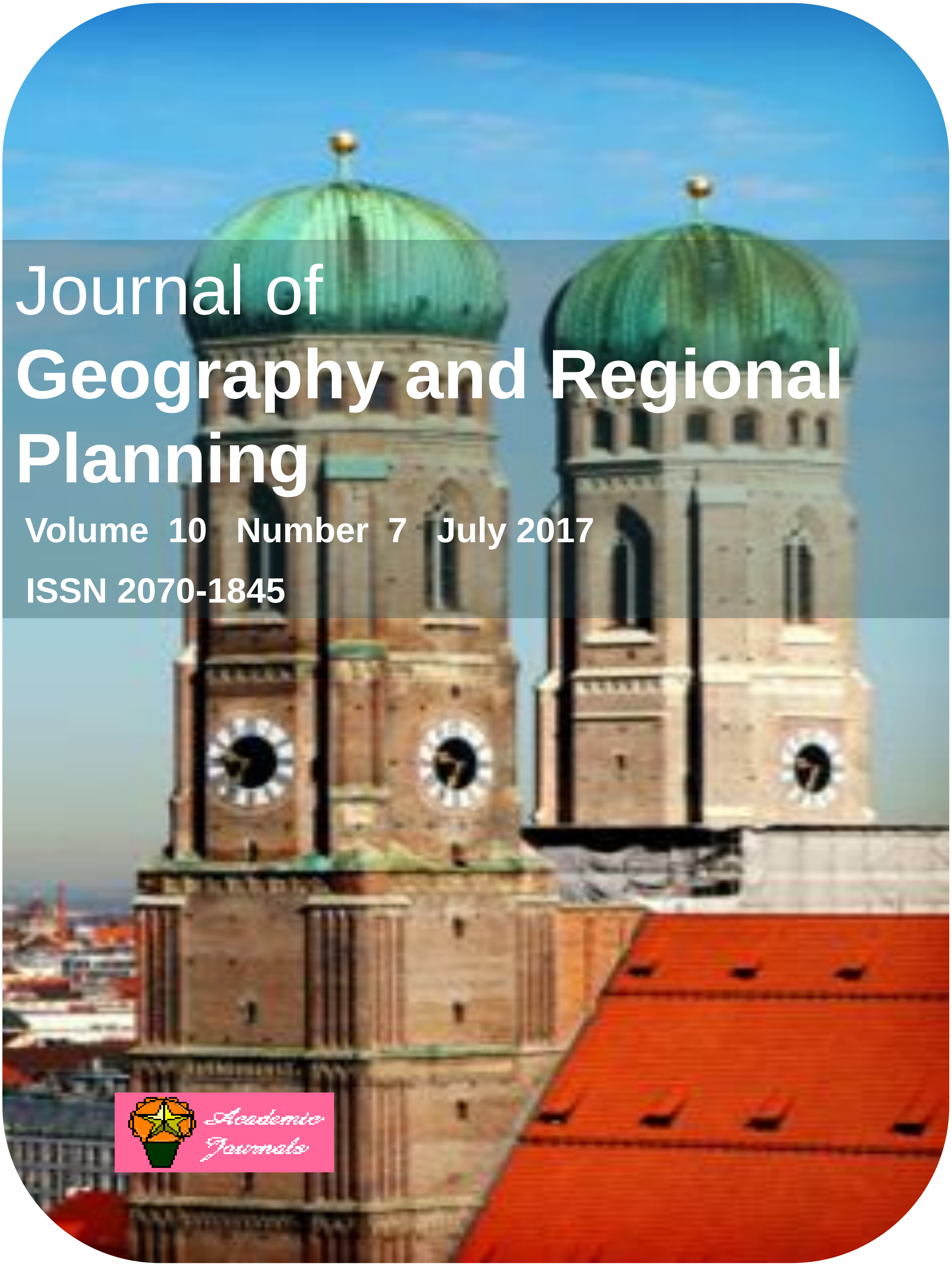

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Table of Contents: Volume 10 Number 7 July 2017

ARTICLES

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Full Length Research Paper

Municipal solid waste and flooding in Lagos metropolis, Nigeria: Deconstructing the evil nexus

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Municipal solid waste (MSW) has contributed significantly to flooding in the Lagos metropolis. This study examined the volume of MSW generated using per capita waste generation, projected population, quantity of MSW collected and deposited at six landfills sites from 2007 to 2013. One thousand and twenty-five copies of a structured questionnaire were administered to obtain data. The points where MSW blocked drainage channels in the metropolis were mapped. Multiple regression was used to establish the association between flooding and MSW at p<0.05. A total of 77,757,749.8 tons of MSW was generated, while 27.7% of it was collected and deposited at six landfill sites from 2007 to 2013. 11% of the municipal solid waste was collected by the Lagos State Waste Management Authority, 9.9% by private sector service providers, 29.2% by cart pushers and 49.7% dumped in canals/lagoons. Weekly collection of MSW was 58.5%. The sampled buildings were flooded at an average of nine times. Two hundred and twenty-two points where MSW blocked drainage channels were identified. The municipal solid waste indicators were statistically significant at $F_{2, 1022}$ = 1034.2, R^2 = 0.669. The study recommends measures to enhance the strengths and address the weaknesses of the current approaches towards the attainment of global best practices in the management of MSW and flooding in the Lagos metropolis.

Key words: Flood, municipal solid waste, generation, collection, drainage channels.

INTRODUCTION

The amount of municipal solid waste (MSW) generated in Nigerian cities keeps soaring as a result of increasing urban population and rapid urbanisation. This, in turn, presents greater challenges for disposal and management of MSW (Ojolowo and Wahab, 2011).

The volume of waste being generated continues to increase at a faster rate than the ability of the authorities to improve on the financial and technical resources needed to respond to this growth (Aderogba, 2012). The global generation of municipal solid waste in 1997 was 0.49 billion tons, with an estimated annual growth rate of 3.2 to 4.5% in developed nations and 2 to 3% in developing nations (Suocheng et al., 2001). An estimated 2.5 to 4 billion tons of waste was generated in 2006 globally, out of which municipal solid waste was 1.84 billion tons (Chandak, 2010). Municipal solid waste

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is projected to increase to 657 million tons in 2025 (Arunprasad, 2009), a projection of 137% in 27 years. Kapadia (2012) asserts that world cities generate about 1.3 billion tons of solid waste per year; this volume is expected to increase to 2.2 billion tons by 2025. The highest volume of MSW is generated in Delhi, India, with estimated 11,500 tons per day or 4.2 million tons per year (Kumar, 2013). The per capita generation of MSW in Delhi is approximately 0.5 kg/capita/day (Ahmad, 2012). The amount of MSW generated per/capita/day in Hong Kong, London, Seoul, Tokyo and Tapei are 1.45, 1.45, 1.08, 1.03 and 0.88 kg, respectively (Hong Kong Environmental Protection Department, Waste Management Policy Division, 2012). Similarly, 10.000 tons of solid waste is generated each day in Lagos, with generation per capita (GPC) of 0.65kg/person/day (Oresanya, 2013).

Collection of waste from households, factories, and other generation points to dump sites is an intractable challenge in developing countries. This is because waste management usually accounts for 30 to 50% of municipal operational budget. However, despite these high expenses, cities, especially those in developing countries, can only collect 50 to 60% of the refuse generated (Arunprasad, 2009). For instance, 33% of the refuse generated is collected in Karachi, 40% in Yangoon and 33 to 77% in Cairo (Zayani, 2010).

In Lagos (Nigeria), the collection rate is about 43% (LAWMA, 2015). A total of 2,468,707.57m^3 of MSW was deposited at landfill sites in Lagos State from January to September, 2014 (LAWMA, 2015). Uncollected solid waste blocks drainages, causes flood, and leads to spread of water-borne diseases. It was the cause of a major flood in Surat in India in 1994, which resulted in an outbreak of a plague-like disease that affected 1000 people and killed 56 (UN-HABITAT, 2012). Annual floods in East and West African, and Indian cities are blamed, at least in part, on plastic bags that block drains (UN-HABITAT, 2012).

