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COMPARATIVE ANALYSIS OF THE CHARACTERISTICS OF RAINSTORMS OVER IBADAN, NIGERIA

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Abstract

This study analysed the spatio-temporal variations of areal coverage (AC) of rainstorms over Ibadan with respect to variations in the AC of rainstorms during early and late rainy seasons in 2013 and 2014 rainstorm events. AC of rainstorms equals to the area covered by the rainstorms as observed by the 50 recording raingauges using square method. Student's t-test was used to test if there is significant difference in the AC of rainstorms during early and late rainy seasons, at $p \leq 0.05$. Of the 154 AC of rainstorm events studied, 21% and 32% occurred during early and late rainy seasons, respectively. The highest AC of rainstorms was recorded in April, as 426.4 km^2 (about 82.7% of the total area) followed by 389.6 km^2 (75.6%) in October. The study also revealed that the AC of rainstorms varied over the city of Ibadan during early and late rainy seasons. There was no significant difference in the mean AC of rainstorms during early and late rainy seasons (t=2.75). This study has provided a basic climatological investigation of Ibadan early and late rainy seasons AC of rainstorms conditions. The result could potentially be used in establishing guidelines for the use of rainwater in agriculture.

Keywords: Spatio-temporal variations, Rainstorm characteristics, Areal coverage, Ibadan

Introduction

A rainstorm is a relatively short period of uninterrupted and intense rainfall and usually lasts for less than two hours. Such storms constitute an important feature of tropical climate for at least three reasons. First, rainstorms account for most of the rainfall received in the tropics. In fact, in some inland areas, they contribute up to 95% of the total annual rainfall. Secondly, they produce moderate to high intensity of rainfall which generates a lot of runoff and sediment yield especially in areas without adequate vegetal cover, and finally, they frequently occur in a random pattern both temporally and spatially. They therefore contribute to the high variability both over time and space of rainfall in the tropics (Ayoade and Akintola, 1982; Oguntoyinbo and Akintola, 1983).

In spite of their predominance as a feature of tropical climate and the relevance of their many characteristics to land conservation and water resources management, only a few studies of rainstorms exist (Ayoade and Akintola, 1982; Oguntoyinbo and Akintola, 1983). These few studies have concentrated on two rainstorm characteristics, seasonality and variability. This is due to the fact that data on rainstorms are generally not available (Ayoade and Akintola, 1986). For the analysis of their spatial characteristics, a large number of such autographic raingauges is required over relatively small areas. The temporal as well as other non-spatial characteristics of rainstorms can, however, be studied through careful analysis of autographic rainfall charts at given locations (Walter, 1967; Ayoade, 1970; Jackson, 1977; Walsh and Lawler, 1981; Oyebande, 1982; Ayoade and Akintola, 1982; Oguntoyinbo and Akintola, 1983; Sekoni, 1992, Chin, 2007; Indrani, 2009; Omogbai, 2010; Kundzewicz, 2012; Audu et al., 2013; Terranova and Gariano, 2014; Oreste et al., 2015 and Zhang and Changhe, 2016).

However, the existing literature suggests that rainstorm characteristics are very important, although they can pose problems if not seriously considered (Ayoade, 2012). When rainstorm characteristics, such as rainfall amount and duration of storms, occur in excess, they become a hazard to the people and farmers in particular. When rainstorms occur in high intensity and long duration, they cause havoc rather than good (Singh, 2002b; Kaixi et al., 2016). Continuous rainstorm events can produce more run-off than single and separated events with significantly higher precipitation depths (Indrani, 2009; Jin, 2009; Kundzewicz, 2012; Audu et al., 2013; Keggenhoff et al., 2014 and Zhihe et al., 2015).

The present study therefore differs from existing studies on rainstorms in Nigeria and other West African countries in that an attempt is being made in this work to analyse the variations in the areal coverage of rainstorms in Ibadan metropolis, Nigeria. The need to undertake a detailed comparative analysis of the areal coverage of rainstorms over Ibadan metropolis become evident as this will provide a better understanding of the magnitude and character of the areal coverage of tropical rainfall over urban areas.

Justification of the Study

The humid tropical environment is blessed with an abundant supply of rainstorms (Oguntoyinbo and Akintola, 1983; Audu et al., 2013; Dao and Hoang, 2016). Rainstorms provide rainfall for a variety of natural and anthropogenic uses, from groundwater and stream recharge to water for domestic uses.

