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SPATIO-TEMPORAL PATTERN OF RAINFALL DISTRIBUTION OVER ILORIN METROPOLIS, NIGERIA

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ABSTRACT

Rainfall varies over time and space and the study of its variability cannot be over emphasized. This paper examines spatio-temporal patterns of rainfall in Ilorin metropolis, Nigeria. 30 years data were collected in 3 locations [Nigeria Meteorological Agency (NIMET), Lower Niger River Basin Development Authority (LNRBDA) and Kwara State Water Corporation (KWWC)]. The analytical procedure includes trend analysis, reduction analysis, and ordinary kriging with Gaussian semivariogam model. The results showed that June and September recorded the highest amount of rainfall in Ilorin across three stations. An upward trend of rainfall of about 0.30mm, 0.40mm and 0.2mm respectively, were recorded in the 3 stations. The reduction pattern analysis revealed the variability and percentage change in the amount of rainfall received in Ilorin over the 30 years of study. Nine regional pattern were also revealed from the kriging analysis, and a variability of 50mm were recorded over the 12km^2 sized metropolis. The south-western part of Ilorin recorded more rainfall than the other parts. It was concluded that spatial distribution of annual rainfall in Ilorin, varied from one part to the other. The increasing upward trend might increase water supply, increase chances of urban flooding, erosion and sedimentation. The paper recommends that wet season rainfall be properly managed to boost water supply in dry season.

Key words: Rainfall, Variability, Spatio-temporal, Trend, Flood, Water supply, Kriging

INTRODUCTION

Several approaches have been adopted in the study of rainfall in West Africa and Nigeria in particular over the years. The approaches include onset, retreat and length of the rainy season, intensity of raindrops, intensity of wet years, trend and pattern of rainfall, rainfall variability and spatio-temporal distribution of rainfall (Oyebande and Oguntoyinbo; 1970, Adejuwon et. al, 1989, Olaniran and Sumner; 1989, Odjugo, 2005; Ati, et al., 2009; Abaje, et al., 2010; Ishaku and Majid, 2010; Yusuf and Muhammed, 2011; Olatunde, 2012; Ifabiyi and Ashaolu, 2013). According to Ayoade (1974) the amount of rainfall received in an area is determined by the intensity and period of rainfall. All these studies have one aim of improving man's knowledge of rainfall as well as its importance to agricultural production and water resources management. It also helps in the prediction and forecast of hazards such as drought and flood associated with little or no rainfall and excessive rainfall.

Adefolalu (1986) observed the trend in precipitation pattern in Nigeria between1911-1980 with sub period of 40 years. He discovered three main features; first, that both the amount and area of the secondary rainfall maximum at 9^0 - 10^0 latitude in Nigeria has depreciated with time. Secondly, that the belt of relative minimum rainfall coinciding with the channels of river Niger and Benue seems to be expanding with time. Lastly, that places north of 8^0 N latitude receive 90-100% of the annual rainfall between April to October. Adefolalu's analysis further depicted the variability and spatial distribution of rainfall in Nigeria. According to Adejuwon et al (1989) rainfall variability can be observed in terms of space and amount of rainfall received. It is pointing to the fact that rainfall is not evenly distributed over space and time.

Spatio-temporal analyses of rainfall have various consequences; this is because an increase or decrease in rainfall will have consequences on water resources, agriculture, flooding, drought, soil conservations, etc. Increase in rainfall may increase the water availability in specific location especially those that are dependent on surface water if properly harnessed and managed. Increased rainfall encourages agricultural activities since most farming activities in a developing country like Nigeria are rain-fed (Ati et al., 2009 and Abaje et. al., 2010). Excessive rainfall due to increasing trend promotes flooding, erosion and sedimentation. Several studies have attributed excessive rainfall as a major cause of floods in Nigeria (Olaniran; 1983, Oriola; 1994, Babatolu; 1996, Odekunle; 2001 and Ologunorisa; 2001, 2004). Decrease in rainfall due to decreasing trend amounts to water shortages and drought which will affect crop and animal production as well as human beings (Oladipo; 1993, Ati et al., 2002). Spatial variation of rainfall also has various implications, it leads to variability in basin yield, it affects runoff production, flood mitigation, and it also has implication for gauge network analyses, all these have implication for environmental management. This study therefore examines the spatio-temporal pattern of rainfall distribution over Ilorin with the view of pointing out the environmental implications associated with such trend and distribution pattern.

The Study Area

Ilorin the Kwara state capital is located between latitude $08^{\circ}24'$N and $08^{\circ}38'$N of the equator, and longitude $04°26'$ E and $04°37'$Eof the Greenwich meridian, and covers about $12km^2$. The landscape ranges in elevation in the western part from 273m to 333m and in the eastern part from 273m to 364m. Sobi hill is the dominant landform, it is an inselberg, and it is the highest point in the city (394 m above sea level.) Ilorin has a tropical wet and dry climate. Wet season is experienced from April to October and dry season from November to March. Days are hot during the dry season from November to January when temperature ranges from 33.0°C to 34.6°C. Between February and April, temperature values are frequently between 34.6°C to 37°C. Mean monthly temperature is high in the city in dry season. Rainfall condition in Ilorin exhibits greater variability both temporarily and spatial. The annual mean rainfall is about 1,200mm (Olaniran, 2002), exhibiting the double maxima pattern between April and October of every year. Relative humidity varies seasonally with an average of 79.7%.

The city is underlain by Precambrian Basement complex; comprising mostly

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gneiss, granite, schist, undifferentiated meta-sediments rocks and overburden that are composed mainly of clay, sand and silt soils. The underlying pre-Cambrian igneous-metamorphic rock of basement complex is neither porous nor permeable except in places where they are deeply weathered or have zones of weakness. Some part of the town is also underlain by Sedimentary rocks, which contains both primary and secondary laterites and alluvial deposits. Groundwater on the alluvium is recharged directly by rainfall or the adjoining overflowing river system. In the dry season, the alluvium sustains considerable subsurface groundwater flow. The alluvial deposits have been exploited, with successful wells and boreholes in Ilorin metropolis and its surrounding. The drainage system of Ilorin is dendritic in nature, and is dominated by Asa River, which flows from south to north and divides the city into two parts, the western and eastern parts. The western part represents the indigenous area. The eastern part coincides with the modern layout. Major rivers draining the city are: Asa, Agba, Alalubosa, Okun, Osere, Aluko.

Ilorin is one of the fastest growing urban centers in Nigeria. There has been a huge increase in the population of Ilorin since it became the state capital in 1976. The population growth rate is much higher than other cities at 2.5 percent of the national growth. The 2006 census put the population of Ilorin city to about 847,582 (NPC, 2006 provisional results). The following are the locations of the three weather stations that were used in this study. NIMET weather station is located within latitude 08° 26' 29.3" N and 4° 29' 36.7" E, the elevation is 340m above sea level. LNRBDA weather station is located between 08° 30' 26.96" N and 4° 35' 51.99" E, the elevation is 321m above sea level while the KWWC weather station is located between 08 ° 28' 32.11" N and 04° 35' 14.15" E, the elevation is 318m above sea level. See figure 1 for the map of the study area with the location of the three weather stations.