The pair of municipal solid waste and floods has become an intractable challenge, particularly in Lagos and many other cities within and outside Nigeria. Waste generation and flooding are inevitable phenomena within natural cycles. As wastes convey nutrients from one part of the environment to another, floods offer water balance and associated resources between areas of excess and shortage. However, human interference engenders the negativity that has been recorded owing to the friction between the pair.

In 1998, flood killed more than 4,000 people and caused economic losses estimated at US$25 billion in Southern China. In July and August 2010, Pakistan was hit by extreme rainfall that led to devastating flooding that killed more than 2,000 people and affected more than 20 million people. In January 2011, floods in South-Eastern Brazil, Including Rio de Janeiro and São Paulo, killed over 800 people (Jha et al., 2012). The situation is the same in Nigeria.

Floods in various parts of Nigeria have displaced millions of people, destroyed property, disrupted socio-economic activities, contaminated water resources and facilitated the spread of water-borne diseases. Over 28 (80.0%) of the 36 states of Nigeria were devastated by flood in July 2012 (Wahab, 2013). Some of the states severely affected were Kebbi, Kogi, Anambra, Plateau, Oyo, and Bayelsa. The impact of the 2012 flooding was very high in terms of human, material, and production loss, with 363 people killed, 5,851 injured, 3,891,314 affected, and 387,153 displaced (The Federal Government of Nigeria (FGN), 2013).

The total value of destroyed physical and durable assets caused by the 2012 floods in the most affected states of Nigeria has been estimated at ₦1.48 trillion, or its equivalent of US$9.5 billion (FGN, 2013). The total value of losses across all sectors of the economy was estimated at N1.1 trillion, equivalent to US$7.3 billion, while the combined value of these damage and losses is N2.6 trillion, or US$16.9 billion (FGN, 2013).

The rate of occurrences of floods in the Lagos metropolis in recent times has been of great concern and challenge to the people and government authorities (Aderogba, 2012a). From the early 1970s to date, flood has occasioned building collapse, submerged markets, destroyed property and affected more than 300,000 people in the city of Lagos (Etuonovbe, 2011). According to *ThisDay* of 15 July, 2011, a number of vehicles and houses were submerged by the flood of 14 July, 2011 and virtually all parts of Lagos State were flooded. The flooded areas included Victoria Island, Lekki-Ajah, Abule Egba, Ikeja, Apapa, Oshodi, Ikorodu, Agege, Iyana-Ipaja, Ayobo-Ipaja, Ajegunle, Oregun, Ogba, Orile-Iganmu, Ejigbo, Okokomaiko, Badagry Expressway, Jakande Estate, Isolo, Ago-Palace Way, Cele Bus Stop, Lawanson Road, Surulere, Ketu, Mile 2, Satellite Town, FESTAC Town, Mile 12, Agbado, Ijaiye, Aboru, Ojota, Ifako, Ijaiye, Alagbado, Dopemu, Iju, Alapere, Ikotun, Makoko, Bariga, Ajegunle, Epe, and Ojo. The flood forced residents to stay indoors. All the areas listed above again experienced flooding in 2012 (Vanguard, 2012); while only Lekki was flooded in 2013 owing to the ocean surge (Street Journal, 2013).

In search of pragmatic solutions to flooding in the Lagos metropolis, researchers have recommended adequate collection of MSW (Oyebande, 1983, 1990, 2005; Adeaga, 2008; Akpodiogaga and Odjugo, 2010; Ikhile and Olorode, 2011; Aderogba, 2012), with little empirical evidence of the relationships between flooding and municipal solid waste management.

This study, therefore, investigated the contributions of municipal solid waste to flooding in the Lagos metropolis by establishing the variations in the amount of municipal solid waste generated and collected from 2007 to 2013. It

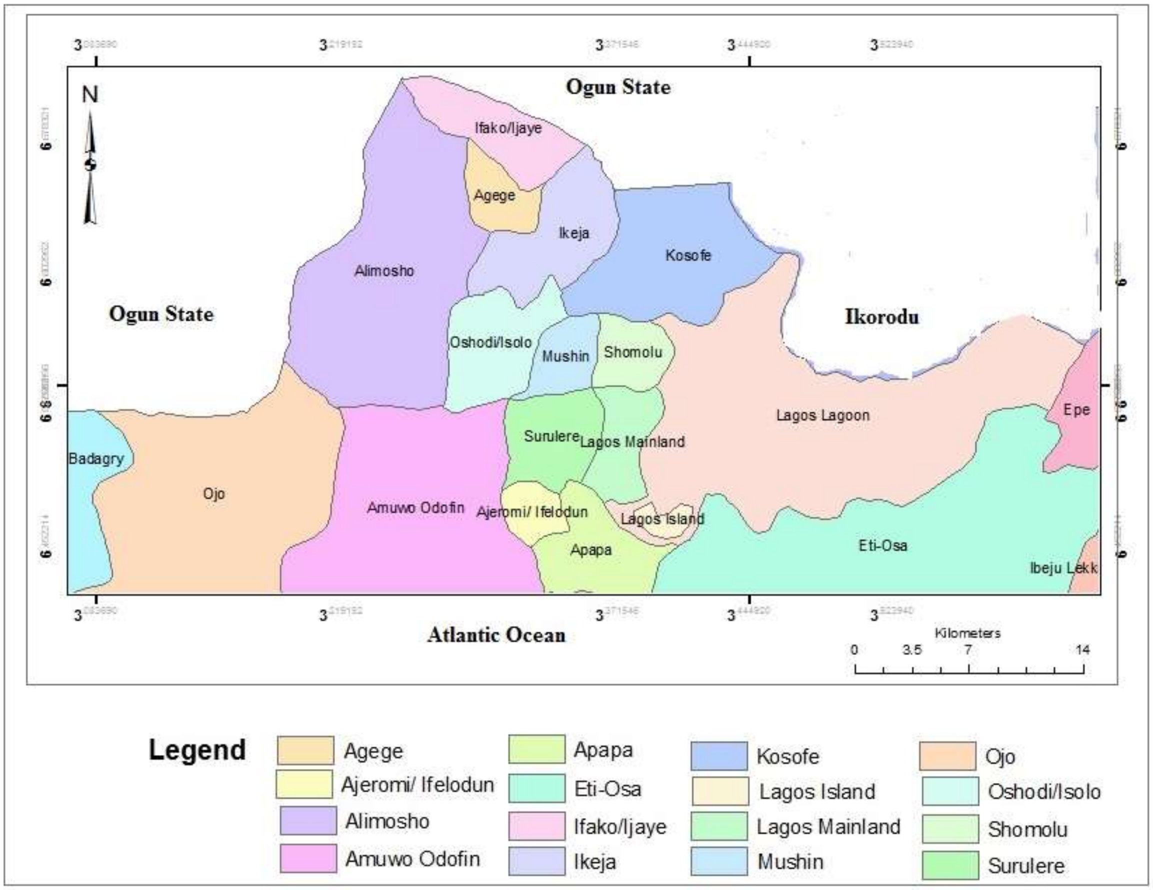

Figure 1. The sixteen metropolitan local government areas in Lagos state (Source: Lagos state ministry of physical planning and urban development, 2014).

also examined methods of disposal and collection, frequency of collection, and number of times buildings were flooded.

The Lagos metropolis

The Lagos metropolis is situated within latitudes 6°23′N and 6°41′N and longitudes 2°42′E and 3°42′E in Lagos State. The metropolis is bounded in the north and north-east by Ogun State and Ikorodu Local Government Area, respectively; in the east by Epe and Ibeju-Lekki LGAs; in the west by Badagry LGA; and in the south by the Atlantic Ocean/Gulf of Guinea (Figure 1). It grew spatially from a traditional core settlement of about 3.85 km^2 in 1881 (Okude and Ademiluyi, 2006) to 46.6 km,^{2} in 1911; 52.3 km^2 in 1921; 66.3 km,^{2} in 1931; 69.9 km,^{2} in 1952; 69.9 km^2, in 1963; 85.44 km,^{2} in 1986; 96.53 km^2, in 1990 (Abiodun, 1997); and 950.72 km^2, in 2006 (NPC, 2010; Lagos State Government, 2014).