In the tropics, the distribution characteristics and variability of rainstorms are extremely vital. Rainstorms are primary features of the climate over areas in the tropical sub-region of the world and they occur variably over space and time (Kane, 2000; Gbuyiro, 2002; Jin, 2009; Audu et al., 2013 and Ivana et al., 2016). This contributes to the high variability of rainfall that is characteristic of tropical areas. However, a proper understanding of the magnitude of areal coverage of rainstorms aids proper planning and physical development. Flooding, damage to infrastructure and amenities, water issues and agricultural difficulties could arise if a proper understanding of rainstorms magnitude is not achieved before man undertakes any endeavour.

In general, several authors have written on rainstorm pattern, rainstorm characteristics and their implications for human welfare (Jackson, 1977; Walsh and Lawler, 1981; Oguntoyinbo, 1982; Ayoade and Akintola, 1986; Sumner, 1988; Sekoni, 1992; Adefolalu, 2001; Kundzewicz, 2012; Ayoade, 2012; Audu et al., 2013; Keggenhoff et al., 2014; Zhihe et al., 2015 and Ivana et al., 2016). These studies did not consider the variation in the magnitude of areal coverage of rainstorms. Studying the areal coverage of rainstorms is important for two reasons. First, it can aid forecasters in urban regions, both on the meteorological level as well as for local and regional climate modelling. Secondly, results from such analyses could potentially be used to inform urban planners in considerations, such as assigning appropriate zoning types for precipitation-enhanced regions.

Study Area

Ibadan is located approximately on latitude 7° 22′ N and longitude 30° 58′ E of the Greenwich Meridian. Nevertheless, the expanse of land normally referred to as the metropolitan (urban) area lies in the portion lying between latitudes 7° 15′ and 7° 30′ North of the Equator; and longitudes 3° 50′ and 3° 00′ East of the Greenwich Meridian. It covers an area about 450 km^2 (Figure 1). The area is in the vegetational transitional zone between the forest and savanna. The area experiences two seasons, the dry and the wet.

The onset of the wet season is estimated at 15 March within a two week variation period and 15 November as the tentative end of the wet season with the same level of variation (Oguntoyinbo and Akintola, 1983; Ayode, 2012). The area also experiences the double maxima rainfall regime with the characteristic break in August known as the "little dry season" (Ayoade and Akintola, 1986; Ayoade, 2012). The mean annual rainfall over the study area is about 1500 mm.

According to Ayoade and Akintola (1986), four seasons of rainfall events exist in Ibadan and they include, dry (November to February), early (March to April), rainy (May to August) and late (September to October) rainy seasons. More than 30% of annual rainfall is received during early rainy season. The study area experiences the double maxima rainfall regime characterized by two peaks, one in June and the other in September/October with a period of relatively lower rainfall in between (Figure 2). This period is often referred to as the 'little dry season'. The mean monthly temperature is about 27°C (Figure 2). Hottest months coincide roughly with the movement of overhead sun. The first hottest months occur between March-April, while the second is between November-December (Ayoade and Akintola, 1986).

Data Base and Analysis

Data on areal coverage of rainstorms were recorded from five synoptic stations (A1-A5) and 45 improvised rainfall stations (B1-B45) in Ibadan (Adediran, 2017). Similarly, a 3x3 km grid was superimposed on the map of Ibadan metropolis and one raingauge was installed in each of the 50 resultant grids (Figure 2). The areal coverage of rainstorms equals to the area covered by the rainstorms as observed by the recording raingauges (Adediran, 2017). This was calculated using measurement of area of irregular shapes (square method). The values obtained were expressed in square kilometre (km^2) (Summer, 1988 and Ayoade, 2008).

The statistical methods employed for this study were descriptive methods and paired samples *t*-test statistics, respectively. The descriptive statistical method was used to summarize the observed areal coverage of rainstorms data collected, while the analytical method was used to draw inferences within a known degree of accuracy regarding the weather data under analysis and the distribution of each of the areal coverage of rainstorms. The interpretation of the result of the descriptive statistics was done based on percentages as well as absolute values. The data recorded for the period of the study were aggregated, examined and analysed. Data collected were analysed using paired samples *t*-test statistics at $p \leq 0.05$. This was done to determine the difference between the areal coverage of rainstorms at two separate seasons in Ibadan and determine whether or not one period is significantly had wider areal coverage of rainstorms than the other (Adediran, 2017; Ayoade, 2008). The paired samples *t*-test statistics, expressed as:

