of the groundwater level along the Tarim Desert Highway. Chinese Sci. Bullet. 53 (II), 53-62.

Gregoric, E., Durovic, N., Rudic, D. and Pocuca, V. 2009. Groundwater types in southeast SREM, J. Agric. Sci. 54, 19-29, doi/1450-8109/2009/1450-81090901019G.

Gribovszki, Z., Szilágyi, J. and Kalicz P. 2010. Diurnal fluctuations in shallow groundwater levels and streamflow rates and their interpretation – A review. J. Hydrogeol. 385 (1-4), 371-383. doi:10.1016/j.jhydrol.2010.02.001.

Loehnert, E.P. 1981. Groundwater quality aspects of dug wells in Southern Nigeria, Proc. Int. Symp. Qual. Groundwater, Stud. Environ. Sci., 17, 147-153.

Rasel, H M., Hasan, M.R., Ahmed, B. and Miah, S.U. 2013. Assessment of Groundwater fluctuation and Recharge due to rainfall in Barind Area under Greater Rajashahi District 9North Western part of Bangladesh. Internatioanl Journal of Civil & Environmental Engineering IJCEE-IJENS Vol:13 No:02

Rojas, R. and Dassargues, A. 2007. Groundwater flow modeling of the regional aquifer of the Pampadel Tamarugal northern Chile, J. Hydrogeol. 15, 537-551, doi:10.1007/s10040-006-0084-6.

Song, Y.D., Fan, Z. L. and Lei, S. D. 2000. The Research of Water resources and Ecology in Tarim River Basin of China (in Chinese). Urumqi: Xin-jiang People's Publishing House.

Todd, D.K. and Mays L.W. 2005. Groundwater Hydrology, 3rd Edition. John Wiley and sons, Sona Ltd., United States, 656p.

Yang, L.Y. and Wang, G.X. 2005. Variations of groundwater in Zhangye basin of the middle reaches of the Heihe River in recent two decades (in Chinese). J. Glaciol. Geocryol. 27(2), 290-296.

Yang L Y, Wang G X. Variations of groundwater in Zhangye basin of the middle reaches of the Heihe River in recent two decades (in Chinese). J Glaciol Geocryol, 2005, 27(2): 290-296.

SITE OPTIMIZATION FOR JATROPHA BIODIESEL PRODUCTION FACILITIES IN NIGERIA USING GIS AND REMOTE SENSING TECHNOLOGIES.

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Abstract:
Nigeria is one of the countries in the world where the problem of land availability for biodiesel production may not be considered as pronounced. This is because about 66% of agricultural land in the Country is not cultivated. The Nigeria Biofuel Policy (2007) stipulated that one of the responsibilities of the Ministry of Agriculture is to support biofuel companies in land acquisition and utilisation strategies. The aim of this research project was to optimize sites for Jatropha – based biodiesel production facilities in the Country. Multi-criteria evaluation (MCE) was the methodology employed and implemented in GIS environment. The first model excluded constraints from the analysis. The second model identified suitable areas for cultivation of Jatropha by weighting the input parameters using Analytical Hierarchy Process (AHP), implemented through the weighted overlay function. Third model optimized locations for Jatropha – based biodiesel production facilities by employing service area modelling through network analysis. Notwithstanding the limitations in the data, the methods and the GIS tools, Toro Local Government Area of Bauchi State was found to be the most ideal location for a Jatropha – based biodiesel production facility in Nigeria with a total of 13,085 Gg within 200km of supply area. Based on the results and Nigeria's potentiality in Jatropha production, it was concluded that the Country can be one of the world leading Jatropha – based biofuel producers. This will create lots of jobs, attracts carbon credit by decreasing carbon emission and generates foreign exchange through export or import substitution.

Keywords: Carbon emission, Jatropha, Biodiesel, GIS, Remote Sensing, Optimal sites

Highlights:

- Toro LGA is the best location for Jatropha based biofuel facility
- Within 200km service area, there is a potential feedstock of 13,085 Gg
- GIS and Remote Sensing are powerful tools in decision making
- Nigeria has the potential to be one of the world leading biodiesel producers

1. Introduction

There is growing concern about the environmental impacts of fossil fuels. Fuels such as petroleum, natural gas, coal, shale oil and bitumen are the main souces of lighting, heating and transport energy. Beside the main constituents such as carbon and hydrogen, these fuels consists of other substances like metals, sulphur and nitrogen compounds [1] which serve as green house gases or pollutants. According to [2], there is no alternative source of energy, in sight, that can replace fossil fuels. Their arguments are that fossil fuels account for 86% of the rising global energy demand and the steady increase in the reserves without immediate depletion in sight, though they are still finite. Growing world population [3] couple with global awareness about climate change had led many national energy systems to adopt different carbon dioxide policies and reduction targets [4], planning several forms of renewable energy utilization. The objectives are to address the shortage of and provide sustainable clean energy and to encourage infrastructure development as stipulated in the Kyoto directive towards global decarbonisation [5]. Major arguments against crop based biofuel development are the impact on food supply and land availability for food crops cultivation. However, according to [6], second generation biofuels such as non-food crops and non-edible vegetable oils does not pose food security concern as they are not used as staple. And according to [7], food – energy analysis in Brazil showed no land conflict between food supply and biofuel crops production. In fact, according to them, there could be direct correlation between biofuel investments and food production in areas with good land availability such as Nigeria. According to [8], Nigeria has a total land area of 91.07 million hectares, of which 77% is cultivable. According to them also, only 44% of the cultivable land is under cultivation, the remaining 66% is under permanent pastures, though it could be argued that some of the pasture lands are used for grazing.

2. Background

One of the strategies used to ameliorate the environmental concerns of fossil fuels is using biofuels as blend to petroleum fuels. This creates huge potentials for agricultural sector development, especially for a crude oil dependent economy such as Nigeria's with a proven reserve of 36b barrels [9] and prospects for more reserves to be discovered. This will improve employment generation because agriculture employs large portion of the populace in the Country. With the ethanol produced locally, foreign exchange will be saved with import sustitution or earned with export. Environmental quality will improve if the E-10 policy is fully implemented and thus, carbon credit could be earned. In 2005, a division was created in the Nigerian National Petroleum Corporation (NNPC) called Renewable Energy Division (RED) to deliver and pioneer development of biofuel industry in the Country. One of the primary aims was to link the oil and gas sector with agricultural sector through commercial production of biofuels from selected energy crops as blend stock for petroleum fuels [10]. Although biofuel programme in the Country was said to have been evaluated in 2012 as unsatisfactory [7] and the development process was very slow due to regime change [11], huge potential still exists for the industry to be developed given the land availability and the current government's commitment to economic diversification through agriculture. According to NNPC [12], the National Biofuel Programme plans to use Sugarcane, Cassava, Sweet sorghum, Oil palm and Jatropha as feedstock and by 2020, 2% of the arable land will be required for the project. The Nigeria National Biofuel Policy [13] outlined the legality of extraction and use of biofuels as well as the roles of various stakeholders. The Policy stipulated that one of the responsibilities of the Ministry of Agriculture is to support land acquisition and utilisation strategies by biofuel companies. According to the policy also, the ethanol is meant for E-10 (10% ethanol blended with 90% petrol). According to [14], Nigeria has the capacity to produce 47,970 Gg from biomass and residues annually. According to [15], no fewer than 20 new bioethanol projects were initiated following the release and implementation of the biofuel policy. Ohimain [15] also concluded that based on some preliminary details of the projects, many of the projects' outputs do not appear to be feasible based on their reported quantity of existing feedstock. Therefore, more feedstock need to be exploited to make those projects viable and sustainable. This could be achieved by exploiting all the non-controversial feedstock sources and putting the available land areas in to production. The purpose of this research project was to identify land areas suitable for Jatropha production and optimize sites for Jatropha based biofuel production facilities.

3. Jatropha

Jatropha has been identified and is being promoted as relatively yielding and multi-purpose biofuel feedstock that can be cultivated on marginal agricultural lands [16], which is one of the crop's advantages regarding impact on food supply. According to [17], the crop is drought-resistant, non-edible and thus does not compete directly with food and can sustainably be promising biofuel feedstock even where there is scarcity of energy input. According to [17] also, the optimum growing conditions are found in areas with free-drain sandy and loamy soils that are not prone to waterlogging, 500 – 1000 mm annual rainfall and temperatures around 20^0 – 28^0C but cannot tolerate temperatures below 7^{0}C. According to [18], Jatropha grows in lower altitudes of 0 – 500 metres above sea level, can flower at any time of the year without sensitivity to day length and can survive 250 – 300 mm annual rainfall, though 600 mm is required to flower and set fruits. Though the crop has been observed to be grown under 3000mm of annual rainfall, higher precipitation may cause fungal attack [18]. The crop can also survive poor dry soils though, survival does mean higher productivity, and the soil pH should be between 6.0-8.0/8.5 [18]. Jatropha, adapted to many African countries, provide several other economic and environmental benefits apart from oil extraction. It is used as a nutrient supplement in the production of animal feeds if toxins are removed, prevention of soil erosion and land reclamation. Due to its being toxicity, it is used as a fence against animals for crop lands [19].

4. Data, Materials and Methods

Agro meteorological data comprising rainfall, relative humidity, minimum and maximum temperatures were acquired from the Nigerian Meteorological Agency (NiMet). It is 20 years' data (1994 – 2013) collected at 44 weather stations distributed over the country and was supplied in Microsoft Excel format. The soil and soil erosion maps were supplied in jpeg format scan of original paper map by the Office of the Surveyor General of the Federation (OSGoF). According to the Office, the soil map update was done between 2010 and 2011 using data from Geological Survey Agency and Nigerian Bureau of Statistics under Federal Government contract. The flood map, scale 1: 7,500,000 as jpeg scan of the original paper map, was sourced from the National Emergency Management Agency (NEMA). It is the flood extent map of the 2012 flood considered to be the worst in five decades. The map of the game reserves, scale 1: 10,000,000 and as jpeg (digital) was downloaded from the website of the National Park Services. The feedstock potential map was extracted in jpeg format from a Powerpoint presentation by Nigerian National Petroleum Corporation (NNPC) at the second Nigerian Alternative Energy Expo, 2012. After considering ASTER Global DEM and GMTED2010, SRTM was found to be more accurate for use as DEM dataset in the study. Fortunately, the recently (2014) released void-filled, 1-arcsecond (30 metres) global data covered Nigeria. It was downloaded from the USGS EarthExplorer website. The settlement datasets were downloaded from the NASA Socio-Economic Data and Application Centre (SEDAC). The water, transport (roads and rail) and administrative boundary datasets were downloaded from DivaGIS which was the last option for these datasets (Table 1).

ArcGIS 10.2.2 and ERDAS-Imaging 2014 were the two main soft wares used in the analysis, though Microsoft Excel 2013 was used to implement Analytical Hierarchy Process (Pairwise Comparison). The three major pre-processing were digitization (for all the jpeg files), interpolation to create raster surfaces for the agrometeorological data (rainfall, relative humidity and temperature) and mosaicking 101 tiles covering Nigeria (for the SRTM). All the raster surfaces were resampled to 100 metres hence, the nominal map scale of 1: 250,000 was used in the analysis. All the input datasets were aligned to UTM Zone N32, WGS84.

The study was conducted in two stages. Multi Criteria Evaluation (MCE) through Analytical Hierarchy Process (Pairwise Comparison) was employed and implemented using weighted overlay function in GIS to determine most suitable areas for cultivation of Jatropha in Nigeria. Based on the principles of the Roundtable Sustainable Biomaterials (RSB), seven (7) constraints were identified and eliminated by creating buffers around them and applying union function in the ArcMap modeler (figure 1). These are settlements, reserved areas, flood zones, severe erosion sites, water bodies, roads and railways. Based on the ecological requirement of the crop and accessibility, eleven (11) factors were considered in the land suitability analysis. These are soil, rainfall, temperature, relative humidity, elevation, slope, nearness to water bodies, nearness to labour and markets (settlements), nearness to roads and rails. Weights (table 2) were generated using pairwise comparison and consistency ratio of

0.07376 was achieved. A model was, therefore, developed and Weighted Overlay Function was applied to determine most suitable areas for Jatropha cultivation in Nigeria (figure 2).

Table 1: Data and sources

S/N	Data	Format	Description/ Attribute	Attribute Type	Resolution/ Scale	Source
1	Agro-meteorology	Field/Point Data (Excel)	Rainfall, Temperature and Relative Humidity	Numerical	44 weather stations	NiMet
2	DEM	SRTM (BIL)	Elevation and Slope	Numerical	30meters	USGS
3	Soil	Jpeg	Soil Types (Map)	Categorical	1: 6,000,000	OSGoF
4	Erosion	Jpeg	Soil Erosion (Map)	Categorical	1: 6,000,000	OSGoF
5	Flood Zones	Jpeg	Flood Extent (2012)	Categorical	1: 7,500,000	NEMA
6	Game Reserves	Jpeg	Area extent	Categorical	1: 10,000,000	NPS
7	Feedstock	jpeg	Potential Zones	Categorical	1:10,000,000 (estimate)	NNPC
8	Settlement	Raster grid	Urban extent	Categorical	30metres	NASA
9	Settlement	Vector/shp	Settlement points	Categorical	134 points	NASA
10	Water Bodies	Shapefiles	Areas and lines	Categorical	1379 lines 1186 polygons	DIVAGIS
11	Road Network	Shapefile	lines	Categorical	4708 lines	DIVAGIS
12	Rail Line	Shapefile	lines	Categorical	33 lines	DIVAGIS
13	States and LGAs Boundaries	Shapefiles	Polygons	Categorical	37 and 774 polygons respectively	DIVAGIS

Table 2: Criteria weights

Criterion	Weights	Weights (%)	Approximate Weights (%)
Soil	**0.204635**	20.46353	**20**
Rainfall	**0.229156**	22.91563	**23**
Temp	**0.117286**	11.72859	**12**
Humidity	**0.085237**	8.523708	**9**
Water	**0.1548**	15.48005	**15**
Elevation	**0.042025**	4.202536	**4**
Slope	**0.026746**	2.674579	**3**
Roads	**0.058423**	5.842298	**6**
Settlements	**0.047319**	4.73192	**5**
Rail	**0.013549**	1.35489	**1**
FeedstockP	**0.020823**	2.082266	**2**

In stage two, road transport was used to determine the location with the highest amount of feedstock within 200km service area, based on which the facilities' sites were optimized (figure 3). Shi *et al.* [20], in their study used potential biomass as the feedstock, but since the evaluation in this study was based on an agricultural crop, yield per hectare was adopted as the potential feedstock amount. According to [21], the average yield for Jatropha after five years and without irrigation 2.75 Mg ha^{-1}. Because 100 by 100 metres is the cell size, each pixel represents a hectare. A raster surface was created for the estimated yield. Service (Supply) area modelling was adopted because of its underlying philosophy that feedstock beyond certain distances are not viable for a given location due to transport cost and therefore may not be considered for a facility at that location. The scope of this study covers the whole Country and by implication, facilities to be spatially optimized may not viably receive supplies from all the suitable feedstock production areas. Because the analysis is along the roads network, [20] created biomass points along the roads to serve as aggregation centres and therefore potential candidate sites. In this study, Local Government Areas' (LGAs) administrative boundaries and their centroids [22] were used as the feedstock aggregation units and centres respectively. This is based on the fact that roads buffer was eliminated as constraint and the assumption that the feedstock can viably be transported to any location within the LGA boundaries. Near analysis showed that all the centroids are within 25 km of at least one road. The amounts of feedstock potentially available in each of the LGAs was calculated and the amounts were aggregated to the centroids. The centroids without any feedstock were eliminated, three centroids with the highest feedstock were selected and service areas created around them. Then all the feedstock within each service area were aggregated to the leading centroid which serve as the potential facility location.

5. Results

Figure 4 shows the potential feedstock amounts in each LGA and it was based on the most suitable areas derived in the land suitability analysis in stage one. Based on single cropping season, the amounts ranges from 2.75 Mg in Bayo LGA of Borno State to 928.10 Mg in Toro LGA of Bauchi State. The aggregation centres serve as the potential candidates and service areas were created around the top three (3) candidates. The three sites selected (Figure 5) were therefore, Toro (Bauchi State), Borgu (Niger State) and Mariga (Niger State). This was done in order of preference based on feedstock amount, though overlap between service areas was avoided. Toro, the top candidate site, is less than 2 km from the road, Borgu is less than 4 km while Mariga is within 7 km of the road. After analysing the service areas of each of the 'facilities', Toro holds its position as the facility with the highest potential feedstock supplies having 13,085 Gg $year^{-1}$ (Figure 6). The table in the figure shows that Toro site can receive supplies from 172 LGAs within the service area. It serves as the candidate with highest optimization priority for Jatropha – based biodiesel production facility among 285 candidates. This location was displayed on GoogleEarth to get more understanding of the location (Figure 7). Because there are many areas in Nigeria much suitable for Jatropha production, the Country can be among the world leading Jatropha – based biodiesel producers/exporters. This will create lots of jobs, improve environmental quality, generate foreign exchange and earn carbon credit.

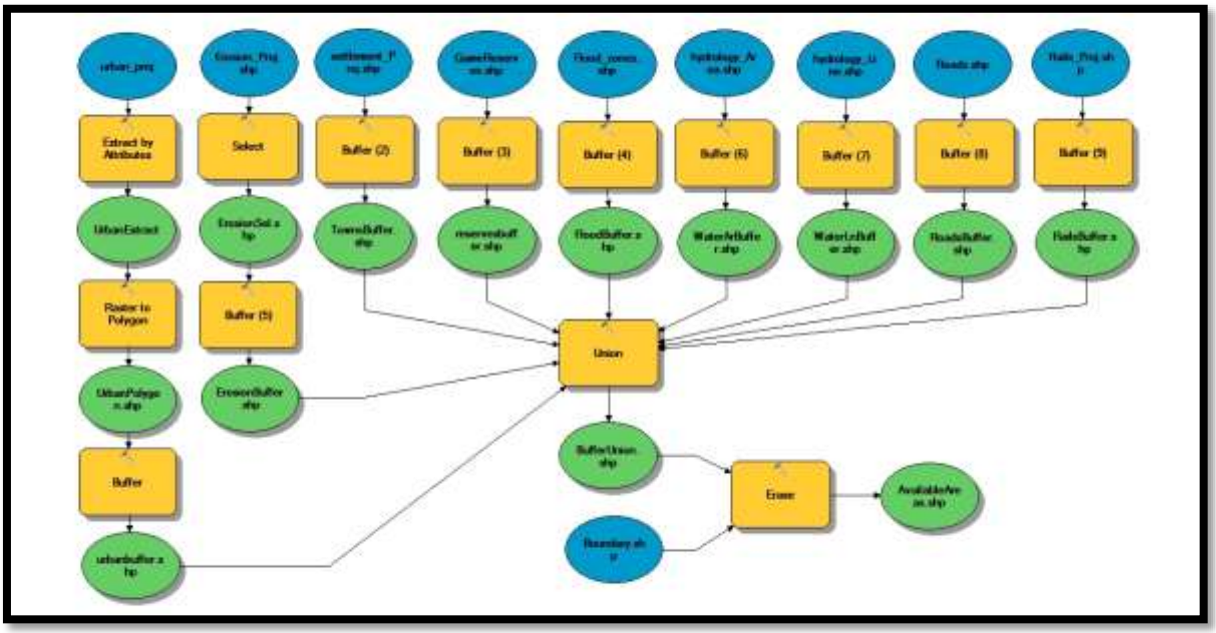

Figure 1: Constraint elimination model

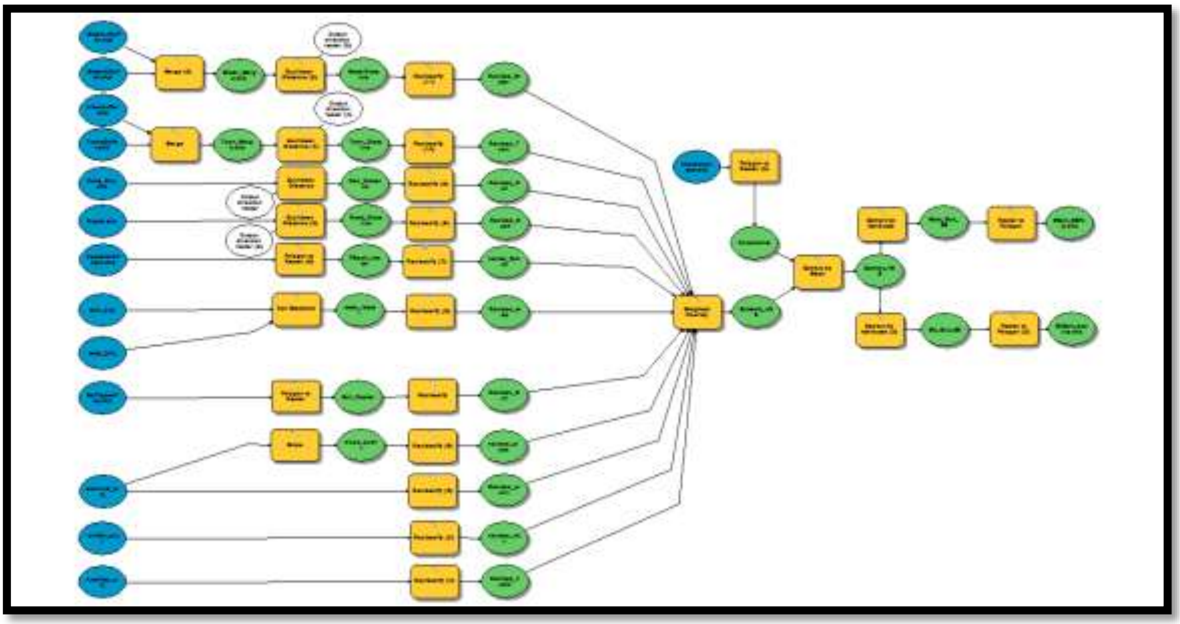

Figure 2: Land suitability model

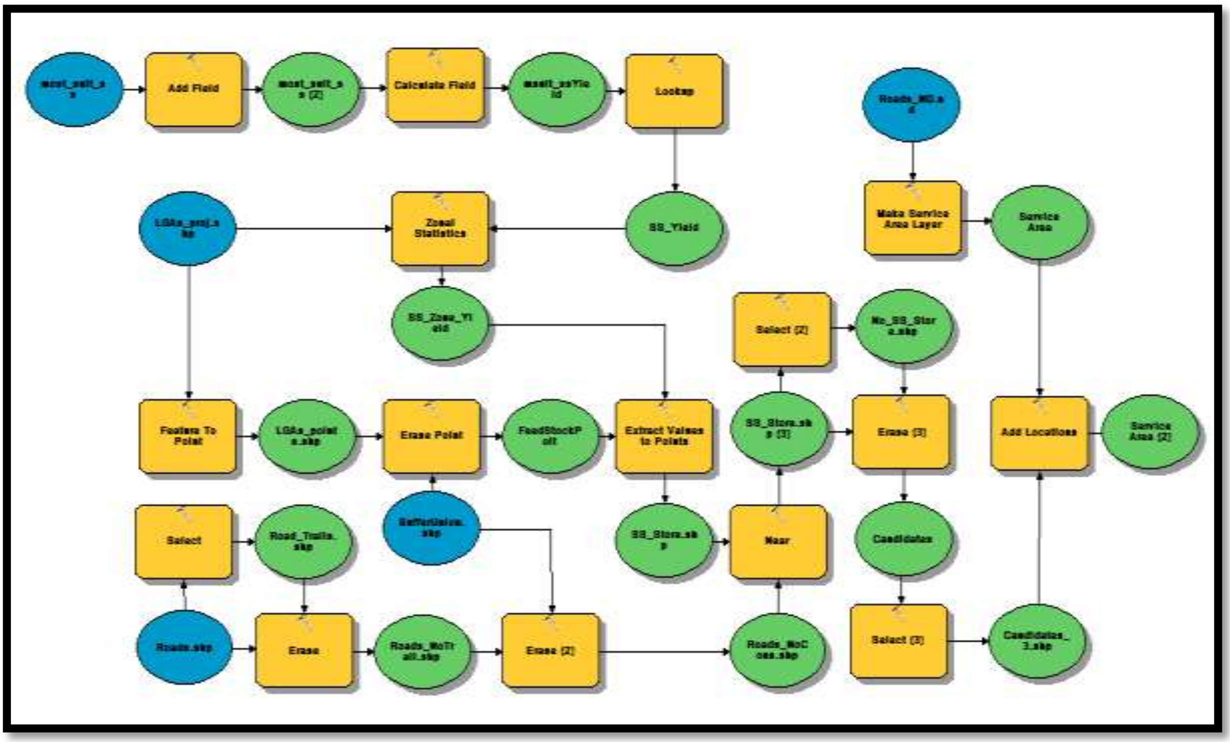

Figure 3: Site optimality model

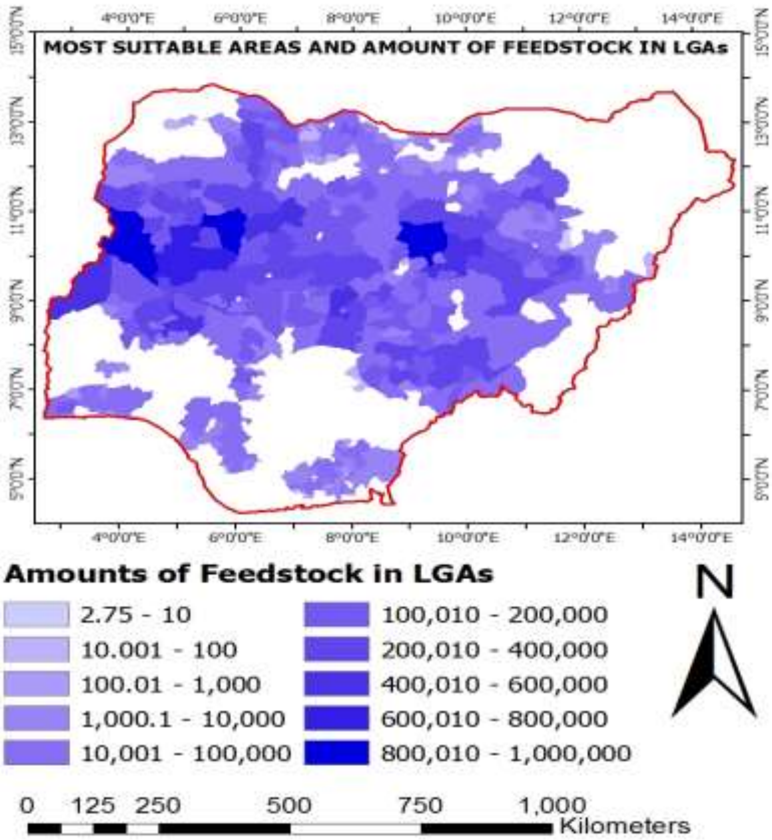

Figure 4: Potential amounts of Sweet sorghum in each Local Government Area

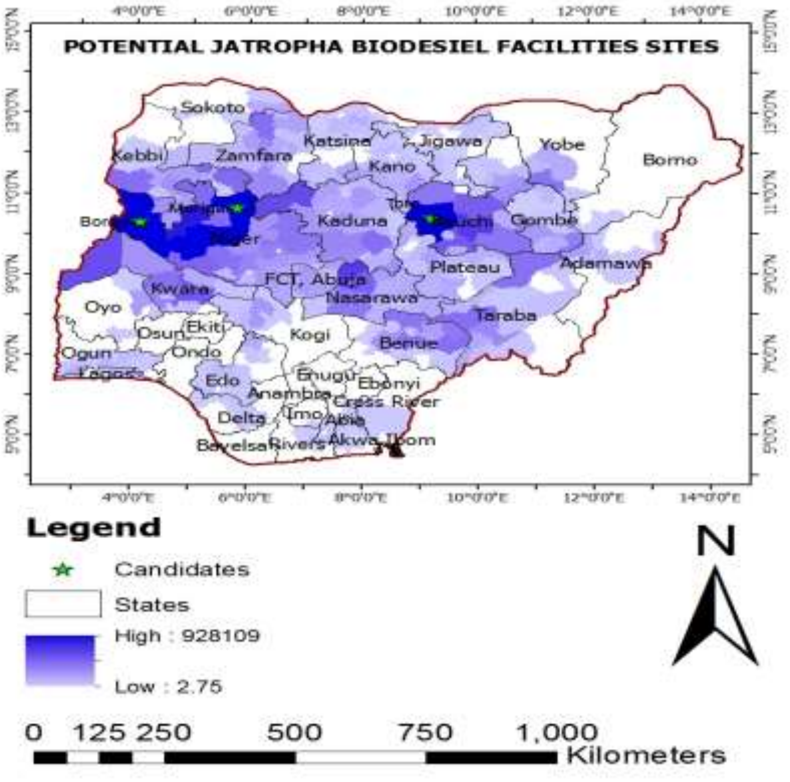

Figure 5: Potential Facility Site

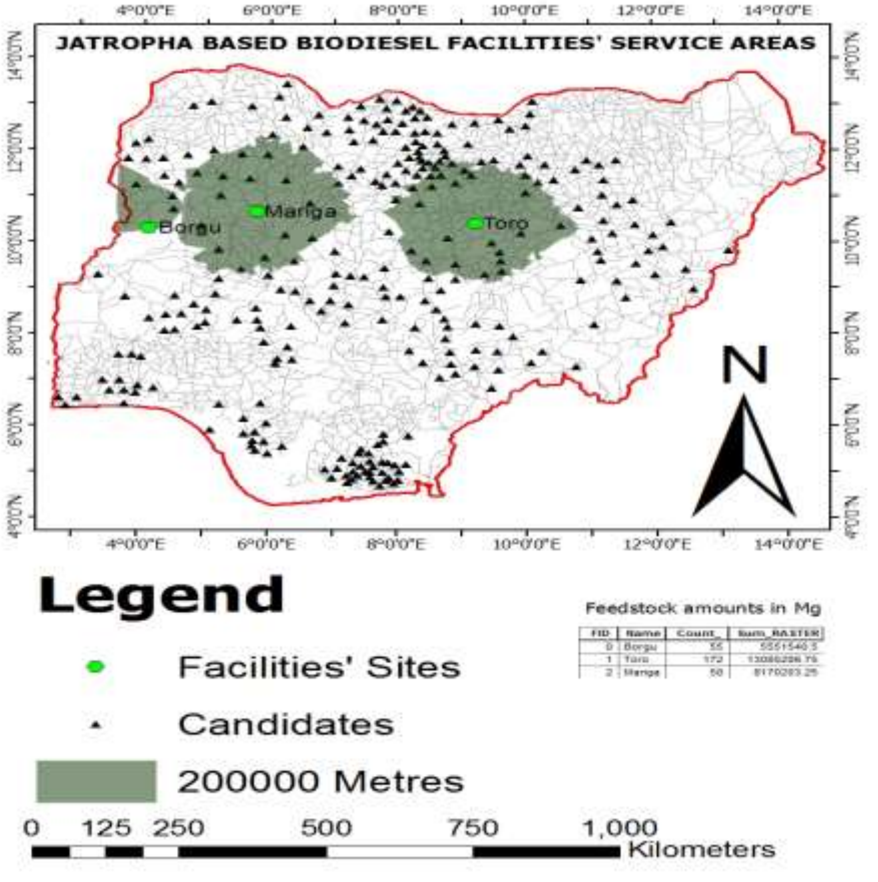

Figure 6: Candidates and Facilities' Service Areas

Figure 7: GoogleEarth display of the optimized facility site

6. Discussion

This location visually appears to be suitable for the purpose; no identified constraint could be seen though the imagery was more than 2 years old. However, the location seemed to be very close to a reserved area, though there is a river barrier in between. Thus there is need for more localized evaluation of the optimized sites. This is to avoid issues resulting from the limitations on the part of the datasets – availability and the uncertainties. Round-table Sustainable Biomaterials (RSB) principles such as legality and the land rights (regulations), the engineering regulations and the current land values as used in [23], could not be incorporated into the model. Thus, the identified optimal sites require more detailed evaluation by the investors. Toro LGA is in the northern guinea savanna vegetation zone and stays under the influence of moisture laden tropical maritime air mass from May to October. For this period, the ITD lies north of the LGA on normal oscillations which can reach up to about 20^0N. There may be anomalous positions as, for example, was observed in 2015 that the ITD stayed 2 degrees south of its normal positions from March to July [24]. Though pairwise comparison, used to generate the criteria weights, is based on the Saaty's scale, some of the issues with it include its being mere decision makers' judgement of the preference importance between the criteria. However, according to [25], the technique has an added advantage of helping decision makers focus on areas of agreement and disagreement with regards to the weights of the criteria. It also allows for the calculation of consistency ratio which defines the probability that the matrix was randomly generated. The use of centroids of the LGA boundaries in the supply area modelling is a limitation of the GIS functionality. As at the time of this study, the scale, size and technology of the biofuel processing facility was not known. Thus, 200 km was heuristically chosen as the service area extent and due to the nature of Nigeria's transport system, distance variable cost was adopted.

7. Summary

Agriculture is the main employer of the Nigerian populace and crude oil is the Country's main foreign exchange earner. But there are the environmental concerns of the petroleum industry. Integrating the two sectors is an avenue for economic diversification, reducing income volatility and improving unemployment situation. Blending petroleum fuels with biofuels is a strategy for integrating the two sectors. This forms the background for this study which aims to spatially optimize biofuel production in the Country. Different types of feedstock are used in biofuel production such as forest biomass and other first and second generation biofuels. This study focused on Sweet sorghum and based on the aim of the study, principles of the Roundtable Sustainable

Biomaterials (RSB) were used to determine the constraints and a model was developed to eliminate them. Based on the ecological factors, for example soil and rainfall and some spatio economic factors such as nearness to roads or labour supply (settlements), suitable areas were determined for the production of Jatropha. One of the major factors of biofuel production – transport – was used to determine optimal sites for locating a Jatropha based biofuel production facility. Distance variable cost was used to achieve this objective with a 200 km service area because the size, scale and technology of the prospective facilities were not known at the time of the study.

8. Conclusion

Toro Local Government Area of Bauchi State is the most ideal location for a Jatropha based biodiesel production facility in Nigeria. Prospective investors can use this information in collaboration with other stakeholders (such as surveyors and engineers), to verify further the appropriateness of the optimized sites for their investment.

Acknowledgement

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References

[1] Chmielewski AG. Environmental effects of fossil fuel combustion. Encyclopaedia of Life Support System, 2012. Institute of Nuclear Chemistry and Technology and Polland University of Technology, Warsaw, Polland. Available at: <http://www.eolss.net/sample-chapters/c09/e4-23-02.pdf> [Accessed: 16/06/2015].

[2] Abas N, Kalair A, Khan N. Review of fossil fuels and future energy technologies. *Futures* 2015;69:31–49. Available at: <http://ac.els-cdn.com/S0016328715000397/1-s2.0-S0016328715000397-main.pdf?_tid=71c9c07a-143e-11e5-875b-00000aab0f01&acdnat=1434469593_ffa0312a9b585b2272d255aae4e53363> [Accessed: 16/06/2015].

[3] Yaliwal VS, Banapurmath NR, Gireesh NM, Tewari PG. Production and utilization of renewable and sustainable gaseousfuel for power generation applications: A review of literature. *Renewable and Sustainable Energy Reviews* 2014;34:608–627. Available at: <http://ac.els-cdn.com/S1364032114002044/1-s2.0-S1364032114002044-main.pdf?_tid=4e193bb6-1442-11e5-97e6-00000aacb35e&acdnat=1434471251_430e3697eb0bdd2f07d843f8224377bf> [Accessed: 16/06/2015].

[4] Juan José Vidal-Amaro, Poul Alberg Østergaard, Claudia Sheinbaum-Pardo. Optimal energy mix for transitioning from fossil fuels to renewable energy sources – The case of the Mexican electricity system. *Applied Energy* 2015;150:80–96. Available at: <http://ac.els-cdn.com/S0306261915004353/1-s2.0-S0306261915004353-main.pdf?_tid=74073208-1440-11e5-af84-00000aab0f26&acdnat=1434470458_4df67fb081a6e50034af8b76ee5882c9> [Accessed: 16/06/2015].

[5] Mohammed SO, Gajere EN, Eguaroje EO, Shaba H, Ogbole JO, Onyeuwaoma ND et al. A Spatio-Temporal Analysis of the National Parks in Nigeria: A Geo-Information Approach. *Proceedings of Global Geospatial Conference, November 4-8, 2013, Addis Ababa, Ethiopia*. Available at: <http://www.gsdi.org/gsdiconf/gsdi14/papers/48.pdf> [Accessed: 08/08/2015].

[6] Azad AK, Rasul MG, Khan MMK, Subhash C. Sharma, Hazrat MA. Prospect of biofuels as an alternative transport fuel in Australia. *Renewable and Sustainable Energy Reviews* 2015;43:331–351. Available at: <http://www.sciencedirect.com/science/article/pii/S1364032114009782> [Accessed: 18/06/2015].

[7] Mofoluwake M Ishola, Tomas Brandberg, Sikiru A Sanni, and Mohammad J Taherzadeh. Biofuels in Nigeria: A critical and strategic

evaluation. *Renewable Energy* 2013;55:554 – 560. Available at: <http://www.sciencedirect.com/science/article/pii/S0960148112007872> [Accessed: 08/02/2015].

[8] Eric C Eboh, Kalu O Oji, Okey G Oji, Uzochukwu S Amakom and Oliver C Ujah. Towards the ECOWAS Common Agricultural Policy Framework: Nigeria Case Study and Regional Analysis, 2004. African Institute for Applied Economics, Enugu. Available at: <http://www.inter-reseaux.org/IMG/pdf_ECOWAP_Nigeria_Full_Final_Report.pdf> [Accessed: 27/09/2015].

[9] Elijah Ige Ohimain. A review of the Nigerian biofuel policy and incentive (2007). *Renewable and Sustainable Energy Reviews* 2013a;22:246–256. Available at: <http://www.sciencedirect.com/science/article/pii/S1364032113000683> [Accessed: 31/01/2015].

[10] Nigerian National Petroleum Corporation (NNPC). Website Available 2015. at: <http://www.nnpcgroup.com/NNPCBusiness/MidstreamVentures/RenewableEnergy.aspx> [Accessed: 31/01/2015].

[11] Elijah I. Ohimain. Can the Nigerian biofuel policy and incentives (2007) transform Nigeria into a biofuel economy? *Energy Policy* 2013b;54:352–359. Available at: <http://www.sciencedirect.com/science/article/pii/S0301421512010348> [Accessed: 31/01/2015].