Metropolitan Lagos is located in a lowland and about 220.6 km^2 (23.2%) of the metropolis is made up of water bodies, wetlands and mangrove swamps (Lagos State Government, 2014). These characteristics have exposed the human population and assets to the risks of flooding in Lagos. Other factors that make the city of Lagos vulnerable to flooding include increased urbanisation, inadequate implementation of planning laws, unregulated and indiscriminate urban physical development in hazard-prone areas, inadequate enforcement of building codes, torrential rainstorms and dearth of storm water drainages (Okpanachi, 2008; Lagos Water Corporation, 2008; Aderogba, 2012b; Aderogba, 2012). The causes of incessant flooding at Mile 12 in Lagos were investigated by Olajuyigbe et al. (2012), and reported to be the consistent high rainfall and water releases from Oyan Dam in the neighbouring Ogun State, Nigeria.

METHODOLOGY

Primary and secondary data were used in this study. The primary data were obtained through questionnaire administration, personal observation and participatory mapping. The simple random sampling technique was employed to select 211 out of the 1403

Table 1. Sample frame and size.

S/N	Local government areas	*No. of Streets	*No. of Streets prone to flood	*No. of selected Streets prone to flood	*No. of houses on the selected Streets	**No. of houses sampled (7.2%)
1	Agege	1095	196	14	587	42
2	Ajeromi-Ifelodun	391	70	11	620	45
3	Alimosho	890	159	13	1121	81
4	Amuwo-Odofin	119	21	10	860	62
5	Apapa	191	34	14	656	47
6	Eti-Osa	275	49	13	582	42
7	Ifako-Ijaye	133	24	17	994	72
8	Ikeja	419	75	13	525	38
9	Kosofe	181	32	10	528	38
10	Lagos Island	279	50	10	676	49
11	Lagos Mainland	301	54	14	813	59
12	Mushin	719	129	17	691	50
13	Ojo	242	43	10	4177	302
14	Oshodi-Isolo	1054	187	17	381	28
15	Shomolu	1065	190	17	601	43
16	Surulere	503	90	11	461	33
Total		7857	1403	211	14.273	1.031

Source: *Drainage department, Lagos state ministry of environment, Alausa Ikeja; **Authors' construct, 2014.

streets prone to flood in the metropolis (Table 1). The number of the sampled buildings was calculated using a formula developed by Yamane (1967) (Equation 1) with the desired level of precision of ±3. The output was 1031 (7.2%) out of 14273 buildings as presented in Table 1. The systematic random sampling technique was used to select buildings where questionnaire were administered in each street. The starting point was randomly selected by using the table of random numbers. One household head was randomly selected from each building and a pre-tested structured questionnaire was administered to them. Each household was assigned a number and the number was written on a piece of paper, which was then wrapped and put in a box. After thorough shaking of the box, a wrapped paper was picked and the number on the paper represented the household head that was sampled.

$$n = \frac{N}{1+N(e)^2} = \frac{14,273}{1+14,273(0.03)^2} = 1,031$$

(1) (Yamane, 1967)

The secondary data included: the list of the 1403 streets where floods had occurred, this was obtained from the Department of Drainage Services, Lagos State Ministry of Environment; the amount of solid waste deposited at six landfill sites and the per capita generation of municipal solid waste of 0.5, 0.6, 0.65 and 0.7kg/person/day for 2007/2008, 2008/2010, 2011/2012, and 2013, respectively obtained from Lagos State Waste Management Authority; and the 2014 projected population of the Lagos metropolis obtained from the National Population Commission of Nigeria.

The points along drainage channels where municipal solid waste had solidified and always prevented rainwater from flowing downstream were mapped with the assistance of one resident from each community who knew the geography of the community and could identify the points. The coordinates of the points were obtained with GPS *Garmin 76*, processed in Microsoft Excel 2007 and mapped in ArcGIS 10.3 environment.

RESULTS AND DISCUSSIONS

Socio-economic characteristics of the respondents

One thousand and twenty-five out of the 1031 respondents (Table 1) were successfully sampled and used for analysis. The socio-economic variables considered relevant to the issues under investigations were household size and income (Table 2). There is tendency that household size and income could affect volume of waste likely to be generated by household. However, this study did not measure the quantity of waste generated by each household, rather, it projected quantity generated per local government area. The information obtained on the size of households revealed that most of the respondents had large household size. By inference, they are likely to generate much waste. The majority (72.0%) had 3 to 6 members; 11.3% had more than 10; 9.7% had 7 to 9 members; while 7.0% had 1 to 2 members. More than a half of the respondents (51.4%) earned ₦19,000 and below monthly; 16.8% earned ₦40,000 to ₦59,000; 15.2% earned ₦80,000 to ₦99,000, 11.7% earned ₦20,000 to ₦39,000; 3.7% earned ₦100,000 and above; while 1.2% earned ₦60,000 to

Table 2. Socio-economic and demographic characteristics of the respondents.

Socio-economic variables	Number of respondents	Percentage (%)
Household size		
1 - 2	72	7.0
3 - 6	738	72.0
7 - 9	99	9.7
10 and above	116	11.3
Total	1025	100.0
Income range per month		
< ₦ 19,000	527	51.4
₦ 19.000- ₦ 39.000	120	11.7
₦ 40.000- ₦ 59.000	172	16.8
₦ 60.000- ₦ 79.000	12	1.2
₦ 80.000- ₦ 99.000	156	15.2
₦ 100.000 and above	38	3.7
Total	1025	100.0

Source: Authors' Field Survey, 2014 ($1 = ₦183:00 as at December, 2014).

Table 3. Percentage of municipal solid waste generated and collected in the Lagos metropolis from 2007 to 2013.

A	B	C	D	E	F	G	H
Year	PCSWG (kg)	Projected Population	MSWPG (tons) (B*C)	MSWD@6LS	% E of D	QUMSW (tons) (D-E)	% G of D
2007	0.5	16574253	8287126.5	2222745.50	26.8	6064381	73.2
2008	0.5	17104609	8552304.5	2814543.45	32.9	5737761.05	76.1
2009	0.6	18551956	11131173.6	3831708.00	34.4	7299465.6	65.6
2010	0.6	18234823	10940893.8	2819024.55	25.8	8121869.25	74.2
2011	0.65	18799756	12219841.4	2156801.00	17.6	10063040.4	82.4
2012	0.65	19401346	12610874.9	4111169.77	32.6	8499705.13	67.4
2013	0.7	20022193	14015535.1	3594817.46	25.6	10420717.64	74.4
Total			77.757.749.8	21.550.809.73	27.7	56.206.940.07	72.3

*PCSWG: Per capita solid waste generated; **MSWPG: Municipal solid waste probably generated; *MSWD@6LS: Municipal solid waste deposited at 6 landfill sites; **QUMSW: Quantity of uncollected municipal solid waste (Sources: * LAWMA (2014); ** Authors' Calculation (2014)).

₦79,000 per month. This means that most of the people living in flood-prone areas earn below the national minimum wage of ₦18, 000 per month.

Municipal solid waste generation, methods of collection and disposal

Municipal solid waste generation and collection rate

Column B of Table 3 shows the per capita solid waste generation (PCSWG) obtained from LAWMA for years 2007 to 2013. While 0.5kg/person/day was generated in 2007 and 2008, that of 2009 and 2010 was 0.6kg, it was 0.65kg for 2011 and 2012; and 0.7kg for 2013 (LAWMA, 2014).

The population of Lagos State for 2006 was projected to 2013 using 3.2% growth rate, as presented in Column C of Table 3. The amount of municipal solid waste deposited at 6 landfill sites (MSWD@6LS) (Olusosun, Abule-Egba, Solous II and III, Ewuelepe and Epe) (Column E, Table 3), obtained from LAWMA, was regarded as the quantity collected in the last seven (7) years. The quantity of municipal solid waste probably generated (MSWPG) in the Lagos metropolis per year was calculated by multiplying the corresponding PCSWG by the projected population as presented in Column D of Table 3. The difference between the amount of MSWPG

Plate 1. A Section of canal at Oreofero Street, Shomolu LGA of Lagos state, filled with municipal solid waste of all descriptions Source: Authors' Field Survey, 2014.