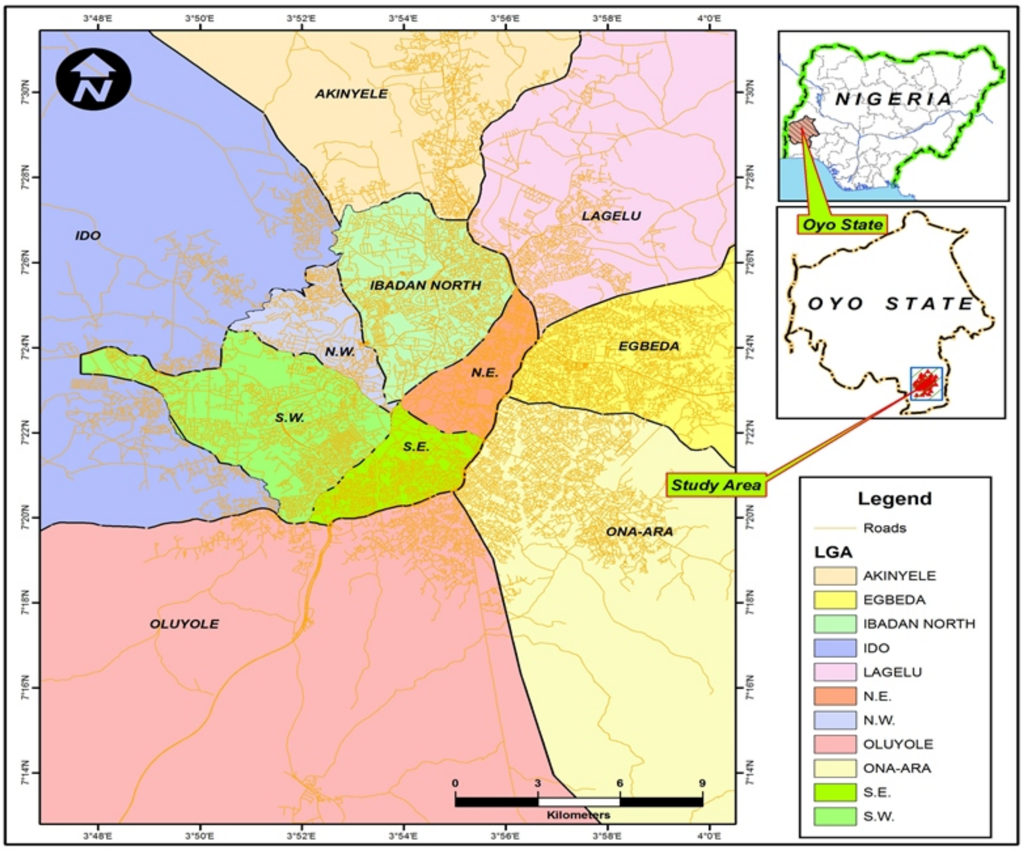


Figure 1: The Study Area

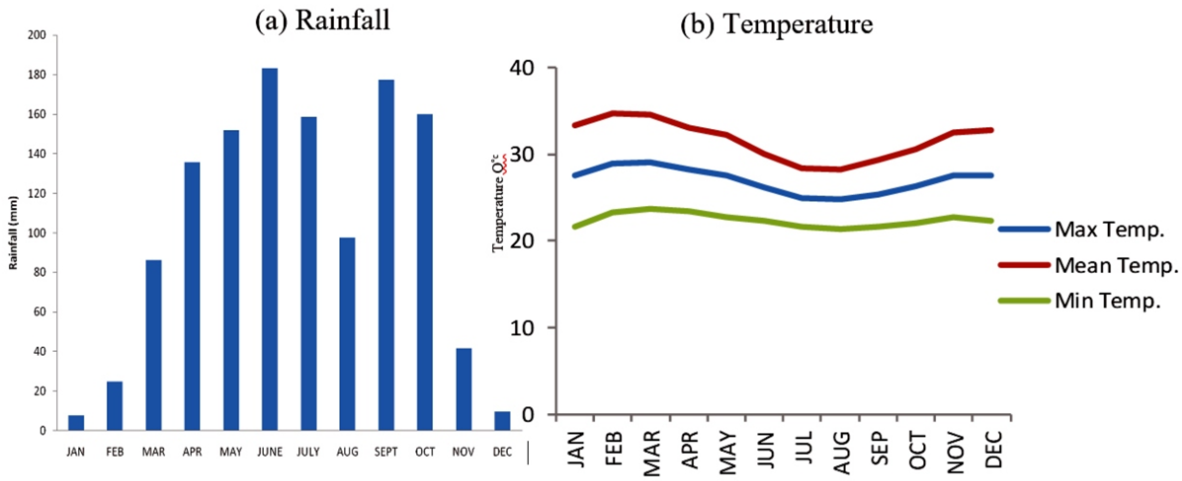


Figure 2: Monthly Distribution of Rainfall & Temperature at Ibadan (1981-2012)
Source: *NIMET Lagos Synoptic Station Report, 2012*

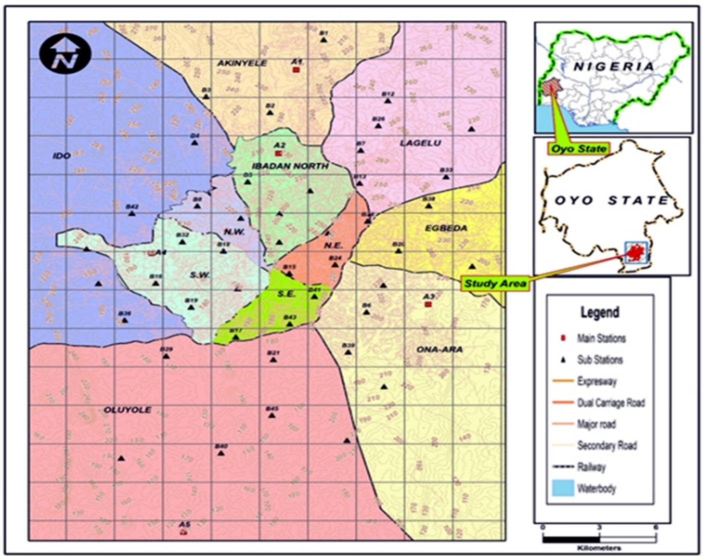


Figure 2b: Location of the rainfall stations in the city of Ibadan

$$t = \frac{|\bar{a} - \bar{b}|}{\sqrt{\frac{\sigma a^2}{n_a} + \frac{\sigma b^2}{n_b}}} \qquad (1)$$

where (a) is mean of the areal coverage of rainstorms during early rainy season, (b) represents mean of the areal coverage of rainstorms during late rainy season, (σ) is standard deviation, (n) represents number of observations.

Results

Temporal Pattern of Areal Coverage of Rainstorms in Ibadan

Of the total areal coverage rainstorm events studied, 14% occurred during dry; 21% during early rainy; 33% during rainy and 32% during late rainy seasons. The areal coverage of rainstorms during dry season showed a range and mean value of 310 and 133.6, respectively. The standard deviation was put at 110 (Table 1). During early rainy season, the range value of areal coverage of rainstorms was 412.7. The mean and standard deviations were 210 and 136. In the rainy period, the areal coverage of rainstorms showed a range of 310 with a mean value of 133. The standard deviation was computed as 70. Besides, during late rainy season, the areal coverage of rainstorms showed a range of 364. The mean value was 203. The standard deviation was put at 109. The coefficient of variation of the dry, early, rainy and late rainy seasons values were put at 55.2%, 78.0%, 67.6% and 63.4%, respectively (Table 1). The results showed that there was temporal variability in the areal coverage of rainstorms during dry, early, rainy and late rainy seasons in Ibadan (Olaniran et al., 2001; Sekoni, 1992).

However, Figure 3 depicts the frequency distribution of the areal coverage of rainstorms during dry, early, rainy and late rainy seasons in Ibadan. As evident in the total data, 36.4% of the areal coverage of rainstorms measured less than 50.0 km^2, 18.2% measured between 50.0 and 100.0 km^2, 9.0% measured between 100.0 and 200.0 km^2, while 36.4% measured between 200.0 km^2 and above during dry season. Besides, 9.3% of the areal coverage of rainstorms measured less than 50.0 km^2, 18.8% measured between 50.0 and 100.0 km^2, 25.0% measured between 100.0 and 200.0 km^2, while 46.9% measured between 200.0 km^2 and above during early rainy season (Figure 3).