[12] NNPC. Sustainable Biofuel Industry in Nigeria – A Getway to Economic Development. *Second Nigerian Alternative Energy Expo,* 2012. Available at: <http://www.slideshare.net/Mathesisslides/sustainable-biofuels-industry-in-igeria?from_action=save> [Accessed: 14/06/2015].

[13] NNPC. Official Gazette of the Nigerian Bio-fuel Policy and Incentives, 2007. Available at: <http://www.sunbirdbioenergy.com/docs/Nigeria_E10_POLICY_GAZETTED.pdf 05/02/2015> [Accessed: 31/01/2015].

[14] Simonyan KJ and Fasina O. Biomass resources and bioenergy potentials in Nigeria. *African Journal of Agricultural Research* 2013;8(40):4975-4989. Available at: <http://www.academicjournals.org/article/article1381916826_Simonyan%20and%20Fasina.pdf> [Accessed: 25/06/2015].

[15] Ohimain EI. The Evaluation of Pioneering Bioethanol Projects in Nigeria Following the Announcement and Implementation of the Nigerian Biofuel Policy and Incentives, Energy Sources, Part B: Economics, Planning, and Policy, 2015;10(1): 51-58, DOI: 10.1080/15567249.2010.512904. Available at: <http://www.tandfonline.com/doi/pdf/10.1080/15567249.2010.512904> [Accessed: 27/06/2015].

[16] Johan Hagman, Michelle Nerentorp, Rickard Arvidsson and Sverker Molander, 2013. Do biofuels require more water than do fossil fuels? Life cycle-based assessment of jatropha oil production in rural Mozambique. *Journal of Cleaner Production* (53). 176e185. Available at: <http://ac.els-cdn.com/S0959652613001777/1-s2.0-S0959652613001777-main.pdf?_tid=30efd284-1433-11e5-bbad-00000aacb35f&acdnat=1434464760_21651047a3ceff77c05fff818ee5572e> [Aceessed: 16/06/2015].

[17] Aziz Elbehri, Anna Segerstedt and Pascal Liu. Biofuel and the sustainability challenge: A global assessment of sustainability issues, trends and policies for biofuels and related feedstocks. FAO, 2013. Rome. Available at: <http://www.fao.org/docrep/017/i3126e/i3126e.pdf> [Accessed: 07/07/2015].

[18] Richard Brittaine and NeBambi Lutaladio, 2010. Jatropha: A small holder bioenergy crop. Integrated Crop Management Vol. 8. FAO, Rome. ISSN1020-4555. Available at: <http://www.fao.org/3/a-i1219e.pdf> [Accessed: 06/07/2015].

[19] Ashwani Kumar and Satyawati Sharma, 2008. An evaluation of multipurpose oil seed crop for industrial uses (*Jatropha curcas* L.): A review. Industrial crops and products (28). 1-10. Available at: <http://ac.els-cdn.com/S0926669008000046/1-s2.0-S0926669008000046-main.pdf?_tid=9fb44650-24af-11e5-bf4b-00000aacb362&acdnat=1436277422_bc22ef20691662e31dbb157fd9e1364c> [Accessed: 07/07/2015].

[20] Xun Shi, Andrew Elmore, Xia Li, Nathaniel J Gorence, Xiaohao Zhang, Fang Wang, et al. Using Spatial Information Technologies to Select Sites for Biomass Power Plants: A Case Study in Guandong Province, China. *Biomass and Bioenergy,* 2008;32:35 – 43. Available at: <http://www.sciencedirect.com/science/article/pii/S0961953407000931> [Accessed: 15/11/2014].

[21] Abba Sani Kura, 2009. Sustainable Biodiesel Feed Stock. *COGA Renewable Energy Development Company*. Kwara State, Nigeria. Available at: <http://ncee.org.ng/centre-archives/conference-reports/doc_download/4-cultivation-of-jatropha-and-biofuel-production-technologies.html> [01/02/2015].

[22] Voivontas D, Assimacopoulos D. and EG. Assessment of biomass potential for power production: a GIS based method. *Biomass and Bioenergy* 2001;20:101 – 112. Available at: <http://environ.chemeng.ntua.gr/en/Uploads/Doc/Papers/Renewable%20Energy/2001_Assessment%20of%20biomass%20potential%20for%20power%20productio.pdf> [Accessed: 02/09/2015].

[23] Michael A. Borowitzka, Bryan J. Boruff, Navid R Moheimani, Natasha Pauli, Yunghui Cao, and Helin Smith. Identification of the Optimum Sites for Industrial Scale Microalgae Biofuel Production in Western Australia Using a GIS Model. *Final Report Prepared for the Centre for Research in to Energy for Sustainable Transport (CREST)* 2012. Murdoch University and University of Western Australia. Available at: <http://www.sciencedirect.com/science/article/pii/S0306261915003918> [Accessed: 30/11/2014].

[24] 2015 Nigeria Climate Review Bulletin. Nigerian Meteorological Agency (NiMet), 2016.

[25] Samo Drobne and Anka Lisec. Multi-attribute Decision Analysis in GIS: Weighted Linear Combination and Ordered Weighted Averaging. *Informatica* 2009 ;33:459–474. Available at: <http://www.informatica.si/index.php/informatica/article/download/263/260> [Accessed: 30/06/2015].

VARIABILITY OF TEMPERATURE AND RAINFALL IN NIGERIA

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Abstract

Changes in the rainfall and temperature for the period1958 – 2014 over ecological regions of Nigeria were analysed using time series and standardized anomaly techniques. The results show a general downward trend in rainfall over the Sahel zone, In the sudan savannah, most stations exhibit downward trends except Kano area. Similarly, the guinea savannah exhibits general downward trends except Lokoja that shows upward trends. The rainfall conditions over the rain forest and mangrove swamp ecological zones of the south exhibit upward trends except Ikeja that show downward trends. For the study period, temperature shows upward trends in all the ecological areas of the country. In general, while there have been wide variabilities in rainfall in various ecological zones of Nigeria over the last five decades, temperature has been consistently rising during the period, a possible indication of the overall effect of global warming in the country.

Keywords: Climate variability, Change, Ecological, Trends, Observation

Introduction

Rainfall and temperature are an important climatic parameter that has been extensively studied. (Adejuwon et al., 1990). It has been an elements that influenced our life and environment in a manner that almost all our resources hinged on them. It long been known that our agricultural activities dependent on rainfall (Omotosho et al., 2007). It has been observed that rainfall decreased substantially across the sahel from the 1950s until at least the late 1980s (Dia et al., 2004). Although it has not returned to levels typically of period of 1920 to 1965 (IPCC, 2007). Observational evidence indicates that the frequency of the heaviest rainfall events has likely increased within many land regions in general agreement with model simulations (IPCC, 2013).

Similarly, temperature has been found to be on the increase globally by about 0.74°C over the past hundred years (IPCC, 2001). This observation has been of serious concerns to many experts in the field, because of its implications. Several monitoring and assessments has been going on globally and locally in order to ascertain the true situation of our environment. Several reanalysis models had been developed and applied to support our understanding and attributing warming of the climate systems (Abiodun et al., 2012). For these reasons, the Nigerian rainfall and temperature trends had been on the monitored, particularly to shed more light on the past studies and update the information thereof.

Methodology

Rainfall data spanning from 1958 to 2014 from Nigerian Meteorological Agency, Lagos has been analysed. Figure 1. is the map of Nigeria showing climatological stations and their classifications within an ecological zones. Sahel zone (<600mm); Sudan savanna (600 – 1000mm); Guinea savanna (1000 – 1500mm); Tropical forest (1500 – <2000mm) and Mangrove swamp forest (>2000mm), (Ojo, 2008).

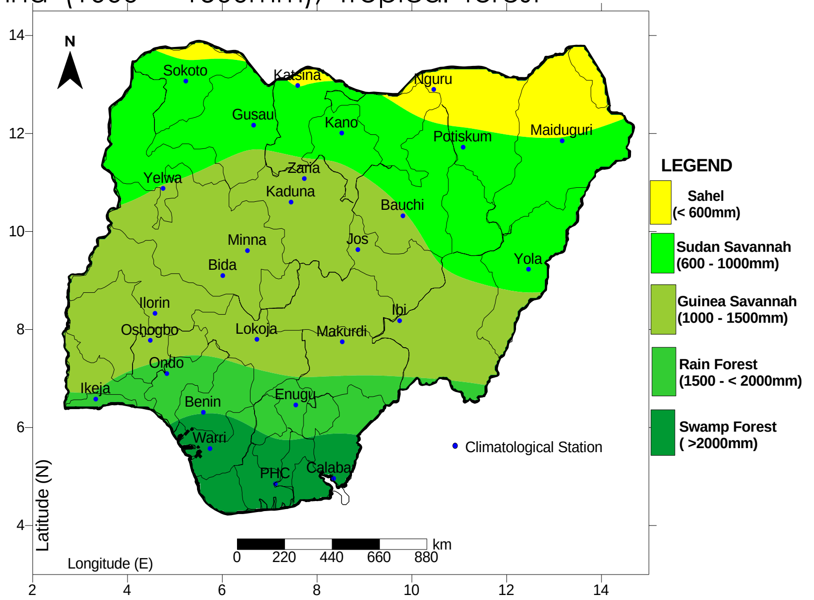

Fig. 1: Map of Nigeria showing Climatological Stations and their Classification into Ecological Zones, Adapted from Ojo, 2008)

Time series analysis were carried out for trending patterns using different smoothing methods (Linear or polynomial). Standardized Anomaly technique were also applied in order to explain the trending situations. Similar analysis was carried out for temperature in the aforementioned ecological zones.

Results

Figures 2; 3; 4; 5 and 6 are the standardized rainfall anomaly over sahel zone; sudan savanna zone; guinea savanna zone, tropical forest and mangrove swamp forest.

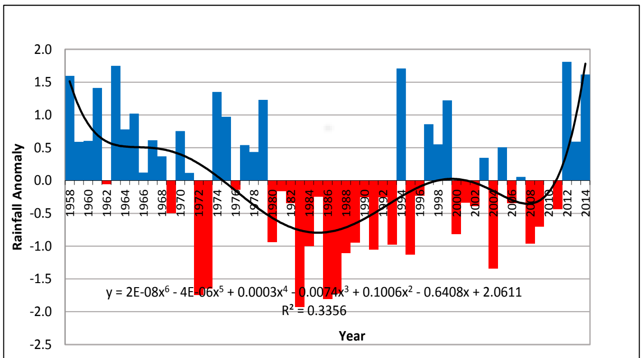

Fig. 2: Standardized Rainfall Anomaly over Nguru (1958-2014)

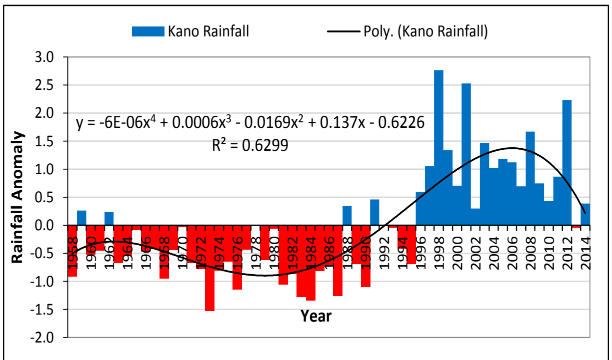

Fig. 3: Standardized Rainfall Anomaly over Kano (1958-2014)

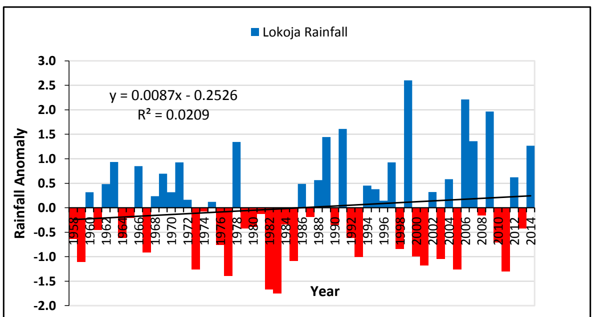

Fig. 4: Standardized Rainfall Anomaly over Lokoja (1958-2014)

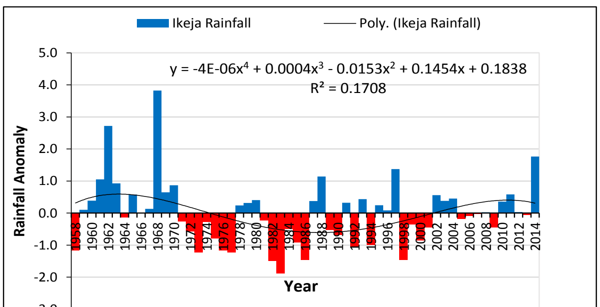

Fig. 5: Standardized Rainfall Anomaly over Ikeja (1958-2014)

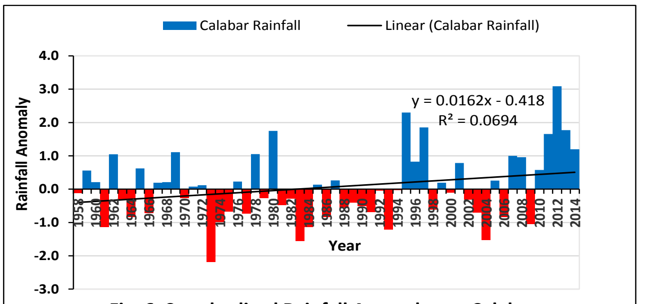

Fig. 6: Standardized Rainfall Anomaly ove Calabar (1958-2014)

Table 1: Highest number of mean annual monthly rainfall (1958-2014)

Ecological Zone	Station	Apr	May	Jun	Jul	Aug	Sep	Oct
SAHEL	Nguru	0	0	1	13	42	1	0
	Katsina	0	1	1	13	39	3	0
SUDAN SAVANNA	Sokoto	0	0	0	13	40	3	0
	Kano	0	0	1	18	38	0	0
GUINEA SAVANNA	Minna	0	3	6	9	28	10	1
	Lokoja	2	6	7	12	14	16	0
TROPICAL FOREST	Oshogbo	1	4	8	11	3	17	13
	Ikeja	2	10	26	12	1	6	0
MANGROVE SWAMP	Warri	1	0	1	22	8	21	4
	Calabar	0	2	10	21	13	11	0

Table 2: Highest number of mean annual monthly rainfall (2005-2014)

Ecological Zone	Station	Apr	May	Jun	Jul	Aug	Sep	Oct
SAHEL	Nguru	0	0	0	2	8	0	0
	Katsina	0	1	0	1	8	0	0
SUDAN SAVANNA	Sokoto	0	0	0	2	8	0	0
	Kano	0	0	0	2	8	0	0
GUINEA SAVANNA	Minna	0	0	1	3	3	3	0
	Lokoja	1	3	1	2	2	1	0
TROPICAL FOREST	Oshogbo	0	1	0	3	0	3	3
	Ikeja	0	2	4	2	0	2	0
MANGROVE SWAMP	Warri	0	0	1	5	1	2	1
	Calabar	0	0	2	5	1	2	0

Figures 7; 8; 9; 10 and 11 are the time series of mean maximum temperature over sahel, sudan savanna, guinea savanna, tropical forest and mangrove swamp forest of ecological zones respectively.

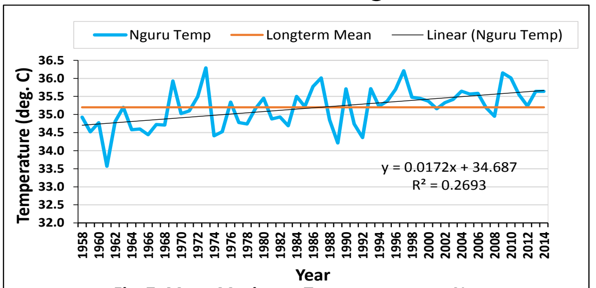

Fig. 7: Mean Maximum Temperature over Nguru (1958-2014)

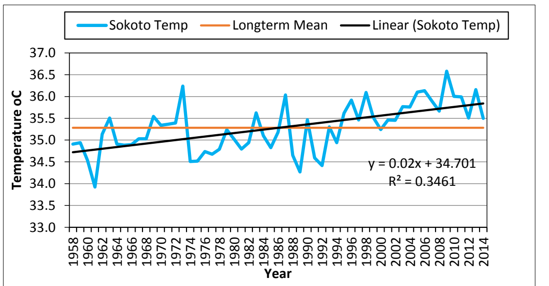

Fig.8: Mean Maximum Temperature over Sokoto (1958-2014)

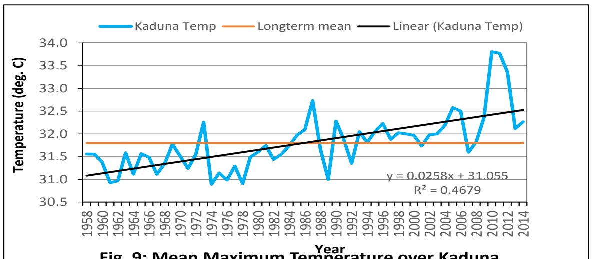

Fig. 9: Mean Maximum Temperature over Kaduna (1958-2014)

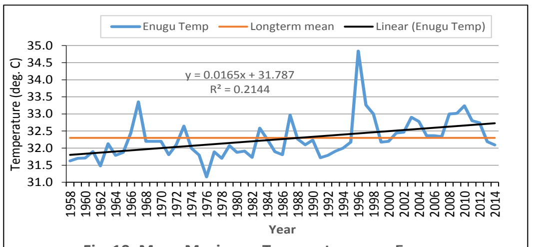

Fig. 10: Mean Maximum Temperature over Enugu (1958-2014)

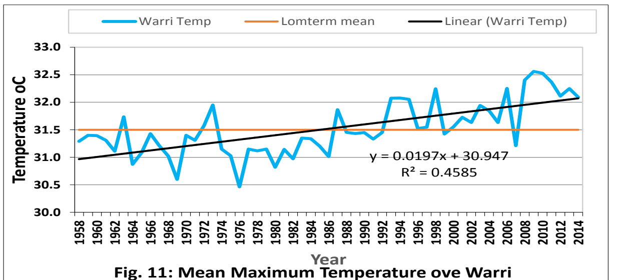

Fig. 11: Mean Maximum Temperature ove Warri (1958-2014)

Discussion

Generally, there was a wetter than normal period in the rainfall pattern of most ecological stations across the country between 1958 and 1979 over the sahel regions. Between 1958 and 1975 over the guinea savanna zones, between 1958 and 1970 over the tropical forest zone and between 1958 and 1972 over the mangrove swamp forest zone, except below normal rainfall period that manifested as from 1980s over the sahelian Eco-zone till 2011 when a recovery periods begins (fig.2-6). Alternating period of below and above normal rainfall were experienced in other ecological zones since 1994 over the sahel zone, 1986 over guinea savanna zone, 1987 over tropical forest and 1995 over the mangrove swamp forest zones. Table 1 shows the highest number of mean annual monthly rainfall between 1958 and 2014. This reveals the peak pattern of rainfall. Table 2 shows the pattern during the last decade (2005-2014). Generally, the time series analysis of maximum temperature reveals rising trends over most stations.

Conclusion

Variability of rainfall over the ecological zones of Nigeria reveals above normal rainfall from late 1950s till 1970s and when below normal rainfall prevailed. There was a clear below normal rainfall period from 1980s over the sahel-sudano zones. A period of recovery began from 1994 over the sahel zone and from 1996 over the sudan savanna zone. Normal single monthly rainfall peak remains the patterns for the sahel, sudan savanna and guinea savanna zones and double peak period for the tropical and mangrove forest since 1958. Similar pattern still prevailed in the last decade.

References

Abiodun, B. J., Lawal, K. A., Salami, A. T., Abatan, A. A. (2012). Potential influences of global warming on future climate change and extreme events in Nigeria. *Regional Environmental Change*. Vol. 12 No. 4., doi: 10.1007/s 10113-012-0381-7. pp 17.

Adejuwon, J. O., Balogun, E. E. and S. A. Adejuwon (1990). On the annual and seasonal variations in sub-sharan West Africa. International J. Climatology 10: 839-848.

Ojo, O (2008). State of the Nigerian Environment Report 2008. SEDEC Associate.

IPCC (2013). *Climate Change(2013). The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.

IPCC (Intergovernmental Panel on Climate Change). (2007). *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth AssessmentReport of the Intergovernmental Panel on Climate Change*. In: S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller, Eds., Cambridge University Press, Cambridge, 996 pp.

Dai, A. G. & Trenberth, K. E. (2004). The diurnal cycle and its depiction in the community climate system model. *J. Clim.*, **17**, 930-951

Fasona, M. Omojola, A. Mark T. Abiodun, B. (2011a). Local Climate Forcing and Eco-climatic complexes in the wooded savanna of Nigeria, Natural Resources , 2011, 20, p155-166. Doi: 10.4236/nr.2011. http://www.scirp.org/journal/paperinfomation.aspx?paperID=7527.

Omotosho, J.B and Abiodun, J. (2007). A numerical study of moisture build-up and rainfall over west Africa. Metorol. Appl. 14:209-225. DOi:10.1002/met.11

ON THE RELATIONSHIPS BETWEEN CLIMATIC ELEMENTS AND MALARIA PROLIFERATION IN THE ECOLOGICAL ZONES OF NIGERIA

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Abstract

Climate, as the average meteorological conditions experienced in particular area over a specified time period, varies in time and space. In its variation, climate exacerbates the occurrence of common diseases such as Malaria. The relationships of various climatic elements with the proliferation of malaria over the ecological areas of Nigeria have been investigated. In general and for all climatic elements considered, the duration of favourable condition for the proliferation of malaria decreases from a maximum of nine months in the mangrove swamp forest in the south, to 8 months in the tropical forest, 6 months in the guinea savannah of central Nigeria and 3 – 4 months in the sudan/sahel savanna of the north. The results of the analysis reveal positive correlation for radiation, maximum temperature and negative correlation for relative humidity, minimum temperature and rainfall. Various factors militating against combating this disease have been highlighted and means to ameliorate and eradicate the disease proffered.

Keywords: Malaria, Climatic condition, Ecological, Proliferation

Introduction

Understanding climate variations in any society is critical to development especially as it relates to health and diseases (Connor et al., 2010). For example, temperature, rainfall, and humidity have strong influence on the reproduction, survival and biting rates of mosquitoes that transmit malaria. In Nigeria, malaria has consistently been the commonest reported deaths (WHO, 2013). The actual incidence and mortality rates are unknown due to incomplete and irregular reporting. However estimates indicate that children under the age of 5 years have 2-4 attacks of malaria a year and approximately 50% of the adult population experience at least one episode of malaria per year (FMOH, 2007). But meteorological variables are the most important environmental factors in the transmission of malaria globally (Rasha and Ayman, 2011). Therefore, there is every need to assess these relationship for Nigeria in order to provide adequate information for effective early warning systems.

Methodology

Climatic data from twenty-eight stations were selected across the country based on the availability of data (1958-2009) from Nigerian Meteorological Agency (NiMet). The Malaria data was from the Epidemiology Division, Federal Ministry of Health, Abuja. Relative frequencies were used (Craig, Snow, Sver, 1999). Rainfall greater than 80mm, temperature ranged between 18°C and 32°C and relative humidity greater than 60% were computed for the ecological zone across the country. Pearson correlation method was used to determine the strength of the linear association.

Result

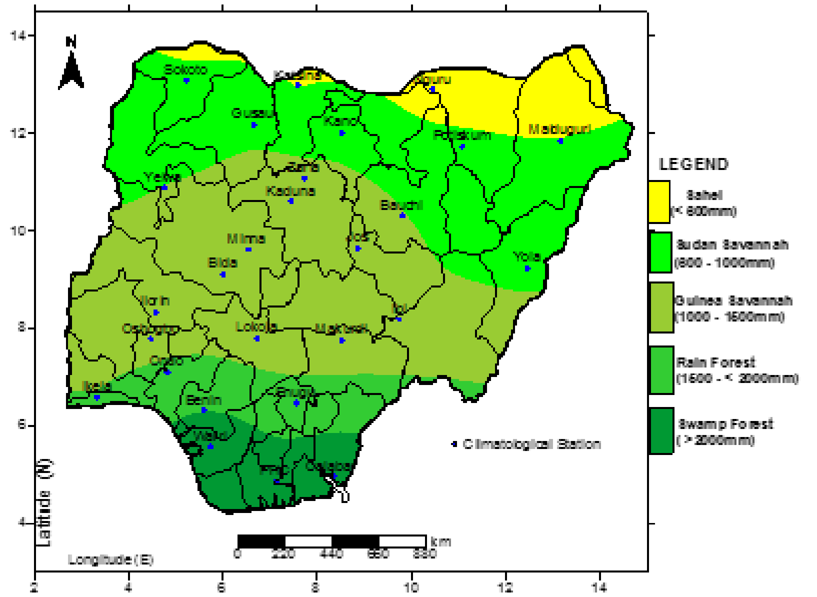

Fig. 1: Map of Nigeria showing Climatological Stations and their Classification into Ecological Zones, Adapted from Ojo, 2008)

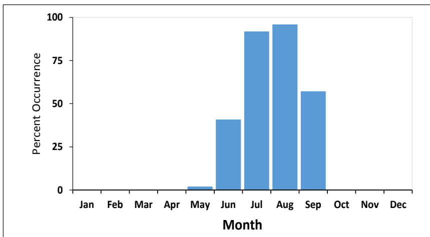

Fig. 2a : Monthly precipitation over Sahel Savanna ecological zone (P>80mm)

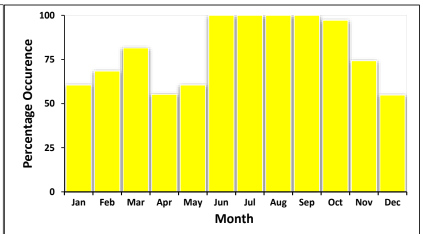

Fig.2b: Monthly mean temperature over Sahel Savanna ecological zone areas (18C<T<32C)

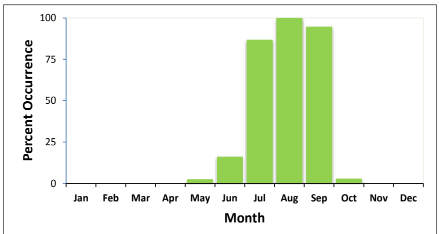

Fig. 2c: Monthly Relative Humidity over Sahel Savanna ecological zone (RH>60%)

Fig. 2a, 2b, and 2c are monthly precipitation, temperature and relative humidity over Sahel ecological zone.

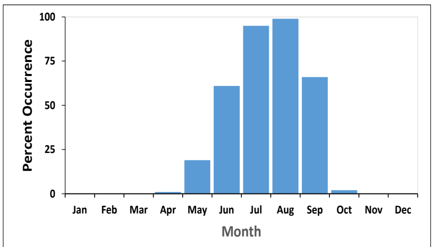

Fig. 3a: Monthly precipitation over Sudan Savanna ecological zone (P>80mm)

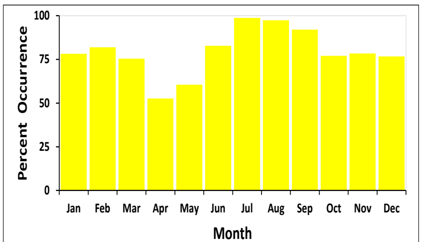

Fig. 3b: Monthly mean temperature over Sudan Savannah ecological zone areas (18C<T<32C)

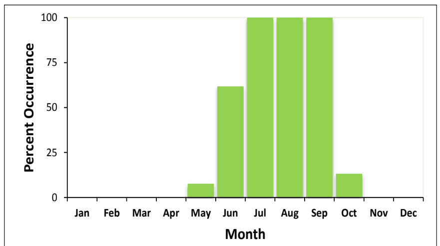

Fig. 3c: Monthly Relative Humidity over Sudan Savannah ecological zone (RH>60%)

Fig. 3a, 3b, and 3c are monthly precipitation, temperature and relative humidity over Sudan savanna ecological zone.

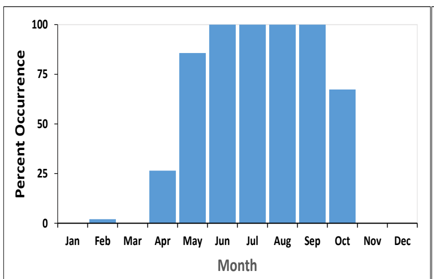

Fig. 4a: Monthly precipitation over Guinea Savanna ecological zone (P>80mm)

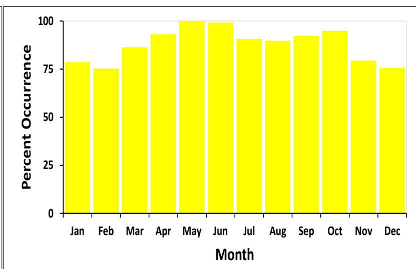

Fig. 4b: Monthly mean temperature over Guinea Savannah ecological zone areas (18C<T<32C)

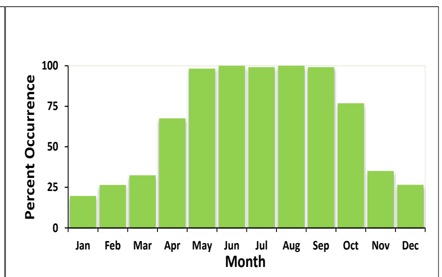

Fig. 4c: Monthly Relative Humidity over Guinea Savannah ecological zone (RH>60%)

Fig. 4a, 4b, and 4c are monthly precipitation, temperature and relative humidity over Guinea savanna ecological zone.

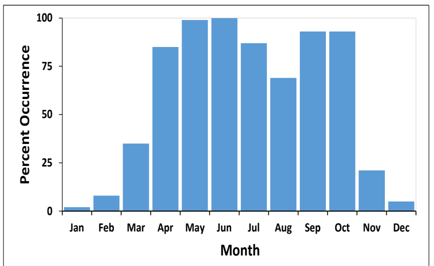

Fig. 5a: Monthly precipitation over Tropical Forest ecological zone (P>80mm)

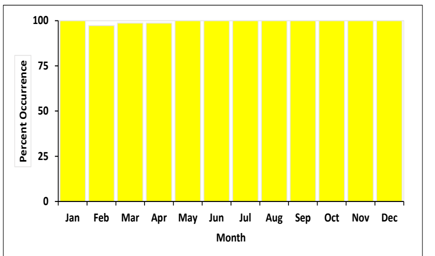

Fig. 5b: Monthly mean temperature over Tropical Forest ecological areas (18C<T<32C)

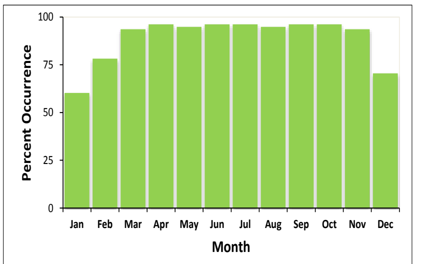

Fig. 5c: Monthly Relative Humidity over Tropical Forest ecological zone (RH>60%)

Fig. 5a, 5b, and 5c are monthly precipitation, temperature and relative humidity over Tropical forest zone.

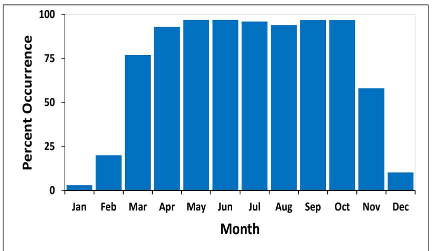

Fig. 6a: Monthly Precipitation over Mangrove Swamp ecological zone (P>80mm)

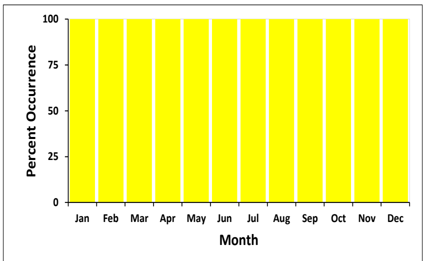

Fig. 6b: Monthly mean temperature over Mangrove Swamps ecological region (18C<T<32C)

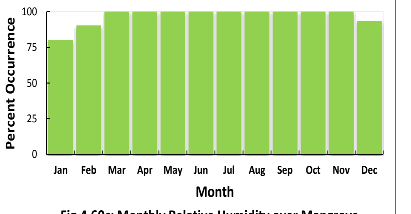

Fig.4.60c: Monthly Relative Humidity over Mangrove Swamps ecological zone (RH>60%)

Fig. 6a, 6b, and 6c are monthly precipitation, temperature and relative humidity over Mangrove swamp forest zone

Table 1: Correlation coefficient (r) between climatic parameters and malaria over the various ecological zones

Ecological Zone	Rainfall	Tmax	Tmin	RH	Radiation
SAHEL	-0.286*	0.288*	-0.421**	-0.340**	0.314**
SUDAN SAVANNA	-0.539**	0.410**	-0.286**	-0.474**	0.449**
GUINEA SAVANNA	-0.604**	0.388**	-0.418**	-0.454**	0.460**
TROPICAL FOREST	-0.523**	0.357**	-0.418**	-0.411**	0.391**
MANGROVE FOREST	-0.484**	0.303**	-0.258**	-0.291*	0.302**

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

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

Discussion

The total annual rainfall over sahel zone ranges between 259.2mm and 1076.3mm during the study period (1958-2009). Stations that fell within this zone include Sokoto, Katsina, Gusau, Potiskum, Maiduguri and Nguru. Climatic conditions suitable for Malaria transmission for this zone varies from 41% in the month of June and 57% on monthly precipitation of 80mm and above (Figure 2a). Temperature of 18°C<T<32°C were also 100% in the month of June, July, August and September. Figure 2b, relative humidity greater that 60% also high only in the month of July through to September, (Figure 2c). Generally, stations within this zone experienced unimodal pattern of rainfall and have only 3 months suitable for malaria transmission.

Selected stations that fell within the Sudan savanna zone include Kano, Yola, Kaduna, Bauchi, Yelwa and Gombe. These stations receive annual precipitation amount in the range of 381.8mm – 1869.3mm during the study period. Based on monthly precipitation of 80mm and more, 61%, 95%, 99% and 66% are observed in the month of June, July, August and September respectively, (Figure 3a). Mean temperature between 18°C and 32°C are more favourable in the month of July and August, (Figure 3b). Percent occurrence of relative humidity greater than 60% were also 62%, 100%, 100% for the month of June, July and September, (Figure 3c). Generally, climatic conditions suitable for malaria transmission was about 4 months.

Selected stations within Guinea Savannah zone include Enugu, Ilorin, Lokoja, Minna, Makurdi, and Jos. Annual precipitation ranges between 672.5mm and 2262.5mm. Based on monthly precipitation of 80mm and above, percent occurrence was 86% for May, 100% for June, July, August, September and 67% for October respectively, (Figure 4a). Mean temperature between 18°C and 32°C are 70% or more for percent occurrence for all the months, (Figure 4b). Similarly, relative humidity greater than 60% are 68% for April, 98% for May, 100% for June, 99% for July, 100% for August, 99% for September and 77% for September, (Figure 4c).

Selected stations within the Tropical forest zone include: Benin, Ikeja, Owerri, Ondo, and Oshogbo. Annual precipitation varies from 784.3mm and 3029.4mm. Rainfall greater than 80mm and more were 85% for April, 99% for May, 100% for June, 87% for July, 69% for August, 93% for September and October, (Figure 5a). Percent Occurrence for mean temperature between 18°C and 32°C and relative humidity greater 60% were favoured throughout the year, Figures 5b and 5c. The climatic conditions for malaria transmission was suitable for about 7months (April-October).

Selected stations within the Mangrove swamp forest zone include Warri, Portharcourt, Calabar, Uyo and Lagos. This zone receives substantial amounts of rainfall in 9months (March-November). Annual precipitation varies between 958.2mm and 3757.1mm. Based on climatic conditions greater than 80mm, mean temperature between 18°C and 32°C and relative humidity greater than 60%. The percent occurrence were more than 70% for 9months (Mar-Nov) for rainfall, relative humidity and 100% for mean temperature respectively (Figures 6a-c).

Table 1 shows the correlation coefficient (r) between malaria and climatic parameters over the ecological zones. Generally in all the ecological zones there was a negative correlation with rainfall, relative humidity and minimum temperature for all the ecological zones.

Various factors militating against combating this disease according to WHO, 2015 include: Inadequate, inaccessible, and poor quality service delivery, particularly at the periphery, where most primary health care facilities offer only a limited package of services; • Lack of necessary referral linkages between the different levels of health care; • Weak logistics systems for commodities, with as many as six separate vertical commodities management systems with little or no coordination between them; • Poorly maintained infrastructure with many buildings and equipment in need of repair and/or maintenance; and • Weak institutional capacity with inadequate supervision of health services. What may be done to ameliorate these problems include: Mass free distribution campaigns. 2. "Keep-up strategy" for continuous distribution of nets. 3. Creation of an enabling environment for private sector involvement. 4. Achieving and sustaining the scale of proven interventions 5. Adapting to changing epidemiology and incorporating new tools.

Conclusion

The climatic conditions considered suitable for malaria development and transmission through the mosquito stage of its life cycles has been investigated over the ecological zones. The sahel zone received the minimum amount of 259.2mm of rainfall in a year. This increases southward to the highest annual rainfall of about 3757.1mm over the mangrove swamp forest. The suitable conditions varies from 3months in the sahel to 9months over the mangrove swamp forest zones. Generally, there was a significant negative correlation for rainfall, relative humidity and minimum temperature with malaria prevalent over the study period.

References

Connor, S. J., J. Omumbo, C. Green, J. DaSilas, G. Mantilla, C. Delacollete, S. Hales, D. Rogers, M. Thomson, (2010). Health and Climate- Needs. Procedia Environmental Sciences. 1: 27-36.

Craig, H. M., Snow, R., and le Sueur, D. (1999). A climate based distribution model of malaria transmission in sub-Saharan Africa. *Parasitology Today*, **15**(3). 105-111.

Federal Ministry of Health, (2007). Revised National Health Policy, Fed. Min. of Health, September, 2007. Pp42

WHO (World Health Organization). (2013). Regional health report, 2013. http://www.whoint/country/ng/en

Rasha, A. and Ayman, A. E. (2011). The effects of climate changes on the distribution and Spread of Malaria in Sudan. American Journal of Environmental Engineering. DOI: 10.5923/J. ajee.20110101-03. Pp 21.