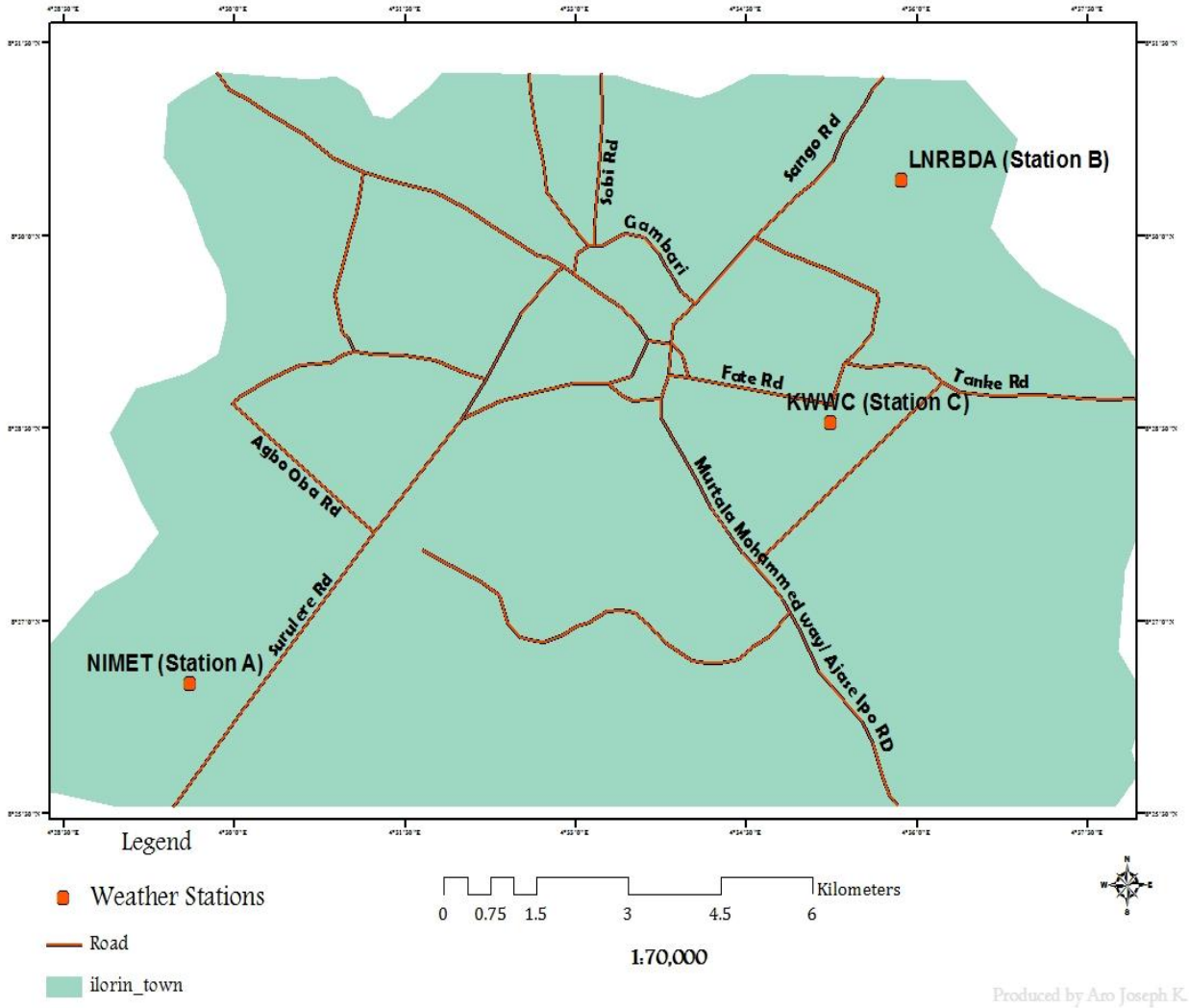

Fig 1: Study area showing the three weather stations

MATERIALS AND METHODS

The data used in this study are rainfall data collected from three weather stations within Ilorin the study area. These are the NIMET weather station in Ilorin airport (08° 26' 29.3" N and 4° 29' 36.7" E), the Lower Niger River Basin Development Authority weather station (08° 30' 26.96" N and 4° 35' 51.99" E) and the Kwara State Water Corporation Agba dam weather station (08 ° 28' 32.11" N and 04° 35' 14.15" E).The data collected from Airport and Lower Niger Basin weather station span from 1981-2010 (30 years) while data collected from Agba dam weather station span from 1971-2000 (30 years), this is because records of the station were no longer available after this period.

The following statistical measures were used in the study:

1. Proximity analysis was carried out to determine the closeness of the weather stations and the distance between the stations as crow flies using ArcGIS software.
2. Mean, minimum, maximum, standard deviation, skewness, and bar graph for data presentation and summary.

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3. Trend analysis was used to determine the trend of rainfall in the three weather stations. The formula is:

$Y_t = a + bx_t$ …..……..(i)

Where Y = the trend value

a---------- intercept = $\frac{y - b\sum x}{n}$ …… (ii)

b----------slope of the trend line = $\frac{n\sum xy - (\sum x)(\sum y)}{n\sum x^2 - (\sum x)^2}$ ……..……..…… (iii)

X_t---------- Time point coded

4. Reduction analysis was also carried out to determine the fluctuation of rainfall in the three weather stations. Reduction analysis was used by Salami et al. (2010), Makanjuola et al. (2010) and Ifabiyi and Ashaolu (2013). The average annual variable (X_m) for the years of record is obtained as in the equation below:

$X_m = \frac{\sum_i^n X}{n}$……..…….. (iv)

Where X=the average annual value for each year

n=number of years of record

The deviation, ($X-X_m$) of each year's record from the average annual variable (X_m) was obtained.

A graph of the deviation ($X-X_m$) is then plotted against the years.

To get the percentage change in rainfall in Ilorin from the three weather stations, the record years of rainfall are divided into groups of five years interval. The average annual variable (X_i) for the five years is calculated. The corresponding deviations from the average (X_m) for the groups and the corresponding percentage changes are obtained. The percentage change is obtained from the equation:

$\frac{X - X_m}{X_m} \times 100\%$ …… (v)

5. Spatial interpolation was carried out using the mean annual rainfall from the three stations to reveal the spatial distribution of rainfall in Ilorin city. This was achieved by ordinary kriging method with Gaussian semivariogram model in ArcGIS 10.2 GIS software. Also, coordinates of about 25 locations (residential areas) within the study area were collected with handheld GPS and imported into ArcGIS 10.2, which was overlaid on the result of the interpolated data.