Plate 2. A PSP operator collecting refuse from residents in sacks and plastic containers along Iganmu Road, Apapa LGA of Lagos State, Nigeria (Source: Authors' Field Survey, 2014).

and quantity of MSWD@6LS was calculated to determine the quantity of uncollected municipal solid waste (QUMSW) in the Lagos metropolis (Column G of Table 3). This represents the amount collected by LAWMA and Private Sector Service Providers (PSP).

Table 3 reveals the gap between the quantities of MSW generated and collected from 2007 to 2013 in the Lagos metropolis. In 2007, the MSW generated was 8,287,126.5 tons, but 2,222,745.50 tons was collected, leaving 6,064,381 tons. In 2008, 2,814,543.45 tons was collected and deposited at 6 landfill sites out of 8,552,304.5 tons; while 5,737,761.05 tons was not collected. However, 2009 recorded the highest volume of 3,831,708.00 tons collection and the least volume of 7,299,465.6 tons uncollected MSW. The story in 2010 was similar to 2007 and 2008, as only 25.8% of the municipal solid waste generated was deposited at landfill sites, leaving behind 74.2% .

The situation of municipal solid waste collection in 2011 was the worst because only 17.6% (the least in seven years) of the municipal solid waste generated was collected; leaving 82.4% uncollected. The situation of municipal solid waste collection improved in 2012, with a record of 32.6% collection out of 12,610,874.9 tons. However, the situation was still below expectation when we consider the fact that a total of 8,499,705.13 tons (67.4%) was not collected. The year 2013 witnessed another poor performance, as the percentage of the collected municipal solid waste declined to 25.6%, leaving 74.4% uncollected (Table 3).

A total of 77,757,749.8 tons of municipal solid waste was generated between 2007 and 2013. However, only 27.7% was collected. This led to indiscriminate disposal of a substantial amount of MSW on open space, air spaces of buildings, road verges and islands, and, in particular, drainage channels and water bodies. The flood incidence of the year 2011 coincided with when only 17.6% of the MSW generated was collected. The incident claimed more than 25 lives, displaced 5,393 households, and destroyed an estimated ₦100 billion worth of property. It is logical to deduce that indiscriminate deposition of MSW in drainage channels (Plate 1) and water bodies contributed significantly to flooding in metropolitan Lagos (Plate 1)

Municipal solid waste disposal and collection methods

This study revealed that only 9.9% of the respondents engaged registered PSP operators to dispose of their waste (Plate 2), while 29.2% patronised cart pushers (Plate 3). Only 11.2 % of them used LAWMA communal waste bins. There was no LAWMA communal waste bin in the following LGAs: Agege, Ajeromi-Ifelodun, Alimosho, Apapa, and Kosofe. About 1.3% of the respondents burnt solid waste in their yards; while 16.7% dumped their waste at communal waste dumps (Plate 4). Those who buried their waste in yards were 4.6%, they were in Alimosho, Amuwo-Odofin, Ifako-Ijaiye, and Ojo LGAs only. Of all the respondents, 27.2% dumped solid waste directly into the canals/lagoons; owing to poor collection rate by authorised agencies.

Over a half (58.6%) of the respondents had their waste collected once a week, while 27.0 and 14.4% had their waste collected twice a week and daily, respectively.

Plate 3. A cart pusher in action along Alhaji Garuba Street, Lawanson, Mushin LGA, Lagos State, Nigeria (Source: Authors' Field Survey, 2014).

Plate 4. A typical communal waste dump situated in a wetland along Alh. Hassan Atoyebi Street, Muwo Ojo LGA, Lagos State (Source: Authors' Field Survey, 2014).

Among the 101 of the respondents who indicated that registered PSP operators collected their waste, 66.3% indicated monthly collection, 20.8% indicated fortnightly, and 12.9% indicated weekly basis. Therefore, it can be safely assumed that only 21.1% of the respondents who disposed of their waste through the PSP operators and in LAWMA's communal waste bins managed their waste responsibly. The majority (78.8%) disposed of waste indiscriminately and was contributing to the incidence of flooding in the metropolis of Lagos. The "alternative" waste disposal channels were illegal and unhealthy and encouraged indiscriminate waste dumping in water bodies and wetlands, which eventually hindered free flow of water during the rain and caused flooding.

Frequency of flooding

Investigation on the number of times that the respondents' buildings were flooded revealed that 5.9% of the buildings had not been flooded (Table 4). However, 10.2% of the buildings had been flooded once; 7.2% twice, 4.8% thrice and 2.8% 4 times. About 3.4%, had been flooded 5 times, 1.9% 6 times, 3.3% 7 times, 3.2% 8 times, 7.6% 9 times, and 1.8% 10 times. It is noteworthy that 2.3% of the buildings had been flooded 21 times. The mean of the frequency was 9.3 times, the minimum was zero, and the maximum was 21 times. The standard deviation of 6.2 indicates that the frequency of flooding occurrence was close to 9 times across the communities sampled without significant outliers.

Proof of the intersection of municipal solid waste and flooding in the Lagos metropolis

Excessive rainfall and blockage of drainage channels by municipal solid waste caused flooding in 126 (60%) streets. The points where MSW blocked drainage channels were either where two or more drainages crossed (Plate 5) or at points of discharge into canals/lagoons (Plate 6). A total of 222 points were recorded (Figure 2). The LGAs with the highest concentration of blockage points were Shomolu (36), followed by Lagos Island (20). Apapa, Lagos Mainland and Surulere had 19 points each; while Kosofe had 18 points. Ajeromi-Ifelodun had 17. Alimosho and Mushin had 13 points each; Agege 12; Ojo had 9, Eti-Osa had 8; Oshodi-Isolo had 7; Ifako-Ijaiye had 6; while Amuwo-Odofin and Ikeja had the least points of 3. Plate 7 shows a section of the canal along Bakare-Faro Street, Ajeromi-Ifelodun LGA, which was flooded owing to blockage by solid waste. The names of the 126 streets along which municipal solid waste blocked drainage channels in metropolitan Lagos is presented in Appendix 1.

Municipal solid waste disposal methods and frequency of collection as predictors of flooding

Waste disposal methods and frequency of collection were subjected to multiple regression model to investigate their contributions to flooding. The result R^2 (Table 5) indicated that about 66.9% of the number of times that flooding was recorded could be explained by waste disposal methods and frequency of collection. The *F*-statistics showed that the overall regression model was a good fit for the data. It means that the independent variables statistically and significantly predicted the dependent variable (number of times sampled buildings were flooded), $F_{(2, 1022)} = 1034.219$, $p<0.0005$. Therefore, municipal solid waste indicators play significant roles in the occurrence of flooding in the Lagos metropolis.

The coefficient of frequency of waste collection was 0.567. This means that 1% increment in the frequency of waste collection could lead to 56.7% in the number of

Table 4. Total number of times buildings were flooded.

Frequency of flood	No. of building	Percentage (%)
0	60	5.9
1	105	10.2
2	74	7.2
3	49	4.8
4	29	2.8
5	35	3.4
6	19	1.9
7	34	3.3
8	33	3.2
9	78	7.6
10	18	1.8
11	35	3.4
12	78	7.6
13	47	4.6
14	70	6.8
15	79	7.7
16	56	5.5
17	37	3.6
18	25	2.4
19	25	2.4
20	15	1.5
21	24	2.3
Total	1025	100.0
Statistics		
Mean	9.3	-
Mode	1	-
Maximum	21	-
Minimum	0	-
Std. Deviation	6.2	-

Source: Field survey, 2014.

Plate 5. Drainage intersection blocked with MSW along Agege Motor Road, Agege Local Government Area of Lagos State, Nigeria Source: Authors' Field Survey, 2014.

Plate 6. Municipal solid waste blocked a point of discharge into canal at Badia, Ajeromi-Ifelodun Local Government Area, Lagos State, Nigeria (Source: Authors' Field Survey, 2014).