Ojo, O (2008). State of the Nigerian Environment Report 2008. SEDEC Associate

WHO (World Health Organization). (2015). World Malaria Report. 2015, Geneva. http://www.who.int/malaria/visual-refresh/en

EFFECTS OF DROUGHT ON CROPS PRODUCTION IN KATSINA AND ITS ENVIRONS

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Abstract

The paper examines the effects of drought on crops production in Katsina and its environs. The objectives of this paper are to: assess the perceived causes and effects of drought in the area; determine annual harvest of crops in the area; determine the average bag of crops harvested in the area, and identify the types of crops cultivated. Purposive sampling technique was adopted for the study. A total of 385 questionnaires were administered to farmers in sixteen selected wards within the study area, although only 361 of these questionnaires were used for the purpose of analysis. Findings revealed that farmers in the study area perceived that drought is act of God and leads to high food price due to food shortages. Findings revealed that drought leads to stunted growth of crops. This is because the inability of rainfall to meet the evapo-transpiration demands of crops result in general water stress crop failures. Findings also revealed that farmers cultivate different types/varieties of crops, with millet farmers having the highest population. This is because millet crop is strongly resistant to drought, and with high yield compared to others. Result also revealed that annual harvest of crops is increasing. Result further indicates that average bags of crops harvest increases and this can be attributed to high rainfall, increase in farm size and availability of fertilizers. The paper concludes that that length of rainy season and the cropping season are consistent. Consequently, affecting crop yield by affecting the cultivation processes such as land preparation, clearing, planting weeding harvesting etc. The paper recommends that Farmers should adopt improved agricultural technologies. This include adoption of new technologies, planting drought resistant and early maturing varieties especially millet, sorghum and cowpea to reduce adverse effects of drought in the area.

Key words: *Drought, crops, production, Katsina, environs*

INTRODUCTION

When we talk of economic impacts, we mean those impacts of drought that cost people (or businesses) money. Many economic impacts occur in agriculture, livestock and related sectors, including forestry and fisheries, because of the reliance of these sectors on surface and sub-surface water supplies (ONRG, 2004). for example, the drought that occur between 1972 and 1973 in northern Nigeria resulted in the death of over 300,000 animals representing about 13% of the total livestock population of the northeastern part of Nigeria (Jaiyeoba, 2002; Ati, 2006),while crop yield dropped by about 60% (Okorie, 2003). Similarly, drought is associated with increase in insect infestations, plant diseases, and wind erosion especially in humid and sub-humid tropics (ONRG, 2004 and Ayaode, 2005). In Nigeria crop loss due to insects pests have been estimated to be of order of 50 to 60% of total crop production (Ayaode, 2005). It is in the light of the above that this paper aimed at assessing the effects of drought on crops production in Katsina and its environs. As a result, the following objectives were set out to:

- assess the perceived causes and effects of drought in the area,
- determine annual harvest of crops in the area,
- determine the average bag of crops harvested in the area, and
- identify the types of crops cultivated.

Study area

The study area (Katsina, Kaita, and Jibia LGAs) is bounded by Niger Republic to the north, Zamfara State to the West, Batsari, Batagarawa and Rimi LGAs to the South and Mashi LGA to the East. It is located between latitude $12^0 59^1$ North and longitude $7^0 36^1$ East. It has a total land mass of 142 km^2. (See fig. 1).

Katsina state can be classified into zones climatically: the tropical continental and semi-continental. The north of Katsina state (from around Kankiya to the extreme North-East has total rainfall figure ranging from 600 – 700mm per annum. Generally, rainfalls vary considerably according to months and seasons. There are: Cool dry (Hamattan) season from December to February, a hot dry season from March to May, a warm wet season from June to September, a less marked season after rains during the months of October to November characterized by decreasing rainfall and gradual lowering temperature (O.N, 2003). The relief of the area is composed of undulating plains which generally lies gently from 360m in the North-East, to 600m around Funtua in the South-West. But, the northern part cretaceous sediments overlap the crystalline rocks. Katsina and its environs are drained by many rivers. Major rivers originate in or traverse the state include: the Koza, Jibiya; Sabke, Tagwai and Gada systems in the northern half of the state (all the following either north or North-West ward). The sandy 'drift' deposits of katsina are coarse, resulting in light sandy soils of buff or reddish colours of low medium fertility. These soils are easily worked and well suited to crops such as millet and groundnut which are less demanding in their water requirement than cotton, maize and guinea corn (O.N 2003). Katsina and its environs, belong to the Sudan Savannah Zone in the northern half of the state. The vegetation consists of trees that grow long tap roots and thick barks that make it possible to withstand the long dry season and bush fires.

Fig. 1 Map of the Study Area
Source: Adapted and modified From Katsina State Map (2016)

MATERIALS AND METHODS

Data were collected on farmers' perceived causes and effects of drought; annual harvest of crops; average bag of crops harvested and the types of crops cultivated through the field survey using closed and open ended questions. This helped to assess the magnitude of effects of drought on crop production in the study area. Purposive sampling technique was adopted for the study. A total of 385 questionnaires were administered to farmers in sixteen selected wards within the study area, although only 361 of these questionnaires were used for the purpose of analysis. Data collected were analysed using descriptive statistics. Thus, results were summarized and presented in percentages, bar graphs, pie charts etc.

RESULTS AND DISCUSSIONS

Table 1 Age of the Respondents

Age	Number of Respondents	Percentage (%)
Less than 20 years	80	22.2
21-30 years	91	25.2
31-40 years	98	27.1
41-50 years	52	14.4
Above 50years	40	11.1
Total	**361**	**100**

Source: Field Survey, 2012.

Table 1 shows that 22.2 percent (80 farmers) are less than 20 years; 25.2 percent (91 farmers) are within the age range of 21-30 years; 27.1 percent (98 farmers) are within the age range of 31-40 years; 14.4 percent (52 farmers) are within the age range of 41-50 years; 11.1 percent (40 farmers) are above 50 years of age. This indicates that majority of the respondents that engage in farming are 'young group' who can evolve modern adaptive strategies.

Table 2 Gender of the Respondents

Gender	Number of Respondents	Percentage
Male	288	79.8
Female	73	20.2
Total	**361**	**100**

Source: Field Survey, 2012.

Table 2 shows that 79.8 percent (288 farmers) are Male while, 20.2 percent (73 farmers) are female. This indicates that majority of the respondents are male who have strength to farm.

Table 3 Educational Qualification of the Respondents

Qualification	Number of Respondents	Percentage
Primary	35	9.7
Secondary	136	37.8
Tertiary	105	29.1
Quranic	85	23.5
Total	**361**	**100**

Source: Field Survey, 2012

Table 3 Shows that 9.7 percent (35 farmers) obtained Primary Education; 37.8 percent (136 farmers) have Secondary Education; 29.1 percent (105 farmers) have tertiary Education; 23.5percent (85 farmers) have Qur'anic Education. This implies that significant percentage of the respondents is educated.

Table 4. Duration of Residency in the Area

Duration	Number of Respondents	Percentage
1-5years	87	24.1
6-10years	74	20.5
11-15years	57	15.9
16-20years	53	14.7
Above 20years	90	24.9
Total	**361**	**100**

Source: Field Survey, 2012

Table 4 shows that 24.1 percent (87 farmers) have been in the area for 1-5years; 20.5 percent (74 farmers) have live in the area for 6-10 years; 15.9 percent (57 farmers) have live in the area for 11-15years; 14.7 percent (53 farmers) have live in the area for 16-20 years; 24.9 percent (90 farmers) have been in the area for above 20 years.Thus, Farmers who live in the area for above 20 years were sampled. The reason for this decision is that those within the age bracket have the information needed about drought.

Table 5 Duration of Farming

Duration	Number of Respondents	Percentage
1-5years	83	22.9
6-10years	85	23.5
11-15years	40	11.5
16-20years	44	12.2
Above 20years	109	30.2
Total	**361**	**100**

Source: Field Survey, 2012.

Table 5 shows that 22.9 percent (83 farmers) have been farming for 1-5 years; 23.5 percent (85 farmers) for 6-10 years; 11.5 percent (40 farmers) for 11-15 years; 12.2 percent (44 farmers) for 16-20 years; 30.2 percent (109 farmers) for above 20 years. This implies that majority of the respondents' falls within farming duration of 20 years and above. This is because those who spend many years in farming have more experience with drought incidence and the traditional adaptation methods

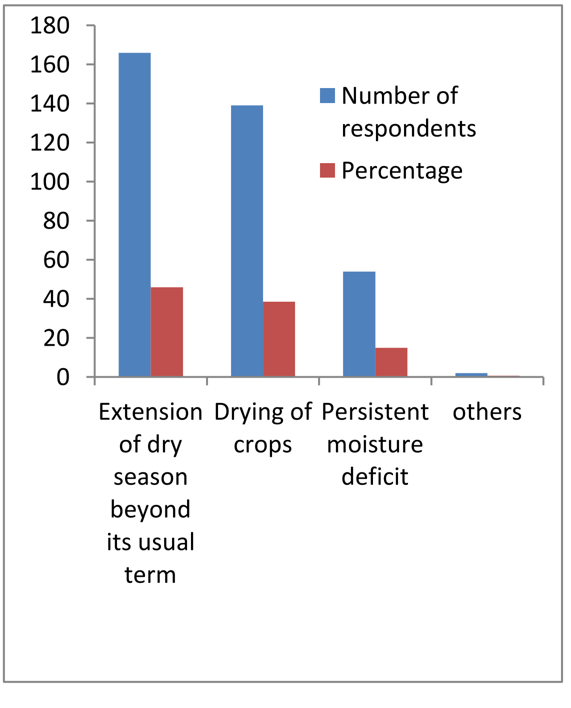

Fig. 1 what do you consider as Drought?
Source: Field Survey, 2012.

Fig.1shows that 45.9 percent (166 farmers) believe that drought is extension of dry season; 38.5 percent (139 farmers) believe that drought is drying of crops; 14.9 percent (54 farmers) stated that drought is drought is persistent moisture deficit; 0.6 percent (2 farmers) others. This indicates that majority of the respondents believed that drought is extension of dry season beyond its usual term. This may be as a result of the extension of dry condition beyond a period – a season, a year, or several years – of deficient rainfall relative to the long- term average rainfall for the area.

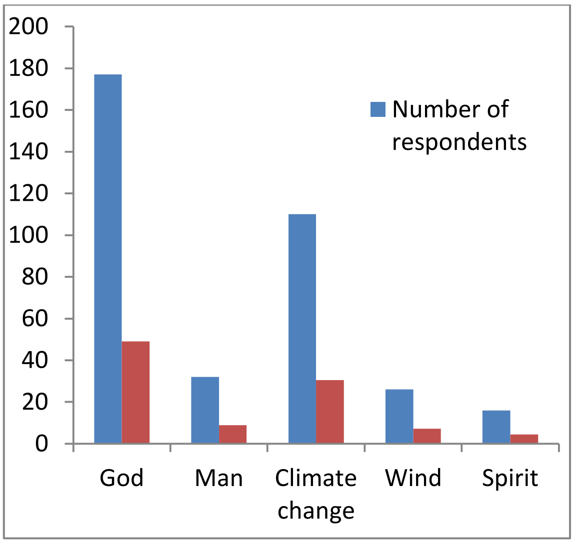

Fig. 2 Causes of Drought
Source: Field Survey, 2012.

Fig. 2 shows that 49.0 percent (177 farmers) believed that drought is caused by God; 8.9 percent (32 farmers) stated that drought is caused by man; 30.5 percent (110 farmers) attested that its caused by climate change; 7.2 percent (26 farmers) attributed drought to winds blowing from Niger republic especially in June and July which 'blow-off' the rains. Therefore, it's the wind that disperses the clouds and rain. 4.4 percent (16 farmers) related drought to spirits. However, this implies that majority of the respondents are of the perception that drought is act of God. This is because Katsina farmers are predominantly religious.

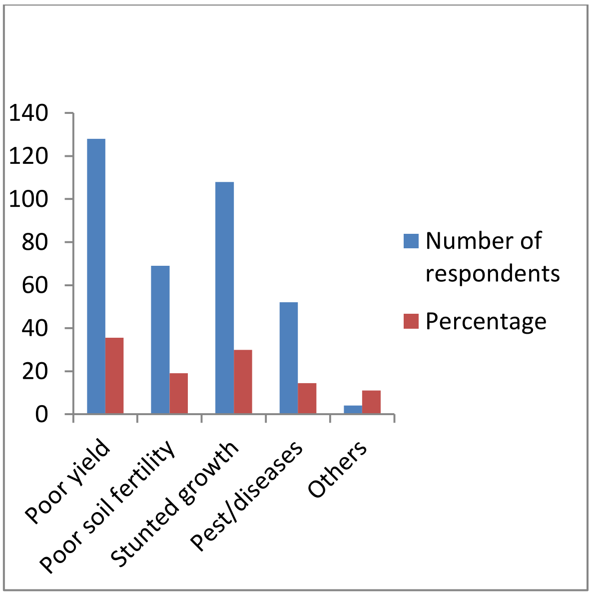

Fig. 3 Climatic Effects of Drought on Farming Activities
Source: Field survey, 2012.

Fig. 3 shows that drought caused poor yield, 19.1 percent (69 farmers) mentioned that drought leads to poor soil fertility; 29.9 percent (108 farmers) observed that drought leads to stunted growth; 14.4 percent (52 farmers) said that it brings pest/diseases; 11.1 percent (4 farmers) others. Therefore, significant percentage of the respondents mentioned that drought leads to stunted growth of the crops. This is because the inability of rainfall to meet the evapo-transpiration demands of crops result in general water stress crop failures.

Table 6 Drought Influence on Yearly Income

Effects of Drought	Number of respondents	Percentage
Yes	270	74.8
No	91	25.2

Total	**361**	**100**

Source: Field Survey, 2012

Table 6 shows that 74.8 percent (270 farmers) attested that drought influences their early income while, 25.2 percent (91 farmers) did not. As for those that attested for the socio-economic implications of drought, 26.3 percent (71 farmers) stated that drought leads to high rate of poverty; 64.1 percent (173 farmers) believed that it causes high food price; 9.6 percent (26 farmers) observed that it increases transport cost. However, this indicates that majority of the respondents attested that drought leads to high food price due to food shortages.

Table 7 Is Annual Harvest Increasing or Decreasing?

Condition	Number of Respondents	Percentage
Increasing	182	50.4
Decreasing	179	49.6
Total	**361**	**100**

Source: Field Survey, 2012

Table 7 shows that 50.4 percent (182 farmers) stated that their annual harvest is increasing. While, 49.6 percent (179 farmers) stated that their annual harvest is decreasing. The respondents were able to give reasons for the increasing annual harvest, as shown in figure 4

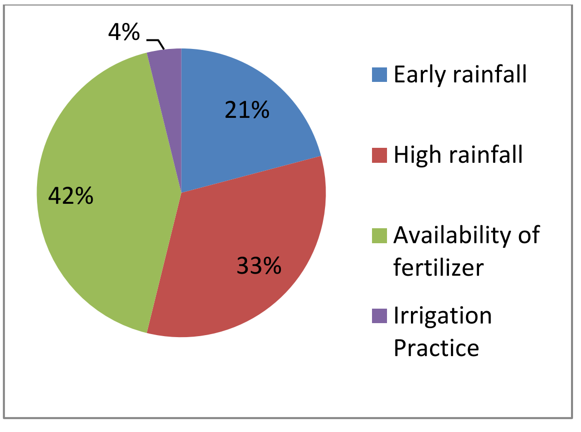

Fig. 4 Reasons for Increasing Annual Harvest
Source: Field Survey, 2012.

From Fig. 4 it can be observed that where 20.9 percent (38 farmers) attributed the increasing yield to early rainfall; 33 percent (60 farmers) attributed it to high rainfall; 42 percent (77 farmers) related the incidence to availability of fertilizer; 3.8 percent (7 farmers) attributed it to irrigation practices etc. Therefore, the increased agricultural productivity in the area can be attributed to increased rainfall and availability of fertilizer.

Table 8 Average Bag of Crops Harvested

Bags	Number of Respondents	Percentage
1-5 bags	88	24.4
6-10 bags	82	22.7
11-15 bags	49	13.5
16-20 bags	49	13.5
Above 20 bags	93	25.8
Total	**361**	**100**

Source: Field Survey, 2012.

Table 8 shows that 24.4 percent (88 farmers) harvest between 1-5 bags of grains annually on the same piece of land; 22.7 percent (82 farmers) harvest between 5-10 bags; 13.5 percent (49 farmers) harvest between 11-15 bags; 13.5 percent (49 farmers) harvest between 16-20 bags; 25.8 percent (93 farmers) harvest 20 bags and above annually. This indicates that average bags of crops harvest increases and this can be attributed to high rainfall, increase in farm size and availability of fertilizers.

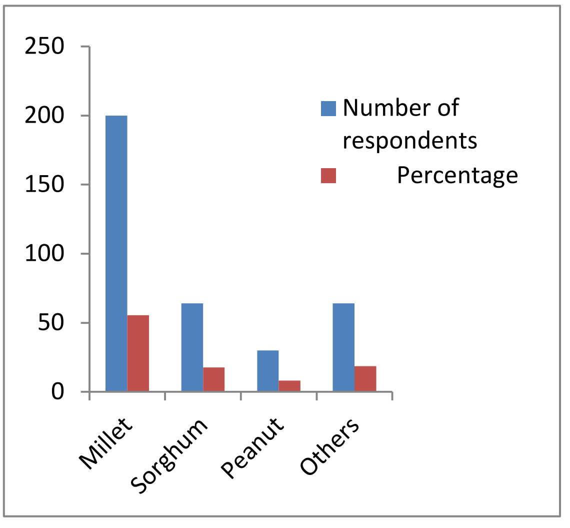

Fig. 5 Types of Crops Cultivated
Source: Field Survey, 2012

Fig. 5 shows that 55.4 percent (200 farmers) cultivate millet; 17 .7 percent (64 farmers) Sorghum; 8.3 percent (30 farmers) cultivates peanut; 18.6 percent (67 farmers) others. From the above, millet farmers have the highest population. This is because millet crop is strongly resistant to drought, it requires little effort and maintenance, with high yield compared to others.

CONCLUSION

The variability of climatic elements such as rainfall and temperature are important factors determining crop yield and food production. However, length of rainy season and the cropping season in the study area are consistent. Consequently, affecting crop yield by affecting the cultivation processes such as land preparation, clearing, planting weeding harvesting etc. Drought threatens agricultural production on the marginal lands, exacerbating poverty and undermining economic development. The poor crop yields due to drought result in mass poverty and starvation as agriculture is the mainstay of Nigeria's rural economy.

RECOMMENDATIONS

Based on the aforementioned findings the following recommendations are made:

i. There is an urgent need to increase the land under irrigation in the study area. Focus should be on the boring of wells, boreholes, earth dams and stock ponds can also contribute to the development of agriculture.
ii. Farmers should adopt improved agricultural technologies. This include adoption of new technologies, planting drought resistant and early maturing varieties especially millet, sorghum and cowpea.
iii. Farmers should adopt simple technique of cross-ridging to concentrate water and increase yield especially in drought conditions.
iv. There is the need to invest in soil and water conservation as well as pest and disease control in the area.
v. There is the need to improve the use of climate information to inform farmers to avoid surprises, and take right decisions in case of impending drought.

REFERENCES

American Meteorological Society [AMS] (2004). Meteorological Drought. Bull. Amer.Met.Soc, 85 Retrieved January 13,2009from http://www.ametsoc.org/policy/drought statement final 0304.html

Ati, O. F. (2006) Rainfall Characteristic in Drought -Prone Sudano-Sahelian Zone of Nigeria. Unpublished Ph.D. Dissertation. Department of Geography, Ahmadu Bello University,Zaria, Nigeria.

Ayoade, J.O. (2004) *Introduction to Climatology for the Tropics.* 2nd ed. Spectrum Books Limited, Ibadan.

Ayoade, J.O. (2005) *Introduction to Agro climatology*. 2nd ed. University Press Plc. Ibadan.

Economic Commission for Africa [ECA], (2007) *Drought and Desertification.* Fifth Meeting of the Africa Committee on SustainableDevelopment (ACSD5/RegionalImplementationMeeti ng (RIM) for CSD – 16 Adis Ababa.

(International Food Policy Research Institute [IFPRI] 2007) Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa IFPRI Discussion Paper 00714 Washington, DC 20006- 1002 USA

Jaiyeoba, I. A. (2002) Environment in: Okafor, S. Osaghae, E. Ikporukpo, C and Abumere,S.(Eds).*Africa Atlases: Atlas of Nigeria,* Les Editions J.A Paris, France, Pp.122-123

Okorie, F.C. (2003). Studies on Drought in the Sub- Saharan Region of Nigeria Using Satellite Remote Sensing and Precipitation Data. Retrieved September 21, 2007, from http://www.mathaba.net/gci/docs/research/nigeria-drought.html

Ojos Mejros Research Group; [ONRG] (2004a). Impacts of Droughts. Retrieved March 17, 2009 from http://threecissues.sdsu.edu/three issues drought facts 02.html.

Online Nigeria [ON] (2003) Nigeria: Physical Setting- Katsina State. Retrieved January,30 2003. From www.onlinenigeria.com/link/katsina adv.asp?blurb=289

Parry, M. L. and Carter, T. R., (1989) 'An Assessment of the Effects of Climatic Change on Agriculture', *Climate Change* 15, 95–116.

United Nation International Strategies for Disaster Reduction [UN/ISDR] (2007) *Drought Risk Reduction Frame Work and Practice*: Contributing to the Implementation of the Hyogo Frame Work Action.

ASSESSMENT OF THE ROLE OF URBAN AGRICULTURE FOR FOOD SECURITY IN IBADAN METROPOLIS OYO STATE, NIGERIA

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ABSTRACT

This study on assessment of the role of urban agriculture for food security in Ibadan metropolis, Oyo state, Nigeria, assessed the level of participation in urban agriculture within Ibadan metropolis, identified factors influencing urban agriculture, synthesized the contributions of urban agriculture towards improving life situation of urban residents in Ibadan and assessed the perception of urban agriculture by urban dwellers using survey research design. The sample size comprised of 206 respondents in the study area, which are engaged in agricultural activities. Simple random sampling technique was used in selecting the respondents and structured questionnaire. Data collected were presented descriptively using charts, percentage distribution, mean and standard deviation. The major findings of the study revealed that majority of the urban residents engaged in urban agriculture (64.5%). The factors that influenced urban farming were *location of farm*, farms on public land were (39.5%), their compound (32.6%) and undeveloped private land (31.8%), *size of farm*, with sizes being at least a plot (77.5%), *type of farming* as crop farming (37.2%) and livestock farming (33.3%) were the major farming. *Self labour* (65%) was the major type of labour that influenced urban agriculture. Contributions of urban agriculture towards improving life situation among urban residents in Ibadan were determined via utilization of farm harvest for both personal and public consumption (41.1%), alternative source of income (51.2%), and profit of about 16 – 30% (34.9%). Majority of the urban residents perceived farming to be a rural occupation (60.5%). The result from the test of hypotheses revealed that there is a significant relationship between a person's primary occupation and engagement in urban agriculture within Ibadan metropolis (X^2_{cal} = 63.279 > $X^2_{tabulated}$ = 7.81, $p < 0.05$) and urban agriculture makes a significant contribution to the livelihood of urban dwellers (Z_{cal} = 2.754 >$Z_{tabulated}$ = 1.96, $p < 0.05$).Based on the findings, the study recommended that Financial institutions, Government should provide urban farmers with facilities such as loans and agricultural inputs; agricultural extension support; farming calendar from agency like Nimet, Urban agriculture should be integrated into land use planning of all urban centers in Nigeria; Urban farming should be incorporated into our national agricultural research agenda so as to involve environment friendly technologies for commercial production and intensified sustainable cropping system.

Key word: urban agriculture, food security, means of livelihood, urban dwellers, farming

1.1: Background of the Study

A general consensus about the exact definition of urban agriculture does not exist. However, many researchers tend to define urban agriculture as any agricultural enterprise within or on the fringes of a town, city, or metropolis that grows or raises, processes, and distributes food and non-food products (Moustier, 1999; Mougeout, 2000; Bryld, 2003 Yet others define urban agriculture as any farming activity occurring in built-up 'intra-urban' areas and 'peri-urban' fringes of cities and towns (Thornton, 2008). These varied definitions illustrate the peculiarity and diversity of urban agriculture and, therefore, the range of policies and actors affected by it. Urban agriculture in Africa is as old as colonialism itself, when farming flourished in urban areas. In Nigeria, the practice of urban agriculture plays crucial role in enhancing urban food security since the cost of supplying and distributing food to urban areas that rely on rural production and imports, continue to increase, and do not meet the demand of urban residents, especially the urban poor. Increase in the demand for food and high rate of unemployment are common features in Nigerian cities. According to Olayioye (2011), traders, civil servants and artisans are finding it difficult to cope with high cost of living. The poor income in the urban area has encouraged agricultural production within the vicinity of the city. Urban agriculture (UA) contributes to local economic development, poverty alleviation, greening of the city and the productive reuse of urban wastes (Oyedipe, 2009).

For years now, the role of urban agriculture in improving the situation of urban residents has been ignored and in some areas treated as having only very little contribution to the urban economy. It has been considered a public health nuisance and activity of the rural community and not of urban economics. As a result, people who engage in urban agriculture have been unsupported and harassed, even in years of food shortages. Now, as the potential benefits of UA for food security and environmental management becomes better understood in policy circles, official attitudes in some countries are slowly but steadily changing (Aguda and Kuuire, 2012). Urban agriculture engages more than 800 million people in the world (UNDP, 1996). It contributes, to large extent, to food security and safety for approximately 50% of city dwellers worldwide. (Appeaning – Addo, 2010).

Food and Agriculture Organization (FAO) research indicates that the condition of adults and children plagued with diseases and living in low-income areas can improve significantly if they are engaged in urban agriculture/farming. (FAO, 2007). Such engagement can reduce malnutrition and increases the quantity of food intake (Bryld, 2003). Urban populace who depend mostly on the urban market for access to food, purchase more than 90% of their food (IFPRI, 2003), and with the rapid growth of Africa's urban population, demand for fresh food stuffs will continue to increase. Therefore, to ensure urban food security there is need to assess the role of urban agriculture, using Ibadan metropolis in Oyo state, Nigeria, as a case study**. Thus the study aim is to assess the contributions of urban agriculture to food security in sustaining livelihoods in urban centers in Nigeria using Ibadan metropolis, with the major objectives of;**

(a) Assessing the level of participation in urban agriculture within Ibadan metropolis.
(b) Identifying factors influencing urban agriculture in Ibadan metropolis
(c) Examine the contributions of urban agriculture towards improving life situation of urban residents in Ibadan, and also assess the perception of urban agriculture by urban dwellers in Ibadan metropolis

2,0 Materials and Methods

2.1 Description of the Study Area:

The city of Ibadan is located approximately between longitude $3^0 30'$ – 4^0E and latitude 7^0 – $7^0 30'$N. Ibadan is a city linked to many settlements in the west and Nigeria as a whole by roads, rail and air routes (Figure 2.1). The physical setting of the city consists of ridges hills that run in northwest – southeast direction. The highest peaks of these hills are found within the central part of the city such a Mokola, Mapo and Aremo. These hills range from 170 –400 meters above sea level. There are eleven Local Governments in Ibadan Metropolitan area consisting of five urban local governments in the city and six semi-urban local governments. The five urban local government areas where the study was conducted are North-West, North, South- West, North-East, and South-East (Figure 2.2). With their respective population size in 1991 and 2006, their percentage increase and growth rate as shown in table 2.1.

Table 2.1: Population of the study area

Local Government	**1991 pop**	**2006 pop**	**%Increase**	***Rate of Growth***
Ibadan North	302,271	306,795	1.5%	*0.10%*
Ibadan North East	275,627	330,399	19.87%	*1.22%*
Ibadan North West	147,918	152,834	3.32%	*0.22%*
Ibadan South East	225,800	266,046	17.82%	*1.10%*
Ibadan South West	227,047	282,585	2.00%	*0.13%*

Source: National Population Commission (NPC), 2009

2.1.1 Land Use and Location of Economics Activities in Ibadan

The administrative and commercial importance of Ibadan has resulted in land being a key investment asset and a status symbol for the population. This has been evident in the frequency of land disputes in the city due to multiple ownership. Although land ownership is theoretically vested in the government through a land decree, land is still very much private owned by families and lineages. Besides multiple ownership, land disputes also arise from non-compliance by people building houses in contravention to building codes and regulation.

The total land area of the eleven Local Governments of the Ibadan metropolitan area is 3.123km out of which about 15% falls in Urban Ibadan while the remaining 85% is in Rural Ibadan. Ibadan North Local Government has the largest land area among the urban Local Governments with 145.58km while Ibadan North West is the smallest with 31.38km. The second largest government in Urban Ibadan is Ibadan South West with 124.55km this represents about 4% of the total land of the City and about one quarter of Urban Ibadan. For the rural Local Government, Ido has the largest land area with 865.49km representing 27.71% of the total land of the City and 32.54% of the total rural land area. This is followed by OnaAra Local Government with 277.10km while Egbeda Local Government has the least land area of 136.83km.

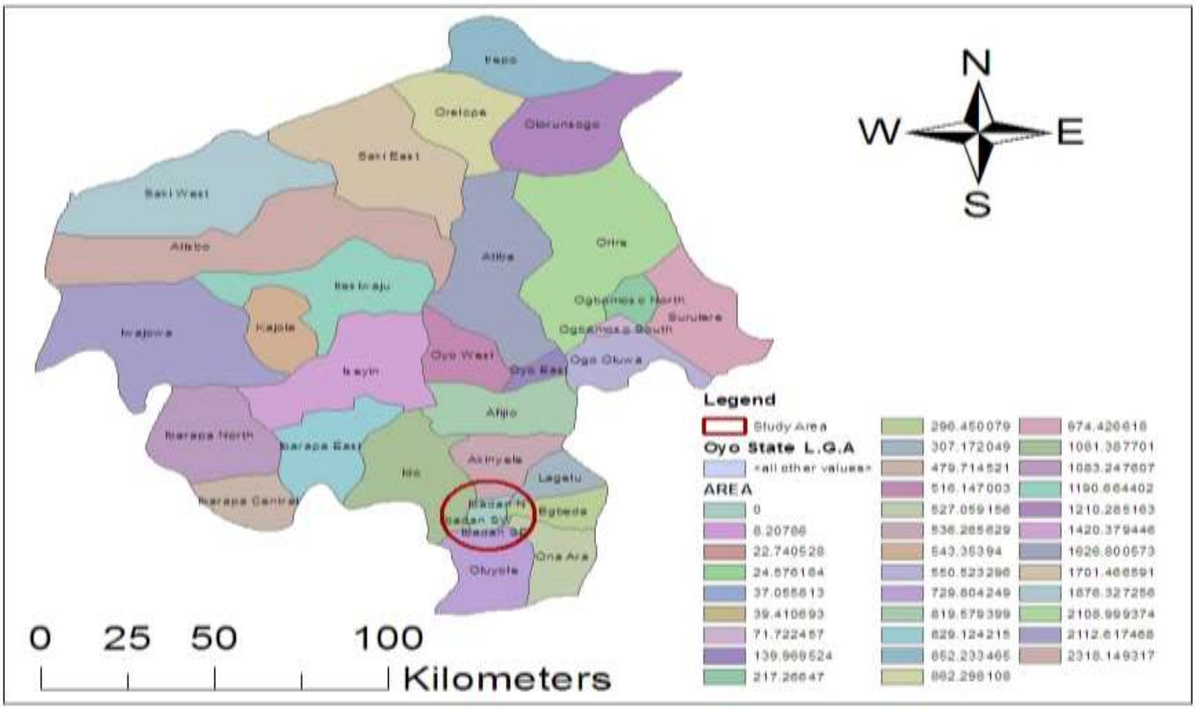

Figure 2.1: Map of Oyo State Showing Ibadan Metropolis the study area

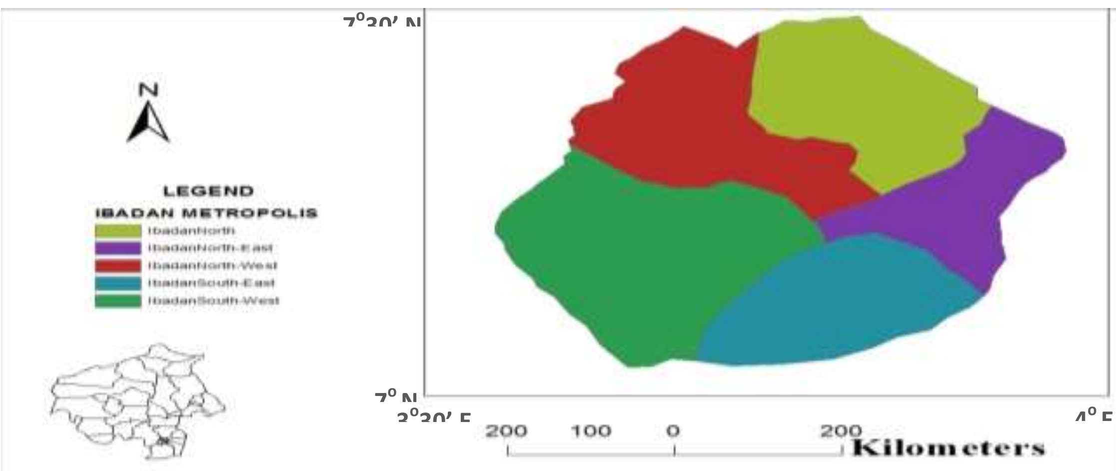

Figure 2.2: Map of Study area

The general land use pattern of the Ibadan metropolitan area shows a clear distribution purely residential use for Urban Ibadan and agricultural use for Rural Ibadan. According to Ayeni (1994) residential land use is the most predominant among all land uses in the built up part of Ibadan. In his analysis, the metropolitan areas refer to the urban only and some of the rural area. The arrival of the railway bringing European goods and personnel for trade and administration marked the beginning of large-scale immigration. The railway system began in 1896 in Lagos and reached Kano in 1911 while the first motorable road in Nigeria was constructed from Ibadan to Oyo in 1906. Ethnic groups such as the Ibos, Edos, Urhobos, Nupe, Igbiras, Hausa and Fulanis began to flood the city. Mokola became occupied mostly by Nupes and Igbiras. Sabo became occupied predominantly by the Hausas and Fulanis with an expensive cola-nut trade while using their heavy presence to influence politics. Oke-Ado and Oke-Bola were then laid out for occupation by Yoruba ethnic groups such as Ijebus and the Egbas. These were 'invaders' of some sort but not the caliber expected to challenge business elite. They constituted mostly the under-class which provided supporting services in the society.

The growth of Ibadan became more rapid from 1946 when it was made the headquarters of the then Western Region of Nigeria. It then began to attract more Europeans as administrators and businessmen, Yoruba's are mostly civil servants but also as traders and other ethnic groups who came into various un-skilled occupations. The settlement pattern continued to follow the triangular form which had been established and Jericho with other New Reservations. For Europeans were established because Agodi Hill had become 2,000, this is a large figure for those times. But Larger and more rapid expansion were taking place in the indigenous areas such as Oke –Padi, Oniyanrin, Oke –Aremo, Oke- Offa, Ode-Aje, Agugu, Elekuro, Kudeti and Ogunpa area. According to Ayeni (1994), "The Metropolitan Area of Ibadan has one of the highest population densities in the country and the mostly densely settled areas remain the central and indigenous core of the city."

3.0 RESEARCH METHODOLOGY

Data were sourced from primary and secondary source. The primary data were sourced; from reconnaissance survey, use of questionnaires and oral interview in and around the five local governments in Ibadan metropolis. First, a reconnaissance survey was carried out by personal observation to get first hand information on how urban populace in the study area participates in urban agriculture; Questionnaires were used to obtain information from respondents in relation to the residents' urban agricultural activities. Finally, interview method which involved asking the relevant questions about urban agriculture and food security in Ibadan metropolis was adopted. Secondary source of data were from existing literature, journals, annual reports, newsletters, internet materials and bulletin.

3.1 STUDY POPULATION

The population of the study was made up of all the inhabitants of Ibadan urban, because the research is investigating urban agriculture. The population Ibadan of metropolis comprises of North-West, North, South- West, North-East, and South-East (See Table2.1 above). From the table above is clear that Ibadan urban population growth has been on the increase in the past 15 years. This increase has its attendant problems like poverty, food insecurity and malnutrition. The population sample comprised 206 people living in the study area and engaged in agricultural activities. Simple random sampling techniques were used to select these respondents for the study. The technique is unbiased since each person, event, object or thing in the population is given equal opportunity of being selected for the study (Table 2.2).

Table 3.1: Sampling frame

Local Government	2006 Population	No of respondents
Ibadan North	306,795	42
Ibadan North East	330,399	42
Ibadan North West	152,834	40
Ibadan South East	266,046	41
Ibadan South West	282,585	41
	Total	206

3.2 METHOD OF DATA COLLECTION/ANALYSIS

A total of two hundred and six questionnaires were administered. All administered questionnaires were collected, although 6 of the questionnaires were unanswered. This represents 97% of the total questionnaire distributed, and this is considered adequate for the analysis.

The analysis was carried out to determine demographic characteristics of the respondents, distribution of respondents by occupation, farm location, types of farm enterprise, ways farm products are utilized, purpose for engaging in urban agriculture, and proportion of total income attributable to urban agriculture activities. The analytical techniques used were:

(a) Descriptive statistics, namely; simple percentages, tables, bar charts and pie charts
(b) The test statistics used for the null hypotheses was the chi-square at alpha level of 0.05. The Chi-Square test measures the difference between the actual frequencies and the expected frequencies, and is expressed as:

$$X^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where O_i-------O_k are observed values

$\sum$--------the sum of the frequencies

E_i------E_k are expected values

Degrees of freedom are V= n-1

The rational for using the chi-square statistical tool is that:

(a) The data is nominal
(b) The research subjects can be allocated into categories
(c) The sample is quite long

In employing the chi-square method of statistical analysis, the level of significance reveals the level at which the actual frequencies differed from the expected frequencies. This calls for either a rejection or acceptance of the null hypothesis.

4.0 Findings

4.1 DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

The demographic characteristics of respondents included gender, marital status, age (years), educational background, primary occupation, monthly income level, number in household and position in household; findings shows that (66%) of the respondents were males while 88 (44%) respondents were females indicating that more males are involved in urban farming than females. This result disagreed with the findings of Paola (2003), who reported that women are more dominant in farming due to the fact that they are responsible in feeding the family.