RESULTS

Proximity Analysis

The result of proximity analysis in Table 1 sho

ws that the near distance between NIMET station, KWWC and LNRBDA stations are 0.008029, 0.002306 and 0.010271 respectively. This suggests that LNRBDA is further away from other stations, NIMET and KWWC. This value suggests that NIMET and KWWC stations are closer to each other compared to LNRBDA. However, KWWC station seems to be located on a lower terrain, while NIMET and LNRBDA are located on higher ground. The distances between NIMET station, KWWC and LNRBDA stations as crow flies are 13.58km and 11.08km respectively. The distance between KWWC and LNRBDA station as crow flies are 3.68km.

Table 1: Proximity Analysis

Weather stations	Near feature distance	Near_Distance
LNRBDA (B)	9	0.010271
KWWC (C)	4	0.002306
NIMET (A)	0	0.008029

Source: Authors' Computation, 2013

Descriptive Analysis of Monthly Rainfall Data for Ilorin at NIMET (Station A), LNRBDA (Station B) and KWWC (Station C)

The statistical monthly summaries of rainfall received in the three stations arepresented in Table2 and figure 3.From the table, it shows that the maximum monthly rainfall received was 457.80mm and the minimum was 0.01mm at station A. The maximum monthly rainfall received was 394.10mm and the minimum was 0.50mm at station B, while the maximum monthly rainfall received was 534.20mm and the minimum was 0.10mm at station C during the period of study. The months of September and June recorded the highest rainfall over the 30 years period of study at the three weather stations. The month of September recorded a mean of 219.47mm, 228.75mm and 219.99mm at NIMET, LNRBDA and KWWC respectively. Also the month of June recorded a mean of 190.05mm, 188.12mm, and 173.01mm at NIMET, LNRBDA and KWWC respectively. The months of November to March recorded the lowest amount of rainfall over the period of study. Standard deviation ranges between 15.82-90.21mm, 9.97-81.73mm and10.12-120.98mm at NIMET, LNRBDA and KWWC respectively.

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Table 2: Monthly Summary of the Statistical Analysis of Rainfall (mm) for the three Weather Stations

Months	Mean			Std. Dev.			Min.			Max.			Skewness		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
January	6.19	4.24	3.52	15.82	13.41	10.12	0.80	1.00	0.10	73.30	70.10	50.50	3.33	4.43	3.91
February	6.21	11.37	9.21	17.19	20.87	15.88	0.01	0.50	2.00	90.70	102.50	53.60	4.43	3.20	2.08
March	43.43	40.20	68.91	28.61	32.14	41.49	13.80	2.00	1.00	109.20	117.70	182.50	0.56	0.69	1.33
April	93.34	91.67	86.26	50.55	52.09	49.56	19.60	0.90	3.00	223.90	219.20	189.90	1.07	0.75	0.31
May	163.32	153.75	159.93	90.21	71.49	59.99	42.30	35.20	61.20	457.80	340.80	329.50	1.42	0.90	0.61
June	190.05	188.12	173.01	64.67	81.73	55.39	89.30	45.10	63.11	370.80	375.20	275.60	0.85	0.54	-0.36
July	159.12	157.27	159.15	76.76	75.02	120.98	69.20	58.50	3.30	323.00	394.10	534.20	0.84	1.41	2.01
August	159.26	164.66	143.42	76.76	79.43	84.61	16.50	16.80	20.60	334.60	333.60	316.60	0.19	0.55	0.97
September	219.47	228.75	219.99	81.56	70.05	78.21	61.40	124.80	55.20	400.10	362.80	359.90	-0.19	-0.99	-0.07
October	136.22	128.97	149.85	71.54	70.31	77.15	16.40	9.00	13.70	250.70	317.90	297.50	-0.12	0.57	0.19
November	10.50	17.42	8.72	16.09	53.13	19.34	0.30	2.00	0.30	55.60	289.90	73.20	1.72	4.97	2.79
December	6.97	2.45	3.00	27.43	9.97	12.28	0.30	1.60	1.50	148.5	53.70	62.50	5.08	5.04	4.47

Source: Authors' Computation, 2013

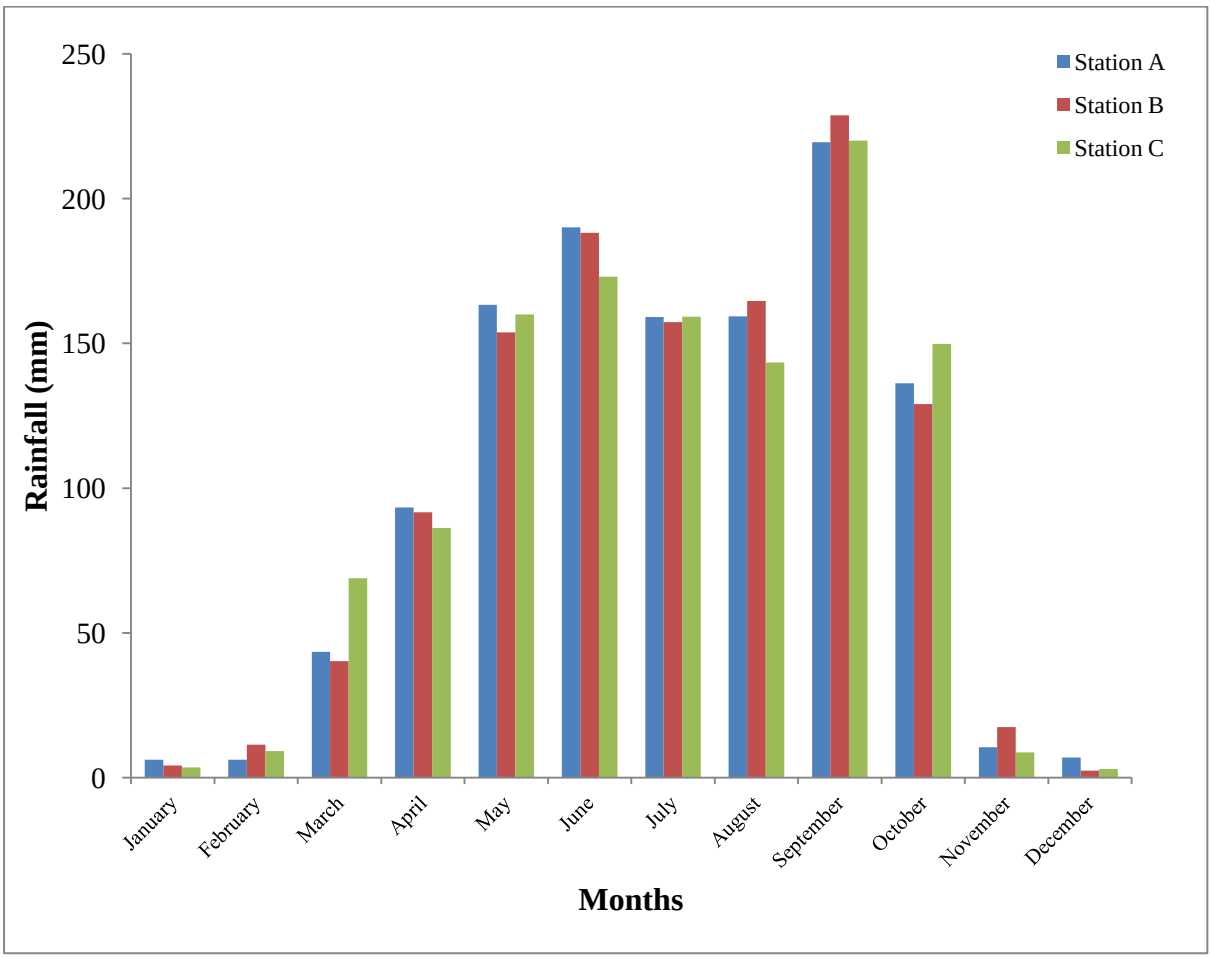

Fig 2: Mean Monthly Rainfall received at NIMET (A), LNRBDA (B) (1981-2010) and KWWC (C) (1971-2000) Stations in Ilorin