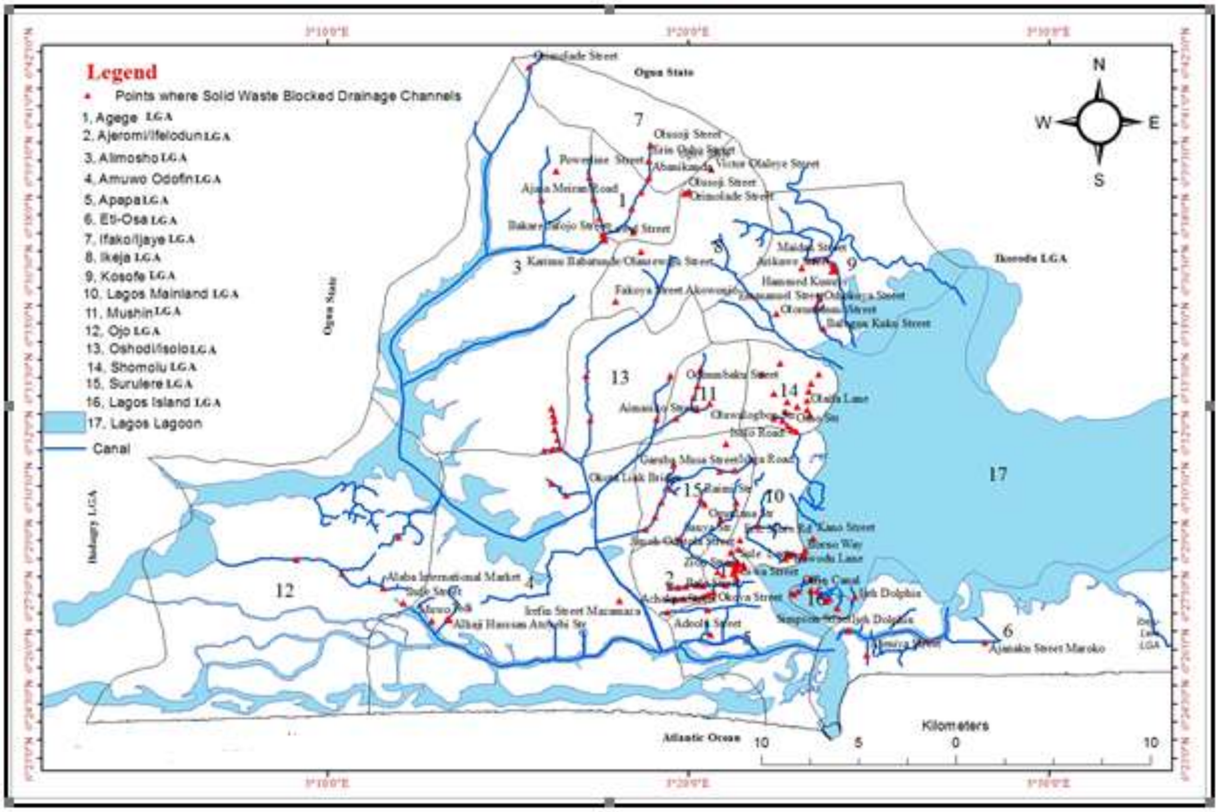

Figure 2. Points where solid waste blocked drainage channels in the Lagos metropolis (Source: Lagos State Ministry of Environment, Ikeja and Authors' analysis (2014)).

Plate 7. Solid waste blocked drainage channels and caused flooding along Bakare-Faro Street, Ajeromi-Ifelodun LGA, Lagos, Nigeria (Source: Authors' Field Survey, 2014).

times the sampled buildings would be flooded. This assertion is owing to the fact that frequency of waste collected by agents who dumped in water bodies was higher than that collected by PSP and LAWMA agents who dumped in designated dump sites.

Also, waste disposal methods produced a coefficient 11.030. This translates into the fact that 1% increment in the number of existing municipal solid waste disposal methods could lead to 11.030% that sampled buildings would be flooded. The two methods approved by LAWMA, as discussed in this study, were dumping in LAWMA communal waste bins, for onward collection by its officials, and collection by PSP. Flooding was predicted from frequency of waste disposal and waste disposal methods. These variables significantly predicted flood, $F_{(2, 1022)} = 1034.219$, $p<0.0005$, $R^2 = 0.669$ at $p< 0.05$.

CONCLUSION AND RECOMMENDATIONS

The study revealed that the quantity of municipal solid waste generated outweighed the amount collected in the Lagos metropolis from 2007 to 2013. Between 2007 and 2013, 77,757,749.8 tons was generated, 21,550,809.73 (27.7%) was collected, while 56,206,940.07 (72.3%) was uncollected.

The uncollected MSW was indiscriminately dumped in unauthorised places, such as road verges, wetlands,

Table 5. Municipal solid waste as predictor of flooding in the Lagos metropolis.

Variable	Coefficient	Standard error	t-statistics	P-Value
Constant	1.216	0.275	4.426	0.000
Frequency of waste collection	0.567	0.255	2.225	0.026
Waste disposal methods	11.030	0.243	45.378	0.000
Diagnostics				
R^2	0.669	-	-	-
Adjusted R^2	0.669	-	-	-
F Statistics	1034.219	-	-	-

Source: Authors' analysis, 2014.

vacant plots and drainage channels. The canals and drainage channels were blocked by MSW of all descriptions and impeded free flow of storm water during heavy rainfall and caused the flooding of 126 streets. The modes of disposal and collection of MSW were PSP (9.9%); LAWMA (11.2%); communal dump-grounds (16.7%), cart pushers (29.2%); burning (1.3%); burying (4.6%); and dumping in canals and lagoons (27.2%). The frequency of municipal solid waste collection was 58.5% weekly, 27.0% bi-weekly and 14.4% daily. The frequency of flooding revealed an average of nine times. The multiple regression test showed that flooding could be predicted from frequency of waste disposal and waste disposal methods; $F_{(2, 1022)} = 1034.219$, $p < .0005$, $R^2 = 0.669$.

The study concluded that the rate and frequency of municipal solid waste collection was unable to keep pace with the rate of generation in the Lagos metropolis, as more solid waste was found in unauthorised places within the environment than designated sites. The unrestrained and indiscriminate disposal of municipal solid waste, particularly in the drainage channels, was identified as one of the major causes of flooding in the metropolis. Owing to the failure of the PSP and LAWMA to adequately collect generated waste, the residents resorted to patronising cart pushers. The cart pushers dumped waste on any available space, drainage channels, wetlands and canals/lagoons, thereby causing flooding. They avoided using LAWMA-designated dumpsites because they had been outlawed.

In order to increase the quantity of MSW collection, the LAWMA framework should be revised by the Lagos State House of Assembly to either include cart in the fleet of LAWMA to enable access to flood-prone areas in the metropolis or integrate cart pushers into formal MSW management systems. As revealed in this study, cart pushers enjoyed more patronage than LAWMA and its agents. Also, LAWMA and PSP should increase both the areal coverage and the number of times they collect waste weekly from residents in order to reduce the incidence of flooding in the Lagos metropolis. Solid waste deposited in communal dump grounds should be properly evacuated by LAWMA. The Drainage Department, Ministry of Environment should establish units in all the LGAs to manage storm water drainages and always keep them free of MSW of all descriptions.

After establishing effective modalities to reach all residents in flood-prone areas and improve areal coverage and frequency of waste collection, refuse guards should be reinvigorated and stationed at communal dump grounds. They should be given the mandate to arrest and subsequently prosecute recalcitrant residents to serve as a deterrent to others. If waste collection issues are handled properly, waste management would serve as a complementary and an effective measure to managing flooding. By this, every effort put forward to manage drainage channels in the metropolis will become meaningful.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Appendix 1. Names of Streets per LGA where solid waste blocked drainage channels in the Lagos Metropolis.