Higher percentages of the respondents are aged 26 to 35 years (31.5%) and 36 to 45 years (31.5%), followed by respondents that are aged 15 to 25 years (20.5%) while respondents aged 46 years and above are in the minority. This is indicative that people that are full of vigor and strength are more involved in urban agriculture. Olofin (2006) established that farmers between 30 to 70 years of age undertake urban crop production. 85 (42.5%) respondents that participate in urban farming are married, 57 (28.5%) respondents are single, 30 (15%) respondents are divorced/separated while 28 (14%) respondents are widowed. This shows that married people were more involved in urban agriculture. This can be associated with the need to take care of their family (Paola, 2003).

Furthermore (45.5%) respondents have tertiary education, 54 (27%) respondents have secondary education, and 34 (17%) respondents have primary education while 21 (10.5%) respondents have no formal education. This shows that a higher percentage of urban residents that engage in urban agriculture have higher education. As noted by Efferson (1994), good education enhances the ability to work out more profitable lines of investment.

Majority of the respondents, comprising 30.5% that are self-employed and 20.5% that are apprentices/self employed, are engaged in urban farming. This shows that respondents that are not engaged in white collar jobs are more engaged in urban farming, as noted by (Omonono, 2001).

Only 16.5% of the respondents earn a monthly income of above ₦45,000. This shows that majority of the urban dwellers that engage in urban agriculture do not earn much, and as such use urban agriculture as an alternative source of income. Thus, urban agriculture serves as a respite to financial inadequacies .Majority of the respondents (58.5%) said they belonged to households that are not more than four. Higher percentage (39%) of the respondents are fathers, followed by the dependents (31%) and finally the mothers (30%). This reveals that more of the urban dwellers that are involved in urban agriculture are fathers.

4.2 Level of Participation in Urban Agriculture within Ibadan Metropolis

As presented in Table 4.2, majority (64.5%) of the respondents have farm. This indicates that majority of the sampled urban dwellers participate in urban agriculture and have a place of their own, on which they practice it

Table 4.2: Possession of Farm

Farm Possession	Response	Percent (%)
Yes	129	64.5
No	71	35.5
Total	200	100.0

Source:Field Survey, 2014

4.3.2 Factors influencing Urban Agriculture in Ibadan Metropolis

Table 4.3, below, shows percentage responses of 39.5%, 32.6% and 31.8%, the respondents that indicated having farm upon which they practice urban farming, have such farms in public lands, their compound of residence and undeveloped private land. This shows the willingness of urban residents to engage in urban agriculture wherever there is available land.

Table 4.3: Farm Location

Location	Response	Percent (%)
Compound	42	32.6
Public Land	51	39.5
Place of Work	12	9.3
Undeveloped private land	41	31.8
Total	129	100.0

Source:Field Survey, 2014

Table 4.4 shows that majority of the respondents that own farms on which they engage in urban agriculture have at least a plot of land. This is revealed in the frequency response of 44 (34.1%) respondents who noted that their farm size is 1 plot while 56 (43.4%) respondents noted that their farm size is greater than a plot. This indicatively shows that the availability of larger sizes of farm encourages urban residents to engage in urban agriculture

Table 4.4: Farm Size

Size	Response	Percent (%)
Half of a standard plot	29	14.5
A plot	44	34.1
Greater than a plot	56	43.4
Total	129	100.0

Source:Field Survey, 2014

Table 4.5: Farm Rentage

Pay Rent	Response	Percent (%)
Yes	26	20.2
No	103	79.8

Total	129	100.0

Source:Field Survey, 2014

Table 4.5 shows that the land used by majority (79.8%) of the respondents for urban agriculture is not payed for or leased. This means that most of the respondents do not pay rent on the land they use in farming. Hence, the availability of free farmlands encourages urban agriculture among urban residents.

Table 4.6: Annual Rent Value

Value	Response	Percent (%)
N5,000 and below	16	61.5
N5,001 and N10,000	8	30.8
N10,001 and N15,000	0	0.0
N15,000 and above	2	7.7
Total	26	100.0

Source:Field Survey, 2014

As presented in Table 4.6, majority (61.5%) of the respondents that pay rent on their farm lands, do not pay more than N5,000 annually. This reveals that rent value determines engagement in urban agriculture, as the lower the rent vales, the higher the participation and vice-versa.

Table 4.7: Type of Farming

Type	Response	Percent (%)
Crop Farming	48	37.2
Livestock Farming	43	33.3
Fish Farming	17	13.2
Horticulture	21	16.3
Total	129	100.0

Source:Field Survey, 2014

As presented in Table 4.7, higher percentages of the respondents are involved in crop farming (37.2%) and livestock farming (33.3%).

Table 4.8: Type of Labour

Labour	Response	Percent (%)
Self Labour	65	50.4
Family Support	33	25.6
Hired Labour	31	24.0
Total	129	100.0

Source:Field Survey, 2014

As presented in Table 4.8, a higher percentage (50.4%) of the respondents tend to their farms themselves, followed by 25.6% respondents who involve other family members while only 24% of the respondents hire external labour. This shows that urban agriculture practiced by urban dwellers, is not on a large scale as more of the labour is self labour.

Table 4.9: Source of Water

Source	Response	Percent (%)
Government provided	16	12.4
Rainfall	39	30.2
Swamp lands	22	17.1
Personal efforts such as buying and fetching from well/stream	52	40.3
Total	129	100.0

Source:Field Survey, 2014

From Table 4.9, it is seen that major sources of water for the farmers are personal efforts such as buying the water and fetching from well/stream (40.3% responses) and rainfall (30.2% responses). Government has not made much concerted efforts in ensuring accessibility to water to urban dwellers, which goes a long way in impacting upon their involvement in urban agriculture and also affects their profit margin.

Table 4.10: Assistance from Government

Assistance	Response	Percent (%)
Subsidy on farm inputs	12	9.3
Government loan	11	8.5
Provision of land	15	11.6
None	91	70.5
Total	129	100.0

Source:Field Survey, 2014

As presented in Table 4.10, assistance from government to the urban dwellers that engage in urban agriculture is minimal, as most (70.5%) of the respondents noted not receiving any form of assistance from government. However, this has not hindered the respondents from engaging in urban agriculture.

Table 4.11: Membership of Farmers' Association

Membership	Response	Percent (%)
Yes	25	19.4
No	104	80.6
Total	129	100.0

Source:Field Survey, 2014

As revealed in Table 4.11, majority (80.6%) of the respondents are not members of any farmers' association. This shows that most of the urban dwellers that engage in urban farming do not engage in farming as the primary occupation, and thus, do not see the need to be part of any farmers' association.

Table 4.12: Benefits derived as Member of Farmers' Association

Benefits	Response	Percent (%)
Access to bank loan	10	40.0
Source of labour	2	8.0
Subsidized farm input	1	4.0

None	12	48.0
Total	25	100.0

Source:Field Survey, 2014

Table 4.12 shows a higher frequency (48%) of the respondents that indicated being members of a farmers' association saying that they did not derive any benefit as members of the association. However, among those that derived benefits, a higher frequency (40%) said that the benefit they derived was having access to bank loans.

4.3.3 Contributions of Urban Agriculture towards improving Life Situation of Urban Residents in Ibadan

The contributions of urban agriculture towards improving life situation of urban residents in Ibadan is captured in the respondents' responses below Tables 4.13 to 4.16.

Table 4.13: Utilization of Farm Harvest

Utilization	Response	Percent (%)
Personal Consumption	20	15.5
Public Consumption	44	34.1
Both	53	41.1
Others	12	9.3
Total	129	100.0

Source:Field Survey, 2014

Fig. 4.12: Utilization of Farm Harvest

From Table 4.13, it is revealed that both the respondents and the public feed from the harvest gotten from urban agriculture. While only 15.5% respondents said they use feed themselves only from the harvest, 41.1% noted that they feed both themselves and the public while 34.1% respondents said they feed the public. This shows that urban agriculture has the capacity to ensure food sufficiency in the urban settlement.

Table 4.14: Contribution of Urban Farming to Livelihood

Contribution	Response	Percent (%)
Nutrition	19	14.7
Alternative source of income	66	51.2
Main source of income	44	34.1
Total	129	100.0

Source:Field Survey, 2014

The presentation in Table 4.14 shows that the respondents indicated that urban farming has contributed to their livelihood. The major contribution it has is serving as an alternative source of income (51.2% responses). It also serves a main source of income for a reasonable percentage of respondents (34.1%). 14.7% respondents noted that it serves as a source of nutritional enhancement to their livelihood. This shows that urban farming contributes to the livelihood of urban dwellers by increasing their financial capacity and enriching their nutrition.

Table 4.15: Profit Obtained From Urban Agriculture

Profit Range	Response	Percent (%)
15% and below	28	21.7

16 – 30%	45	34.9
31 – 45%	24	18.6
46 – 60%	14	10.9
61% and above	18	13.9
Total	129	100.0

Source:Field Survey, 2014

As presented in Table 4.15, all the respondents noted that they had profits from urban agriculture. In particular, a higher percentage (34.9%) of the respondents had profit levels of 16% to 30% from urban agriculture. This reveals that urban agriculture is profitability and very rewarding.

Table 4.16: Expenditure Items

Item	Response	Percent (%)
Labour	23	17.8
Fertiliser	24	18.6
Seeds	32	24.8
Feed	29	22.5
Land	21	16.3
Total	129	100.0

Source:Field Survey, 2014

As presented in Table 4.16, higher percentages of the respondents spend most of their income from urban farming on seeds (24.8% responses) and feeds (22.5%). This is in line with the findings presented in Table 4.7 which shows that higher percentages of the respondents are involved in crop farming (37.2%) and livestock farming (33.3%); thus the expenses on seeds and feeds.

4.3.4 Perception of Urban Agriculture by Urban Dwellers

In determining the perception of urban agriculture by urban dwellers, the respondents' opinion as reflected is presented in Table 4.17 below

Table 4.17: Perception of Farming

Perception	Response	Percent (%)
A rural occupation	78	60.5
A dirty job for illiterate	34	26.4
Lucrative job for everybody	17	13.2
Total	129	100.0

Source:Field Survey, 2014

As presented in Table 4.17, majority of the respondents (60.5%) said that people perceive farming to be a rural occupation. 26.4% respondents said that it is perceived as a dirty job for illiterates while 13.2% respondents noted that it is a lucrative job meant for everybody. The above presents the reason, why a lot of people are not involved in urban agriculture, as they general believe it is meant for rural occupation and the illiterate.

4.4 TEST OF HYPOTHESES

The various hypotheses are tested in this section are shown below.

4.4.1 Test of Hypothesis One

Ho: There is no significant relationship between a person's primary occupation and engagement in urban agriculture within Ibadan metropolis

Hi: There is a significant relationship between a person's primary occupation and engagement in urban agriculture within Ibadan metropolis

In testing this hypothesis, the cross-tabulation between primary occupation and engagement in urban agriculture is presented. This data was tested using the Chi-Square test statistics.The result is presented below.

Table 4.18: Cross-tabulation between Primary Occupation and Engagement in Urban Agriculture

		Engagement in Urban Agriculture		
		Yes (%)	**No (%)**	**Total (%)**
primary occupation	civil/public servant	26 (55.3)	21 (44.7)	47 (100.0)
	organised private sector worker	10 (21.7)	36 (78.3)	46 (100.0)
	self-employed	32 (80.0)	8 (20.0)	40 (100.0)
	apprentice/unemployed	61 (91.0)	6 (9.0)	67 (100.0)
Total		129 (64.5)	71 (35.5)	200 (100.0)

As presented in Table 4.18, it is observed that respondents that are apprentice/unemployed have the highest percentage (91%) participation level in urban agriculture, followed by those that are self-employed (80%) and then the civil/public servants (55.3%) and finally those in organised private sector (21.7%).

Table 4.19: Chi-Square Test Result for Hypothesis One

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	63.279[a]	3	.000
Likelihood Ratio	66.969	3	.000
Linear-by-Linear Association	33.639	1	.000
N of Valid Cases	200		

From the table of percentile value for chi-square distribution, critical value of X^2 at 95% critical level of significance is 7.81.

Table 4.19 presents the calculated Chi-Square value of 63.279. Since the calculated X^2 value of 63.279 is greater than the critical value of 7.81, Ho is rejected, while Hi is accepted accordingly. Thus, there is a significant relationship between a person's primary occupation and engagement in urban agriculture within Ibadan metropolis.

This implies that inhabitants of Ibadan Metropolis who belong to informal sector (that is the self employed group and others) participates more in urban Agriculture than the other group of people who belong to formal sector. This could be may be because they do not have white collar jobs.

4.4.2 Test of Hypothesis Two

Ho: Urban agriculture does not make any significant contribution to the livelihood of urban dwellers

Hi: Urban agriculture makes a significant contribution to the livelihood of urban dwellers

In testing this hypothesis, the data presented in Table 4.15 was tested using the one-sample Kolmogorov-Smirnov (Z) test statistic. The result is presented below.

Table 4.20: One-Sample Kolmogorov-Smirnov (Z) Test

		Profit
N		129
Normal Parameters[a,,b]	Mean	2.6047
	Std. Deviation	1.31944
Most Extreme Differences	Absolute	.243
	Positive	.243
	Negative	-.112
Kolmogorov-Smirnov Z		2.754
Asymp. Sig. (2-tailed)		.000

a. Test distribution is Normal.

b. Calculated from data.

As presented in Table 4.20, the calculated Kolmogorov-Smirnov Z value is 2.754. This is greater than the critical Z-value of 1.96 (5% level of significance). This result is significant as $p < 0.05$. Therefore, the null hypothesis is rejected and the alternative hypothesis accepted accordingly. Hence, urban agriculture makes a significant contribution to the livelihood of urban dwellers. This implies that Urban Agriculture contributes to the livelihood of the inhabitants of Ibadan Metropolis, thereby playing an important role in contributing to food security of the people in the study area.

5.0 Conclusion

The contribution of urban agriculture to the socio-economic development of urban dwellers cannot be underestimated as it goes a long way in improving their living hood. This study has revealed that major benefits derived by urban families were household food supply, income and full time employment, opportunity. Most of the respondents were found to attain certain level of education and engaged in crop production, livestock, fishery and other types of farming. It’s evident from the study that most of the urban farmers did not belong to association or group. Consequently, the result further revealed that most respondents did not benefit from government in order to expand their farm. Current employment situation in the urban areas do not generate adequate income for the poor urban population. Thus, urban agriculture should be regarded as an integral component in urban income, employment and food security. However, certain constraints were facing the enterprise which include lack of access to credit facilities, land scarcity, inadequate water supply, highest of planting materials and important meteorological information (farming calendar) to improve productivity.

It is apparent from this study that urban agriculture enjoys the advantages of providing fresh food for home consumption, income for the family and employment for the poor, therefore it broader goals of national agriculture, livelihood and food security.

Recommendations include Community participation in municipal key decision on urban agriculture, Develop linkages with other sectors, Coordination multiple levels of responsibility, Water for food, Appropriate land tenure choices, More inclusive land zoning codes, Mobilization for urban agriculture, finally Urban farming should be incorporated into our national agricultural research agenda so as to involve environment friendly technologies for commercial production and intensified sustainable cropping system.

REFERENCES

AppeaningAddo K., (2010). "Urban and Peri-Urban Agriculture in Countries Studies Using Remote Sensing and In Situ Methods." *Remote Sensing*, 2(2): 497- 513

Ayeni, B. (1994), "The Metropolitan Area of Ibadan, Its Growth and Structure" a contribution in the Titled *Ibadan Region*, Edited by: Filani, M.O., Akintola, F.O. and Ikporukpo, C.O., Ibadan – Oyo State: Rex Charles Publication in Association with Connel Publications

Bryld, E., (2003). "Potentials, Problems and Policy Implications for Urban Agriculture in Developing Countries." *Agriculture and Human Values*, 20(1): 79-86.

Cleaver, A. and Toner., (2006). "The Evolution of Community Water Governance in Uchira, Tanzania: The Implications For Equality Of Access, Sustainability And Effectiveness." Natural Resources Forum, 30(3): 207-218.

Cofie, O., (2009). *Emerging Issues In Urban Agricultural Development In West Africa*. Accra, Ghana: International Water Management Institute.

Cofie, O., and Drechsel, P., (2007). "Water for Food in The Cities: The Growing Paradigm of Irrigated (Peri)-Urban Agriculture And Its Struggle In Sub-Saharan Africa." *African Water Journal*, 1(1): 22-32.

Drakakis-Smith, D. (1992). "And the cupboard was bare: Food security and food policy for the urban poor". *Geographical Journal of Zimbabwe* 23: 38-58.

Dreschel, P., Cofie, O., Van Veenhuizen, R., and Larbi, T.O., (2008). "Linking Research, CapacityBuilding and Policy Dialogue In Support Of Informal Irrigation In Urban West African." *Irrigation and Drainage*, 57(3): 268-278.

Effersion (1994): *Principle of farm management*, first edition, London: Mc Graw Hill Book company Inc.

Egyir ,I., And Beinpuo, E., (2009). *Strategic Innovations In Urban Agriculture, Food Supply And Livelihood Support Systems Performance In Accra, Ghana*. College of Agriculture and Consumer Sciences. University of Ghana.

FAO (Food and Agricultural Organization), (2012) *Growing Greener Cities in Africa*, FAO: Rome

FAO, (2007). *The Urban Producer's Resource Book: A Practical Guide for Working with Low Income Urban And Peri-Urban Producers Organizations*. Rome: FAO.

Federal Office of Statistics (FOS)(1998); *Poverty Profit for Nigeria, An analysis of 1996/1997, Nationwide Consumer Survey.*

Fowler, A., (1997). *Striking A Balance: A Guide To Enhance The Effectiveness Of Non-Governmental Organizations In International Development.* London: Earthscan.

Graefe, S., Schlecht, E., And Buerkert, A., (2008), "Opportunities and Challenges Of Urban And Peri Urban Agriculture in Niamey, Niger." *Outlook on Agriculture* 37(1): 47-56.

Harrigan, J., (2008). "Food Security, Poverty and the Malawian Starter Pack: Fresh Start Or False Start." *Food Policy* 33(3): 237-249.

International Food Policy Research Institute (IFPRI), (2002). Ghana: The Accra Urban Food and Nutrition Study Washington D.C

International Food Policy Research Institute (IFPRI), (2003). The Accra Urban Food and Nutrition Study Washington D.C.

Kombe, W., (2005). "Land Use Dynamics in Peri-Urban Areas and Their Implications on The Urban Growth And Form: The Case Of Dar Es Salaam, Tanzania." *Habitat International* 29(1): 133-135

Macgregor, J. And Vorley, B., (2006). "Fair Miles The Concept Of "Food Miles" Through A Sustainable Development Lens". *International Institute for Environment and Development*

Mayeko, K.K., (2009). "Wastewater Use and Urban Agriculture in Kinshasa, Dr. Congo." In Redwood, M.Ed., (2009). *Agriculture in Urban Planning: Generating Livelihoods and Food Security*. Ottawa: Earthscan and IDRC. Ch. 8: 147-166.

Millennium Development Goals (MDG) Report, (2010). MDG Report 2010 R15 – Low 20100615- Pdf (Application/Pdf Object) Retrieved 7/19/2011, 2011, From Http://Www. Un.Org/Millenniumgoals /Pdf/ MDG Report 2010 En R15-Low 20100615- Pdf#Page=13

Molden, D., (2007). *Water for Food, Water for Life: A Comprehensive Assessment of Water Management In Agriculture*. London: Earthscan

Moore, D., (1998). "Subaltern Struggles and The Politics of Place: Remapping Resistance In Zimbabwe's Eastern Highlands." *Cultural Anthropology*, 13(3): 344-82.

Mougeout, L.J. A., (2000). *Urban Agriculture, Definition, Presence, Potentials and Risks and Policy Challenges*. IDRC, Cities Feeding People Series. Report 31

Mougeout, L.J. A., (2005). "Conclusion- Neglected Issues on Form and Substance Of Research On Urban Agriculture". In L J A Mougeot (Ed.), A*GROPOLIS- The Social, Political and Environmental Dimensions of Urban Agriculture*. Earthscan/IDRC, Ottawa.

Moustier P., (1999). Definitions and Boundaries of Peri-Urban Agriculture in Sub-Saharan African. Peri Urban Agriculture in Sub-Saharan African, 29-42.

Moustier P., (2007). "Urban Horticulture in African and Asia, an Efficient Corner Food Supplier Proceedings of the International Symposium on Horticultural Plants." *Urban and Peri-Urban Life*, (762): 145-158.

National Population Commission (2009). *National and State Population and Housing Tables. Priority Tables*. Volume I, Abuja: NPC

Nkurunziza, E., (2007). "Informal Mechanisms for Accessing and Securing Urban Land Rights: The Case Of Kampala, Uganda." Environment and Urbanization And Agriculture Development Centre (ZEL), 19(2): 509-526.

Obuobie, E., Danso, G. And Drechsel, P., (2003). "Access to Land and Water For Urban Vegetable Farming In Accra". *International Water Management Institute (IWMI)*.

Obuobie, E., Keraita, B., Danso, G., Amoah, P., Cofie, O., Rashid-Sally, L., and Drechsel, P., (2006). *Irrigated Urban Vegetable Production In Ghana. Characteristics, Benefits and Risks*. Canada: City Farmer.

Olayioye, J. T. (2012). "Urban Agriculture in Ilorin, Kwara State". A dissertation in the Department of Urban and Regional Planning. University of Ibadan, Nigeria. Nigeria.

Olofin, O. P. (2006), "Foreign Aids, Food Supply and Poverty Reduction in Nigeria B Examination of possible nexus", www.mpra.ub.unimuenchen.de/16263/

Omonona, B.T. (2001). "Poverty and its correlates among rural farming households in Kogi State, Nigeria". Ph.D. Thesis, University of Ibadan, Ibadan. Nigeria.

Oyedipe, E. O. (2009), *Nigeria: National Food Crisis Response Progam*, Abuja: FAO

Paola, I.I. (2003); "The problem of access land in Diuo in Urban Agriculture Magazine" No 11 pg 18-19

Payne, G., (2000). "Urban Land Tenure Policy Options: Titles and Rights?" Paper Presented At the World Bank Urban Forum, Westfields, Marriott, Virginia, USA 03-05 April 2000

Payne, G., Durand, A., And Rakodi, C., (2007) "Social And Economic Impacts Of Land Titling Programs In Urban And Peri-Urban Areas: A Review Of Literature", Peri-Urban Agriculture in Africa: Proceedings Of A Workshop: Netanya, Israel, 23-27 June. Aldershot, UK: Ashgate Publishing.

Qadeer, M.A., (2004). "Urbanization by Implosion." *Habitat International* 28: 1-12

Rakodi, C., (2002). "Interactions between Formal and Informal Urban Land Management: Theoretical Issues and Practical Options". In *Urban Land Management in African*, (Eds) V. Kreibich and W. Olima, 11-33. Dormund: SPRING Research Series.

Rakodi, C., And Leduka, C., (2004). "Informal Land Delivery Processes And Access To Land For The Poor: A Comparative Study Of Six African Cities." Policy Brief No. 6. Informal Land Delivery Processes In African Cities. Birmingham: University Of Birmingham.

Ravallion, M., Chen, S., And Sangraula, P., (2007). "New Evidence on the Urbanization of Global Poverty." *Population and Development Review*, 33(4): 667-701

Robinson, J., (2006). *Ordinary Cities: Between Modernity and Development*. London: Routledge.

Ruel, M.T., Minot, N., and Smith, L., (2004). "Patterns and Determinants of Fruits and Vegetable Consumption In Sub- Saharan African." Background Paper for the Joint FAO/WHO Workshop On Fruit And Vegetables For Health, 1-3 September (2004), Kobe, Japan.

Salle, J.And Holland, M., (2010). *Agricultural Urbanism: Handbook for Building Sustainable Food Systems of 21st Century Cities*. Manitoba: Green Frigate Books.

Sawio, C. J. (2004). *Who are the Farmers of Dar Salaam? In Cities Feeding People*. Ottawa: IDRC.

Sen, A.K. (2001); *Poverty and Families: An Essay on Entitlement and Deprivation* Oxford: Press.

Sheldon, K. (1991). *Farming in the City: Urban Women and Agricultural Work in Mozambique*. University of California, Los Angeles: Centre for the Study of Women, University of California.

Simatele, D. M., AndBinns.T., (2008). "Motivation and Marginalization In African Urban Agriculture: The Case Of Lusaka, Zambia." *Urban Forum*, 19: 1-21

Smit, J., Ratta, A. & Nasr, J. (1996) *Urban Agriculture: Food, Jobs and Sustainable Cities,* United Nations Development Programme: New York.

Smith, D. (1996). "Urban Agriculture InHarare: Socio-Economic Dimension Of A Survival Strategy." In D. Grossman, L.M. Van Den Berg, and H.I. Ajaegbu (Eds.), Urban And

Smith, O.B., (2002), *Overview of urban agriculture in West African cities*, Ottawa: IDRC.

Swindale, A., &Bilinsky, P., (2006). "Development of a Universally Applicable Household Food Insecurity Measurement Tool: Process, Current Status and Outstanding Issues." *Journal Of Nutrition*, 136(5): 1449-1452 .

Tacio, D. (2007). "Urban Farming Can Help Feed Millions". Poepleandplanet.com.

Thornton, A., (2008). "Beyond the Metropolis: Small Towns Case Studies of Urban and Peri-Urban Agriculture in South Africa." *Urban Forum*, 19: 243-262 .

Tibaijuka, K., (2009). *Building Prosperity: Housing and Economic Development*. London, UK and Sterling, VA, USA: Earthscan Publishing London.

Tinker, I. (1994), "Urban Agriculture is already feeding cities." In *Cities Feeding People: An Examination of Urban Agriculture in East Africa*. IDRC: Ottawa; vii – xiv

Tokunbo, S.O (2003) *Urban Poverty in Nigeria: A Case Study of Agege Area of Lagos State, Nigeria*, University of Ibadan Press: Ibadan

Tony J.N and Nel E. (2013). The Significance Of Urban Agriculture In Food Security And Sustainable Livelihoods In Response To Economic Restructuring In Zambia's Copperbelt Province, final report of Global Education Programme International Development Research Fund

UNDP (1996). *Urban Agriculture- Food, Jobs and Sustainable Cities*. New York: United Nations Development Programme Publication Series for Habitat II, Volume One.

UNDP. (2006). *Employment Opportunities and Working Conditions of Rural and Peri-Urban Youth in Liberia*. UNDP: New York

United Nations Food and Agricultural Organization (UNFAO) (1998). *The State of Food and Agriculture*, UNFAO: Rome.

United Nations Food and Agricultural Organization (UNFAO) (1999). *The State of Food and Agriculture*, UNFAO: Rome.

United Nations Food and Agricultural Organization (UNFAO) (2001). *The State of Food and Agriculture*, UNFAO: Rome.

World Bank (1996), *World Development Reports*, Oxfords: Oxford University Press

Zezza, A. and Tasciotti, L. (2010), "Urban agriculture, poverty, and food security: Empirical evidence from a sample of developing countries", *Food Policy* 35 (2010) 265–273

APPLICATION OF MOISTURE AGROCLIMATIC MODEL TO THE GROWTH OF MAIZE AND OKRA IN SOLE-CROPPING AND MIXTURES IN ABEOKUTA, NIGERIA

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ABSTRACT

Moisture agroclimatic parameters are critical to crop growth in rain-fed agriculture. The application of moisture agroclimatic model i.e. Rainfall-Potential-Evapotranspiration (P-PE) to the growth of maize (*Zea mays*) and okra (*Abelmoschus esculentus*) in sole and mixtures was undertaken in both early and late cropping seasons in 2012. According to the model, the commencement of land preparation is marked when accumulated difference between rainfall (P) and one-tenth of potential evapotranspiration (0.1PE) is zero: ($\sum$P-0.1PE) = 0, while the onset and cessation of rains were marked when ($\sum$P-0.5PE) = 0. During the early season, land preparation started June 5 and July 4 when ($\sum$P-0.1PE) = 9.7 mm and 9.4 mm respectively. Planting commenced June 7 (Pl_1early) and July 5 (Pl_2early) when ($\sum$P-0.5PE) = 53 mm and 50 mm respectively. During the late season, land preparation started September 8 and October 8 when ($\sum$P-0.1PE) = 9.4 mm and 10.3 mm respectively. Planting started September 26 (Pl_1late) and October 9 (Pl_2late) when ($\sum$P-0.5PE) = 52 mm and 51 mm respectively. The treatments consisted of sole cropping (maize and okra) and intercropping (maize:okra, 1:1 alternate rows and maize:okra, alternate planting/row) arranged in a randomized complete block design with three replicates. Five phenological stages (establishment, vegetative, flowering, grain filling/fruiting and maturity) were used to evaluate impact of moisture indices on the crops' performance. Rainfall (P) and potential-evapotranspiration (PE) were correlated with crops' growth parameters (plant height, number of leaves and leaf area (LA)). Also, the data collected from the crops' growth and yields' parameters (maize yield/plant, ear diameter and length, number of ears/plant, cob diameter, cob length, number of fresh grain/cob, weight of fresh grains/cob and weight/100 fresh grains; pod weight/plant and pod yield/ha) were subjected to analysis of variance. The results of the early and late cropping seasons showed a positive interaction among the moisture indices as 0.1PE, 0.5PE and 1.0PE, which were less than P. In both seasons emergence of maize and okra was 15 - 30% higher at Pl_2early and Pl_2late than at Pl_1early and Pl_1late. PE had no significant ($p>0.05$) correlation with all the growth parameters, but P had significant ($p<0.05$) but negative correlations with LA, height and leaf production in maize in sole and mixtures; and LA of okra in 1:1 alternate rows; heights of okra in both sole and 1:1 alternate rows. Treatments had no significant ($p>0.05$) effects on the yields' parameters of maize and okra at Pl_1early and Pl_2early and also at Pl_1late and Pl_2late in sole and mixtures. The yields of maize and okra at Pl_1early and Pl_2early were significantly ($p<0.05$) higher than those at Pl_1late and Pl_2late in sole and mixtures. The study concluded that land preparation should commence when P is between 0.1PE and 0.5PE and planting when P is above 0.5PE. Also planting of maize and okra should not be delayed during the late cropping season till late September or early October as a result of inadequate moisture availability during their reproductive stages.

INTRODUCTION

In Abeokuta, south-western Nigeria, agricultural production is largely rainfed. Therefore, crop growth and the length of growing season are mainly controlled by the incidence and distribution of rainfall. In the last two decades, there have been anomalies in the incidence and distribution of rainfall. Therefore, the onset, cessation, duration and distribution of rainfall are very erratic. The effects on annual and biannual crops are severely felt. The tropical regions particularly the southwest regions are vulnerable to the uneven distribution of rainfall (Bello, 2000; Igwebuike *et al.,* 2010). It is also becoming more important to raise crop productivity in order to meet the increasing food requirements of an increasing population all over the world. Food shortage is therefore linked with rainfall variability (Adefolalu, 2004; Tunde *et al*., 2011). Kurukulasuriya and Rosenthal (2003); Nyong, (2008) and Tunde *et al*., (2011) observed that variability in rainfall characteristics has the potential to influence crop production significantly and can even alter the distribution of agro-ecological zones and runoff or water availability is critical in determining the impact of rainfall variability on crop production, especially in Nigeria. According to FAO (2005), by 2100 Nigeria and other West African countries are likely to have agricultural losses of up to 4% due to variability in rainfall amount and distribution. Maize *(Zea mays)* is an important traditional food crop grown in nearly all the ecological regions of Nigeria (Agboola, 1979; IITA, 1988 and Bello, 2000). It serves a multipurpose use for both man and livestock animals in the country (Bello, 2000). Okra is the second important vegetable crop that belongs to the genus *Abelmoscvhus*, family *Malvaceae* and has two main species: *Abelmoscvhus esculentus (L.)* Moench and *Abelmoscvhus caillei (*A.Chev.) Stevels (Siemonsma, 1982). It originates probably from East Africa and today is widely distributed in the tropics, subtropics and warmer portions of the temperate region (ECHO 2003). The economic importance of okra cannot be overemphasized. Okra contains carbohydrates, proteins vitamin C and minerals in large quantities for the human diets (Adeboye and Oputa, 1996; Lee *et al.*, 2000; Olasantan *et al*, 2004; Adebisi, *et al*., 2007 and Dauda, *et al*., 2010).

MATERIALS AND METHODS

The experiment was conducted at the Federal University of Agriculture Abeokuta (FUNAAB), in Odeda Local Government Area, Ogun State, South Western Nigeria, during the 2012 early and late planting seasons. It is located between Lat.7°20ˊ–7°25ˈN and Long. 3°40ˈ- 3°45ˈE at an altitude of 141 m above the mean sea level. FUNAAB has area coverage of 98,105.39 km^2. The study area is characterized by a tropical climate with distinct wet and dry seasons. The wet season is associated with the prevalence of the Moist Maritime Southwesterly Monsoon from Atlantic Ocean and dry season by the Continental Northeasterly harmattan winds from Sahara desert. The study area is located within a region characterized by bimodal rainfall pattern. The first peak is in June and the second in September. These peaks are usually separated by a short dry spell towards the end of July or beginning of August. The long dry period extends from late November to March. The annual rainfall of the study area ranges between 1400 and 1500 mm. The study area is characterized by relatively high mean annual air temperature of about 30°C. The humidity is lowest (30%) at the peak of dry season in February and highest (96%) at the peak of the rainy season between June and September. The length of the growing period is approximately 200 days.

Climatic data were collected from Agrometeorological weather station on a daily basis and processed into decades and months.The onset and cessation of rains and the reliable time to start planting during the early and late growing seasons were determined using the P-PE model. Following the rainfall-potential evapotranspiration model, the onset (P_{onset}) of the rains is expressed as the time when accumulated difference between rainfall and half potential evapotranspiration is equal to or greater than zero provided that a dry spell of five days or more did not occur in the week following and preceding the date of onset and cessation respectively (Bello, 1996).
This is expressed as:

$$\sum(P-0.5PE)\geq 0$$

Where

PE = Potential evapotranspiration

P = Rainfall

0.5PE = Half of the potential evapotranspiration

Preparatory periods both for early and late rains, which are the periods when accumulated difference between rainfall and one-tenth of potential evapotranspiration is equal or greater than zero. This is expressed as

$$\sum(P-0.1PE)\geq 0$$

Where

0.1PE =One tenth of the potential evapotranspiration,

The end of rains which is the time when accumulated difference between rainfall and half potential evapotranspiration is equal or less than zero. This is expressed as

$$\sum (P-0.5PE) \leq 0,$$

RESULTS AND DISCUSSION

Figure 1 showed the result of rainfall-potential evapotranspiration (P-PE) model for the early and late rains during the experimental periods. The model showed that the interval between dekad 3 – 6 appeared as a false time for land preparation for maize and okra crops. This is due to the fact that shortly after this period and particularly between dekad 6 – 11, the accumulated difference between rainfall and one tenth of potential-evapotranspiration fluctuated a great deal. This trend is detrimental to the required soil moisture for land preparation for seasonal crops like maize and okra for instance, the exposure of land surface/land preparation during this period might lead to the deterioration of soil nutrients due to leaching of phosphorus flush and nitrate that are usually high during the period. Therefore, conservation tillage during this period should not be discouraged. The model further depicted that dekad 4 was clearly a false onset of the rains. For instance, shortly after the accumulated difference between rainfall and half potential-evapotranspiration exceeded zero i.e. ($\sum$P-0.5PE)>0, there was a prolonged dry spell of about 7 dekads. This implies that rainfall was unable to satisfy the evaporative demand of the plant environment. And if farmers should plant at this period, they will experience caking of the top soils as well as total crop failure as a result of dry spell. This is one of the reasons why planting were done at dekad 16 and 19 for the early season. The model further depicted that dekad 12 marked the start of land preparation because the accumulated difference between rainfall and one-tenth of potential evapotranspiration is equal to zero. Therefore, dekads 12 – 14 represented as ‘A-B’ were the reliable land preparatory periods when farmers would profitably prepare the land for annual crops like maize, okra etc. At point B (i.e. within the dekad 14), where $\sum$(P-0.5PE)=0 marked the reliable onset of rains and the beginning of early rains and that coincided with the second week of May. Furthermore, within the dekad 14 represented as ‘B-C’ was the first intermediate period for the early rains when rainfall is greater than 0.5potential-evapotranspiration (0.5PE) and less than potential-evapotranspiration. From dekad 14 – 22 represented as ‘C-D’ were the humid periods where the rainfall is greater than potential-evapotranspiration. Within the dekad 22 which is represented as ‘D-E’ is the second intermediate period for the early rains where rainfall is greater than 0.5potential-evapotranspiration and less than potential-evapotranspiration. The early rains ranged from dekad 14 - 22. Towards the end of dekad 22 i.e. ‘E-G’ was the short period of little dry season. At the end of dekad 22 marked the start of land preparation for the late rains because the accumulated difference between rainfall and one-tenth of potential evapotranspiration is equal to zero. Therefore, from dekads 23 – 24 represented as ‘F-G’ were also the land preparatory periods when farmers would profitably prepare the land for annual crops like maize, okra etc for late rains. At point G, (i.e. within the dekad 24), where $\sum$(P-0.5PE)=0 marked the reliable onset of late rains and the beginning of late rains which coincided with the third week of August. From the dekad 24 – 27 represented as ‘G-H’ was the first intermediate period for the late rains when rainfall is greater than 0.5potential-evapotranspiration and less than potential-evapotranspiration. From dekad 27 – 31 represented as 'H-I' were the humid periods where the rainfall is greater than potential-evapotranspiration PE. From the dekads 31 - 32 which is represented as 'I-J' was the second intermediate period for the early rains where rainfall is greater than 0.5potential-evapotranspiration (0.5PE) and less than potential-evapotranspiration (PE). Within the dekad 31, when ($\sum$P-0.5PE)$\leq$0 marked the cessation of rains. The late rains ranged from dekad 24 - 32. Therefore, the length of the growing periods ranged from dekad 14 - 32 which gave an approximation of 197 days. However, due to the late onset of rains, rainfall was experienced towards the end of dekad 33 and the early period of dekad 34 during the residual moisture depletion periods

Table1 showed the yield components of maize during the early and late seasons. During the early season, the harvested ears at Pl_2early was significantly ($p<0.05$) higher than those at Pl_1early in sole and 1:1 alternate rows. The harvested ears at Pl_2early in alternate planting/row was significantly ($p<0.05$) higher than those at Pl_2early in 1:1 alternate rows. The ear weight at Pl_2early was significantly ($p<0.05$) higher than that at Pl_1early in sole and 1:1 alternate rows. Comparably, the ear weight at Pl_2early in alternate planting/row was significantly higher than that at Pl_2early in 1:1 alternate row. There was no significant difference ($p>0.05$) in the yield/plant, diameter and length of ear, number of ear/plant, diameter of cob, length of cob, number of fresh grain/cob, weight of fresh grain/cob and weight/100 fresh grains at Pl_1early and Pl_2early in sole and mixtures.