Descriptive Analysis of Annual Rainfall Data for Ilorin at NIMET (Station A), LNRBDA (Station B) and KWWC (Station C)

The statistical annual summaries of rainfall received in the three stations are presented in Tables 3 and 4 and figure 4. From the tables,the maximum annual rainfall received is 457.80mm and the minimum is 0.40mm at station A. The maximum annual rainfall received is 394.10mm and the minimum is 0.01mm at station B, while station C recorded maximum annual rainfall of 534.20mm and minimum of 0.10mm over the period of study.The year 1998 recorded the highest amount of annual mean rainfall (132mm)at station A, while stations B and C recorded the highest amount of mean annual rainfall in 1994 (145.87mm) and 1989 (148.93mm) respectively over the 30 years period of study which is, which can be referred to as the years of abundance rainfall. The year 1992 recorded the lowest amount of annual mean rainfall of 71.63mm at station A, while stations B and C recorded the lowest amount of mean annual rainfall in the years 1985 (51.81mm) and 1998 (65.13mm) respectively. Standard deviation ranges between 59.24-138.88mm, 61.94-150.24mm and 65.45-179.25mm for stations A, B and C respectively. The results of the standard deviation reflect the magnitude of annual variability in rainfall at these three locations in Ilorin.

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Table 3: Annual Summary of the Statistical Analysis of Rainfall (mm) for NIMET (Station A) and LNRBDA (Station B), 1981-2010

Years	Mean		Std. Dev.		Minimum		Max.		Skewness	
	A	B	A	B	A	B	A	B	A	B
1981	103.55	100.58	91.49	104.04	2.30	16.8	245.00	265.80	0.146	0.54
1982	98.78	100.68	93.10	91.40	8.00	1.00	247.50	247.80	0.30	0.31
1983	96.44	73.44	85.07	78.87	1.60	7.90	228.30	235.60	0.27	1.13
1984	109.31	111.04	102.31	104.12	2.40	10.00	272.50	282.50	0.45	0.47
1985	90.80	51.81	102.58	69.92	0.01	0.40	293.10	191.50	1.02	1.12
1986	110.56	106.04	86.76	97.35	5.50	42.00	264.20	307.80	0.32	0.96
1987	92.13	110.33	92.67	129.99	3.60	9.40	236.70	337.80	0.46	0.94
1988	72.20	80.95	59.24	77.65	0.30	23.20	196.30	224.80	0.94	0.44
1989	72.88	102.76	73.72	94.08	42.70	56.20	199.50	239.90	0.72	0.25
1990	100.01	94.10	138.88	76.46	5.40	8.50	457.80	225.10	1.87	0.01
1991	121.88	110.60	118.44	115.79	0.50	17.50	356.70	340.80	0.98	1.16
1992	71.63	69.88	73.89	72.26	55.60	2.00	220.50	193.20	0.83	0.46
1993	98.48	124.58	89.04	124.9	0.60	35.00	234.80	362.80	0.23	0.95
1994	103.50	145.87	96.92	114.68	2.10	7.90	260.00	317.90	0.46	0.10
1995	117.38	116.09	89.40	101.05	0.90	12.00	232.10	272.50	-0.13	0.26
1996	78.76	82.52	82.53	73.53	0.80	67.10	262.70	199.80	0.96	0.18
1997	111.20	125.27	109.19	115.77	0.30	15.00	334.80	375.20	0.76	0.73
1998	132.96	81.49	130.66	80.79	15.10	0.80	338.10	224.80	0.38	0.42
1999	128.24	107.91	106.57	95.02	19.60	22.80	296.20	265.60	0.25	0.49
2000	82.53	74.34	91.84	102.29	13.80	2.20	281.70	268.00	1.16	1.25
2001	58.09	62.02	63.31	64.94	5.90	18.00	173.60	176.40	0.79	0.62
2002	79.91	89.07	81.10	77.47	18.40	6.50	257.90	182.70	0.94	0.02
2003	107.89	101.33	136.95	102.21	2.10	12.40	400.10	360.70	1.62	1.46
2004	107.99	106.00	102.93	95.37	1.00	4.00	310.40	260.50	0.56	0.49
2005	108.83	91.00	100.76	90.06	0.60	5.50	271.50	282.60	0.45	0.83
2006	107.64	112.77	98.22	106.33	0.30	1.20	259.00	276.20	0.31	0.34
2007	109.09	122.86	101.82	112.27	4.80	2.50	285.50	306.20	0.35	0.13
2008	121.21	126.33	124.86	150.24	1.20	3.40	318.60	394.10	0.37	0.90
2009	111.86	107.83	108.30	91.55	6.90	0.50	313.40	231.00	0.45	0.11
2010	79.43	87.22	80.26	90.16	23.00	2.00	267.30	266.80	1.12	0.93

Source: Authors Computation, 2013

Table 4: Annual Summary of the Statistical Analysis of Rainfall (mm) for KWWC (Station C), 1971-2000

Years	Mean	Std. Dev.	Min.	Max.	Skewness
1971	93.02	84.81	0.10	230.00	0.31
1972	84.76	72.74	20.60	194.00	0.07
1973	122.96	125.61	19.30	359.90	0.59
1974	90.05	102.05	4.00	348.00	1.58
1975	90.79	93.52	0.30	294.10	0.91
1976	93.80	87.02	29.70	281.70	1.03
1977	77.60	86.20	41.70	227.30	0.71
1978	94.76	79.62	3.30	237.70	0.30
1979	108.63	96.42	36.10	260.80	0.16
1980	82.02	84.74	10.40	201.30	0.38
1981	103.55	91.49	2.30	245.00	0.15
1982	106.63	97.06	2.00	302.50	0.55
1983	66.58	65.45	2.00	173.10	0.64
1984	149.90	156.87	7.50	524.00	1.26
1985	81.29	92.26	21.60	261.40	1.09
1986	103.93	82.62	2.70	246.00	0.67
1987	96.80	105.32	3.00	275.00	0.65
1988	80.96	68.79	3.90	190.90	0.23
1989	148.93	94.77	61.20	246.10	0.37
1990	85.07	84.61	4.00	229.20	0.63
1991	115.76	103.21	53.60	329.50	0.86
1992	83.24	99.59	1.00	287.00	1.03
1993	109.26	97.74	88.20	309.60	0.83
1994	97.87	113.57	3.30	311.80	0.84
1995	182.56	179.25	1.90	534.20	0.73
1996	107.78	102.81	65.50	330.10	0.75
1997	87.79	84.96	6.90	218.50	0.41
1998	65.13	75.34	3.00	245.58	1.30
1999	88.57	90.43	21.00	284.50	1.02
2000	80.02	90.87	1.40	265.60	1.11