LGAs	Streets
Agege	Bank-Shonibare, Kareem Babatunde, Kasumu, Lambe Kudasi, Lanre Towobola Crescent, Amoo, Odejobi
Ajeromi-Ifelodun	Adeponle, Ago Hausa, Akanbi, Makanjuola, Market, Akinbola lane, Church, Akinola, Igbaja, Ikenne, Ugbewankwo lane
Alimosho	Ajasa Meiran Road, Abanushi (Egbe), Pipeline (Abule-Egba), Powerline, Ogo-Sioni, Prince Adeyemi, Fakoya (Akowonjo), Akinrosoye (Egbe)
Amuwo-Odofin	Irefin Street Mazamaza, Sheu Area
Apapa	church (badia), ireti owoseni (badia), lawani close badia, hamzat lawal (badia), sule lane (badia), adetola (badia), daramola (badia) ojora (badia), giwa (badia), obale (badia), akoshile (badia), oranyan, gaskiya college road, warehouse road
Eti-Osa	Ajanaku (Maroko), Ajegunle (Maroko), Ajeniya (Obalende) ,Ijeh Dolphin
Ifako-Ijaiye	Hamadiya, Erin Osho, Orimolade Street, Victor Olaleye, Lijoka
Ikeja	Adekunle Fajuyi Road, Iyanda Salawu
Kosofe	Awolowo, Oladoja, Arikawe, Benson Omodunni, Hammed Kunuyi, Olatunji Ige, Emmanuel, Oshokoya, Segun Salau, Ladega
Lagos Island	Griffin, Anikantamo, Dosumu, Simpson, Odunfa, Oroyinyin, Offin Canal, Ojogiwa, Olowu, John
Lagos Mainland	Freeman, Akilolu, Fagbayi, Borno, Kano, Redemption, Odunfa, Oko-Baba Area, Adebisi, Herbert Macaulay
Mushin	Garuma Market, Garuba Musa, Seriki Compound, Ishaga Road, Tappa, Tawose
Ojo	Alaba Inter. Market Rd, Tedi Area, Muwo Area, Ilufe, Alaji Hassan Atoyebi
Oshodi-Isolo	Okeleye, Odunbaku, Ogunkoya, Aimasiko
Shomolu	Osho, Basorun, Oreofero, Oluwalogbon, Ali, Anifowose, Oderemo, Awofoju, Ajiwun, Onajimi, Pedro Road, Omo Alade, Alafia, Arikewuyo, Ojelode, Johnson, Odunlami, Somunmi
Surulere	Ahaji Masha Crescent, Iponri, Rabiatu Thompson Crescent, Ajao Road, Shonu Road, Shotanwa, Ogunlana Road, Ogunlana, Okesuna Road, Olukole Street, Oshogbo street

Source: Author's Field Survey, 2014.

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Analysis of trends in rainfall and water balance characteristics of Awka, Nigeria

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This paper analyses the trend in rainfall and water balance characteristics of Awka, Nigeria using the monthly rainfall data retrieved from the archives of the Nigeria Meteorological Agency in Lagos from 1976 to 2015. The tools employed for the study are linear regression analysis, cumulative sum (CUSUM) technique, Walter's cumulative index analysis and Thornthwaite's method. Rainfall was observed to have declined and generally below the climatological mean in the first decade, while from1988 to early 2000s, rainfall has maintained a steady rise. The length of rainy season has shown significant number of variations, but has recorded a general increase. The rainfall onset and cessation periods were predominantly March/April and October, respectively though significant changes in onset periods has been evident in the last 10 years with 6 out of the 10 having onset occurring in February. This study observed a reduction by one month in the periods of soil moisture utilization and increase by the same amount in the periods of soil moisture recharge. As a consequence, amount of water surplus has increased. However, this study provides explanation on the current state of rainfall in relation to climatic water budgeting for Awka and as such important for agricultural and water resource planning.

Key words: Cumulative sum technique, water balance components, Walter's cumulative index analysis, Thornthwaite's method.

INTRODUCTION

Precipitation, in all its forms, is an important element of the physical environment and as such constitutes one of the most valuable sources of water, a strategic resource for human survival and social development. It is the most important hydrological input parameter and hydro climatic factor affecting man and his productivity (Bardossy, 2001; Ojo, 1990). Rainfall is one of the major factors affecting food security especially in countries largely or highly dependent on rain-fed agriculture, given that, in addition to evaporation rate and soil characteristics, it controls the state of soil moisture. The role of moisture in agricultural production is even more important in the tropics, especially Nigeria, where rainfall is highly seasonal over most parts and varies from year to year, while the growing season is determined by the availability of rain to meet crop water requirements (Ayoade, 2008). Consequently, IPCC (2007), in its synthesis report: summary for policy makers, projected that by 2020, in

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some countries, yields from rain-fed agriculture could be reduced by up to 50%, while agricultural production including access to food, in many African countries is projected to be severely compromised.

Among the hydrological aspects of precipitation studies, as outlined in Ayode (1988), are studies relating to variations in precipitation distribution in both space and time and analysis of precipitation data for hydrological purposes such as determination of run-off, groundwater recharge, soil moisture, flood forecasting and prediction. Precipitation is both spatially and temporally very variable while such characteristic has its attendant consequences. Ojo (1990) acknowledged that recent variabilities in precipitation have led to considerable shortages in water supply and a lot of hardships for urban population, while Bardossy (2001) is of the view that intense local precipitation, prolonged and spatially distinct rainfall events have provoked floods both in small/medium catchments and large rivers. In a more recent study, Ezenwaji et al. (2013) observed that climatic elements (temperature and rainfall) were the greatest contributors of flooding in Awka town, Nigeria during the period 2000 to 2009. Similarly, relative to the largely homogenous changes expected in temperature, precipitation trends and changes with climate reflect a more regional nature as Blake et al. (2011) noted that over the past century, the most rapid rate of precipitation increase has occurred in Sao Paulo, Brazil (+29 mm per decade) and the largest decrease has occurred in Harare, Zimbabwe (-21 mm per decade).

Thus, recent climatic variability, and most particularly rainfall variations are becoming increasingly of concern to researchers, institutions and governments. To predict future developments, past statistical trends can be considered along with physically-based climate model projections (Bardossy, 2001). Some studies based on statistical examination (Odjugo, 2010) and climate model projections (Abiodun et al., 2011) have shown that changes in precipitation behaviour is already evident in Nigeria. In addition, other scientific interests in Nigeria range from studies examining rainfall anomalies (Olaniran, 1991, 2002), to works analyzing rainfall trends and periodicities (Obot et al., 2011; Adefolalu, 1986; Ayoade, 1973; Ojo, 1990; Ezenwaji et al., 2014), to studies on rainy days (Olaniran, 1990; Omagbai, 2010a; Olaniran, 1984, 1987), seasonality (Adejuwon, 2012; Adefolalu, 1983; Adejuwon, 1990; Omagbai, 2010b), Onset, periodicities and reliability (Ilesanmi, 1972; Ayoade, 1974, 1975) and the trend of precipitation and annual water balance (Ojo, 1990).

However, examination of precipitation characteristics and trends is of great importance. It is known that possible changes in precipitation behaviour can have huge effect on the entire water balance characteristics of a region. Yet, there are few studies on the recent trends and climatic water budgeting in Nigeria, while none of such studies is in existence for the Awka region under consideration in this study. Thus, the aim of this study is to examine the result of the water balance computation in relation to current trends of precipitation and aspects of the problems such as flooding, water supply, erosion, etc., highlighted by some studies in the study area. Thus, this study intends to contribute to the growing understanding of rainfall characteristics and variability in Nigeria.

Study area

Awka is located in the eastern part of Anambra State, South-Eastern Nigeria (Figure 1). It is bounded by latitudes 6° 10^{1}Nand 6° 17^{1}N and longitudes 7° 2.4^{1}E and 7° 7.2^{1}E. The topography is characterized by rugged relief and it lies completely on the Awka-Orlu upland (Ezenwaji et al., 2013). The climate of Awka is the tropical wet and dry type according to Koppen's classification system. The seasonal distribution of rainfall is controlled by the movement of the intertropical discontinuity air masses (ITD).

The rainfall pattern, which is controlled by the movement of the ITD, is characterized by a dry season, November to March, with dry continental North-East winds dominating during this period and a long wet season which occurs normally from April to October and dominated by the moist maritime south-west winds. In recent times, the onset and cessation periods of the rain in the study area has been observed to vary over time. The mean annual rainfall is about 1900.5 mm. The mean minimum and maximum temperatures are 23.5 and 32.1°C, respectively.