During the late season, the harvested ears at Pl_1late and Pl_2late in sole and alternate planting/rows were significantly ($p>0.05$) the same while those at Pl_1late was significantly ($p<0.05$) higher than those at Pl_2late in 1:1 alternate rows. The ear weight at Pl_1late was significantly ($p<0.05$) higher than that at Pl_2late in sole and mixtures. There was no significant difference ($p>0.05$) in the yield/plant, diameter and length of ear, number of ear/plant, diameter of cob, length of cob, number of fresh grain/cob, weight of fresh grain/cob and weight/100 fresh grains at Pl_1late and Pl_2late in sole and mixtures.

Treatments had no significant ($p<0.05$) effects on maize yield/plant, ear diameter and length, number of ears/plant, cob diameter, cob length, number of fresh grain/cob, weight of fresh grains/cob and weight/100 fresh grains at Pl_1early and Pl_2early and also at Pl_1late and Pl_2late. Though, there was no significant difference ($p<0.05$) in the yield/plant of maize in sole and mixture but the yield obtained at early rains was significantly higher than that at late rains. This agreed with the result of *Michael* et. al., (2012) who stated that irrespective of season, intercropping did not significantly affect maize yield but maize yield obtained when planted as sole and in mixture with okra was greater for the wet season compared to that obtained under dry season condition.

Table 2 showed the yield characteristics of okra according to different cropping systems and planting periods (early and late). During the early season, there was no significant difference ($p>0.05$) between the number of pod/plant produced by okra, weight of pod/plant, pod yield/ha, pod diameter and length at Pl_1early and Pl_2early in sole and mixtures.
Similarly, during the late season, there was no significant difference ($p>0.05$) between the number of pod/plant produced by okra, weight of pod/plant, pod yield/ha and pod diameter at Pl_1late and Pl_2late. The pod length at Pl_1late was significantly ($p<0.05$) greater than that at Pl_2late in sole and alternate planting/row while that at Pl_1late and Pl_2late in 1:1 alternate rows was significantly ($p>0.05$) the same.

Moreover, within each cropping season, intercropping had no significant ($p>0.05$) effects on yield parameters of okra. However, pod yield/ha obtained when planted as sole and in mixtures with maize was greater for the early season compared to that obtained under late season condition. This could be due to the adequate rainfall experienced during the early season that had contributed to the increased yield of pods. This agreed with the result of Bisaria and Shamsherry (1987) who observed that good rainfall and early sowing increased fresh pod yield of okra. Though, there was no significant difference between the pod yield/ha in sole and mixtures but the pod yield/ha was greater for sole okra, compared to that obtained from okra intercropped with maize. The decrease in the yield of okra in mixtures could be as result of firstly,

greater competition for available nutrients and light as found by Seran and Jeyakumaran; (2009), when they reported that the number of pods per capsicum plant was lower in capsicum-vegetable cowpea intercropping compared to monocropping due to competition for light and nutrients. Secondly, due to the fact that the powdery tassels at tasselling stage from the maize plant inhibit the growth and development of associated okra plants by blocking the stomata on their leaves with a resultant impairment on the rate of photosynthesis. This finding is not in agreement with the results of *Michael et al*., (2012) who observed that intercropping okra with maize significantly depressed okra yield.

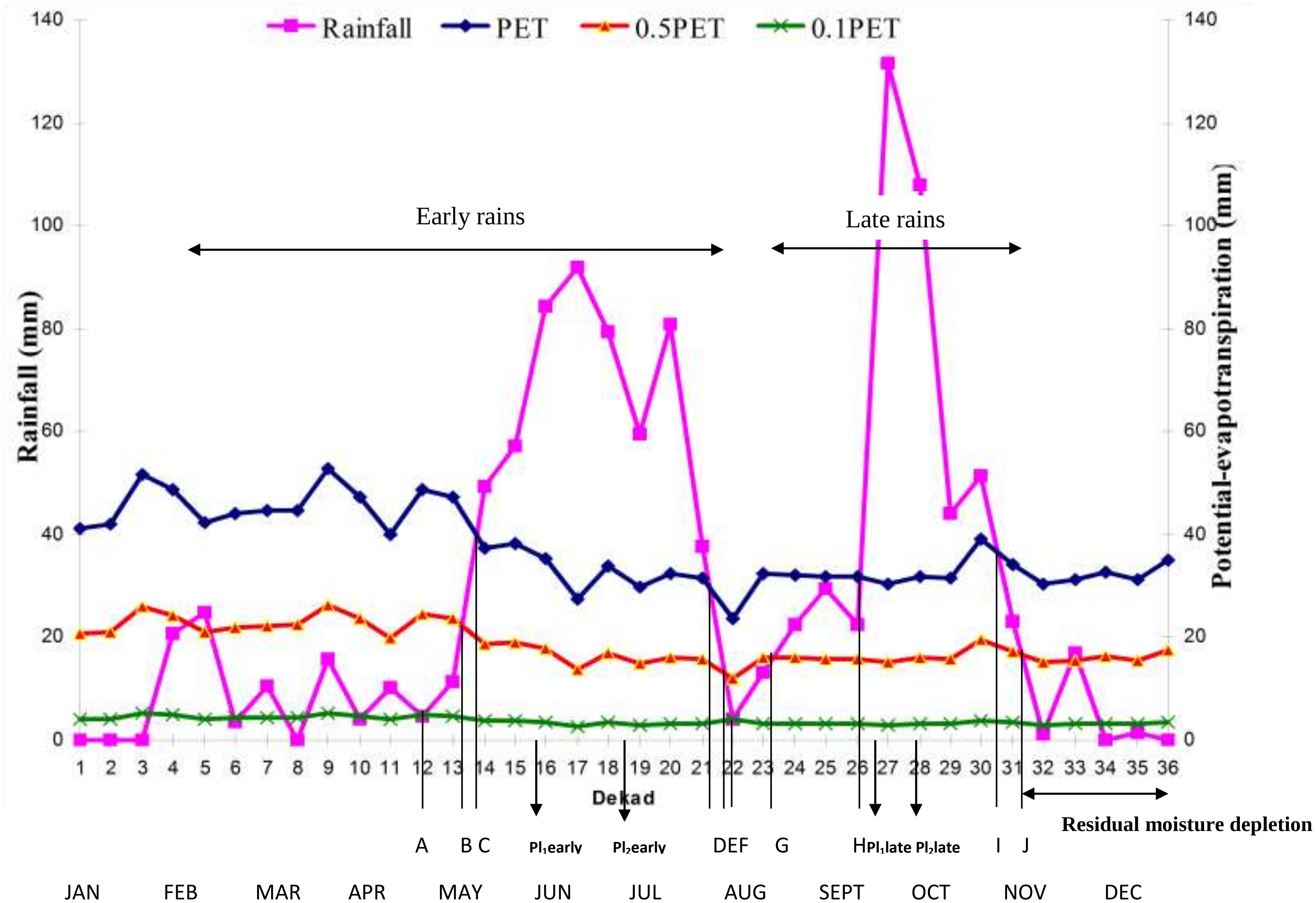

Figure 1: Rainfall-potential evapotranspiration model for the early and late rains during the experimental period (2012).

'A – B $ F - G' =land preparatory periods for early and late rains respectively, 'B - C $ G - H'= first intermediate periods for early and late rains respectively, 'C - D $ H - I' = humid periods for early and late rains respectively, 'D - E $ I - J'= second intermediate periods for early and late rains respectively.

Table 1: Yield characteristics of maize according to different cropping systems and planting periods (early and late)

Cropping systems	Planting dates	Number harvested ears.	Weight harvested ears (kg)	Yield/plant (kg)	Ear diameter (cm).	Ear Length (cm).	Number Ear/plant	Cob diameter (cm).	Cob Length (cm).	Number of fresh grain/cob.	Weight of fresh grain/cob (g)	Weight/ 100 fresh grains (g)
Sole Maize	Pl_1early	8^{ed}	1.36^{d}	0.17^{a}	5.2^{ab}	25.98^{ab}	1.00^{a}	4.20^{a}	20.24^{ab}	399^{ab}	140^{ab}	35^{a}
	Pl_2early	29^{a}	5.50^{a}	0.19^{a}	5.30^{ab}	26.87^{ab}	1.00^{a}	4.30^{a}	20.43^{ab}	402^{ab}	140^{ab}	35^{a}
	Pl_1late	5^{ed}	0.65^{d}	0.13^{b}	4.35^{d}	23.80^{cd}	1.00^{a}	3.43^{b}	18.43^{cd}	176^{cd}	17^{c}	10^{b}
	Pl_2late	6^{ed}	0.28^{e}	0.05^{b}	4.10^{d}	23.00^{d}	1.00^{a}	3.30^{b}	15.20^{de}	154^{de}	15^{c}	10^{b}
Maize in 1:1 alternate row with okra	Pl_1early	7^{ed}	1.05^{d}	0.15^{a}	5.43^{ab}	26.33^{ab}	1.00^{a}	4.30^{a}	20.31^{ab}	400^{ab}	140^{ab}	35^{a}
	Pl_2early	14^{c}	2.27^{c}	0.16^{a}	5.55^{a}	27.22^{a}	1.00^{a}	4.73^{a}	20.77^{a}	451^{a}	156^{a}	35^{a}
	Pl_1late	7^{ed}	0.91^{d}	0.13^{b}	4.80^{cd}	25.00^{bc}	1.00^{a}	3.90^{b}	18.20^{cd}	194^{cd}	19^{c}	10^{b}
	Pl_2late	2^{f}	0.09^{f}	0.05^{b}	4.50^{cd}	24.00^{cd}	1.00^{a}	3.48^{b}	16.87^{de}	156^{de}	15^{c}	10^{b}
Maize in alternate planting with okra	Pl_1early	–	–	–	–	–	–	–	–	–	–	–
	Pl_2early	23^{b}	4.17^{b}	0.18^{a}	5.48^{ab}	26.50^{ab}	1.00^{a}	4.73^{a}	20.94^{a}	463^{a}	160^{a}	35^{a}
	Pl_1late	9^{ed}	1.3^{d}	0.14^{b}	4.60^{cd}	25.41^{bc}	1.00^{a}	3.90^{b}	19.07^{cd}	198^{cd}	19^{c}	10^{b}
	Pl_2late	7^{ed}	0.37^{e}	0.05^{b}	4.30^{d}	25.12^{bc}	1.00^{a}	3.45^{b}	16.00^{de}	157^{de}	15^{c}	10^{b}

Means having the same letter(s) within each growing season are not significantly ($p<0.05$) different

Table 2: Yield characteristics of okra according to different cropping systems and planting periods (early and late)

Cropping systems	Planting dates	Number of pod/plant	Weight of pod/plant (g)	Pod yield/ha (ton/ha)	Pod diameter (cm)	Pod length (cm)
Sole okra	Pl_1early	2.1^{a}	48.5^{a}	1.6^{a}	3.87^{a}	7.90^{a}
	Pl_2early	1.6^{a}	34.3^{a}	1.5^{a}	3.57^{a}	7.53^{a}
	Pl_1late	1.2^{ab}	15.4^{cd}	0.4^{c}	3.00^{c}	6.48^{b}
	Pl_2late	1.8^{a}	15.5^{cd}	0.4^{c}	2.63^{c}	5.2^{c}
Okra in 1:1 alternate row with maize	Pl_1early	1.4^{ab}	37.3^{a}	0.6^{ab}	3.63^{a}	7.8^{a}
	Pl_2early	1.8^{a}	43.8^{a}	0.9^{ab}	3.83^{a}	7.6^{a}
	Pl_1late	1.9^{a}	22.2^{c}	0.3^{c}	3.30^{c}	6.32^{b}
	Pl_2late	1.4^{ab}	17.1^{cd}	0.3^{c}	2.75^{c}	5.80^{b}
Okra in alternate planting/row with maize	Pl_1early	_	_	_	_	_
	Pl_2early	1.5^{ab}	18.5^{ab}	0.5^{ab}	3.57^{a}	7.3^{a}
	Pl_1late	1.1^{ab}	13.6^{cd}	0.3^{c}	3.27^{c}	6.24^{b}
	Pl_2late	1.2^{ab}	10.9^{cd}	0.3^{c}	2.54^{c}	5.3^{c}

Means having the same letter(s) within each growing season are not significantly ($p<0.05$) different.

Conclusion and recommendation

Since maize and okra are sensitive to water availability for good yield and P-PE model is critical to ascertaining the actual water availability of the soil during both early and late cropping seasons, it implies that this model can be extended to other tropical food crops for improved agricultural yield. The study further concluded that for intercropping okra with maize in 1:1 alternate rows rather than alternate planting/row is more valuable cropping option to diversify food production and improve economic returns for farmers in southwestern Nigeria.

Based on the findings of the study, it is therefore recommended that in Nigeria and southwest in particular where maize and okra intercrop are commonly practiced, that land preparation should commence when P is between 0.1PE and 0.5PE and planting when P is above 0.5PE. This is because during these periods, land is wet enough for land preparation and rainfall has fully stabilized for planting respectively. Also during the late cropping season, planting of maize and okra should be carried out earlier September so as to avoid inadequate moisture availability during their reproductive stages. The P-PE model can be successfully applied to both sole cropping and mixtures. Lastly, the relevance of the study to food security cannot be overemphasized.

REFERENCES

Adebisi, M.A., Akintobi, D.C.A. and Oyekale,K.O. 2007. Preservation of Okra Seed Vigour by Seed Treatment and Storage Containers. In Nigerian Journal of Horticultural Science (NJHS), 12 pp 1 – 7.

Adeboye, O.C. and Oputa, C.O. 1996. Effects of galex on growth and fruit nutrient composition of okra (Abelnurschus esculentus). *Ife Journal of Agriculture*, 18 (1 & 2): 1-9.

Adefolalu D.O. 2004. Climate change, evidence and trends (1000B-2000AD) in climate and water resources in the 21st century for food 700 J. Geogr. Reg. Plann. Security and health.NMS P91-94.

Bello, N.J. 1996. An investigation of the characteristics of the onset and cessation of the rains in Nigeria. Journal of Theoretical and Applied Climatology- (in press).

Bello, N.J. 2000. Application of rainfall-potential evapotranspiration model for determining optimum planting date of maize (Zea mays) in a tropical wet and dry climate. Indian Journal of Agricultural Sciences 70 (7): 437- 40.

Bisaria and Shamsherry, 1987. Effect of rainfall on the growth and development of okra. *Journal of Vegetable Crop Prod*., 9: 11-18.

Dauda, T.O., Agbaje, G.O. and Akintoye, N.A. 2010. Okra Yield – Period Model in a Derived Savannah eco climatic zone of Nigeria. Report and Opinion 2(5).

ECHO 2003. Plant information sheet, N. FT. Meyers, USA. http.www.echonet.org

FAO, 2005. Food and agricultural Organisation, Annual Statistical Report, 56:16.

Igwebuike, M. N., Odoh, F. C., Ezeugwu, C. I., Oparaku, N. F. and Oparaku, O. U. 2010. Climate Chang, Agricul- ture and Food Security. In: R. N. C.

Anyadike, I.A. Madu and C. K. Ajaero, *Conference Proceedings on Cli-mate Change and the Nigerian Environment*, UNN.

IITA (International Institute of Tropical Agriculture) 1988. Maize improvement programme Annual report, 87-88pp.

Kurukulasuriya P and Rosenthal S 2003. Climate Change and Agriculture:A review of impacts and Adaptations. Paper No 91 in Climate Series,Agriculture and Rural Development Department and Environmental

Department, World Bank, Washington, D.C.

Lee, K. H., Cho, C. Y., Yoon, S. T. and Park, S. K. 2000. The effect of nitrogen fertilizer, plant density and sowing date on the yield of okra. *Korean Journal of Crop Science*. 35(8): 179–183.

Michael O. I, Teryima I and Joseph A. I. 2012. Yield Response of Intercropped Maize (Zea mays L.) and Okra (Abelmoschus esculentus L. Moench) to Seasonal Conditions at Makurdi, Nigeria. Journal of Natural Sciences Research. 2(6).

Nyong, A. O.2008. Climate Change, Agriculture and Trade: Implications for Sustainable Development. ICTSD.

Olasantan, F.O and N.J Bello 2004. Optimum sowing dates for okra (Abelmoschus esculentus) in monoculture and mixture with cassava(Manihot esulenta) during the rainy season in the south-west of Nigeria. *Journal of Agricultural Science, Cambridge* 142:49-58.

Seran and J. Jeyakumaran 2009, “Effect of planting geometry on yield of Capsicum (Capsicum annum L.) intercropping with vegetable cowpea (Vigna unguiculata L.),” Journal of Science, 6:11–19.

Siemonsma, J.S. 1982. The cultivation of okra (*Abelmoschus* spp.), tropical fruit- vegetable (with special reference to the Ivory coast). D.H.O, thesis Wageningen Agricultural Wageningen, the Netherland. 297pp.

Tunde, A. M., Usman, B. A. and Olawepo, V. O. 2011. Effects of climatic variables on crop production in Patigi L. G. A., Kwara State, Nigeria. Journal of Geography and Regional Planning 4 (14): 695-700.

EFFECTS OF CLIMATE CHANGE ON HYDRO-CLIMATIC VARIABLES IN NIGERIA DURING EPISODES OF SEA SURFACE TEMPERATURE ANOMALIES IN THE GULF OF GUINEA

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ABSTRACT

Sea surface temperature anomaly (SSTA) is critical to climate monitoring at the local, regional and hemispheric scales. It is well established that sea surface temperature (SST) plays a significant role in the hydrologic cycle in which precipitation is the most important part. The hydro-climatic variables vis-a-vis Dates of Onset of Rains (DOR), Dates of Cessation of Rain (DCR) Duration of Rains (DR) and Frequency of Occurrence of Rain Day (FORD) were determined. Characteristics (Early, normal and late) of hydro-climatic variables in Nigeria at various Agro-ecological zones were then examined. SSTA data obtained from International Research Institute center for climate prediction at selected longitudes (10 °W, 8 °W, 6 °W, 4 °W, 2 °W, 0°, 2 °E, 4 °E, 6 °E, and 8 °E) along latitudes 5 °N, 4 °N, 2 °N and 0° (equator) respectively and continental climatic data (moisture, thermal and aerodynamic parameters) obtained from the archives of Nigerian Meteorological Agency at selected locations were used for the analysis. Both descriptive and inferential statistical analyses were employed to establish the relationship. It is observed that higher frequency of occurrences of the different characteristics of hydro-climatic variables was during warm episodes of SSTA. Furthermore SSTA over GOG had significant ($p<0.05$) correlation with DOR, DCR, DR, FORD and RR in Nigeria. It was confirmed in this study that warm SSTA over GOG has significant impacts on the hydro-climate variables in Nigeria.

1.0 Introduction

The pattern of global and hemispheric temperatures has shown a threatening trend since the early 19th century. According to World Meteorological Organization report (WMO, 1998), global air temperature fluctuated below the norm until the early 19th century. Since then remarkable positive anomalies have persisted in the global and hemispheric scales.

Sea Surface Temperature (SST) have been playing an important role in the annual cycle of precipitation over the globe with layers of warmer water temperatures ranging from 20 - 30°C found all the year round in different parts of tropical Atlantic region including that of the Gulf of Guinea (GOG). This region has been observed to be the main source of moisture for the West African Monsoon (WAM). Temperature *anomalies* in the region are likely to influence hydro-climatic parameters (rainfall incidence and cessation, duration of rainfall, frequency of rain days) over West African countries including Nigeria. Climatology and variability of hydro-climatic parameters are valuable information for scientists, engineers, planners and managers working in water-related sectors (agriculture, ecology, and hydrology and water resources).

Since the late 20th century, SST anomaly field has been a key driver of decadal climate variability (Folland et al. 1986; Palmer 1986; Rowell et al. 1995; Mohino et al, 2011). Several studies that have shown relationship between the SST anomalies and climate of West Africa sub regions includes Salahu, Edafienene and Afesiemama (1996); Gbuyiro *et.al* (2002); Okumura and xie (2004); Wang *et al* (2004); Okeke (2006); Odekunle and Eludoyin (2008) and Omogbai, 2010). Studies conducted by (Lamb, 1978, Fontaine *et al*, 2000, Folland *et al.*,1986) have linked rainfall variability to occurrences of Atlantic and/or global SST dipole patterns. Several attempts have been made to study the characteristics of hydro-climatic variable in order to provide an explanation for the patterns of rainfall incidence, cessation, length of growing period and water availability for agricultural purposes in Nigeria. Notable examples include Oguntoyinbo (1981),Olaniran and Sumner (1990) and Bello (1996a).

Understanding the hydro-climatic features during episodes of SST anomalies is essential for effective agricultural and hydrological operations. On the face of global climate change where food security is becoming threatened, affecting food systems in several ways ranging from direct effects on crop production, changes in rainfall pattern leading to drought or flooding, warmer or cooler temperature which leads to changes in the length of season, pattern of incidence and cessation of rain etc., background and scenario projections of the problem assumed greater importance; therefore attempts have been made in recent decades world-wide to understand the problem on regional/local scales. This comprehensive study of the characteristics of hydro-climatic variables across agro-ecological zones in Nigeria during different episodes of SSTA in GOG is undertaken with the following objectives in mind. To examine the trend of Sea Surface Temperature Anomalies in the Gulf of Guinea region in order to establish its variability over time and determination of hydro-climatic variables (onset, cessation and duration of rains as well as rain-days and rainfall amount) in the various agro-ecological zones in Nigeria also to examine the influence of SSTA on them. In order to combat the risk such as famine, incidence of failure of annual crops, replanting and low ultimate yield etc pose by unpredictable climate pattern, there is need for proper monitoring and preparedness. We hypothesized that there is no significant influence of Sea Surface Temperature Anomalies in the Gulf of Guinea on the hydro-climatic variables in the different Agro-ecological zones in Nigeria.

The paper is organized as follows. Section 2 briefly describes study locations and the general climate pattern in the area. Section 3 introduces the method of determining the hydro-climatic variables and other data used in this study. Section 4 shows the result where we examine the trends of SSTA over the Gulf of Guinea region to provide a context for the variability analysis; it also shows the characteristics of frequency of occurrence of the hydro climatic variables that is the onset, cessation, and duration and rain days. These characteristics are compared with those of the SST anomalies to explore their relationship. Section 5 discusses the relationship between the various hydro-climatic and the GOG SST anomalies. The role of the GOG SST anomalies in all the agro-ecological zones in Nigeria was also discussed. Summary and concluding remarks are given in the final section.

2.0 Study area

Figure 1 is the map of the study area showing the GOG region and the different agro- ecological zones in Nigeria with the data collection points. The GOG is situated along the West Africa Ocean. In West Africa, it extends from the equator (0^0) to approximately latitude 5^0 N (0^0 - 5^0 N) and longitudes 15^0 W to 8^0 E. Along the Nigerian coast, it extends from latitude 0^0 to 5^0 N and longitude 2° 2'E to 8^0 20'E. Nigeria is bordered to the west by Benin, to the northwest and north by Niger, to the northeast by Chad and to the east by Cameroon, while the Atlantic Ocean forms the southern limits of the country's territory.

Climate of both the GOG and Nigeria are influenced by two major wind currents namely, the tropical maritime (mT) air mass and the tropical continental (cT) air mass. The (cT) air mass originates over Sahara, while the warm and humid (mT) air mass originates from the Atlantic Ocean. Separating the two air masses is a zone which is generally referred to as the Inter Tropical Convergence Zone (ITCZ) over the Ocean. And it is a region of atmospheric instability at the convergence of the northern and southern trade winds.

3.0 Methodology

3.1 Type and timescale of data

Two types of data utilized for this study were the continental climatic data and oceanic climatic data. The continental climatic data used are: daily rainfall (mm), mean air temperature (^{0}C) (Maximum and Minimum) Relative humidity (%), wind speed (m/s) at elevation of 2 metres, shortwave radiation (MJ/M^2/day), albedo over the selected meteorological stations in the different agro ecological regions in Nigeria. The oceanic climatic data utilized are the remotely sensed monthly Sea Surface Temperature (^{0}C) anomalies over the GOG region. Hydro-climatic and sea surface temperature anomalies data for a period of 20 years (1991-2010) were utilized.

3.2 Data processing and analysis

The data were processed and analyzed statistically using Climate predictability tools (CPT) (version 13.4.2) and INSTAT$^+$ software.

To determine the trend of Sea surface temperature Anomalies (SSTA) in the GOG region, SSTA data on a spatial resolution of 2˚ by 2˚ (latitude and longitude) grid were extracted from latitudes (4^0N, 2^0 and 0^0) and longitudes (8^0E, 6^0E, 4^0E, 2^0E, 0, 2^0W, 4^0W, 6^0W, 8^0W and 10^0W). Linear regression analysis method was employed to determine the overall-trend in a time series analysis. For a given time series, the trend equation is of the form:

$$y = a + bx \quad (1)$$

where 'a' is the base intercept of the line on the y-axis, 'b' is the regression coefficient or slope of the line, **x** is the independent variable, here time in year was used, where each year is represented by a numerical value e.g 1991=1, 1992=2 etc and the dependent variable **y** is the SSTA values obtained over each latitude considered in the GOG region.

The regression coefficient (b) and the correlation coefficient (r) between y and x were later related by the equation:

$$b = r\frac{\delta y}{\delta x} \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

where δy and δx are the standard deviation of y and x respectively. This was used to study the relationship between the SSTA and the hydro-climatic attributes considered in the different agro ecological zones in Nigeria.

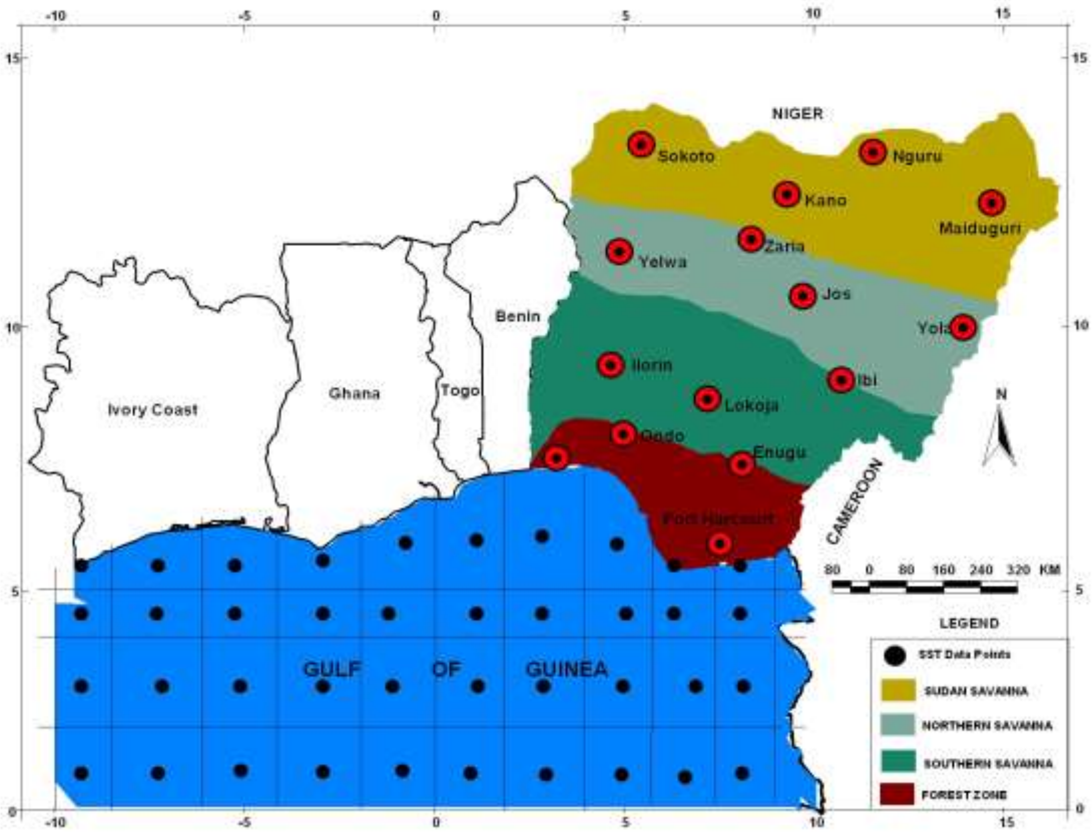

Figure 1: Map of study area showing data collection points

The hydro-climatic characteristics considered are:

(i) Dates of onset and cessation of rain

(ii) Duration of rain

(iii) Rain days

Dates of onset and cessation of the rains was determined using rainfall-potential evapotranspiration model. According to Bello (1996), the date of onset was marked by the time when the accumulated difference between rainfall and half the PE exceed zero, provided that it is not followed by a dry spell of 5 days or more in the week of the date. The cessation date of rains was also taken but in this case the accumulation was done in the reverse order from December of the same year. This was in line with the modification made by Bello (1989) and Olaniran and Summer (1989).

$$\sum(P - 0.5PE) > 0\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

P is the rainfall amount and PE is the potential evapotranspiration.

Duration of rains was taken as the difference between the cessation and onset days of rain. In determination of rainy days, 0.85mm was found appropriate for Agricultural purposes in West Africa (Garbutt et al. (1981)). This implies that, all values below this threshold value are considered as zero. Based on this, the frequency of occurrences of rain day (FORD) was obtained.

Characteristics of hydro-climatic variables was determined by adopting Bello (2000) methods in which early, normal and late onset/cessation of rains were obtained by calculating the deviation of each year mean date from the norm at each station. This was obtainable if its deviates from the norm date below, equal and more than 5 days respectively. Based on this method, early, normal and late onset and cessation of the rains was determined. Shorter, normal and longer duration of rains was also determined if it deviates from the norm below, equal and above respectively. Rain days were considered to have below, normal and above if it deviates from the norm. Thereafter, their frequency of occurrences during normal, warm and cold SSTA were also determined.

4.0 Result

The trend of annual mean SST is shown in figure 2. It shows that positive sea surface temperature anomalies (SSTA) are generally high at the equator (0^0) over the gulf of guinea, but it decreases from here northwards to latitude 5^0N, while negative SSTA are lower at the equator (0^0) but increases northwards. Positive SSTA were observed in all the latitudes from 1998 to 2010, except in the year 2000 when negative SSTA was experienced at all the latitudes, 2004 and 2008 also experienced negative SSTA only at the equator (0^0). A remarkable high positive and negative SST anomaly was observed in 2001 and 1995 respectively.

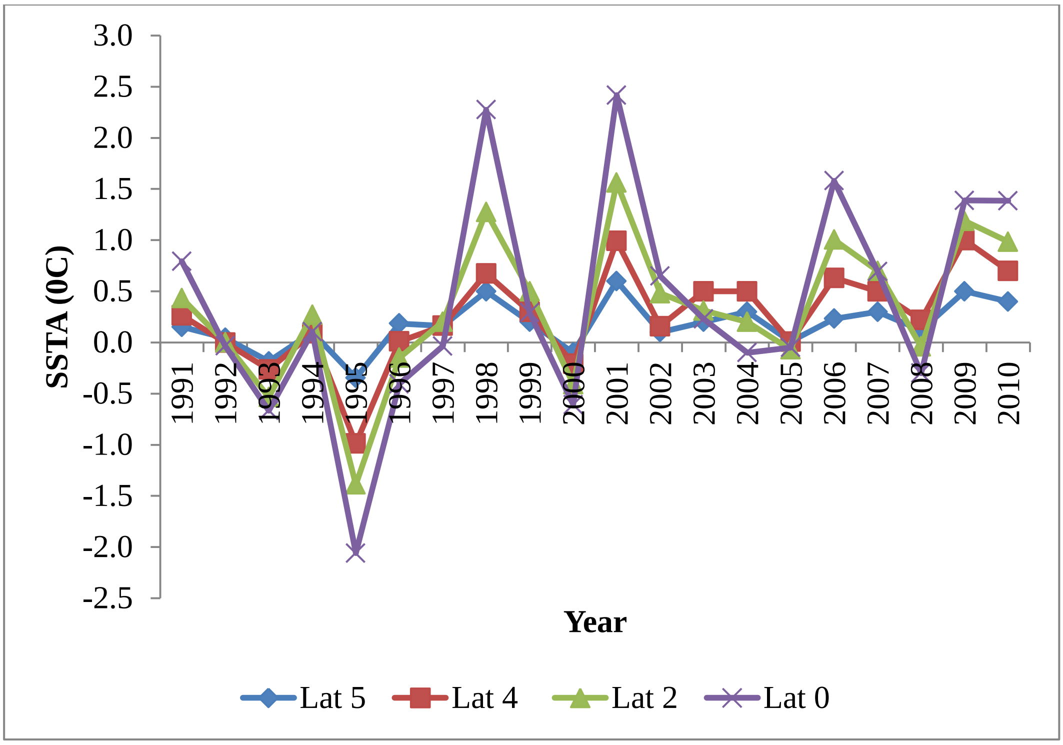

Fig 2: Annual Sea Surface Temperature Anomalies of Latitude 5^0N, 4^0N, 2^0N and Equator (0^0) in the Gulf of Guinea region.

Table 1 shows the result of the linear trend line equation of SSTA over Latitude 5^0N to the equator (0^0). It revealed that the GOG region from the equator up to latitude 5^0N experience upward trend in sea surface temperature and the highest trend observed over latitude 4^0 N with a coefficient of determination (R^2) of 36%, while the lowest temperature trend was observed over latitude 2^0 N with a coefficient of determination (R^2) of 19%. . The result has revealed that the SST observed positive trend during the study period.

Table 2 shows the episodes of Cold and Warm SSTA and normal years in the GOG region. It revealed that generally warm episodes of SSTA occurred most often followed by normal years and lastly the cold SSTA episode during the period of study. The result on the average SSTA of all the latitudes considered in the GOG, showed that 11 out of the 20 years of observation have warm SSTA episode, 6 out the years experienced normal condition while only 3 out of the 20 years of observation experienced cold SSTA episode. The result of the analysis of the frequency of occurrence of onset of rains during different SSTA episodes is presented in Table 3. The dates of onset revealed that late onset dates is more associated with warm SSTA in the entire zone.

Table 4 result revealed that late cessation dates was observed specifically over Forest zone during warm SSTA when 6(55%), 8(72%), 7(64%) and 5(46%) out of the 11 warm years over Lagos, Port Harcourt, Ondo and Enugu respectively. For the Northern Savanna zone, late cessation dates occurred during the warm SSTA years with Yola observing the highest no of late cessation occurring in 7(64%) out of 11 years. The result of Southern Savanna shows that only Ilorin recorded late cessation dates for 7(64%) out of the 11 warm years of SSTA.

For Sudan savanna zone, all the station observed high late cessation dates during the normal episodes. Frequency of occurrence of duration of rains during different episodes of SSTA in the GOG region is presented in Table 5. It reveals that during warm SSTA shorter duration of rain occurred more frequently over the forest and southern savanna zones except over Ibi while longer during of rain was more prominent over the northern and sudan savanna zones. Over the Northern savanna zone, normal SSTA episodes are conspicuous in all the stations. For cold SSTA episodes, longer duration of rains dominates over the Forest and Southern guinea savanna zones while shorter duration of rains dominated the Northern guinea and Sudan savanna zones. Table 6 shows the result of frequency of occurrences of rainy days (FORD) during the different SSTA episodes in the GOG region. The result revealed that in the forest and southern savanna zones, above normal rain days was more frequent during the warm SSTA years. Northern guinea savanna zone experienced above normal rainy days only in Yelwa with 7 (64%) out of the 11 warm years, the remaining stations observed below normal rain days observed during the warm SSTA years. Result of Sudan savanna zone also revealed higher frequency of below normal rainy days during the period of study. For the normal episode, Forest and Southern guinea savanna zone observed that below normal rainy days dominates while above normal rainy days dominates over Northern guinea and Sudan savanna zones. Except in Lagos, Ibi, Zaria, Yelwa and Nguru where the trend differs, during cold SSTA years, only Zaria and Maiduguri showed association with all the cold SSTA years when 3(100%) out of the 3 cold years have below normal rainy days in the two stations.

The result of the correlation coefficient analysis to assess the significant impact of the SSTA at each of the selected locations in the GOG on the hydro-climatic variables is presented on Tables 9-12. It revealed that there is a relationship between the SSTA in the GOG and hydro-climatic variable in the various agro-ecological zones selected with the highest positive significance ($P<0.05$) obtained over the forest zone.

Table 1: Trend line equation of SSTA over Latitude 5^0 N to the equator 0^0

SSTA Location	Regression coefficient (b)	Regression equation (Y)	Coefficient of Determination (R^2)	Standard Error of slope (SE)
Lat 5^0N	0.0182	-0.0178 + 0.0182 *X	0.28	0.0082
Lat 4^0N	0.0253	-0.1775 + 0.0253 * X	0.36	0.0078
Lat 2^0N	0.0074	-0.0136 + 0.0074 * X	0.19	0.017
Equator 0^0	0.0131	-0.0865 + 0.0131 * X	0.21	0.012

Table 2: Years of Cold and Warm SSTA and normal episodes from Lat 5^0 N to the Equator (0^0) and the GOG average In the GOG region between 1991-2010

Lat 5^0 N			Lat 4^0 N			Lat 2^0 N			Lat 0^0 N			GOG Average		
Warm	**normal**	**Cold**	Warm	normal	Cold	Warm	normal	Cold	Warm	normal	Cold	Warm	normal	Cold
1991	**1992**	**1993**	1998	1991	1995	1991	1992	1993	1991	1992	1993	1991	1992	1993
1996	**1994**	**1995**	2001	1992	1996	1994	1997	1995	1998	2003	1994	1998	1994	1995
1997	**2002**		2003	1993		1998	2005	1996	2001	2005	1995	1999	1996	2000
1998	**2005**		2004	1994		1999		2000	2002	2007	1996	2001	1997	
1999	**2008**		2006	1997		2001		2003	2006		1997	2002	2005	
2001			2007	1999		2002		2008	2009		1999	2003	2008	
2003			2009	2000		2004			2010		2000	2004		
2004			2010	2002		2006					2004	2006		
2006				2005		2007					2008	2007		
2007				2008		2009						2009		
2009						2010						2010		
2010														

Table 3: Frequency of occurrences of deviation in onset dates during cold, normal and warm episodes of SSTA in the GOG.