Source: Author's Computation, 2013

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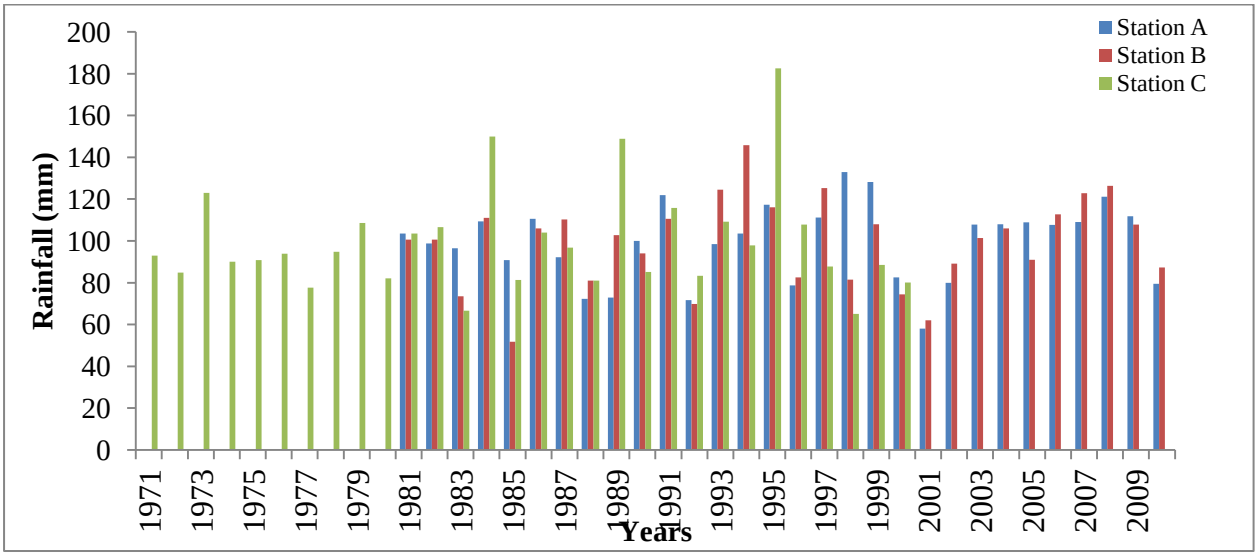

Fig 3: Mean Annual Rainfall received at NIMET, LRNBDA (1981-2010) and KWWC (1971-2000) Stations in Ilorin

Trend Pattern of Rainfall over Ilorin Metropolis

The trends (variation) in rainfall received over Ilorin in the three stations (NIMET, Lower Niger River Basin and KWWC) were obtained by plotting each variable against year. Trend analyses of rainfall over Ilorin are presented in figures 4, 5 and 6 respectively.

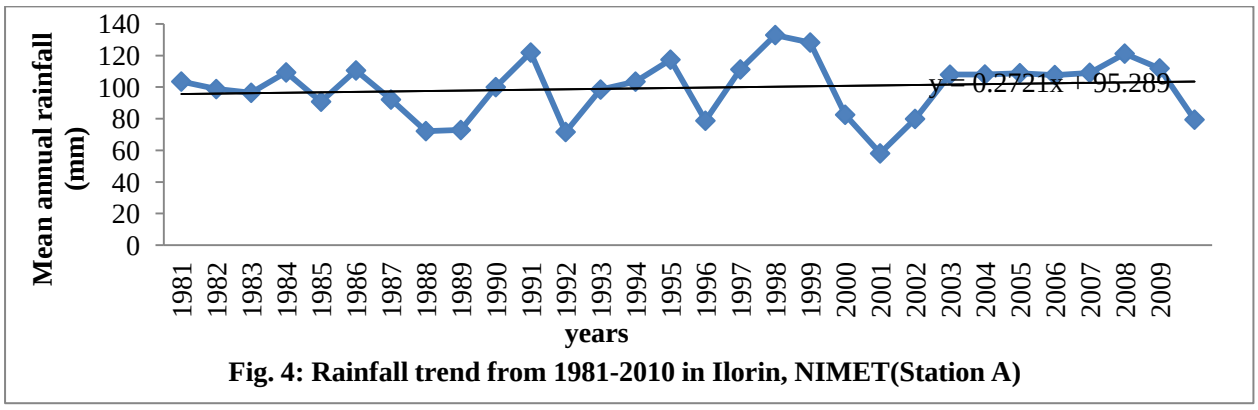

Fig. 4: Rainfall trend from 1981-2010 in Ilorin, NIMET(Station A)

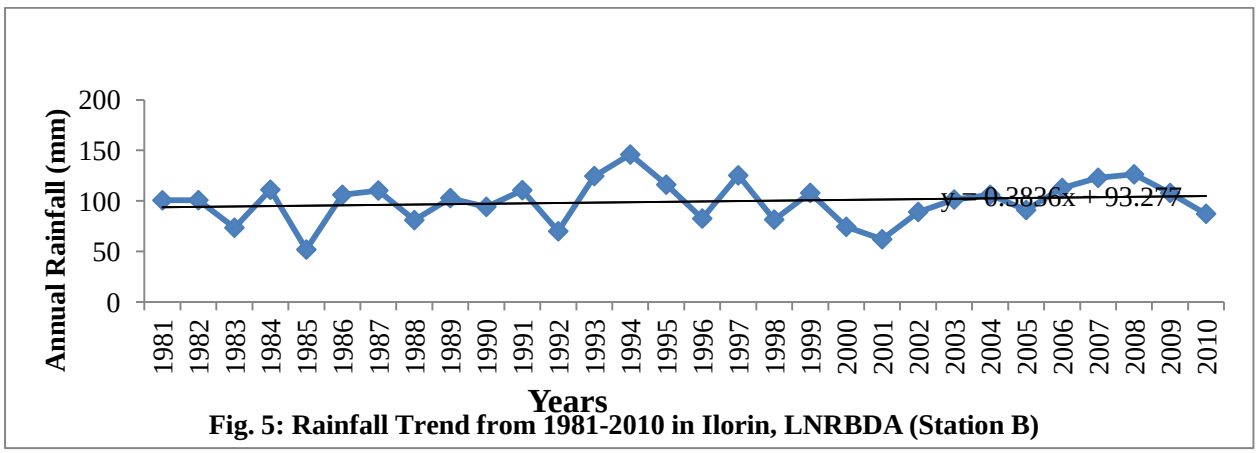

Fig. 5: Rainfall Trend from 1981-2010 in Ilorin, LNRBDA (Station B)