METHODOLOGY

Data collection

Monthly rainfall dataset for this study was obtained from the Archive of the Nigerian Meteorological Agency (NIMET), Lagos, Nigeria for the study area. It covers a period of 40 years (1976 to 2015). The data was used to evaluate the temporal variations in precipitation characteristics of Awka and to determine other precipitation characteristics. The monthly values of rainfall for each year were summed for the 40 year period to generate annual rainfall values for the study area.

Data analysis

The temporal variation in the annual rainfall values at the study area was investigated. Trend in the time series was determined using linear regression. Having revealed so many fluctuations that the general trend of the individual variable may not be easily determined, a smoothening function was applied to the data. Thus, trend analytical technique and regression analysis were used to analyze the data.

For rainfall variabilities within the study area, mean deviation and standard deviation were calculated. In order to further explore charges in rainfall with time, mean annual rainfall was calculated at decadal intervals, that is, 1976 to 1985, 1986 to 1995, 1996 to 2005 and lastly, 2006 to 2015.

The cumulative sum technique (CUSUM, 1975), a variant of the

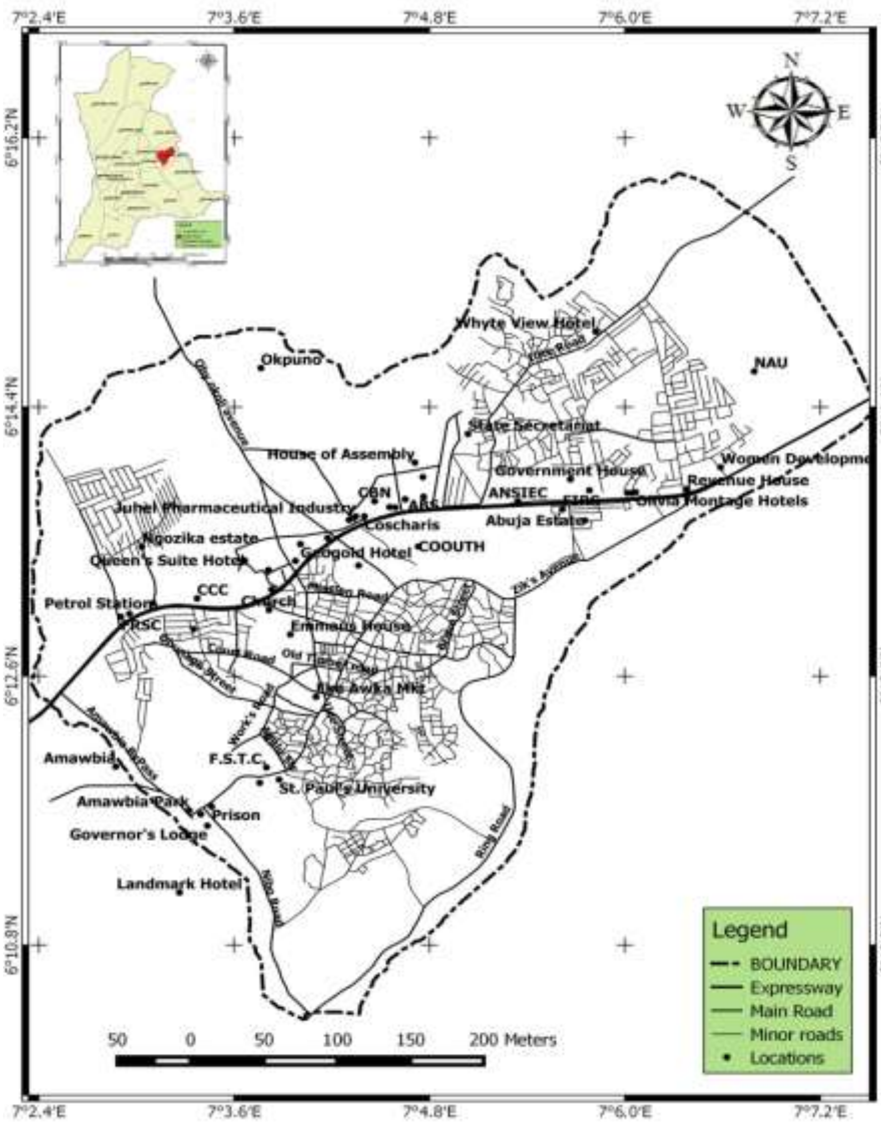

Figure 1. Map of Awka urban area.

residual mass technique, was used to examine the temporal sequence of rainfall. This technique has been proved to be a valuable tool in detecting intermediate-term changes in the mean value of a sequence of regularly spaced observations (Crapper et al., 1996). The cumulative sum s_i can be defined as:

$$s_i = \sum_{i=1}^{i} (x_i - \dots$$

where x_i is the regularly spaced observation.

It can be used to detect intermediate changes in the mean values. The ordinate values are not relevant, it is the slope that is important (Crapper et al., 1996).

Attempt was made to determine the onset, duration and cessation of the rainy season in the study area for the period under investigation. This was based on method of Walter (1967) where onset of rains in Nigeria is defined in terms of the time of receiving an accumulated amount of rainfall in excess of 51 mm. The actual date of onset of rain is computed using the formula:

Days in the month × (51 - Accumulated rainfall in previous month) / (Total for the month)

The cessation is the date after which no more than 51 mm of rain is expected. The formula is applied in reverse order by accumulating total rainfall backwards from December to obtain the actual date of cessation. The duration between onset and cessation of rains represent the number of rainy days or length of rainy season. The method described in Walter (1967) is an effective method for determining effective rainfall by growing season in the tropics. This method has been applied by Adejuwon (2012) to study seasonality in the Niger Delta belt of Nigeria. The rainfall threshold value is defined thus: a day in which the rainfall amount is accumulated to51 mm is regarded as a rainy day and designated onset, while the

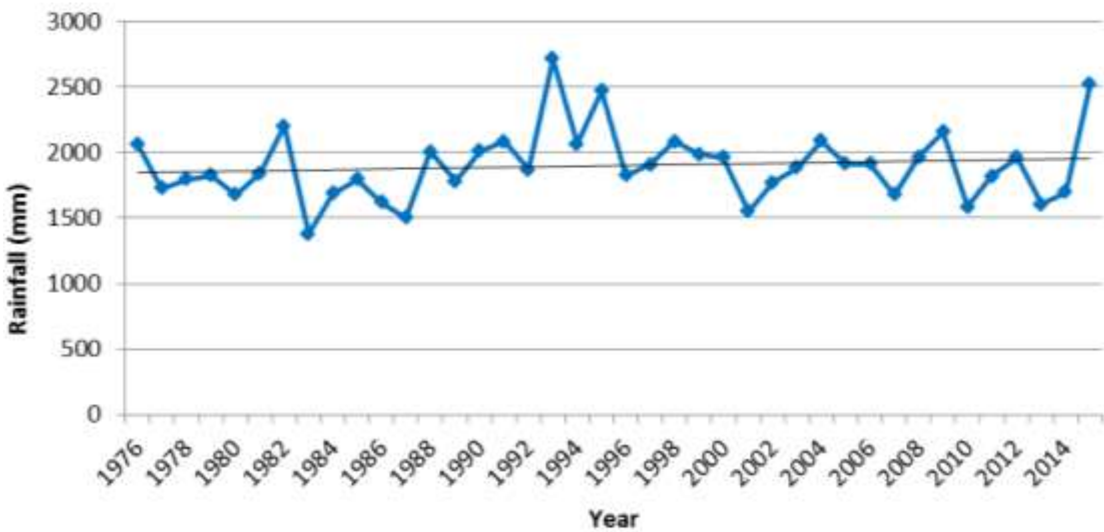

Figure 2. Rainfall distribution in Awka between 1976 and 2015.

cessation of rains is the date after which less that 51 mm of rain is expected. This amount ensures sufficient moisture in the soil to maintain crop growth and gives a reasonable guarantee that planting would be successful if started two weeks later (Adejuwon, 2012). The onset, cessation and duration of rainfall was calculated for Awka using the Cumulative Index Analysis (Adejuwon, 2012) of Walter (1967).