More so, 7.8% of the areal coverage of rainstorms measured less than 50.0 km^2, 33.4% measured between 50.0 and 100.0 km^2, 43.1% measured between 100.0 and 200.0 km^2, while 15.7% measured between 200.0 km^2 and above during rainy season. In addition, 4.1% of the areal coverage of rainstorms measured less than 50.0 km^2, 18.4% measured between 50.0 and 100.0 km^2, 34.7% measured between 100.0 and 200.0 km^2, while 42.8% measured between 200.0 km^2 and above during late rainy season (Figure 3).

Distribution Pattern of the Areal Coverage of Rainstorms

The pattern of the areal coverage of rainstorms events in during this period exhibited four distinct patterns (Figure 4). One during dry season months; two, during early rainy season months; three, during main rainy season months and four, during late rainy season months. Generally, the rainy phases during the "dry season rains" began in February and ended in November. On the western part, the rains set in slightly earlier, to the east, in the area around Alakia area, a bit later, which means about the first week of February. The same held true for the northeastern part of the city (Figure 4). The rainy phases and the areal coverage of rainstorms shared similar patterns during the dry season months.

The pattern of the areal coverage of rainstorms

Table 1: Descriptive Statistics of Areal Coverage of Rainstorms in Ibadan

Season of Areal coverage	N	Range	Mean	Std. Deviation	Coefficients of variation (%)
Dry	22	310.00	133.6909	110.98360	55.2
Early	32	412.70	210.3344	136.21610	78.0
Rainy	51	310.80	133.2784	70.95832	67.6
Late	49	364.10	203.5796	109.18756	63.4
Valid N (listwise)	22				

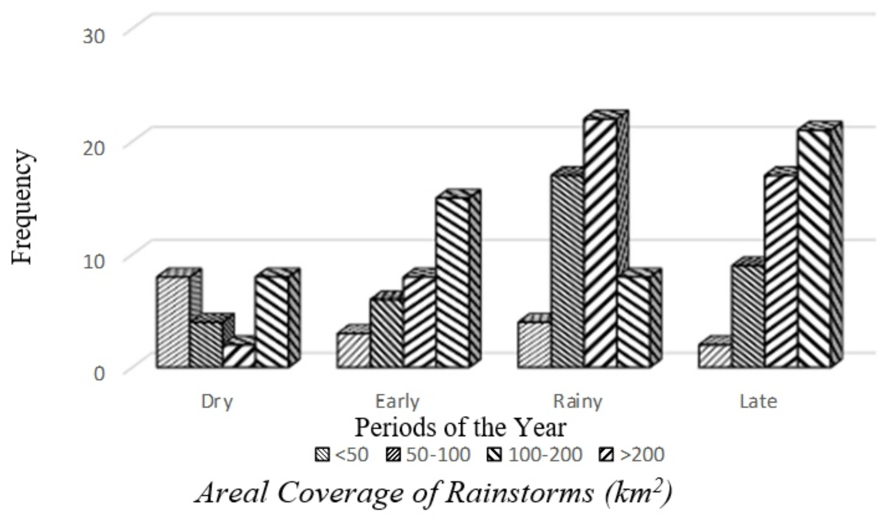
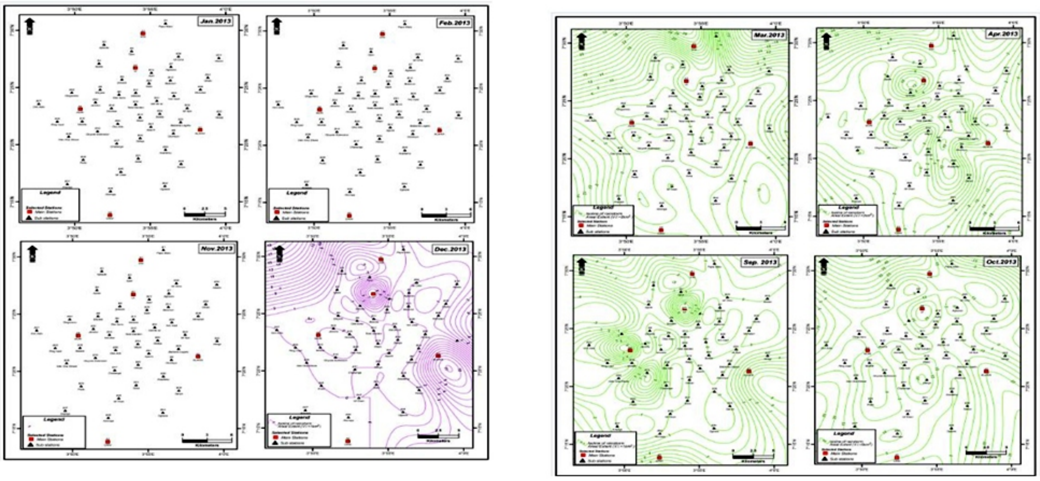
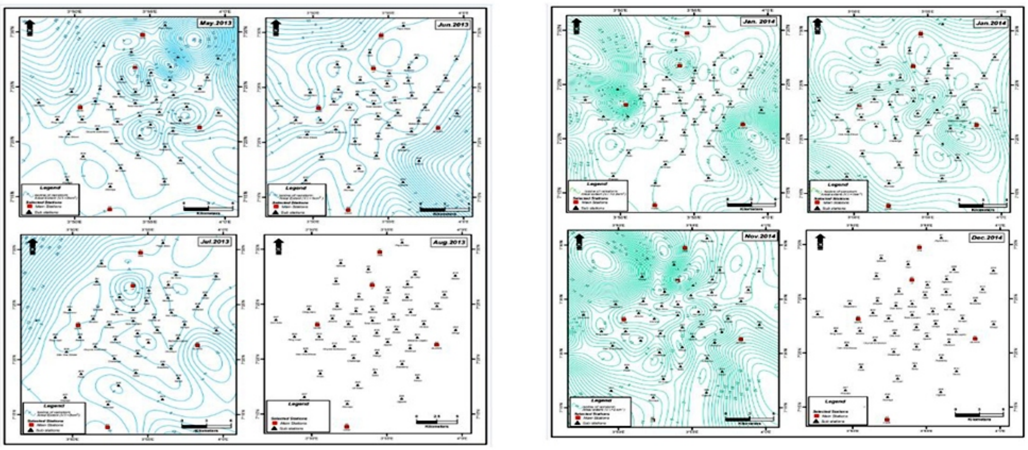