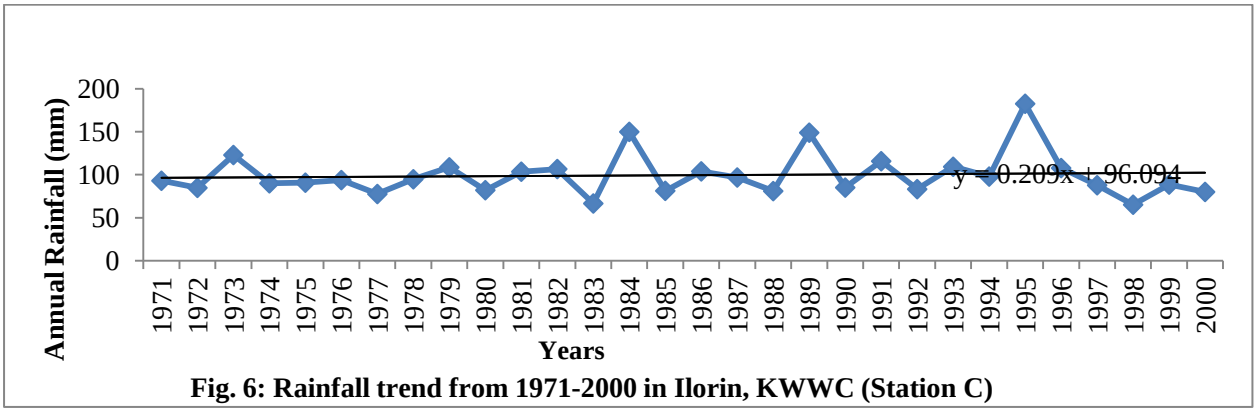

Fig. 6: Rainfall trend from 1971-2000 in Ilorin, KWWC (Station C)

By plotting the rainfall values against year in figure 4, a graph with a positive trend line with gentle slope was obtained, showing that rainfall increased with time at a very low rate. From the trend line equation, it can be inferred that rainfall increases at 0.3mm every year over the 30 years period of study at NIMET weather station. Also, a positive trend line with gentle slope was obtained in Figure 5, showing that rainfall received increases with time at a very low rate at LNRBDA weather station. From the trend line equation, it can be inferred that rainfall increases at 0.4mm every year over the 30 years period of study. The graph obtained in Figure 6 shows that rainfall received at the KWWC weather station increases at 0.2mm every year over the period of study.

Reduction Pattern Analysis of Rainfall over Ilorin Metropolis

Reduction analysis was carried out in order to study the deviation of the data for five year periods from the overall mean (average) of the whole data. This analysis was done on rainfall received at the three weather stations; NIMET (Station A), LNRBDA (Station B) and KWWC (Station C); the results are as shown in Table 5. Also, the fluctuations in the rainfall received at the three stations over the years of concern are showed in figure 7.

Percentage Change in Rainfall in the Three Weather Stations in Ilorin over Time

The record years of rainfall are divided into groups of five years intervals. This was used to get the percentage change in rainfall in the three weather stations over time in Ilorin. Table 5 shows the rainfall record of 1981-2010 in Ilorin recorded at NIMET weather station, the average rainfall was 99.51mm. From 1981-1985rainfall increased slightly to 99.78mm, showing a percentage change of0.27%. From 1986-1990, rainfall reduced to 89.56mm, showing a negative change and a percentage reduction of -9.99%. From 1991-1995, rainfall at Ilorin increased to 102mm, with a percentage difference of 3.08%. Rainfall continues to increase till 2000 with a percentage change of 7.27%. It however shows a negative change again from 2001-2005. From 2006-2010, rainfall rose again to 105.85mm with a positive change of 6.37%. From the results, the year 1986-1990 and 2001-2005 were the period where the percentage changes were negative.

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Table 5: Percentage Changes in Rainfall over Ilorin from 1971-2010 (Station A, B and C)

Period	Average annual for five years (X_i)			Average annual of the series (X_m)			Deviation from the average annual(X_i-X_m)			% Changes		
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
1971-1975	n/a	n/a	96.32mm	n/a	n/a	99.33	n/a	n/a	-3.01	n/a	n/a	-3.03
1976-1980	n/a	n/a	91.36mm	n/a	n/a	99.33	n/a	n/a	-7.97	n/a	n/a	-8.02
1981-1985	99.78mm	87.51mm	101.59mm	99.51	99.22	99.33	0.27	-11.71	2.26	0.27	-11.80	2.28
1986-1990	89.56mm	98.84mm	103.14mm	99.51	99.22	99.33	-9.95	-0.38	3.81	-9.99	-0.38	3.84
1991-1995	102.57mm	113.4mm	117.74mm	99.51	99.22	99.33	3.06	14.18	18.41	3.08	14.29	18.53
1996-2000	106.74mm	94.31mm	85.86mm	99.51	99.22	99.33	7.23	-4.91	-13.47	7.27	-4.95	-13.56
2001-2005	92.54mm	89.88mm	n/a	99.51	99.22	n/a	-6.97	-9.43	n/a	-7.00	-9.41	n/a
2006-2010	105.85mm	111.40mm	n/a	99.51	99.22	n/a	6.34	12.18	n/a	6.37	12.28	n/a

Source: Authors' Computation, 2013;***n/a= not available***

The rainfall record of 1981-2010 in Ilorin recorded by the Lower Niger River Basin Development Authority, the average rainfall was 99.22mm. From 1981-1985 rainfall decreased slightly to 87.51mm, showing a negative change and percentage change of -11.80%. From 1986-1990, rainfall increased to 98.84mm in relation to the previous five years but slightly decreased in relation to the long term average which is a percentage change of -0.38%. From 1991-1995, rainfall at Ilorin increased to 113.4mm, with a percentage difference of 14.29%. Rainfall decreased again from 1996-2000 to 94.31mm and to 89.88mm from 2001-2005 with a percentage change of -4.95% and -9.41% respectively. From 2006-2010, rainfall rose again to 111.40mm with a positive change of 12.28%. From the results, the year 1991-1995 and 2006-2010 were the period where the percentage changes were positive.

Rainfall record of 1971-2000 in Ilorin recorded at the KWWC weather station, the average rainfall was 99.33mm. From 1971-1975 rainfall decreased slightly to 96.32mm, showing a percentage change of -3.03%. From 1976-1980, rainfall reduced further to 91.36mm, showing a negative change and a percentage reduction of -8.02%. From 1981-1985, rainfall at Ilorin increased to 101.59mm, with a percentage difference of 2.28%. Rainfall continues to increase till 1990 with a percentage change of 3.84%. From 1991-1195, rainfall rose again to 117.74mm with a positive change of 18.53%.It however shows a negative change again from 1996-2000 with a percentage change of -13.56%. From the results, the year 1971-1980 and 1996-2000 were the period where the percentage changes were negative. The fluctuation in rainfall received at the three weather stations were depicted in figure 7.