Agro–ecological zones	Stations	Cold SSTA			Normal			Warm SSTA		
		EO	N	LO	EO	N	LO	EO	N	LO
Forest zone	Lagos	2	-	1	1	1	4	4	1	**6**
	Port Harcourt	1	1	1	3	1	2	4	-	**7**
	Ondo	2	-	1	4	1	1	2	2	**7**
	Enugu	2	1	-	1	3	2	-	5	**6**
	Mean	2	1	1	3	2	2	3	3	**7**
Southern Savanna zone	Ilorin	1	1	1	3	1	2	3	1	**7**
	Lokoja	2	1	-	4	1	1	3	3	**5**
	Ibi	2	1	-	1	1	4	3	2	**6**
	Mean	2	1	1	3	1	2	3	2	**6**
Northern Savanna zone	Yelwa	1	1	1	3	1	2	4	-	**7**
	Jos	2	-	1	4	1	1	5	3	**3**
	Zaria	1	-	2	2	1	3	4	2	**5**
	Yola	-	2	1	1	3	2	2	4	**5**
	Mean	1	1	1	3	2	2	4	3	**5**
Sudan Savanna zone	Kano	1	1	1	2	1	3	3	2	**6**
	Nguru	-	1	2	-	3	3	2	1	**8**
	Sokoto	-	1	2	-	4	2	2	3	**6**
	Maiduguri	1	1	1	2	1	3	2	2	**7**
	Mean	1	1	1	2	2	3	2	2	**7**

EO-Early Onset, N-Normal, LO-Late Onset

Table 4: Frequency of occurrences of deviation in cessation dates during cold, normal and warm episodes of SSTA in the GOG.

Agro–ecological zones		Cold SSTA			Normal			Warm SSTA		
	Stations	EC	N	LC	EC	NC	LC	EC	N	LC
Forest zone	Lagos	1	1	1	3	-	6	2	3	6
	Port Harcourt	2	-	1	4	2	2	2	-	8
	Ondo	2	-	1	2	2	5	1	-	7
	Enugu	1	2	-	2	3	4	1	2	5
	Mean	2	1	1	3	2	4	1	2	7
Southern savanna zone	Ilorin	1	-	2	2	-	5	2	-	6
	Lokoja	1	-	2	7	-	2	4	3	1
	Ibi	2	-	1	6	1	2	4	2	2
	Mean	1	-	2	5	1	3	3	2	3
Northern savanna zone	Yelwa	2	1	-	3	1	5	2	3	3
	Jos	2	1	-	4	1	4	3	1	4
	Zaria	1	1	1	3	1	5	3	4	1
	Yola	1	-	2	1	-	5	5	-	6
	Mean	2	1	1	4	1	5	4	3	4
Sudan savanna zone	Kano	2	1	-	1	2	6	4	1	3
	Nguru	1	-	2	3	1	5	2	1	5
	Sokoto	1	1	1	2	2	5	3	2	3
	Maiduguri	2	1	-	3	-	5	3	2	3
	Mean	2	1	1	3	2	5	4	2	4

EC-Early Cessation, N-normal, LC-Late Cessation

Table 5: Frequency of occurrences of deviation in duration of rains during cold, normal and warm episodes of SSTA in the GOG.

Agro–ecological zones	Stations	Cold SSTA			Normal			Warm SSTA		
		S	N	L	S	N	L	S	N	L
Forest zone	Lagos	1	-	2	4	2	-	2	4	5
	Port Harcourt	2	-	1	1	3	2	4	1	6
	Ondo	1	-	2	1	2	3	4	6	1
	Enugu	-	1	2	1	2	3	3	2	6
	Mean	1	1	2	2	2	3	3	3	5
Southern guinea savanna zone	Ilorin	1	-	2	3	1	2	8	-	3
	Lokoja	1	-	2	4	2	-	6	1	4
	Ibi	1	-	2	3	1	2	4	1	6
	Mean	1	-	2	3	1	2	6	1	4
Northern guinea savanna zone	Yelwa	2	1	-	2	1	3	3	6	2
	Jos	-	2	1	2	2	2	2	5	4
	Zaria	2	-	1	1	2	3	4	5	2
	Yola	1	1	1	1	1	4	3	6	2
	Mean	2	1	1	1	1	3	3	6	3
Sudan savanna zone	Kano	2	-	1	3	1	2	5	1	5
	Nguru	2	1	-	2	-	4	5	3	3
	Sokoto	1	1	1	2	1	3	4	3	4
	Maiduguri	1	2	-	3	-	3	6	2	3
	Mean	2	1	1	3	1	3	5	2	4

S-Short, N-normal, L-Long

Table 8: Frequency of occurrences of deviation in rainy days during cold, normal and warm episodes of SSTA in the GOG.

Agro–ecological zones	Stations	Cold SSTA			Normal			Warm SSTA		
		BN	N	AN	BN	N	AN	BN	N	AN
Forest zone	Lagos	-	2	1	3	-	3	2	4	5
	Port Harcourt	1	1	1	3	1	2	4	2	5
	Ondo	2	-	1	3	1	2	3	3	5
	Enugu	1	-	2	2	3	1	3	3	5
	Mean	1	1	2	3	2	2	3	3	5
Southern Savanna zone	Ilorin	1	-	2	4	-	2	4	1	6
	Lokoja	2	-	1	3	1	2	4	2	5
	Ibi	1	-	2	2	1	3	3	3	5
	Mean	1	-	2	3	1	2	4	2	5
Northern savanna zone	Yelwa	1	1	1	-	4	2	4	-	7
	Jos	1	2	-	1	-	5	5	2	4
	Zaria	3	-	-	3	-	3	5	2	4
	Yola	-	1	2	2	1	3	4	5	2
	Mean	2	1	1	2	2	3	5	3	4
Sudan savanna zone	Kano	-	2	1	2	1	3	6	-	5
	Nguru	2	1	-	2	3	1	2	4	5
	Sokoto	2	1	-	1	2	3	2	7	2
	Maiduguri	3	-	-	-	3	3	4	3	4
	Mran	2	1	1	2	3	3	4	4	4

BN-Below normal, N-normal, AN-above normal

Table 9: **Correlation analysis between SSTA and DOR at various agro-ecological zones in Nigeria**

Agro-ecological zones	SSTA_Lat 5^0N r (R^2)	SSTA_Lat 4^0N r (R^2)	SSTA_Lat 2^0N r (R^2)	SSTA_Lat 0^0N r (R^2)
Forest zone	0.4790*(0.23)	0.3231*(0.10)	0.4673*(0.22)	**0.6339* (0.40)**
Southern guinea Savanna	0.6081* (0.37)	0.4931*(0.24)	0.5771*(0.33)	0.5726*(0.33)
Northern guinea savanna	0.451* (0.20)	0.3021*(0.09)	-0.014 ^{ns}(0.002)	0.0621 ^{ns}(0.004)
Sudan savanna	0.055 ^{ns}(0.003)	0.0103 ^{ns}(0.001)	0.2837* (0.08)	-0.1924*(0.04)

Table 10: Correlation analysis between SSTA and DCR at various agro-ecological zones in Nigeria

Agro-ecological zone	SSTA_Lat 5^0N r (R^2)	SSTA_Lat 4^0N r (R^2)	SSTA_Lat 2^0N r (R^2)	SSTA_Lat 0^0N r (R^2)
Forest zone	0.5224*(0.28)	0.4833*(0.23)	0.596*(0.36)	0.3295*(0.11)
Southern guinea savanna	0.2281*(0.05)	0.0076^{ns}(0.006)	0.0751^{ns} (0.006)	0.441*(0.19)
Northern guinea savanna	0.4203*(0.18)	0.164^{ns}(0.003)	-0.228*(0.05)	-0.0331^{ns} (0.001)
Sudan savanna	0.0831^{ns}(0.006)	-0.3575*(0.13)	-0.0746^{ns} (0.006)	-0.2481*(0.06)

*** significant (P<0.05), ns- not significant. r-correlation coefficient, R^2-coefficient of determination**

Table 11: Correlation analysis between SSTA and DR at different agro-ecological zones in Nigeria

Agro-ecological zone	SSTA_Lat 5^0N r (R^2)	SSTA_Lat 4^0N r (R^2)	SSTA_Lat 2^0N r (R^2)	SSTA_Lat 0^0N r (R^2)
Forest zone	0.3137*(0.10)	0.1253^{ns} (0.002)	-0.1753*(0.03)	-0.289*(0.08)
Southern guinea savanna	-0.45*(0.20)	-0.4499*(0.20)	-0.4887*(0.24)	-0.527*(0.28)
Northern guinea savanna	-0.0571^{ns} (0.004)	-0.2174*(0.05)	-0.2463*(0.06)	-0.1951*(0.04)
Sudan savanna	0.0506^{ns} (0.003)	-0.0424^{ns} (0.002)	-0.1892*(0.04)	-0.1234*(0.02)

Table 12: Correlation analysis between SSTA and FORD at different agro-ecological zones in Nigeria

Agro-ecological zone	SSTA_Lat 5^0N r (R^2)	SSTA_Lat 4^0N r (R^2)	SSTA_Lat 2^0N r (R^2)	SSTA_Lat 0^0N r (R^2)
Forest zone	0.1966*(0.04)	-0.1571*(0.02)	0.1911*(0.04)	0.1448*(0.02)
Southern guinea savanna	0.2755*(0.08)	-0.2224*(0.05)	-0.0449^{ns} (0.002)	-0.2546*(0.06)
Northern guinea savanna	0.0427^{ns} (0.002)	-0.1294*(0.02)	-0.0187^{ns} (0.003)	-0.1881*(0.04)
Sudan savanna	0.0158^{ns} (0.002)	-0.2057*(0.04)	0.1733*(0.03)	0.1236*(0.02)

*** significant ($P<0.05$), ns- not significant. r-correlation coefficient, R^2-coefficient of determination**

5.0 Discussion

Result showed that the occurrence of positive temperature anomaly (warming trend) was highest (55% of the time) in the GOG. Negative anomaly (cooling) occurred just for 15% of the time while the norm was 30% of the time. On the average there is generally a warming trend over GOG. While association of late DOR and DCR, above normal DR and FORD with positive SSTA over GOG is probably evidence of the global climatic warming causing climate deterioration in Nigeria this had been reported by some authors (Olaniran, 1983b, Bello, 1996). This could invariably affect reliable agricultural practices in the various agro-ecological zones. As observed by Bello (2000) that incidence of failure of annual crops, replanting and low ultimate yield have become an annual occurrences. Furthermore SSTA over GOG had significant ($P<0.05$) impacts on DOR, DCR, DR and FORD in Nigeria. Furthermore SSTA over GOG had significant ($P<0.05$) impacts on DOR, DCR, DR and FORD in Nigeria.

Though the results have shown that the frequency of occurrences of hydro-climatic attributes as related to SSTA indicated that positive anomalies in SST and normal SST resulted in late occurrences of all the attributes which could invariably affect reliable agricultural practices in the various agro-ecological zones while negative anomalies in SST and normal SST resulted in early occurrences of all the attributes especially over Northern and Sudan Savanna zone with the highest weight over the Sudan Savanna zone. It is therefore pertinent to note that information on the occurrence of normal, early and late onset and cessation of the rains may be of practical value to the planning of agricultural activities in Nigeria. The result has shown clearly that reliability of hydro-climatic attributes for optimum agricultural activities cannot be achieve without contributing SSTA over the Gulf of Guinea.

6.0 Conclusion /Recommendation

This study has examined the SST anomalies in the GOG and discussed their association with the characteristics of hydro-climatic variable over the agro - ecological zones in Nigeria. For this period of study the SSTA over GOG indicated that it has undergone some warming over time and positive SSTA are significantly related with hydro-climatic variables in Nigeria.

Therefore SSTA should be seen as one of the factors responsible for climatic deteriorations in Nigeria such as flood, drought, acid rain, heat waves etc.

The study concluded that, the SST anomalies over GOG have impacts on the hydro-climatic variable in Nigeria.

Sea surface temperature should be seen as one of the forecasting tool in determining the various climatic attributes that is essential for optimal agricultural practices. This can be achieved with the use of reliable climate predictability tools. To enhance optimal schedule of farm operations for farmers, proper adaptation and mitigation practices should be put in place.

References

Adejuwon, J.O. and Odekunle, T.O. 2006. Variability and the severity of the “Little Dry Season” in Southwestern Nigeria. *Journal of Climate* 19: 483–493.

Afiesimama, E. A. 1996 : On the variability of the mean sea surface temperature and its influence on the rainfall pattern over a coastal station in West Africa. Proc. of the 4th Inter. Conference on School and Popular Met. and Oceanographic Edu. R. *Met. Soc. Publication* p321.

Bello, N.J. (1989) On the reliability of the methods of predicting the onset and cessation of the rains in a tropical wet and dry climate: ondo as a case study.

Bello, N.J. (1997) Investigating the spatial pattern of the characteristics of the onset and cessation of the rains in Nigeria. *Geojournal* 43 : 113-123.

Bello, N.J. 2000 : Application of rainfall potential evapotranspiration model for determining optimum planting date of maize (Zea mays) in a tropical Wet and Dry Climate. The Indian *Journal of Agricultural Sciences* Vol. 70 (6) 437-440.

Edafienene, at al, (1997): Sea surface temperature analysis from institu data at East Mole, Lagos Nigerian Meteorological Society proceedings of the 12th and 13th Department Symposia. Pp 35

Gbuyiro SO, Lamin MT, Ojo O. 2002. Observed characteristics of rainfall over Nigeria during ENSO years. *Journal of Nigerian Meteorological Society (NMS)* 3: 1 - 17.

Folland C. K., Palmer, T. N., and Parker, D. E, 1986: Sahel rainfall and worldwide sea temperatures. *Nature,* 320, 602-607.

Losada, T., B. Rodriguez-Fonseca, S. Janicot, S. Gervois, F. Chauvin, and P. Ruti, 2010a: A multimodel approach to the Atlantic ecuatorial mode. Impact on the West African monsoon. *Clim. Dyn.*, Doi: 10.1007/s00382-009-0625-5.

Mohino, E., B. Rodríguez-Fonseca, C.R. Mechoso, S. Gervois, P. Ruti, and F. Chauvin, 2011a: Impacts of the Tropical Pacific/Indian Oceans on the Seasonal Cycle of the West African Monsoon. *Journal of Climatology.,* Doi: 10.1175/2011JCLI3988.1

Odekunle, T.O, and Eludoyin A.O, 2008: Sea surface temperature patterns in the Gulf of Guinea: their implications for the spatio-temporal variability of precipitation West Africa, *international. Journal of. climatology.*

Okeke F.N,; Marengo J.A., Nobre, C. (2006), Investigation of El Nino and La Nino effects and the impact of Atlantic Sea Surface Temperatures (SSTs), on precipitation in Nigeria from 1950 to 1992. *Surveys in Geophysics* Volume 27, Number 5, 545 - 555.

Okumura, Y. and Xie, S. 2004. Interaction of the Atlantic equatorial cold tongue and the African Monsoon. *Journal of Climate* 17: 3589 - 3602.

Olaniran, O. J. and Summer, GN. (1990). Long-term variations of annual and growing season rainfalls in Nigeria. *Theoretical. and Applied Climatology*., 41:41 – 53

Omogbai B.E. 2010. Rain Days and Their Predictability in South-western Region of Nigeria. *Journal of Human Ecology*, 31(3): 185-195

Omotosho JB, Balogun AA, Ogunjobi K. 2000. "Predicting monthly and seasonal rainfall, onset and cessation of the rainy season in West Africa, using only surface data". *International Journal of Climatology* **20**: 865–880.

Wang, C., S.P. Xie and J. A. Carton. 2004 A global survey of ocean-atmosphere interaction and climate variability, Geophysical Monograph.

ASSESSMENT OF CLIMATIC TRENDS IN NIGERIA

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Abstract

There are considerable contrasts between the coastal areas and the interior. The mean annual temperature in the northern zones varies between 32.5◦c (Katsina) and 35.1◦c (Bauchi), in the south, the mean annual temperature varies, the mean annual temperature varies from 29.2◦c and 31.5◦c Calabar, which is along the coastal area, Ibadan has 30.3◦c and 33.3◦c, has more oceanic influence and the influence of Little Dry Season. Enugu is in the interior has mean annual temperature .Oscillation between 31.1◦c and 33.1◦c. Lokoja is in interior but has the influence of Niger-Benue rivers has the mean annual temperature between 31.8○c and 34.6○c. Temperature varies from season to season throughout the year in Nigeria, temperatures are generally high since Nigeria lies within the tropics. There are 3 factors that may cause rain thus:

(a). excessive heating which generates vertical air current.

(b). Relief which presents a barrier to winds and thus, forces them to rise.

(c). A cold air which undercuts a warm, wet and therefore, lighter air may cause rain.

INTRODUCTION

Climate of a place is referred to as the average weather conditions observed and recorded over a long period, like 30 years and above. Climate of a place is made up of weather parameters like: temperature, rainfall, pressure, air-masses, wind and atmospheric humidity. These elements are in turn affected by major factors like: latitude, altitude and relief, proximity to sea, ocean currents and wind. Other factors that are minor include: vegetation, nature of the soil, position of a place in relation to the direction of the sun's rays.

Nigeria temperature records/data from the northern part of the country are different from data from the south, certain weather conditions and other factors that could be found in the south may not be available in the north.

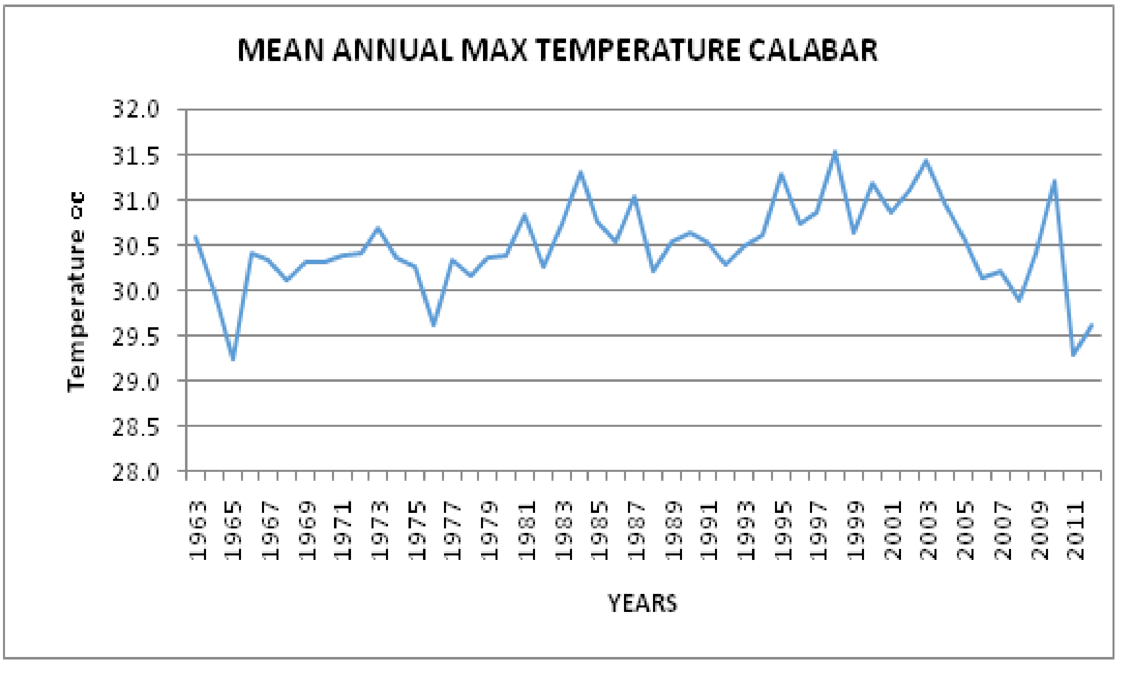
MATERIAL AND METHODS

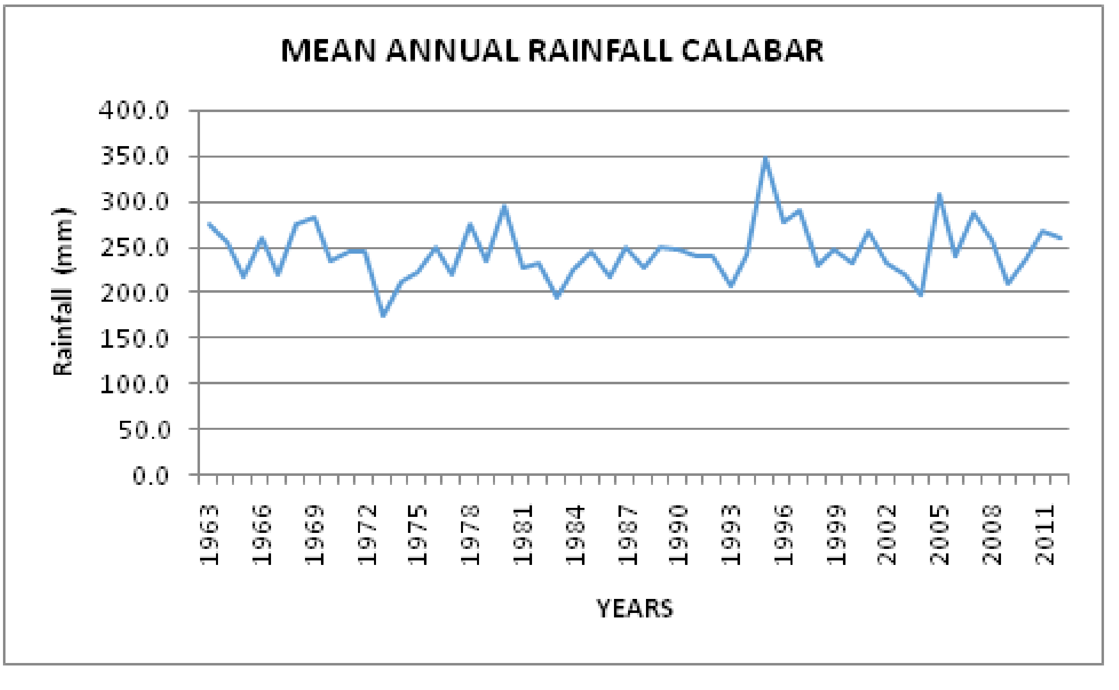
- A 50-year data (1963-2012) of temperature and rainfall data was employed for this study.
- This data was obtained from the archives of the Nigerian Meteorological Agency

STUDY AREAS

- Six stations were selected to represent the six geographical zones of Nigeria. These stations include:

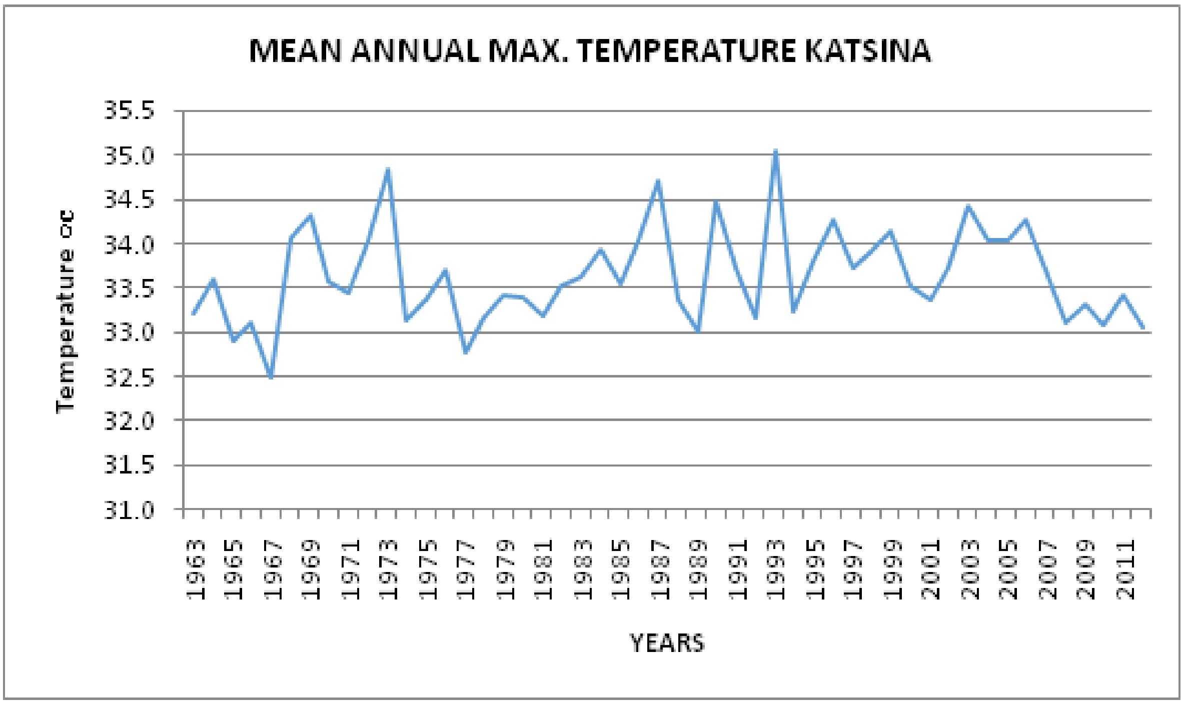
STATION	LOCATION	ZONE
Calabar	4°34'N 6°58'E	South-South
Katsina	12°59'N 7°35'E	North-West
Bauchi	10°18'N 9°50'E	North-East
Ibadan	10°23'N 12°05'E	South-West
Enugu	6°26'N 7°29'E	South-East
Lokoja	7°48'N 6°44'E	North-Central



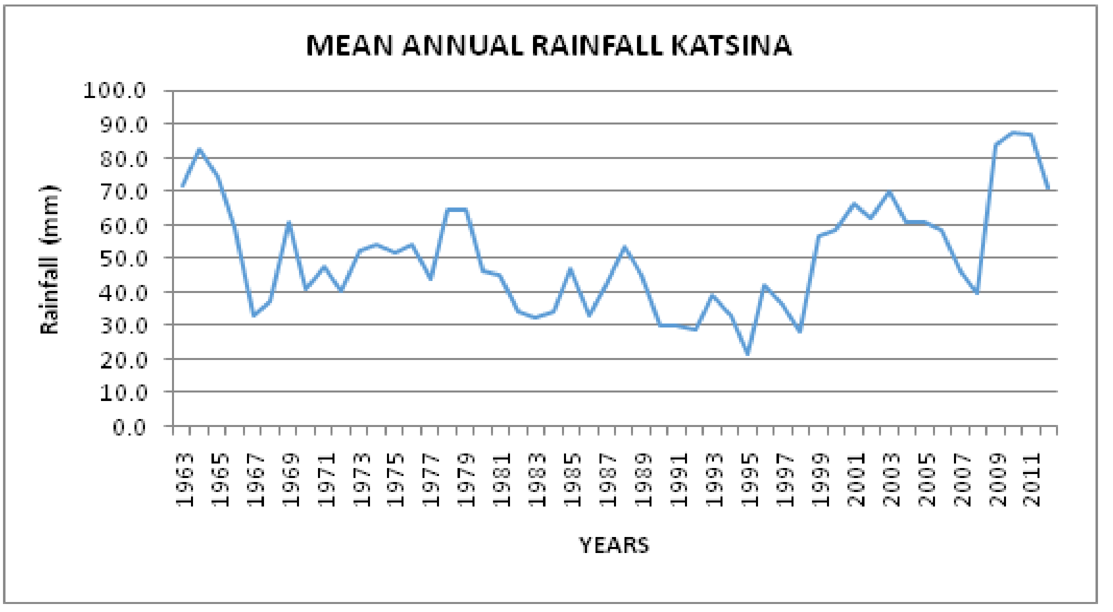


3 major negative temperature anomalies: in 1965, 1976 and 2011 (the most heated years). Fluctuations within 1995 and 2008 reflected in the drop of rainfall within 1995 and 2004. Highest temperature occurred in 1998, 31.5°C, positive

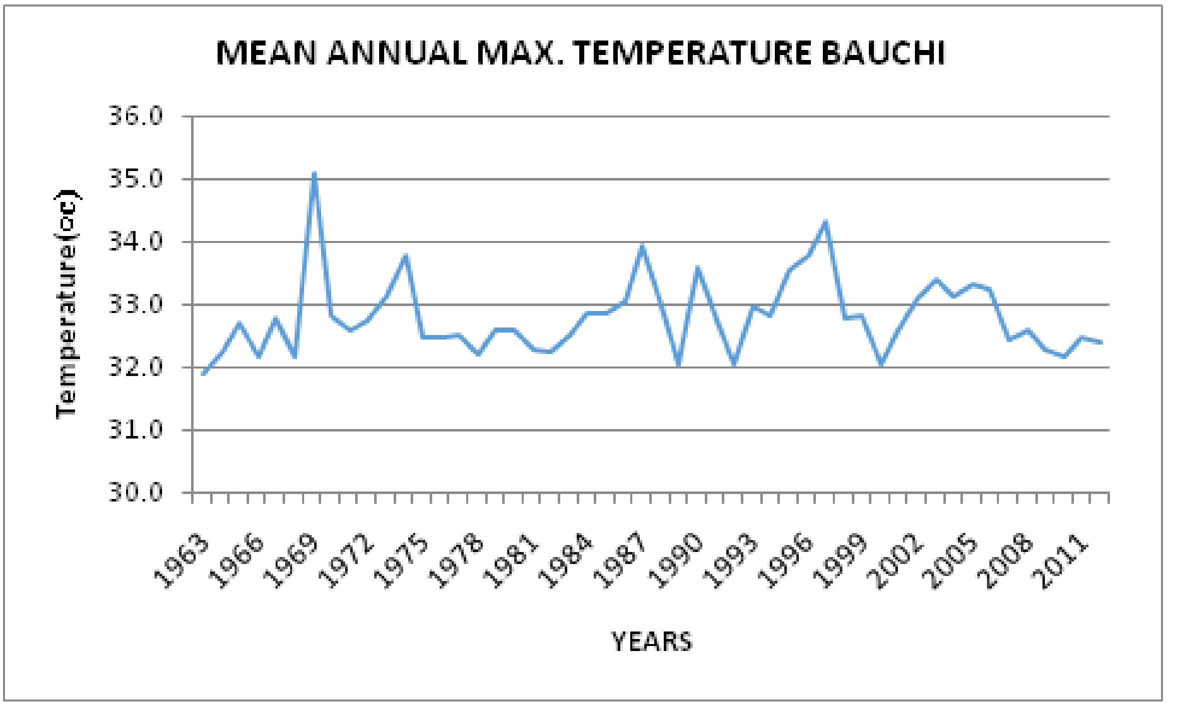
Wettest year was 1995 with 347.8mm, with the temperature 31.3○C positive anomaly, temperature started appreciating in 1976-1981 but rainfall was not consisted, possibly for the wide fluctuation in temperature and the sea effect.
Driest year was 1973, with 175.8mm, after negative rainfall anomaly, there was a rise in rainfall in 1973-1980.



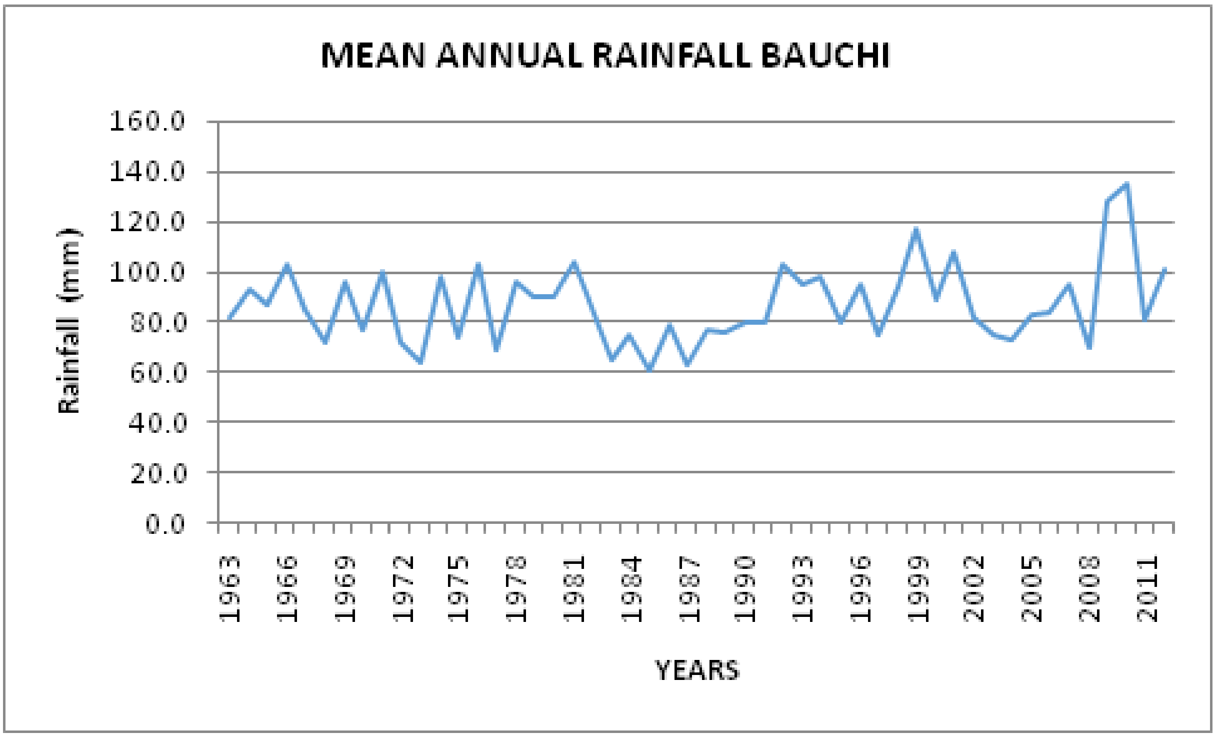
1967 was the year of low heat with 32.5°C, followed by a sharp increase in the temperature of wide variation.1977 has both temperature and rainfall had sharp increase after a negative temperature anomaly. 1967-1974 and 1987-1994 there was a large amplitude oscillation which shows appreciable years of variability.
Highest temperature occurred in 1993 with 35°C.



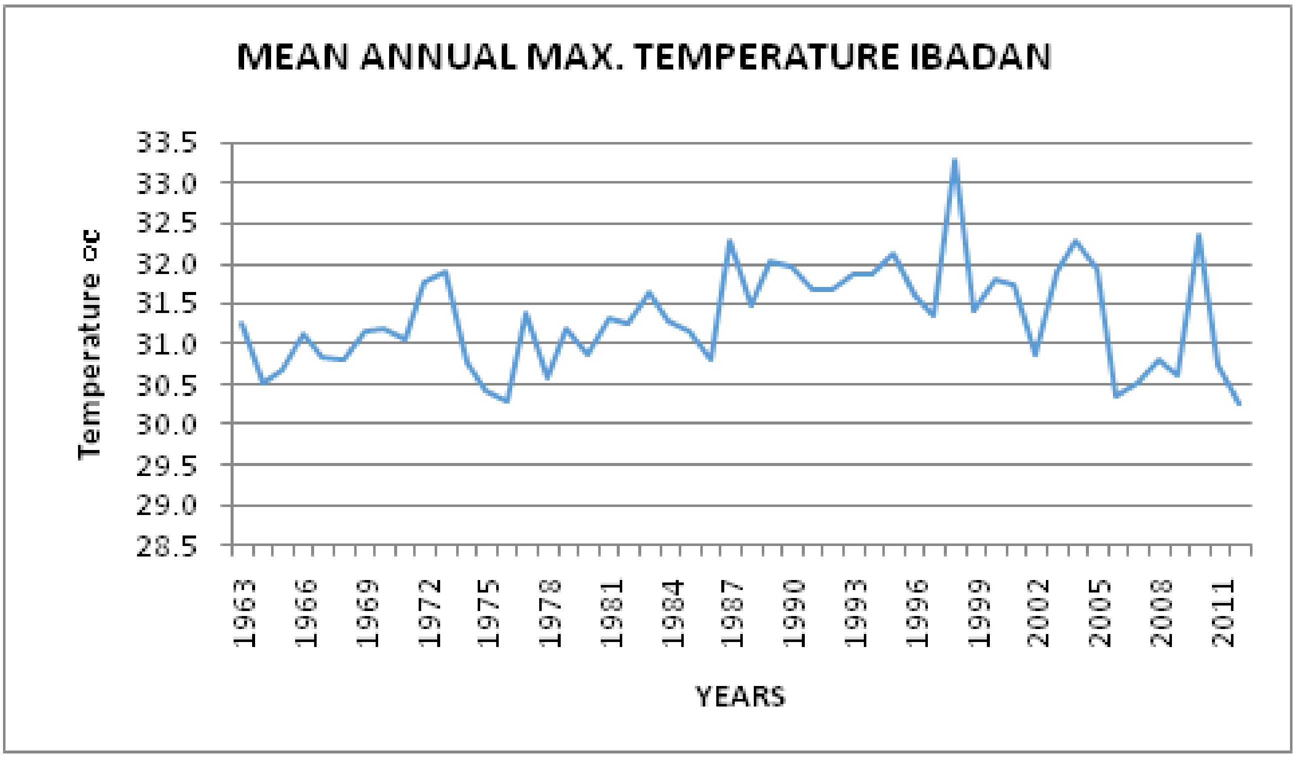
Wettest year was 2010 with 87.3mm, positive anomaly Driest year was 1995 with 21.7mm, negative rainfall anomaly of 1967 (33.3mm) lags negative rainfall anomaly of the same year, drastically appreciate in rainfall amount after the reduction in 1967 to 60.9mm. 1998-2003 has sharp rainfall increase immediately after the negative rainfall anomaly of 28.3mm.