Figure 3: Areal Coverage of Rainstorms at different periods in Ibadan

(a) Dry Season



(b) Early & Late Rainy Season



(c) Rainy Season

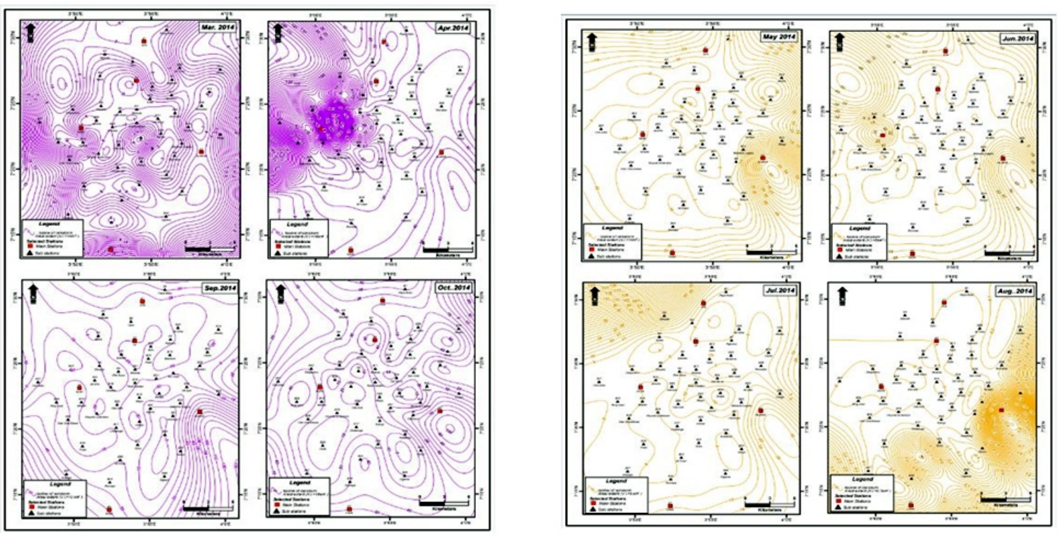


Figure 4: Distribution Pattern of the Areal Coverage of Rainstorms at different Periods (a-c)

relatively increased during early rainy season, as a result of the prevailing moisture-laden maritime airmass over the city. During this period, the highest areal coverage of rainstorm events was recorded in April, as 426.4 km^2 (about 82.7% of the total area) followed by 313.4 km^2 (60.8%) in March (Figure 4). Besides, during rainy season, the areal coverage of rainstorms was highest in the area around Alakia area and east of the city, here the figure stood at 54.7 km^2 (about 12.1% of the total area) (Figure 4). Towards the south, west and north, areal coverage of rainstorm events decreased rapidly. The central axis showed areal coverage of rainstorm events about 100 km^2(about 22.2% of the total areal) (Figure 4).