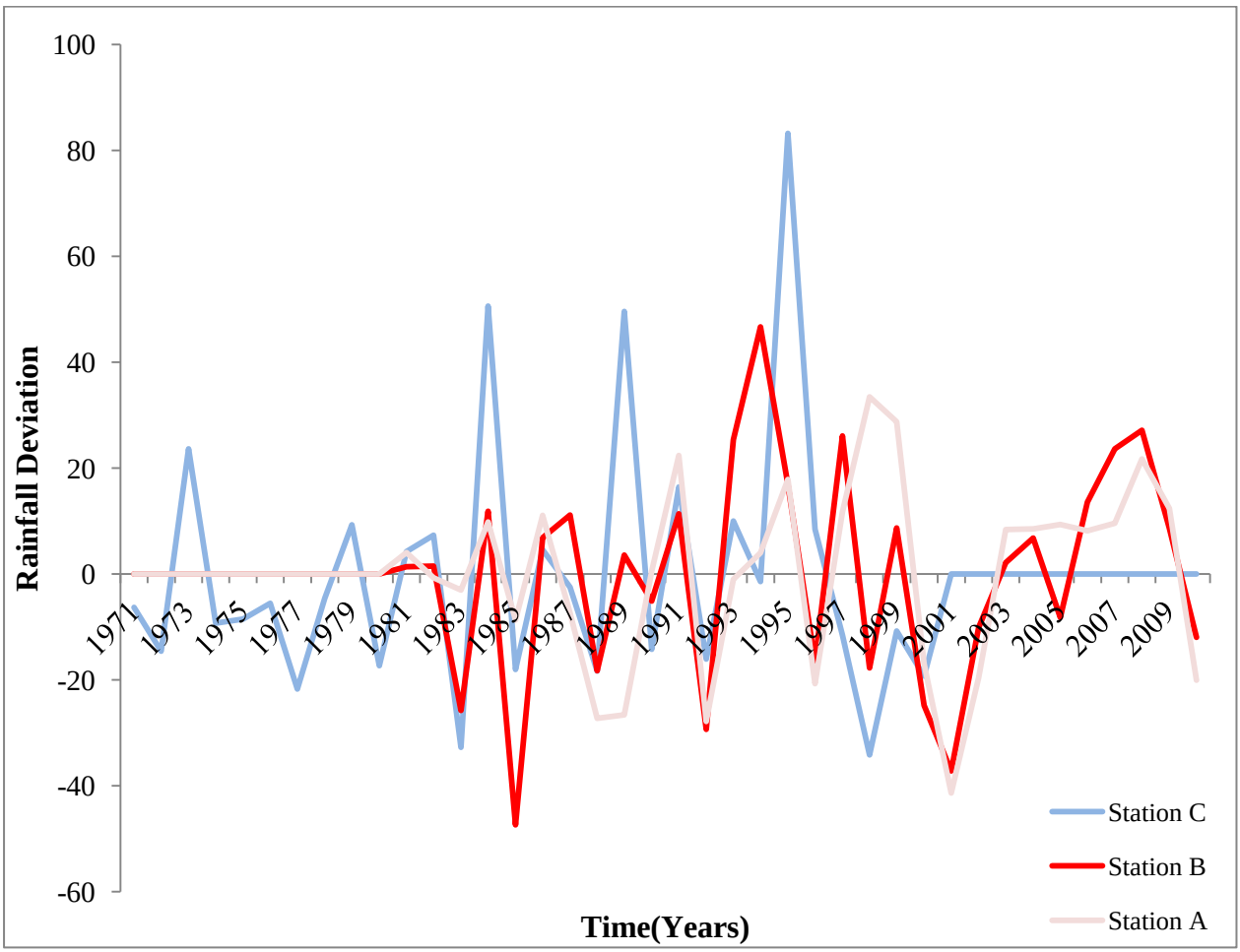

Fig. 7: Fluctuation of rainfall over time in Ilorin, NIMET (Station A), LNRBDA (Station B) and KWWC (Station C)

Spatial Pattern of Rainfall in Ilorin Metropolis

The result of the spatial pattern and distribution of mean annual rainfall (1981-2010) in Ilorin is presented in Figure 8. This was achieved through GIS interpolation (Kriging) of mean annual rainfall recorded in the three (3) weather stations available in the city. The weighted average of rainfall recorded in neighbouring weather stations were interpolated to estimate the values of mean annual rainfall received in other areas with no weather station. This analysis availed us the opportunity to depict how rainfall amount varied over space in the metropolis, in view of the low gauge density over the metropolis.

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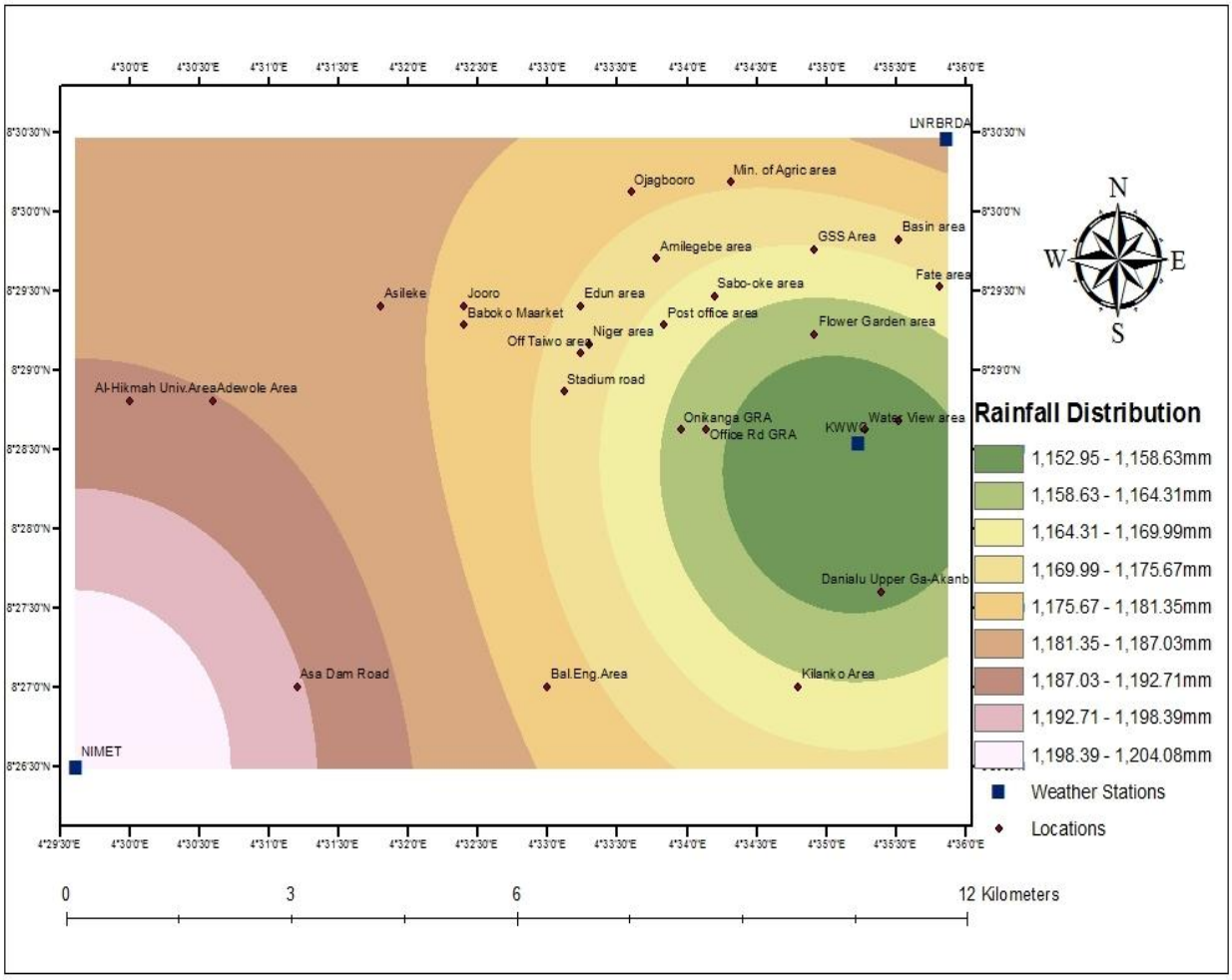