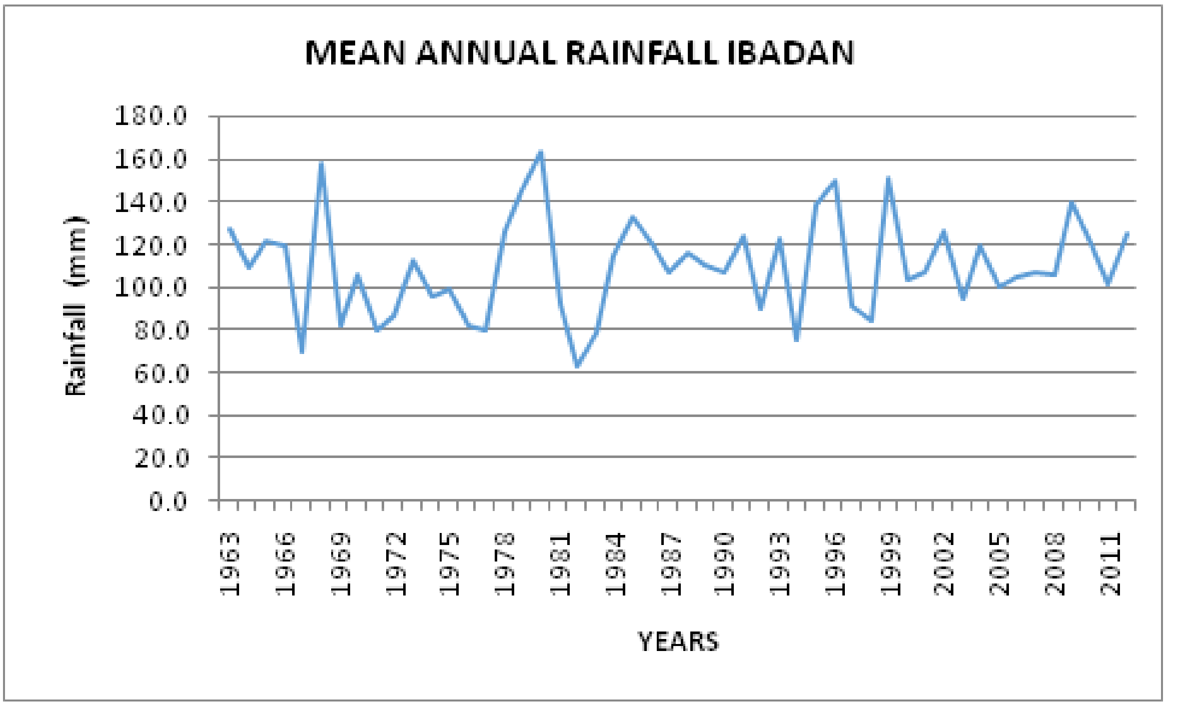
The most warmest year 1969, but low rainfall.1974-1982, there was a sharp and steady reduction in temperature following positive anomaly while 1977-1981 has a gradual increase in rainfall. 1982-1987 and 1992-1997 had similar amplitudes show climatic variability. 2003-2010, there was a steady reduction in temperature while 2004-2007 shows gradual rise in rainfall. 2008-2010 there was a positive rainfall anomaly followed by steady drop in temperature from 2004-2009.



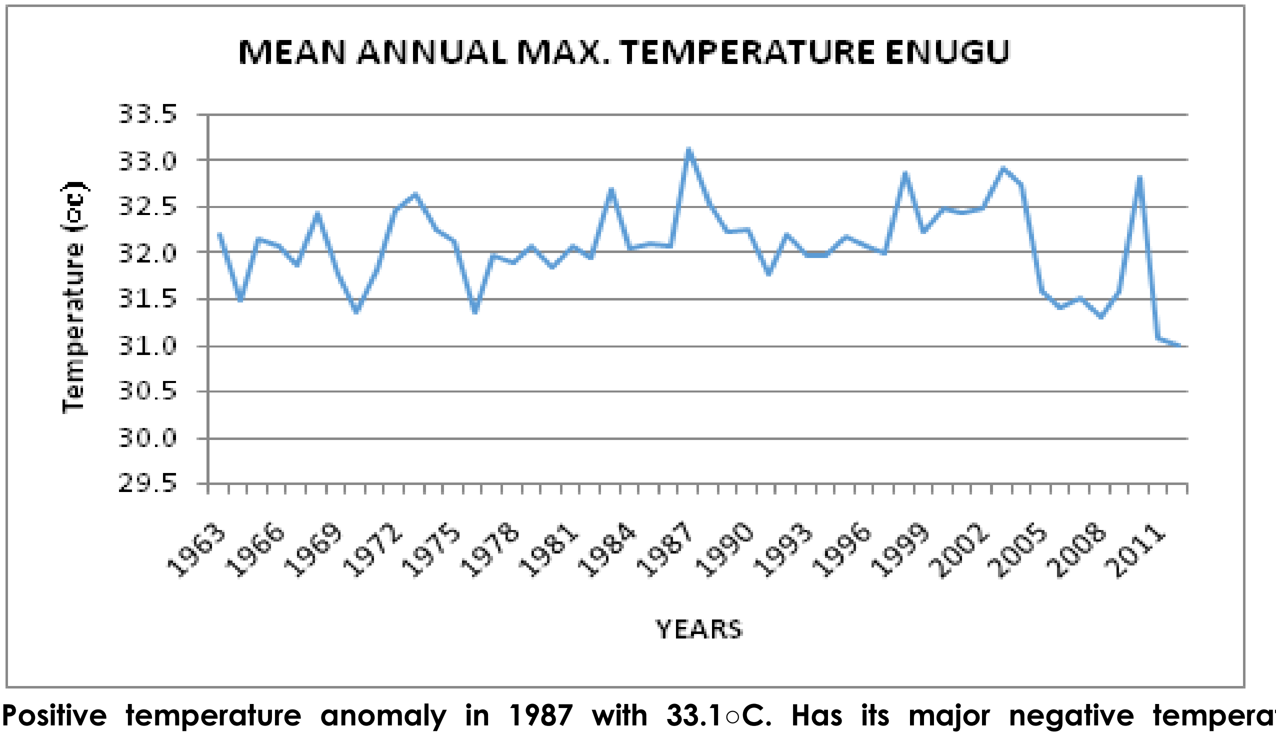
Wettest year was 2010 with 135.1mm, positive anomaly
Driest year was 1985 with 60.5mm, negative anomaly



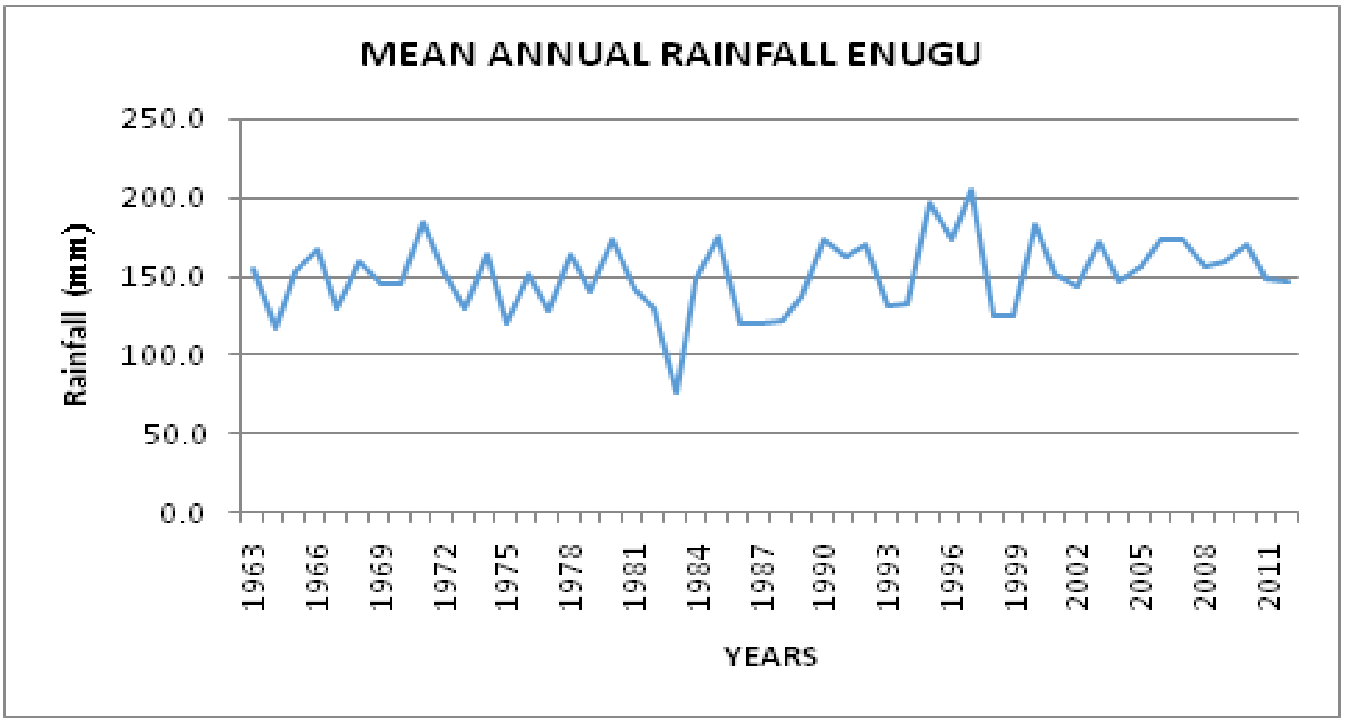
Negative temperature anomalies in 1976, 2006 and 2012 show climatic variability with the same temperature value, 30.3○C and 2012 coldest years. 2004-2008 has steady drop in temperature curves and rainfall curves lag the same.
Highest temperature occurred in 1998 with 33.3○C, positive anomaly



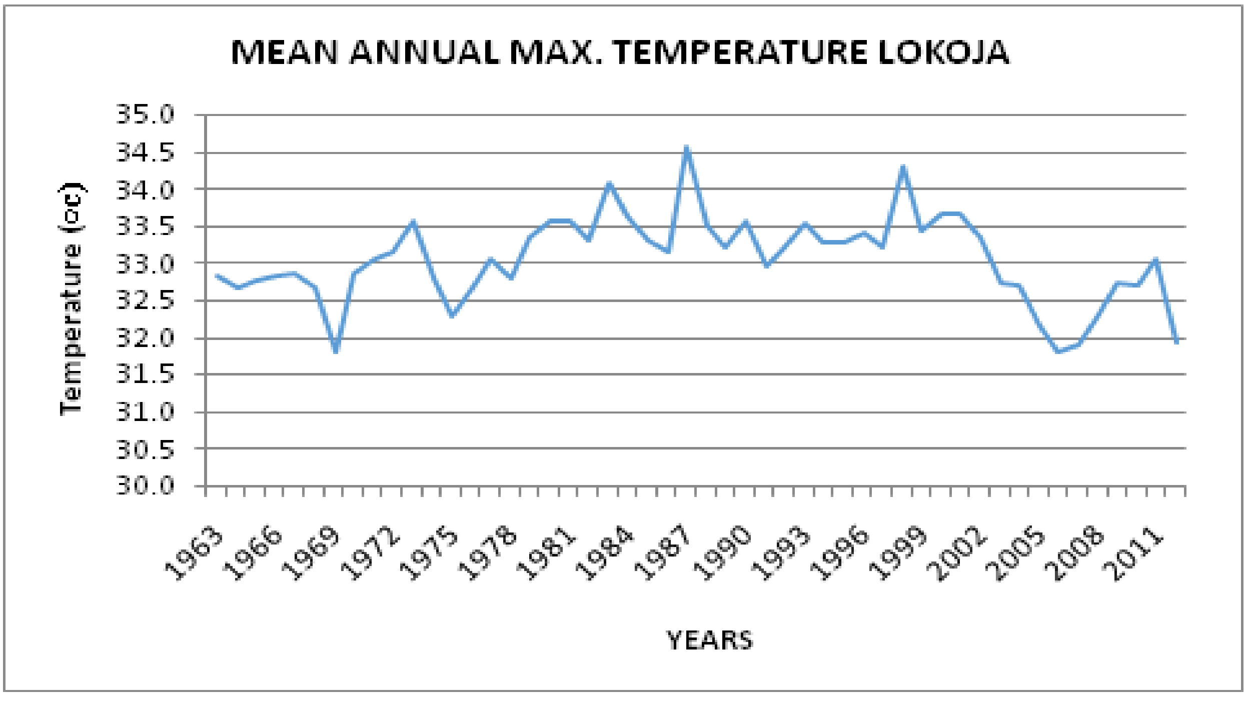
Has 2 major positive rainfall anomalies in 1968 and 1980. Rainfall dropped in 1998 which was the most heated year. 1973-1977 and 1985-1992 had similar amplitude oscillations. The 3 negative rainfall anomalies show similar wide amplitude oscillations in every 10years of consisted intersperse temperature oscillation punctuated by peaks.



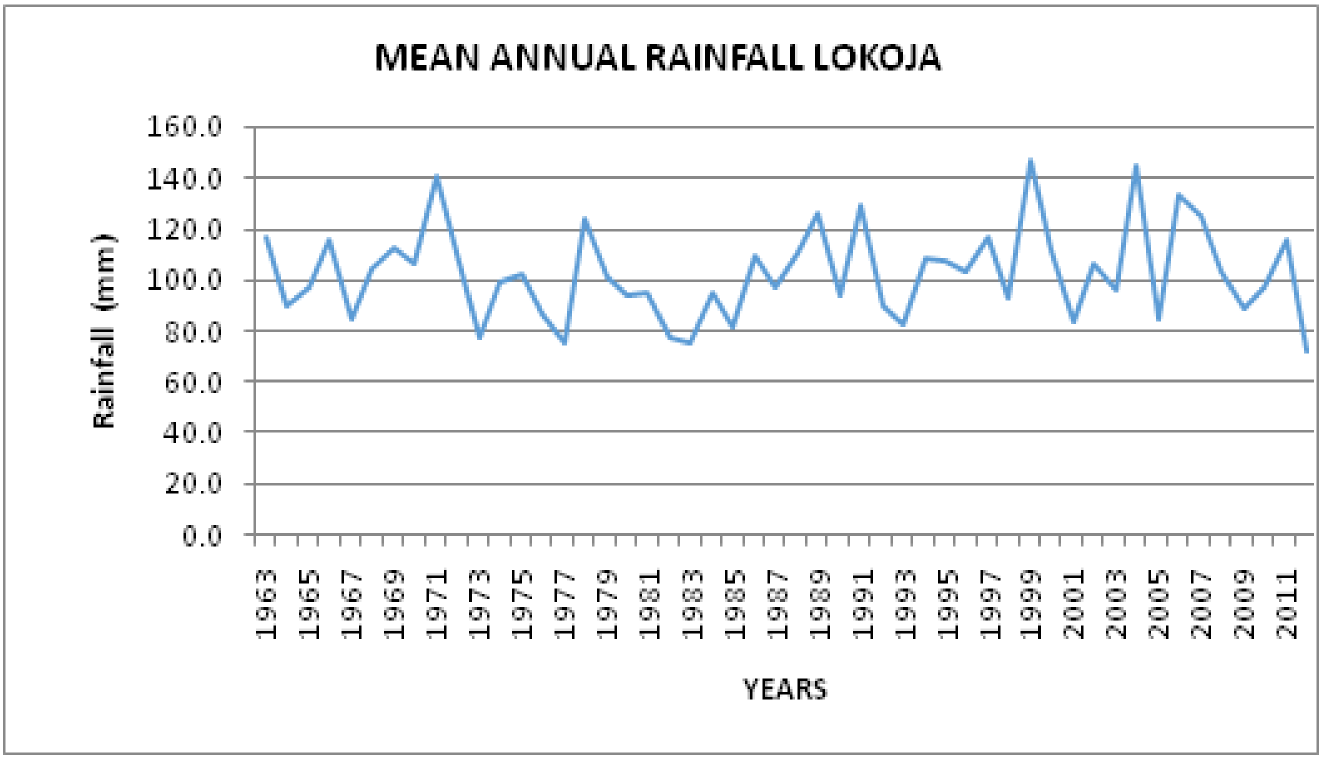
Positive temperature anomaly in 1987 with 33.1○C. Has its major negative temperature anomaly in 2011 with 31,1○C.Similar amplitudes in 1976-1983 and 1992-1997 showing climatic variability and each preceded by a sharp drop in temperature.



The major negative rainfall anomaly was in 1983 with 96.1mm and positive rainfall anomaly was in 1997 with 205.7mm., but a gradual rise in rainfall



1969 and 2006, the 2 major negative temperature anomalies. 1969-1973, a sharp rise of temperature after a negative anomaly . The most heated year was 1987 with 34.6○C. The lowest temperature years were 1969 and 2006 with 31.8○C.



Wettest year was 1999 with 147.3mm, positive anomaly Driest year was 2012 with 72.6mm, negative anomaly. 1969 there was rainfall curves that lag temperature curves after a negative temperature anomaly.

CONCLUSION

- **Based on the analysis and the deductions, a lot of small oscillations confirm 3-5years in between them.**
- **There were large amplitudes between the small oscillations, because, the climate is not showing consistent direction as a result of both high and low amplitudes.**
- **It therefore, shows much consistent variations within the period of the study, 1963-2012.**

ANALYSIS OF SOME CLIMATIC PARAMETERS IN GBOKO LOCAL GOVERNMENT AREA OF BENUE STATE, NIGERIA

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Abstract

The study was undertaken to analyze some climatic parameters in Gboko Local Government Area, Benue State Nigeria. Data for this study were collected from the Nigerian Meteorological Agency (NIMET), AirForce Base, Makurdi.. The rainfall pattern analysis was carried out through the use of rainfall data which was subjected to computer software, The Arc Map was used to designed isoline maps which shows communities that have the same amount of rainfall pattern in the Study Area. The analysis looked into areas that normally experienced low and high amount of rainfall in the study area, which indicated that different months has different amount of rainfall based on the pattern considered. The study also established that the high and low amount of rainfall in Gboko Local Government Area shown different patterns in different months. The trend analysis was used to shows the trends in rainfall, temperature and relative humidity using thirty years data. The analysis shows that most years under study experienced total dry spell with high temperature and low relative humidity while other years experienced heavy rainfall with low temperature and high relative humidity. It was also discovered that rainfall in the study area is not evenly distributed and perhaps results in dry spells and heavy floods which resulted to the suffering of the people in the study area. It was therefore recommended that Weather Forecasting Agencies such as the Nigerian Meteorological Agency (NIMET) should intensify more effort on seasonal forecasts of dates of rainy season, onset, cessation, duration of rainy season as well as daily temperature and relative humidity down to the Local Government level so as to be prepared them for any emergency.

***Key Words**:* Rainfall Pattern, Climatic parameters, Geographic Information System, Arc Map, Isoline Map

Introduction

Climate simply means the mean state and behavior of the atmospheric condition over a long period of time. The constituents of climatic parameters include Rainfall, Temperature, Relative humidity, Sunshine, solar radiation etc. In most of the researches carried out by many scholars the emphasis has been on rainfall, this is because people belief that rainfall is the most important natural factor that determines the agricultural production in Nigeria, particularly in the Northern part of Nigeria. Relative humidity and temperature are also two climatic parameters that have direct and significant effect on crop production. Potential crop yield varies across locations due to the temperature and relative humidity regime. The variability of rainfall and the pattern of extreme high or low precipitation are very important for agriculture as well as the economy of the state. It is well established that the rainfall, temperature and relative humidity is changing on both the global and the regional scales due to global warming (Hulme, 1998). As the moves to encourage agriculture to ensure food security continues to gain ground and acceptability, information on rainfall, temperature and relative humidity pattern is vital for the design of water supply, supplement irrigation schemes, evaluation of alternative cropping and soil water management plans. Such information can also be beneficial in determining the best adapted plant species and the optimum time of seeding to re- establish vegetation on deteriorated rangelands. Much as long rainfall records are mostly available in many countries, little use is made of this information because of the unwieldy nature of the records (Fisher, 2005). The current pattern of rainfall, temperature and relative humidity in Benue State has been a source of concern to the inhabitants, especially those who rely on it for their economic activities. Rainfall pattern is increasingly becoming a source of concern, particularly in the rain fed agricultural regions of the world, this is due largely to its variability, distribution and seasonality.

A typical rain fed agricultural region, where the scarcity of water and uncertainties in both the amount received and in spread, have continued to pose major threat to the development of agriculture and have contributed significantly to the poor yield and high variability in crop production from year to year. According to Fakorede (1993), it is clear that, of the climatic factors which influence the pattern and productivity of rain fed agriculture in Nigeria, the availability of water and temperature to crops is by far the most important. Generally, based on rainfall distribution, certain patterns are found at a different geographical location. Nyagba (1995) pointed out that rainfall distribution pattern explains why the drought resistance crops such as millet and sorghum are grown largely in different parts of the study area while crops that are more moisture demanding such as and maize are grown extensively. To date, much of the effort to analyze rainfall variability in Nigeria with respect to agriculture has generally focused on the exploitation of the seasonal rainfall (Adefolalu, 1986). For a better understanding of the issue of water availability in tropical rain fed agriculture, more attention had been given to the quantification of season rainfall variability. The importance of the knowledge of rainfall pattern has necessitated many researchers to carryout studies on the subject and the findings that some regions have experienced marked decline in rainfall, temperature and relative humidity patterns depending on the location. For state whose economy largely depends on efficient and productive rain-fed agriculture, rainfall patterns and trends are often quoted as one of the major causes of several socio-economic problems like food insecurity in the state. The present study therefore examined rainfall and some climatic parameters in Gbokk Local Government area Benue State

The Study Area

Gboko LGA is located in the north-eastern part of Benue State between latitudes 7°13'N and 7°35'N, Longitudes 8°30'E and 9°03'E Nyagba (1995). It collected lies on Latitude 7°26'N and Longitude 8°55'E. Gboko LGA is bordered to the north by Tarka and Buruku LGAs, to the South by Konshisha LGA, to the west by Gwer LGA and to the south-east by Ushongo LGA. It comprises of five districts, Mbatierev, Mbayion, Mbatiav, Yandev and Ipav The area experiences the Aw tropical wet and dry cli- mate type. Rainfall occurs between April to October with maximal peaks in July and September while the dry sea-son occurs between November and March. Mean annual rainfall is about 1300 mm per annum. Mean monthly temperature ranges between 25°C to 30°C with February and March being the hottest months while relative humidity is about 75%. The relief of the area consists generally of rolling plains with Mkar Hills to the east and Gboko Hills to the north. The area is drained by the several streams and rivers including Kontien, Ahungwa, Ambor, Ngo, Nguembi and the head stream of River Konshisha. The main soil type in the study area is tropical ferruginous. It is generally well drained, low in organic matter, bases and cation exchange capacity. Also, hydromorphic soils are found along the major streams and river courses. These soils are generally suitable for the cultivation of certain crops including maize Nyagba (1995). The people in the study area are Tiv and predominantly farmers who specialize in the cultivation of crops such as yams, cassava, maize, guinea-corn, tomatoes, pepper, rice, citrus, mango and cashew. Farming is climate-dependent, especially on rainfall. Climate influences all farming activities in the area, hence crop production takes place within the rainy season.

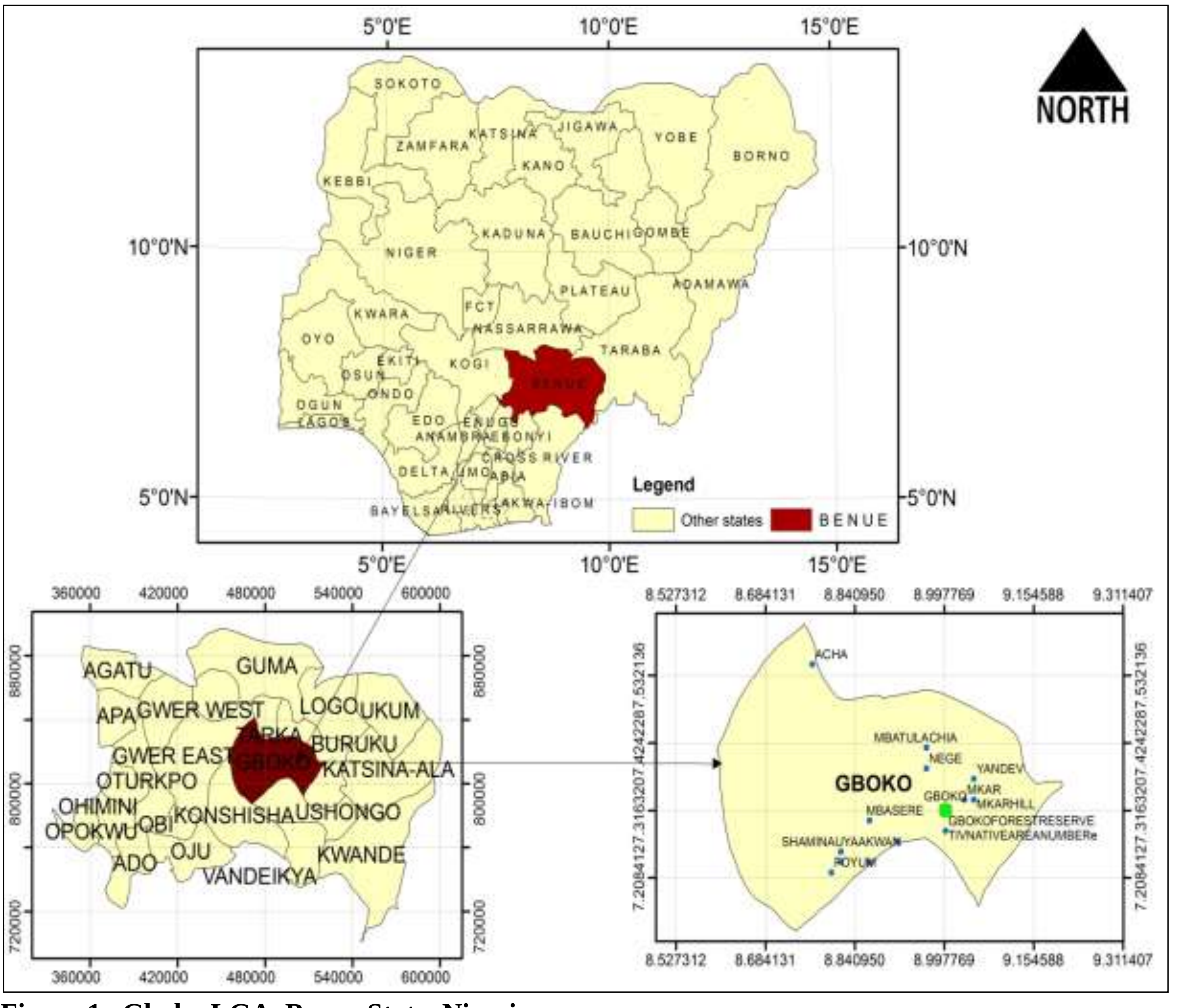


Figure 1. Gboko LGA, Benue State, Nigeria
Source: (Benue State Ministry for Lands and Survey, 2015).

Materials and Methods

Base map of the area was obtained and a hand hold GPS was used to take coordinate of the various communities captured in the study area. Arc map was used to produce the Isoline map of the communities that shown different amount of rainfall pattern.

The data used for the study were archival data on rainfall (mm), Temperature (0^0C) and relative humidity (mm). Rainfall, Temperature and Relative humidity data were obtained from the Nigerian Meteorological Agency (NIMET), AirForce Base, Makurdi from 1985- 2014.

Methods of Data Analysis

The arithmetic mean of a set of value, $xi, x2, x3 \ldots\ldots\ldots\ldots\ldots\ldots Xn$, is equal to the sum of the measurement divided by n were used for calculating daily rainfall, temperature and relative humidity express as formula:

$$\overline{X} = \frac{\sum Xi}{n}$$

Where;

Xi = Annual rainfall, temperature and relative humidity for a given period or year

n = total number of year under consideration

$\sum$ = summation of all value of variable

Standard Deviation was used to analyzed the daily data collected on rainfall, temperature and relative humidity. It can be express as:

$$\alpha = \sqrt{\frac{\sum (xi - \overline{x})}{n}}$$

where:
$\overline{x}$ = mean value
xi= class mark value
n = number of observation
$\sum$ = Greek symbol meaning sum of the value

Trend Analysis

Trend analysis was used to show differences in yearly amount of rainfall, temperature and relative humidity over a period of 30 years.

Rainfall pattern analysis

Rainfall pattern were analysed through the use of rainfall data which was subjected to Arc Map to produce isoline maps which shows communities that have different amount of rainfall pattern in the Study Area

Results and Discussion

This section discusses the analysis of climatic parameters in Gboko Local Government Area of Benue State. . Rainfall pattern and Trend analysis of climatic parameters such as rainfall, temperature and relative humidity were analyzed.

Analysis of Trends of some climatic variables in the study area

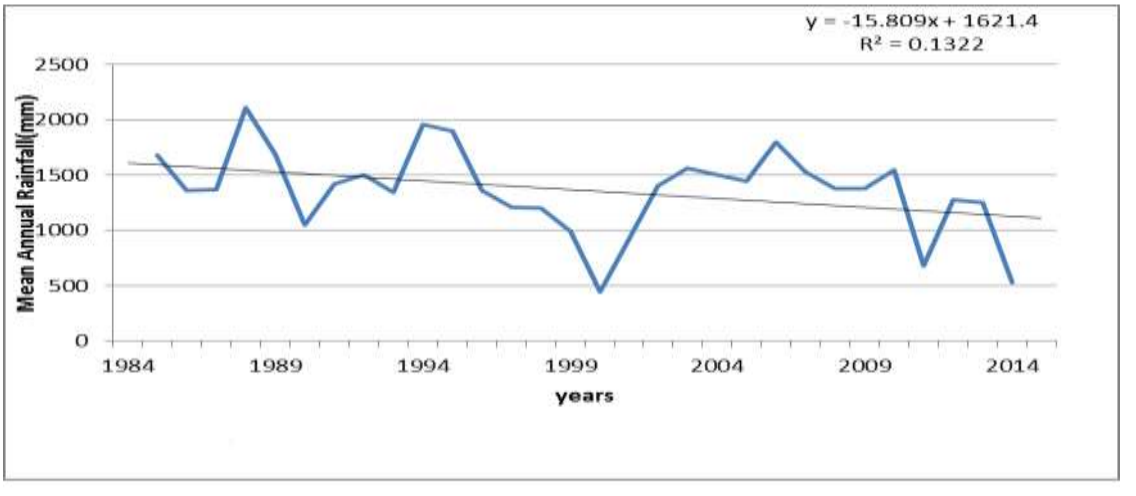


Figure 1. Trend analysis of Annual Rainfall for Gboko from 1985-2014

The trend of annual rainfall from 1985- 2014 in Gboko Local Government Area of Benue State shows an increasing and decreasing trend over the years. From 1985- 2014 shows an increasing trend in most of the years which have the average annual rainfall of above 1500mm, such years includes 1985 and 1988 respectively. Furthermore, 1994, 1995, 2003, 2006 and 2010 had an upward trend of annual rainfall of above 1500mm. The downward trend of 1999, 2000, 2001and 2011 indicated low amount of rainfall which is below 1500mm. the figure shows that there is an upward trend in the rainfall with an indication that there is about 13.2% (R^2 = 0.1322) which shows a positive correlation with most of the years. In summary, the trend of annual rainfall in the study area fluctuated over the years. According to Nyagba (1995), this fluctuation explains why most years in the study area experienced drought which resulted to poor yield and other years experienced high rainfall which resulted to flooding.

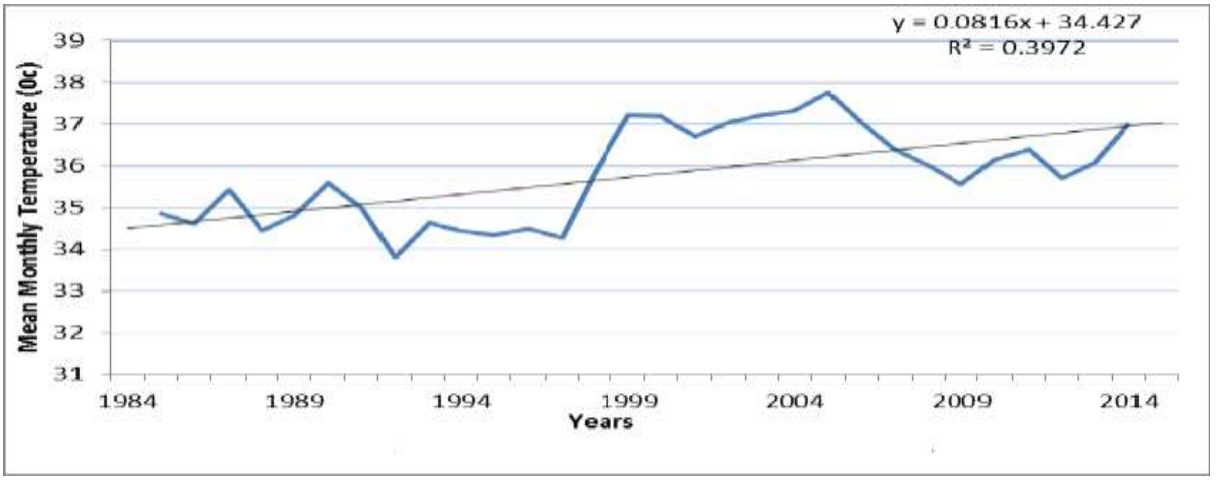


Figure 2. Trend analysis of Annual Temperature for Gboko from 1985-2014

Looking at the temperature trend in the study area from 1985- 1998 exhibited a similar trend where the annual temperature is between 34^0C-35^0C which does not show much differences, from 1999- 2006 there is an upward trend in annual temperature between 36^0c and above, this shows a reflection of global warming resulting into general increase in the earth's temperature (Adebayo, 2012). The graph shows an upward trend with about 39.7% (R^2 = 0.3972) at 95% level of significance

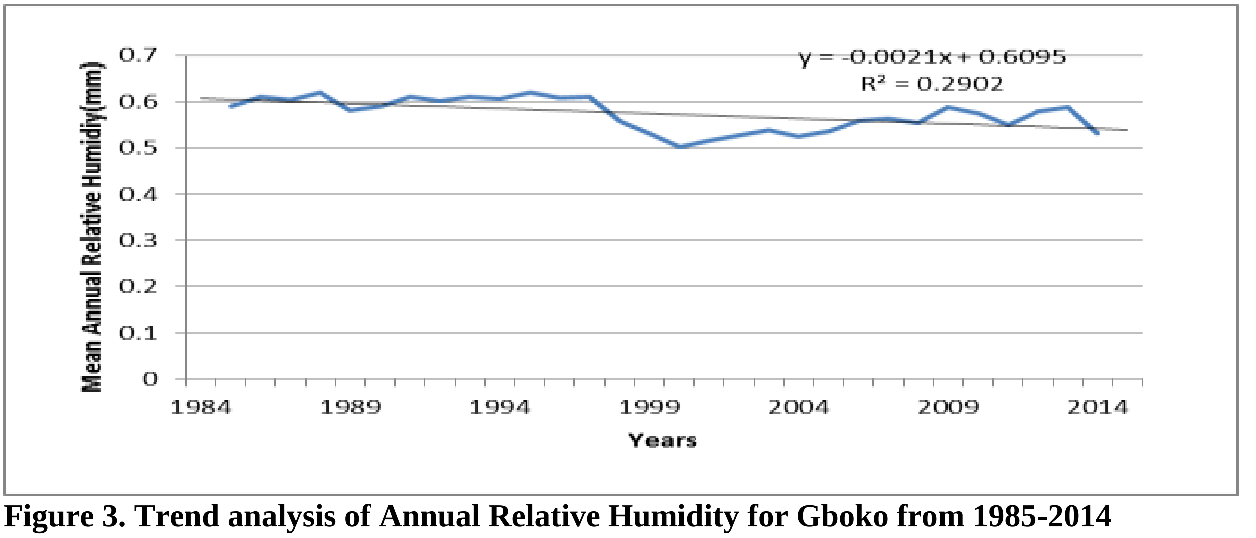


Figure 3. Trend analysis of Annual Relative Humidity for Gboko from 1985-2014

The trend of relative humidity exhibited fluctuations with a corresponding increased and decreased graph, for instance, 1984- 1998 experienced a gentle slope with an increased in relative humidity from 0.6mm and above. While a downward trend occurred from 1999- 2006 with indication that the study area experienced little dryness where the relative humidity is below 0.6mm. Furthermore, 2008-2014 experienced an upward trend of relative humidity that is above 0.6mm indicating wetness in the study area. The graph shows an upward trend with about 29% (R^2 = 0.2902) at 95% level of significance. Based on the above trend of relative humidity, most years which experienced less than 0.6mm of relative humidity brought about total dryness which imposed sufferings on people in the study area according to Nyagba (1995).

Analysis of Rainfall pattern experienced in Gboko

Mean Monthly Rainfall

Gboko Local Government Area experienced a similar mean monthly rainfall as compared to most of the areas in Benue State and beyond. These are the dry and wet seasons. These seasons correspond to the period when the Tropical Maritime and Tropical Continental air- masses along with their associated winds respectively influence the study area and other parts of Nigeria.