By the late rainy season, the areal coverage of rainstorms changed and there was almost a northwest-and-southeast pattern. The areal coverage of rainstorms again decreased from the southern section to the northern section of the study area. Generally, during late rainy season, the highest areal coverage of rainstorm events was recorded in October as 389.6 km^2 (about 75.6% of the total area) followed by 364.0 km^2 (70.6%) in September (Figure 4).

Comparison of Areal Coverage of Rainstorms during Early and Late Rainy seasons

This section is aimed at comparing the areal coverage of rainstorms examined in this study during early and late rainy seasons in Ibadan. The analysis of two-independent sample comparison of means of areal coverage of rainstorms between the early and late rainy seasons was done using paired sample *t*-test method. Paired sample *t*-test method was adopted due to inequality in the total number of observations of the areal coverage of rainstorms during early and late rainy seasons. The summary of the result is shown in Table 2. The results of the analysis of the differences between the mean of areal coverage of rainstorms between the early and the late rainy seasons (Table 2) revealed that there was no significant difference in the speed of rainstorms during the early and the late rainy seasons, with calculated T-value of 2.75, which was less than the T-critical value of 2.06 at 0.05 confidence level. This result means that the areal coverage of rainstorms between both the early and the late rainy seasons did not vary significantly.

Discussion

The study revealed some features about the urban climatology of Ibadan with respect to areal coverage of rainstorms. Of the 154 areal coverage of rainstorm events recorded, 32 and 49 (about 21% and 32%) of the areal coverage of rainstorms were recorded during early and late rainy periods, respectively. The average areal coverage per storm were about 210.3 and 203.5 km^2 during early and late rainy seasons. This result supported the findings of Huff and Changnon, 1971, Grimmond et al., 1998 and Arnfield, 2003. The pattern of the areal coverage of rainstorms relatively increased during early rainy season, as a result of the prevailing moisture-laden maritime airmass over the city. Generally, during this period, the highest areal coverage of rainstorm events was recorded in April, as 426.4 km^2 (about 82.7% of the total area) followed by 313.4 km^2 (60.8%) in March.

By the late rainy season, the areal coverage of rainstorms changed and there was almost a northwest-and-southeast pattern. The areal coverage of rainstorms again decreased from the southern section to the northern section of the study area. Generally, during the late rainy season, the highest areal coverage of rainstorm events was recorded in October as 389.6 km^2 (about 75.6% of the total area) followed by 364.0 km^2 (70.6%) in September. It can be deduced from these results that there is seasonal variation in the pattern of the areal coverage of rainstorms over Ibadan during early and late rainy seasons.

Table 2: Summary of the Analysis of T-Test for Two-Independent-Sample Comparison of the Areal Coverage of Rainstorms between the Early and the Late Rainy Seasons

Season	T-cal	T-critical	Level of significance
Early and late rainy	2.75	2.06	Not significant at 0.05 level

The implication of these variations in the pattern of the areal coverage of rainstorms over the city of Ibadan is that the rainstorm events associated with the highest areal coverage prevailed over the city during early rainy period especially, while those with lowest areal coverage prevailed over the city during late rainy period. The rainstorm events associated with highest areal coverage covered a large area while those with lowest areal coverage covered only a small area. However, the seasonal variations in the areal coverage of rainstorms during early and late rainy periods could be attributed to the climate change phenomenon.

Conclusion

The study also revealed that the AC of rainstorms varied over the city of Ibadan. The result showed that there were temporal variability in the areal coverage of rainstorms during dry, early, rainy and late rainy seasons. The statistical result showed that there was no significant difference between the areal coverage of rainstorms during early and late rainy seasons in Ibadan. This result means that the areal coverage of rainstorms between the early and late rainy seasons did not varied significantly. These findings are in consonance with studies conducted by Huff and Changnon (1971), Grimmond et al. (1998) and Arnfield (2003). The results from this study could potentially be used to inform urban planners in considerations, such as assigning appropriate zoning types for precipitation-enhanced regions as well as used in establishing guidelines for the use of rainwater in agriculture.

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