Figure 8: Spatial Rainfall (Mean Annual) Distribution over Ilorin (1981-2010)

The result of the kriging interpolation presented in Figure 8, shows the spatial pattern of mean annual rainfall (MAR) recorded in Ilorin from 1981-2010. Nine regional pattern are discernable, using Gaussian semivariogram model. The pattern showed that MAR is highly varied; the recorded value varies from 1,152.95 to 1,181.35mm in the North-East to South-Eastern part. This pattern differs from what obtains in the North-western and South-Eastern part of the study area where values range from 1,181.35 to 1,204.08mm. This shows that rainfall amount varies from one part of the city to the other. This is expected in view of the fact that tropical rainfall is highly varied. The result of the GIS analysis showed that Ilorin metropolis has a surface area of $12km^2$. The result of the kriging analysis suggests a variability of rainfall amount of 50mm over the city. This suggests a reasonable level of variability of the $12km^2$ expanse of the city.

DISCUSSION

The result of the trend analysis carried out on the rainfall received in Ilorin signifies an increasing trend on both monthly and annual basis. This increasing trend in rainfall over Ilorin has been confirmed by Ifabiyi and Ashaolu (2013). Environmental implication of the increase in rainfall is like a two sided

coin having both opportunity and risks. The increasing rainfall will improve water availability, a condition which will impact on water supply and improve sanitation, and health care delivery. According to Ifabiyi and Ashaolu (2013) any month with high rainfall tend to have low public water supply, which they attributed to water treatment challenges at the KWWC water works. This is expected because of the increased pathogens and sediment loads of the raining season. Increasing rainfall will improve urban agriculture and food production around the city. This will also impact on income of majority of subsistence farmers. Meanwhile, other studies such as Ati et al., (2009) and Abaje et al. (2012) also reported that increasing rainfall will increase agricultural activities and farm production.

Furthermore, increasing rainfall might have negative effect; such as leading to flooding and soil erosion. Many scholars have attributed flood occurrences to increase in rainfall (Odekunle, 2001; Ologunorisa, 2001, 2004; Abaje et al., 2012). As the population of the city increases, the ground surface is increasingly been replaced with concretes and pavements. This has reduced water in filtration, it has increased overland flow, resulting into flooding. Flood may lead to loss of lives and property, disrupt socio-economic activities and impair water reservoirs. The aftermath of which include water pollution and diseases outbreak. Increase in rainfall will lead to washing away of top soil and reduction in soil fertility. Erosion has been a serious environmental hazard, cutting off communication routes, exposing pipelines and destroying farm products. Abaje et al., (2012), reported that increasing trend in rainfall total will lead to flood and soil erosion.

The study also revealed that rainfall amount in Ilorin metropolis varied both temporally and spatially. The result of the spatial Interpolation show that the lowest MAR (1,152.95-1,181.35mm) were recorded in the North-Eastern and South-Eastern part of Ilorin metropolis which comprises Gaa-akanbi, Danialu, Fate area, Basin area, GRA, Flower garden, Sabo-oke, General Post office, Niger Road, Stadium road, Ojagbooro, Amilegbe among others within the metropolitan area. The highest MAR(1,181.35-1,204.08mm) was recorded on the other hand in the North-Western and South-Western part of the study area, around Asa dam water works, Asa dam road, Asileke, Adewole Estate, Al-Hikma University area among others, also within the metropolis. This implies that, rainfall amount received in different parts of the city differs from one part to the other.

According to Olaniran (2002), the annual mean rainfall in Ilorin is about 1,200mm. Similar amount of rainfall was recorded in places around the NIMET weather station, which was used by Olaniran in his study. Also, around Asa dam road MAR ranges from 1,192.71-1,198.31mm which also agrees with the 1,200mm reported by Olaniran (2002). Reasons for the higher MAR in the SE (around Asa dam) is due to the presence of the Asa dam lake, which has aggravated evaporation and consequently

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induces rain around the area, thus encouraging higher precipitation compared to other parts of the city.

This paper examines the spatio-temporal pattern of rainfall distribution over Ilorin metropolis with a view of pointing out the environmental implications associated with such pattern. The results of temporal analyses of the three stations show that there is an upward trend of rainfall amount within the metropolis from 1981-2010 (30 years). The kriging interpolation method used for showing pattern of rainfall depict 9 regional pattern over the city, with the South-Eastern part having the highest rainfall, while the Eastern side had the least rainfall. On the whole, the range of rainfall variability across the city is estimated to be about 50mm. Ilorin city is estimated to be 12km^2 in size. This variability is relatively high. This high variability experienced over the city is expected in view of the characteristically high spatial variability of the tropical rainfall. There are also differences in the percentage changes in rainfall received at the 3 stations, which is an indication that the amount of rainfall recorded were not the same. The increasing rainfall trend will increase water resources, increase the chances of flooding, soil erosion, sedimentation and siltation of water bodies. It is therefore recommended that wet season rainfall and runoff be properly managed to boost water supply in Ilorin particularly in dry season. Also, there should be awareness on flood occurrences and prevention. Indiscriminate flood plain development should be discouraged. The major rivers should be desilted to increase their water carrying capacities. Further, the existing artificial drainage or gutters should be deepened and expanded to increase their water carrying capacities. More drainages should be constructed to act as conduit for overland flow.

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