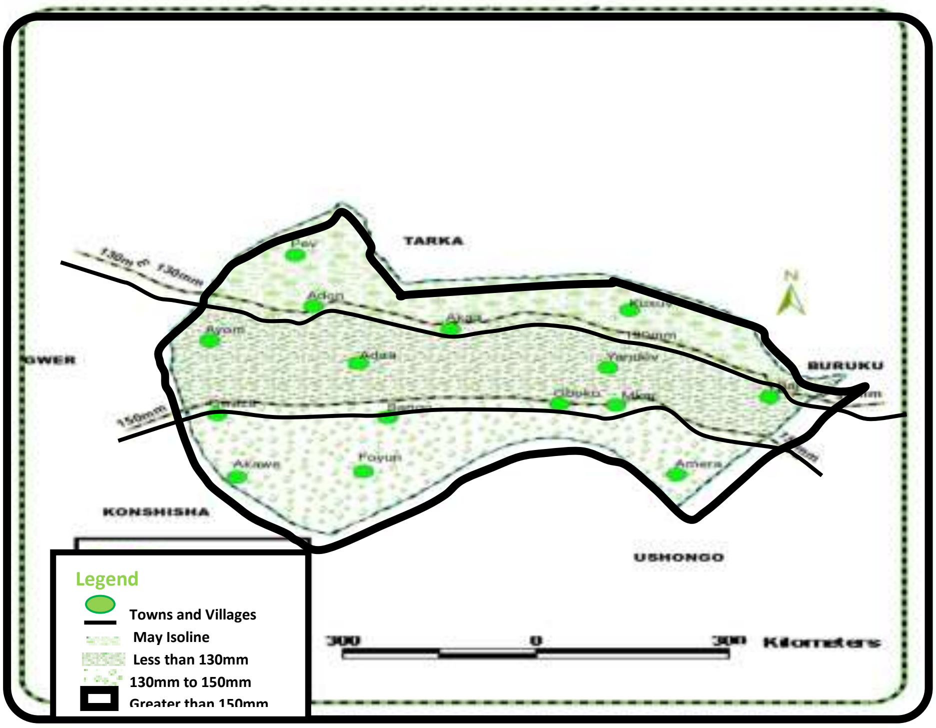
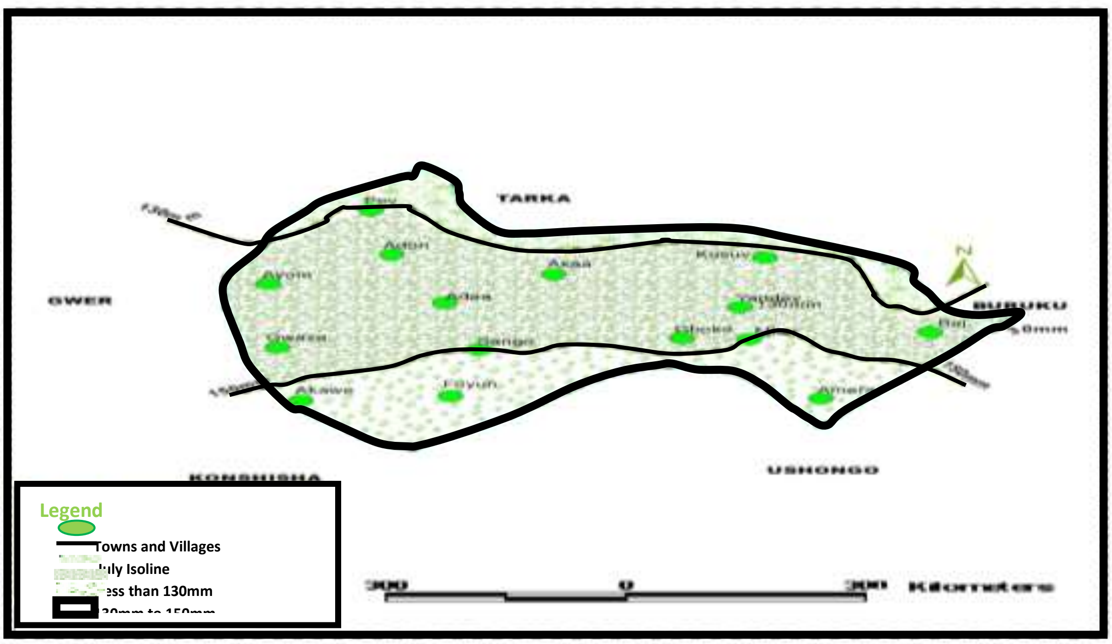


Figure 4. Mean monthly rainfall (mm) in May in Gboko
Source: Field work survey (2015)

Rainfall in the month of May increase from the South towards the North. For instance, settlement such as Akawe, Sango, Amera and Bango receive more than 150mm. Therefore most villages from the southern part experience rainfall on high amount and this boost their agriculture production. This explain while According to (Fakorede, 2001), agriculture largely depends on climate to function, hence, precipitation, solar radiation, wind, temperature, relative humidity and other climatic parameters affect and solely determine the global distribution of crops



Source: Field work survey (2015)
Figure 5. Mean monthly rainfall (mm) in July in Gboko

Rainfall in July increase northward as the ITCZ continues to shift northward and most areas in the north experienced more rainfall as compared to the Month of May. During the month of July, only Pev in the northern part receive the lowest rainfall of less than 130mm, which is being subjected to little drought than other settlement. The highest rainfall was recorded in the South- Eastern part of the study area. The Month of July receives between 140mm and 150mm.

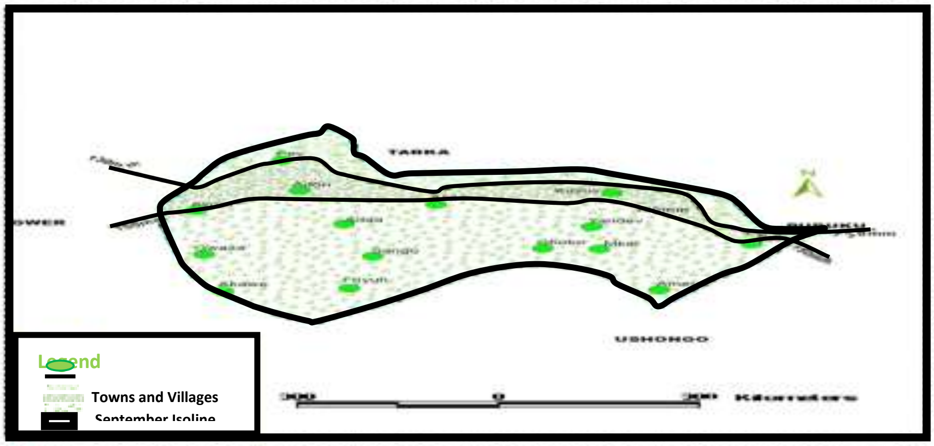


Figure 6. Mean monthly rainfall (mm) in September in Gboko
Source: Field work survey (2015)

September month experienced an increase in the amount of rainfall from the southern part towards the north. In September, rainfall amount has increased relatively. The amount of rainfall in September ranges above 150mm southward in places which include Akawe, Mkar, Yandev, Gboko and Gwazo, this explains why floods occurred in these areas during this month while the remaining settlement northward experienced the amount of rainfall from 150mm and below in the study areas. Rainfall pattern determines decision making to water users.

Conclusion

The study concludes that rainfall trend and pattern of the study area differs in different months and years in different localities as most areas receives rainfall earlier than other areas and it is largely dependent on rainfall amounts, this explains why most settlements experienced drought while others experienced flooding. Increasing rainfall means increasing recharge of the various surface and underground water resources. This increase can create adequate water storage against periods of shortage in the study area.(Nyagba, 1995)

Recommendations

This study therefore advocates for an alternative technology by way of advanced water supply to ensure regular pattern for a more reliable rainfall. This will go a long way to ensure that government's effort to improve on agriculture to ensure food security and economic development will not be a fruitless venture (Fakorede, 2001).

References

Akintola, J.O. (2001) and Klaiji (1990). Comparative analysis of the distribution of rainy days in different ecological zones in Nigeria agriculture. J. Environ. Ext., 2(1):31-48.

Dewit, J. (2007). Assessing Rainfall Variability: Impacts on cassava yield in Guinean Savanna Part of Nigeria, 76, 134-140.

Fakorede, A. (1993) Rainfall climatology and Agricultural Extension Services.W.M.O Training lecturer series 93:3.

Fakorede, A. (2001) Global water resources: Vulnerability from climate change and population growth.

Federal Government of Nigeria (FGN), (1999). Drought management in Nigeria: What can people do to minimize its impact? Abuja, Nigeria, 30-32.

Fisher, K. S. (2005). Climate change and organic agriculture: *The journal of agriculture and environment, 10, 100-110*.

Hare, J. (1985). Climate change (1985): The Scientific Basis: Contribution of Working Group to the Third Assessment Report to the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, United Kingdom.

Hildén, M., Lehtonen, H., Bärlund, I., Hakala, K., Kaukoranta, T. & Tattari, S. (2005).The practice and process of adaptation in Finish agriculture: Finnish Environment Institute Mimeographs, Finland: 234-257.

Hulme, M., Osborn, T.J. and Johns, T.C. (1998) Precipitation sensitivity to global warming: Comparison of observations with HADCM2 simulations. *Geophysical Re-search Letters*, 25, 3379-3382.

IPCC (Intergovernmental Panel on Climate Change), (2001).The scientific basis, Summary for policymakers, impacts, adaptations and vulnerability of climate change: Scientific-technical analyses. Contribution of Working Group II to the IPCC Second Assessment Report, Cambridge University Press, Cambridge, United Kingdom

Nyagba, S. (1995). Comparative Analysis of the Distribution of Rainy Days in Different Ecological Zones in Benue State Nigeria. *Agriculture Journal of Environment, 2, 31-48.*

Okolo, J.S. (1999). Rainfall Effects on Water Use and Yield of Cassava in Nigeria, 52-60.

Olaniran, O. J. (1991). Water Resources Development Optimization in a climate change scenario: Benin-Owena Basin, Nigeria, 234-342.

Olaniran, O. J., and G.N. Summer. (1989) Climate change in Nigeria:change in the rainfall receipt per rain day. Weather: Vol. 43 No.6. 242-248.

Olaniran, O. J., and G.N. Summer. (1990) Long-term variations of annual and growing season rainfalls in Nigeria. Theor. Appl. Climatol. 41 : 41-53.

Olaniran, O.J. (1990). Changing patterns of rain -days in Nigeria. GeoJournal. 22(1): 99: 107-137.

THE ROLE OF RADIO STATIONS IN CREATING AWARENESS OF CLIMATE CHANGE AMONG CROP FARMERS IN ABIA STATE

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Abstract

Radio is a very important medium in creating awareness of issues. The extent to which radio stations in Abia State, Nigeria are making farmers to be aware of climate change was examined in this study. The study majorly adopted the survey research design. A total of 80 copies of questionnaire were administered: 25 to crop farmers in each of the three Senatorial Zones of the state; and the remaining 5 to the 5 radio stations in the state. The questionnaire was divided into parts A and B: A for the crop farmers; and B for the radio stations. The data collected were analyzed using simple percentage and Chi-square statistical techniques. The results revealed that 78% of the farmers have low or no knowledge of climate change. Similar result was obtained in the testing of hypothesis one, where H_0 was rejected implying very low knowledge of climate change by the farmers. Only 2 radio stations out of 5 in the study area have programmes on agriculture where climate change issue has ever been discussed. With regard to source of awareness of climate change, only 20% of the respondents got it though the radio while 52% got from personal observation. H_0 was accepted in the testing of hypothesis two, implying that climate change has adversely affected the yields of crops in Abia State. The farmers are adapting to climate change by planting fast maturing varieties of crops; early or late planting of crops; increasing mulching of crops to conserve moisture and reduce heat; and staking of crawling crops. It is therefore concluded that food security in the study area is being threatened as very few crop farmers are aware of climate change. Radio stations in the state that are without agricultural programmes where climate change is discussed should introduce one.

Key Words: Radio Station, Awareness, Climate Change, Crop Farmers, Abia State

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Sub-theme: Climate Change Action and Policy (Education and Economic Responses)

Introduction

Radio is widely used as a mass communication medium and has a great potentiality in disseminating information as radio signals cover almost entire population. Radio being a convenient form of entertainment caters for a large audience (Payal, 2012). It has advantages over the other mass media like television and newspapers in terms of being handy, portable, easily accessible and cheap (Department for International Development (DFID) Research, 2012). Radio is the most portable of the broadcast media, being accessible at home, in the office, in the car, on the street or beach, virtually everywhere at anytime. It is effective not only in informing the people but also in creating awareness regarding many social, economic, political and environmental issues (Kakonge, 2011). In the developing countries, radio is the powerful and effective medium to project the information and knowledge related to agriculture (Nakabugu, 2001; Food and Agricultural Organization

(FAO), 2001). As the farmers receive useful information from radio, gradually they bring change in farming methods applying new technologies (Daramola, 2003; Khanal, 2011).

Generally, agricultural activities mostly food crop production are climate dependant, especially in Nigeria as any change in the ideal plant requirement may affect the overall yield and productive capacity of the crop (Odewumi *et al*., 2013). Presently, climate is said to be changing and it is affecting agriculture depending on the region. Climate change, which refers to long shift in climate pattern of a specific location, region or planet measurably by changes in features associated with average weather components of temperature, wind patterns and precipitation (Warrick and Barrow, 1991, Nwagbara *et al*.,2009), is the result of the great many factors including the dynamic process of the earth itself, internal forces including variation in sunlight intensity and more recently by human activities. This calls for monitoring of climate change and dissemination of information or creating of climate change awareness to farmers to encourage adaptation. Radio can play a vital role in creating awareness about climate change.

Crop farmers need to clearly understand this interdependence of climate variables and agriculture in order to fully understand the concept of climate change. It is important to note that despite the awareness of climate change and its impact on agriculture, must farmers especially in Africa do not really understand this phenomenon, and it has been said that the perception of farmers about climate change will go a long way to determining the extent of adaptation that will be adopted by farmers (Adams *et al*., 1998; Smith and Skinner, 2002).

Effective communication of useful information will be critical to help farmers adapt to climate change (Pam, 2007). Radio is the most effective way to share their knowledge and experience (Maria *et al*., 2013; Onkargonda *et al*., 2013). African farmers are experienced at dealing with climate variations and have a rich heritage of methods to deal with changes. There is a great deal of information available on climate change. But most is not aimed at a farming audience (Vijah, 2009; Pradeep and Ingita, 2013). The challenge for radio broadcaster is to ensure that their audience understands climate change message and finds them relevant. Radio can encourage communities to assess local problems and identify local solutions to climate change. Radio programmes that talk to farmers about climate change can provide researchers with knowledge of what is happening at the field level and encourage communication between researchers and farmers (James, 2009).

From the foregoing, there is a good relationship between crop farming or agriculture in general and climate, and by extension climate change. Therefore, the extent to which and how often this relationship is presented as programme in radio stations in Abia State are examined in this study, and the following hypotheses postulated: Awareness of climate change among crop farmers in Abia State is very high; and There is no significant difference between the yields of crops before and after climate change.

Study Area

The study area is Abia State. It is one of the 36 States in Nigeria and lies between latitudes 4^0 45' and 6^0 00' North and longitudes $7^0$00' and $8^0$09' East (Figure 1). The State shares boundaries with seven: Imo State is in the west, Anambra State in the north-west, Enugu State in the north and Ebonyi State in the north-east. In the east and south –east, it is bounded by Cross River and Akwa Ibom States and by Rivers State in the south. It occupies a total area of about 6,320 square kilometres (Nwagbara and Uzowulu, 2015). Abia State is divided into 17 Local Government Areas (LGAs). These LGAs have been grouped to form three senatorial zones as it is the case in other states of Nigeria. The senatorial zones are namely North, Central and South. The state is largely inhabited by Igbo people (one of the three major ethnic groups in the country). It had a population of 2,833,999 in 2006 (National Population Commission (NPC), 2007). With the total area of 6,320 square kilometres, it means that the state has a population density of approximately 448 persons per kilometre. The predominant economic activities of the people are subsistence agriculture and commerce. The state has much arable land that produces yams, maize, potatoes, cassava etc. Agriculture which employs 70% of the workforce is the second economic sector (Abia State Government, 2011). Abia State experiences a high annual rainfall (about 2000mm per year) thus making relative humidity to be high throughout the year, reaching a maximum during the rainy season when values above ninety percent (90%) are recorded (Golden, 2013). The rainy season peaks in July and September. The hottest months are January, February and March when the mean temperature is above 27°C with the temperatures ranging between about 21.8°C and 31.2°C (Nwagbara and Uzowulu, 2015).

Materials and Methods

The data used for this study were from two sources namely primary and secondary sources. The primary data were obtained using questionnaire and oral interview. Where the respondent cannot read and write, the author interpreted the questions in the questionnaire in the local language which is Igbo and answers to the questions written in English. The secondary source of data involved the use of relevant literature, magazines, journals, textbooks, library internet facilities and other research materials of related topics to the role of radio in creating awareness on climate change.

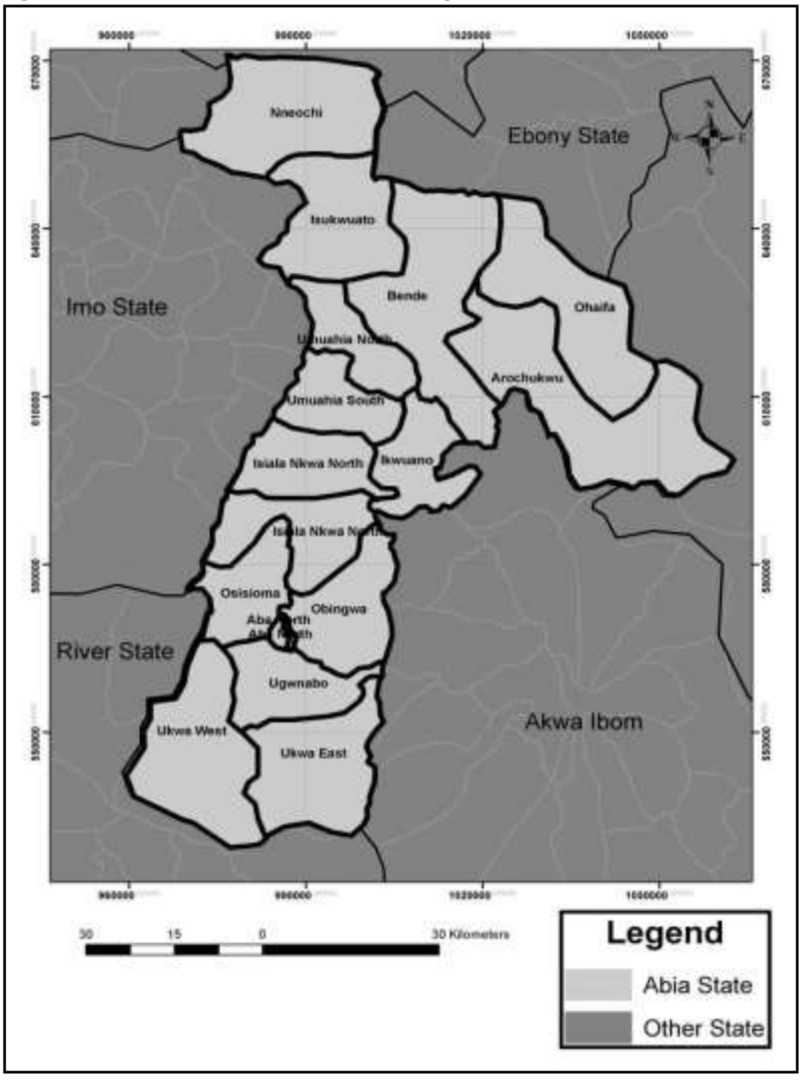

Figure 1: Abia State: Study Area

The population from which the sample frame for the research was drawn from comprised the three senatorial zones of Abia State namely north, central and south. A Total of 80 (Eighty) questionnaire sheets were distributed, 25 (Twenty-five) each to the crop farmers from the three senatorial zones, and 5 (Five) to the five radio stations in the state namely Broadcasting Corporation of Abia State, Vision Africa Radio, Family Love FM, Pacesetter Radio and Magic FM.

The following statistical tools were used in this study:

Percentage (%) = $\frac{e}{n} \times \frac{100}{1}$ ---------------- (1)

Where e is the number of each response, and n is the total number of responses.

The chi- square which is expressed as:

$X^2 = \sum\frac{(O-E)2}{E}$ ------------------------------ (2)

Where O is observed frequency and E is expected frequency.

Expected frequency (E) = $\frac{(Total\ Row\ Response)}{Total\ Responses}$ ---- (3)

Degree of Freedom (d.f) = (n – 1) ---------- (4)

Where n = number of row responses

The test was carried out at 0.05 or (95%) level of significance.

Descriptive statistical tools or analyses were applied which includes: percentages, tables, pie and bar chart.

Results and Discussion

In Table 1, out of the 80 respondents, 50 (62.5%) were males while 30 (37.5%) were females.

Table 1: Gender of Distribution Respondents

S/N	Gender of Respondents	Frequency	Percentage
1	Males	50	62.5
2	Females	30	37.5
Total		**80**	**100**

The ages of the respondents were also captured by the questionnaire. This is presented in Table 4.2. The ages of the respondents are important here as they form a strong basis for determining who has lived long enough to experience a change in climate since climate deals with a period not less than thirty (30) years. It also be seen in this Table 4.2 that farmers aged 51 years and above were only 10 (that is, 13.4%) interviewed. This is not surprising owing to the fact that many people within this age bracket are not as active as those in the 41 – 50 age bracket in crop farming due to health challenges in the study area where farming activities are highly manual. In other words fewer persons above the age of 50 are involved in crop farming, and so also the number of copies of questionnaire administered. The highest number of copies of questionnaire was

Table 2: Age Distribution of Respondents (Farmers)

S/N	Age	Frequency	Percentage

1	31-40	25	33.3
2	41-50	40	53.3
3	Above 50	10	13.4
Total		**75**	**100**

administered to farmers ages 41 – 50 (that is, 53.3%). This group is still strong enough for the kind of farming in the study area which involves so much physical exertion. For the last group, 31 – 40, is made up of people who are recent entrants into active crop farming after leaving school or trade. Therefore, they are not as many as those within the ages 41 and 50. Table 2 indicates that 25 of them received a copy of the questionnaire each, implying 33.3% of the total number administered.

On the educational status of the respondents, Table 3 reveals that 60 respondents, that is, 75% of the respondents, can read and write since the least educated respondent had a primary school education. This implies that this number was able to fill the questionnaire without the aid of the author or anyone. It also implies that only 20 respondents had no formal education since a total of 80 respondents were involved in the survey. For the 20, the author helped out in reading out the questions to the respondents and wrote their responses in the questionnaire. Among the respondents, those with primary school education has the highest number, 40 (that is, 50%) whereas those with tertiary education make up only 6.25% as the least (that is, 5 respondents).

Table 3: Educational Status of Respondents

S/N	Educational Status	Frequency	Percentage
1	Tertiary Institution education	5	6.25
2	Secondary School education	15	18.75
3	Primary school education	40	50
4	No formal education	20	25
Total		**80**	**100**

Table 4 shows the length of time in years respondents have spent in crop farming. In the table, 35 respondents (that is, 46.7% of the respondents) have been in crop farming for 31 to 40 years, thus making it the years of experience of the greatest number of respondents. Those with 1 to 10 years experience are only 5 (that is, 6.6% of the respondents) while the least number of respondents, 3 (that is, 4%), said they have got more than 50 years experience in crop farming. This number is not surprising since many crop farmers with this number of years experience would have retired from farming or too weak for energy sapping type of crop farming in the study area as it is the case in most developing countries. Table 5 presents the number of years the farmers interviewed have resided in the study area. With such information, it becomes easier to determine how qualified those who were interviewed were to say whether climate change has occurred in their area or not and its effects on the yield of crops (if it has occurred). For example, those who have stayed in the study area 30 years and above made up 81.33% of those interviewed (that is, 61 respondents out of a total of 75) as compared with 18.67% for farmers (that is, 14 respondents out of a total of 75) who have lived in the study area for 29 years and below. The implication of this is the most of the farmers are in good position to say whether the climate of the study area has changed or not.

Table 4: Years of Experience in Crop Farming

S/N	Years	Frequency	Percentage
1	1-10	5	6.6
2	11-20	9	12
3	21-30	11	14.7
4	31-40	35	46.7
5	41-50	12	16
6	Above 50	3	4
Total		**75**	**100**

Table 5: Length of Years Farmers Have Resided in Study Area

S/N	Years	Frequency	Percentage
1	Above 49	10	13.33
2	40-49	21	28
3	30-39	30	40
4	20-29	11	14.7
5	Below 20	3	4
Total		**75**	**100**

The issues treated by Tables 4 and 5 viz. Years of experience in crop farming, and Length of years farmers have resided in study area, were meant to show the extent to which the respondents were competence to discuss the extent of climate change in the area of study. Even where the farmer has not farmed or lived in the study area for 30 and above, he could have a reasonable idea of what has happened or is happening to the climate of the area.

The level of awareness of climate change by crop farmers in Abia State is presented in Table 6. The respondents were asked to state their awareness level of climate change. Most respondents, 52% of them (that is, 39 respondents), indicated that they have low knowledge of climate change whereas only 12% of them (that is, 9) said that they have high knowledge of the change. Among the respondents, 20% (that is, 15 respondents) stated that they have no knowledge at all of climate change. Those with high and moderate levels of climate change awareness made up of 28% of the respondents (that is, 21 of them). The responses of the respondents closely concurred with the work

Table 6: Awareness Level of Climate Change by Respondents

S/N	Level of Awareness	Frequency	Percentage
1	High	9	12
2	Moderate	12	16

3	Low	39	52
4	No	15	20
Total		**75**	**100**

of Odjugo (2013) which discovered that only 22% of the respondents in Nigeria have much knowledge of climate change and only 9% of them are from the rural areas. Based on this he concluded that information on climate change in the grassroots or rural areas is poor. He further stated that such level of awareness of climate change at the grassroots is good for Nigeria's economy as the rural area holds the agricultural strength of the country.

Based on Table 4.6, which deals with the level of awareness of climate change of the respondents, hypothesis one which states thus, H_0: Awareness of climate among crop farmers in Abia State is very high, and H_1: Awareness of climate change among crop farmers in Abia State is very low was tested using the Chi-square statistical technique (χ^2) (see Table 7).

Table 7: Chi-Square Analysis of Climate Change Awareness among Crop Farmers in Abia State

	High	Moderate	Low	No	Total
Observed frequencies	9	12	39	15	75
Expected Frequencies	18.75	18.75	18.75	18.75	75

After the subjecting the data in Table 7 to Chi-square (χ^2) calculation, the following results emerged:
χ^2 = 30.12 (calculated value)
The degree of freedom (V) = 4 - 1 = 3
At 0.05 level of confidence, critical value = 7.81

Based on the results above, with the calculated value of 30.12 being more than the critical value of 7.81, Ho is rejected. Thus, there is very low awareness of climate change among crop farmers in Abia State. This implies that the farmers are highly vulnerable to the adverse effects of climate change. The result also implies that the five radio stations in the study area are not living up to their primary duty or function of educating the people on issues of public concern especially as it has to do with climate change which is global concern.

Table 8 indicates the names and locations of the radio stations, and listenership of crop farmers to them in the study area. The farmers' listenership to the radio stations vary conspicuously. The Pacesetter FM (Radio Nigeria), Umuahia, had the greatest listenership by the respondents. Of the farmers interviewed, 33.3% of them said they listen majorly to the Pacesetter FM (Radio Nigeria), Umuahia. This is followed by Vision

Table 8: Listenership of Radio Stations in Abia State

S/N	Radio Station	Listenership (%)
1	Broadcasting Corporation Abia State (BCA), Umuahia	10.7
2	Vision Africa Radio, Umuahia	20
3	Pacesetter FM (Radio Nigeria), Umuahia	33.3

4	Family Love FM, Umuahia	20
5	Magic FM, Aba	16

Africa Radio, Umuahia and Family Love FM, Umuahia with 20% for each. The least listened radio station is the Broadcasting Corporation Abia State (BCA), Umuahia with only 10.7% listenership by the respondents.

Table 9 reveals that only two radio stations in Abia State have agricultural programmes where they once in a while discuss climate change issues. These stations are Broadcasting Corporation of Abia (BCA), Umuahia and Magic FM, Aba. Incidentally, these two stations are poorly listened to by crop farmers in Abia State (Table 8). This explains the low or poor level of awareness of climate change by the respondents (Table 6). Those who are aware of climate change were asked to indicate their source of information. Majority of them, 52%, as shown in Table10 got to know of changes in climate mainly through their personal observation, followed by radio, 20%, extension agents, 10%, farmers' cooperatives, Newspapers and Television, 18%.

Table 9: Radio Stations and Availability of Agricultural Programme with Discussions on Climate Change

S/N	Radio Station	Response
1	Broadcasting Corporation of Abia (BCA), Umuahia	Yes
2	Vision Africa Radio, Umuahia	No
3	Pacesetter FM (Radio Nigeria), Umuahia	No
4	Family Love FM, Umuahia	No
5	Magic FM, Aba	Yes

This revelation shows the importance of these channels of communication in information dissemination, hence should be patronized especially radio in passing information about climate change to crop farmers. Basically, radio, just as other mass media, is meant to inform and educate the people. Creation of awareness of climate change is majorly to reduce its impact. Radio is effective not only in informing the people but also in creating awareness regarding many issues and need for reformation, developing interest and initiating actions. Corroborating, Shanaghan (2007, 2011) and Sharma (2008) stated that radio has advantages over the other mass media like television and newspapers in terms of being handy, portable, and easily accessible at

Table 10: Source of Information on Climate Change by Respondents

S/N	Source	Respondents	Percentage
1	Radio	15	20
2	Personal Observation	39	52
3	Extension Agents	7.5	10
4	Farmers' Cooperatives, Newspapers and Television	13.5	18

Total		**75**	**100**

home, in the office, in the car, on the street, in the farm, virtually everywhere at anytime. Radio has been proved to be an important tool in the enhancement of agriculture in rural areas. Nakabugu (2001) and FAO (2001) affirmed that in the developing countries such as Nigeria, radio is a powerful and effective medium to project the information and knowledge related to agriculture.

Those that indicated radio as the source of their information on climate change (that is, 20%) said they heard it from Broadcasting Corporation of Abia State (BCA), Umuahia and Magic FM, Aba (see Table 9). This means two stations out of the five in Abia State. When asked what their perceived causes of climate change were, 60% of them attributed the changes to Act of God and 40% of them attributed it to human activities which include of industrialization, Urbanization, transportation and agriculture that release greenhouse gases into atmosphere (see Table 11).

Table 11: Perceived Causes of Climate Change by Respondents

S/N	Perceived Causes of Climate Change	Respondents	Percentage
1	Act of God	45	60
2	Man's Activities	30	40
Total		**75**	**100**

Odjugo (2013) equally listed these human activities as the causes of present day climate change. The perception of the respondents about the causes of climate change is clearly an indication of their poor knowledge of climate change implying that the radio stations in Abia State are failing in educating and creating awareness of an issue (climate change) which is of global interest especially as it affects crop production and food security.

The crop farmers in the study area were asked to state the intensity of the indices of climate change on their crop production. The perceived intensity impacts of climate change by the respondents were based on the following indices: Decreased rainfall amount; unusual heavy rainfall; unexpected rainfall; changes in rainfall pattern; increased cases of flooding; prolonged drought; High temperature and heat; and Increase in pest and disease problem. Others were Heavy winds; Reduction in crop yield; Heat stress on crops leading to burning; and stunted growth of crops. The impact of climate change identified by the respondents (crop farmers) especially the three outstanding the impact of changing rainfall pattern, prolonged drought and increasing temperature are the actual climate change problems affecting crop production. These identified impacts are having scientific backing because the performance of crop production is depended on a large number of climatic factors. The most important climatic factors include rainfall, temperature and relative humidity. These play an important role in the realization of higher or lower crop yields depending on their trends.

Chi-square statistic was employed in the testing of hypothesis two which states thus: **H_0**: There is no significant difference between the yields of crops before and after climate change, and **H_1**: There is significant difference between the yields of crops before and after climate change as in Table 12.

Table 12: Chi-Square Analysis of Farmers Response to Question on Yields of Crops Before and After Climate Change

	Favourable	Adverse	Total
Observed frequencies	15	60	75
Expected Frequencies	37.5	37.5	75

Subjecting the data in Table 12, the following results were got:
χ^2 = 2.48 (calculated value)
There are 3 parameters
The degree of freedom is V= 3 – 1 = 2
At 0.05, critical value = 5.99

Since the calculated (χ^2) of 2.48 is less than the critical value of 5.99, H_0 is accepted. Thus, there is a significant relationship between climate change and crop production. The implication of this is that indeed climate change is affecting crop production in Abia State. This is most worrisome as the change is on the adverse side as yields of crops are reducing, which means reduced returns from farming for the farmers and less food for the market and by extension for the people. In other words, there is a threat to food security in the study area.

Mark *et al*. (2008) highlighted some of the direct impacts of climate change on agricultural systems to include seasonal changes in rainfall and temperature, which include uttering growing seasons, planting and harvesting calendars, water availability, and weeds, pests and diseases population. In Table 13, the respondents in the study area enumerated some major measures they are using to remedy the impacts of climate change. These adaptation methods/mitigation strategies include planting of fast maturing varieties of crops; early or late planting of crops; increase mulching of crops to conserve moisture and reduce heat; and staking of crawling crops such as yam to avoid burns.

Table 13: Major Adaptation Methods by Respondents

S/N	Adaptation Methods
1	Planting of fast maturing crop varieties
2	Early or late planting of crops
3	Mulching of crops
4	Staking of crawling crops

The adaptation measures identified by the respondents are in line with the findings of earlier researchers, for example Onyeneke (2010), Enete and Amusa (2010) . They listed the measures they found to include use of new crop varieties that are suited to drought; crop diversification; changing planting dates; radical departure from reliance on rain-fed food production to irrigation farming; and growing of cover crops like potatoes and melon to protect soils from erosion. However, Yohe *et al.* (2007) observed that in any given context, the identified adaptations may be constrained by factors such as their expense; lack of knowledge etc. These impediments notwithstanding, farmers who are at risk of climate change can be provided with the needed awareness, advice and guidance.

Conclusion

In this research work, attention has been on the role of Radio Stations in Abia State in creating awareness on climate change among crop farmers in Abia State. The study revealed that the demographic and socio-economic characteristics of the respondents of gender, age, educational status, length of years farmers have resided in study area and farming experience have influence on their views about climate change discussion and analysis. These require longer living period within the study area. 75% of the respondents do not have much knowledge about climate change 28% of them who claimed to have knowledge of climate changes got to know it through personal observation and from radio. Many attributed it to Act of God, instead of the scientific factors.

The respondents are aware that the climate is changing because of what they have observed. Changes in terms of increase in temperature, changing in rainfall pattern (for example onset and cessation of rainfall), prolonged drought which to them have adverse impact on their crop production. However, the respondents enumerated some measures of remedying the effects through planting of fast maturing crop varieties and planting of different varieties of crops among others.

From the responses of the Radio Stations, it was discovered that there are no specific or special programme on climate change and its impact on crop aired by them. Even where agricultural programmes exist, there is little or no emphases on climate change. Indeed. This is a great challenge to radio stations in the study area (Abia State). The respondents that answered yes to the question of awareness of climate change from radio stations suggested that such programme should be aired regularly. This is based on what they have gained from the awareness of climate change.

Recommendations

Public awareness and enlightenment on climate change using the mass media like radio should be encouraged. Such enlightenment should be in simple English and local dialects of the audience.

The radio stations should once in a while invite climatologists to educate especially crop farmers on the impact of climate change with regard to crop farming, adaptation measures and mitigation strategies. It should be an interactive or call in programme, so as to give crop farmers opportunity to ask question.

Since climate change is a major threat to food security not only in the study area but in many regions of the developing world, other means of communication outside radio should be employed too to create the needed awareness of climate change to crop farmers.

References

Abia State Government (2011):*Abia State Investment Brochure*. Umuahia: Abia State Government.

Adams, R. M., Hurdi, B.H., Lewnarts, S. and Leary, N. (1998). Effects of Global climate change on Agriculture. An interpretative review. *Climate Research, Vol. 11 (11), pp. 19 - 30.*

Adejuwon, J.O. (2006). Food crop production in Nigeria. Potential effect by climate change. *Climate Research, Vol. 32, pp. 229 – 245.*

Daramola, I. (2003). *Introduction to mass communication*. Lagos: Rothan press.

DFID Research (2012). *Communicating the power of communication*. Department of International Development: Part of research news and Governance in developing countries.

Golden, J. O. (2013). Assessment of the Effects of Deforestation in the Rainforest Ecosystem of Abia State. An unpublished B.Sc., Project, Department of Environmental Studies and Resource Management, National Open University of Nigeria, Lagos.

Enete, A. A. and Amusa, A. T. (2010). Challenges of agriculture adaptation to climate change in Nigeria: A synthesis from the literature. *The Journal of Field Actions, Vol 2, pp. 1 – 22.*

FAO (2007). Adaptation to climate change in Nigeria, forestry and fisheries, perspective, framework and priorities. *Food and Agricultural Organization of United Nations, Rome, Vol.32, pp.103 – 123.*

James, F. (2009). climate change: How o report the story of the century. *http/www.scidev.met/ent. Practical guide/ climate. Change –how-to-report-the- story-of –the cent.html.*

Kakonge, J. O. (2011). The Role of media in the climate change debate in developing countries. *http://www.global policyJournal.com*.

Khanal, S. R. (2011). Role of radio on agricultural development: A review. *Bodhin: An interdisciplinary Journal, Vol. 5.*

Maria D. S., Diego, B. and Giovanni, S. (2013). Measuring the effect of climate change on agriculture: A literature review of analytical models. *Journal of Development and Agricultural Economic Vol. 5 (2), pp. 499 - 509.*

Mark, W. R., Mandy, Y., Gary, B., Lann, H., Saleemu, I. and Ravena, V. S. (2008). *Climate change and agriculture: Threat and opportunities*. Federal Ministry of Economic Corporation and Development, Germany.

Nakabugu, S. B. (2001). The Role of Radio in Agricultural and Rural Development Translating Agricultural Research Information into messages for farm Audience. Programme of the workshop in Uganda.

National Population Commission (NPC) (2007). *2006 Population Census of Nigeria.* Abuja: NPC.

Nwagbara, M. O., Ijeoma, M. A., Chima, G. N .(2009). Climate change and flood in Northern Nigeria. An examination of Rainfall Trends over the region". In R. N. C. Anyadike, I. M. Madu and C. K Ajaero, Eds. *Climate change and the Nigeria Environment, pp. 525 – 538.*

Nwagbara, M. O. and Uzowulu, O. (2015). Climate change, soil temperature and cassava yield in Abia State, Southeastern Nigeria. *International Journal of Agricultural and Bio-Chemical Science, Vol. 4, Issue 4, pp. 1 – 9.*

Odewumi, (2013). Farmers perception on the effect of climate change and variation on urban agriculture in Ibadan metropolis South-Western Nigeria. *Academic Journals, Vol. 6 (6), pp. 209 – 217.*

Odjugo, P. A. O. (2013). Analysis of climate change awareness in Nigeria. *Scientific Research and Essays, Vol. 8 (26), 1203 – 1211.*

Onkargonda, K, Shilpa. H and Namrata. R. (2013). Role of media in creating awareness about climate change. *Journal of Humanities and social sciences Vol 10 (1), pp. 37 – 43.*

Onyeaeke, R. U. and Madukwe, D. K. (2010). Adaptation measures by crop famers in the Southeast rainforest. Zone of Nigeria to climate change. *Science World Journal, Vol. 5 (No 1), pp. 32 – 34.*

Pam, P. A. (2007). Climate change and the information technology. *Journal of Science and Technology, 5(1), pp. 64 – 80.*

Payal, K. (2012). *preserve article.com*

Pradeep, K. D. and Ingrita, P. (2013). Role of media in social awareness. International Journal of Humanities and Social Sciences, Vol. 1, (01), pp. 67 – 70.

Shanahan, M. (2007). *Talking about a revolution: Climate change and the media*. London: IED.

Shanahan, M. (2011). *Why the media matters in a warming world: A guide for policy makers in the global South*. London: IED

Sharma, N. K. (2008). Impact study of farm radio programme produced by agriculture information and communication centre: A case study from the farmers of phalebas Kannigian V.D.C of Parvat District, *Unpublished Master's Thesis, T.U.*

Smith, B. and Skinner, M. W. (2002). Adaptation of options in agriculture to climate change. *A no. UNFCCC 1992, pp. 85 – 114.*

Vijah, C. (2009). Farm Radio International issue pack: Awareness of climate change. *Script 89.1*.

Warrick, K.A. and Barrow, M. (1991). Climate change scenaries for the UK. *Transactions of the Institute of Geographers, Vol.16, pp. 397 – 399.*

Yohe, G. I., Burton, S., Hug and Rosegrant, M. W. (2007). Climate change: pro poor adaptation, risk management and mitigation strategies. 2020 focus brief on the world's poor and hungry people.