In addition, correlation analysis was performed to determine possible relationship between the number of rain days in a year and annual rainfall for that year.

Water budget computation was done for Awka in order to estimate values of evaporation (AE), water deficit (WD) and water surplus values (WS). This was done for the specified decades earlier. The model used is based on Thornthwaite and Mather (1957) which has also been used by Ayode (1973) to compute water balance for Jos and Calabar, Nigeria. If the appropriate monthly values of these parameters are plotted as indicated in Figure 2, we can determine as outlined in Ayoade (2008) the following:

(1) The period of moisture utilisation which is the period when AE > P.
(2) The period of water deficit which is the period when PE > AE.
(3) Period of soil moisture recharge which is the period when P > PE but the soil is not yet at field capacity.
(4) Period of water surplus which is the period when P > PE and soil is at field capacity.

Soil moisture holding capacity of 250 mm was adopted for Awka based on Thornthwaite and Mather (1957) in Ayode (2008). The potential evaporation (PE) was estimated using the formula by Thornthwaite and Mather (1957), while the relative amounts of water surplus were estimated at decadal intervals based on the same method.

RESULTS

The average annual rainfall for the 40 year data is 1900.2 mm and the standard deviation is 269.8 mm, giving a coefficient of variation of 14.2%. The trend characteristics of rainfall achieved is as shown in Figure 2.

The high irregular nature of the plot shown in Figure 2 demanded the application of a smoothening function which is the moving average. The plot of a 5 year moving average of rainfall is as shown in Figure 3. While the trend is not statistically significant with a coefficient of 0.125 at 0.05 level of confidence , it is evident that the direction of rainfall is positive and the rate of this trend is indicated by an annual rate shown by the slope of the regression coefficient (b = 2.925). The trend plot of rainfall shows that at the start of the studied period (1976 to 2015), rainfall decline was recorded within first few years of the first decade (1976-1985) and was generally below the climatological mean rainfall (1900 mm) up until 1987 after which increasing rainfall was noticed for Awka. However, rainfall was found to be more pronounced between 1988 and 2000, a period that could be ascribed as wetter than any other within the studied period. A graph of rainfall anomaly (Figure 4) was also shown to give a clearer picture on rainfall condition in Awka. The rainfall anomalies relative to 1976 to 2015 normal provide evidence to the 1988 to 2000 wet period and to a more recent increase in the rainfall trend, which was more from 2004. Between 1976 -1987, rainfall was below the 1976 to 2015 normal, while from 1988 to 2013, the years with rainfall values above normal are more; 21 out of the 40 years were below normal but only 19 years (47.5%) out of the 40 years were above the normal.

The maximum and minimum rainfall for the 40 years period were recorded in 1993 and 1983, respectively (Figure 4). The 40 years mean monthly rainfall distribution (Figure 5) shows that the monthly rainfall characteristics is bi-modal with the first peak occuring in July followed by the second peak recorded in September.

The CUSUM distribution for the annual rainfall is as shown in Figure 6. The cumulative sum reveals runs of

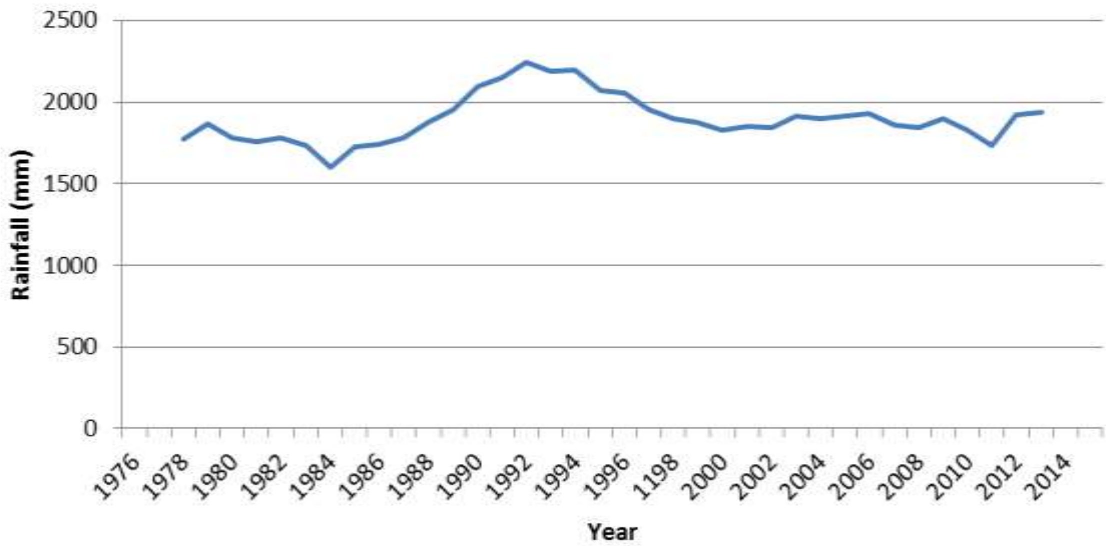

Figure 3. Five years moving average plot for rainfall of the area 1976-2015.

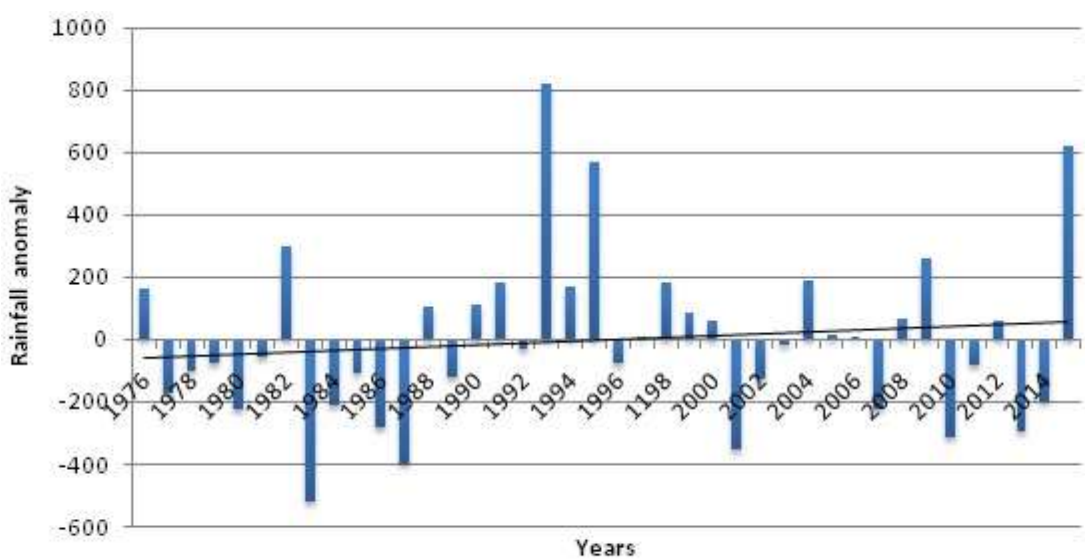

Figure 4. Rainfall anomaly in the Lake area using the period of 1978 – 2013 as normal.

observations greater than the long-term mean with a positive slope and those less than the long-term mean with a negative slope.

An examination of Figure 6 reveals that the 40 years of records can be treated as consisting of two distinct average rainfall periods. The first period from 1976 to 1987 consist in a period of less than average rainfall; the second period, from 1988 to 2000 was a period of above average rainfall followed by a more recent period of slight uncertainty given that subsequent years after 2004 have rainfall fluctuation intermittently above and below the mean. The term average rainfall is used to refer to the 40 years mean. These trends are also apparent in Figure 2, but much more difficult to discern and in Figure 5.

Onset, cessation and rainfall duration

It was evident that onset of rains was predominatntly in the month of March followed by April and February with the number of years for the individual months under the 40 years period being 20, 9 and 7 years, respectively (Table 1). The cessation period was found to be predominantly October followed by November. Thus,

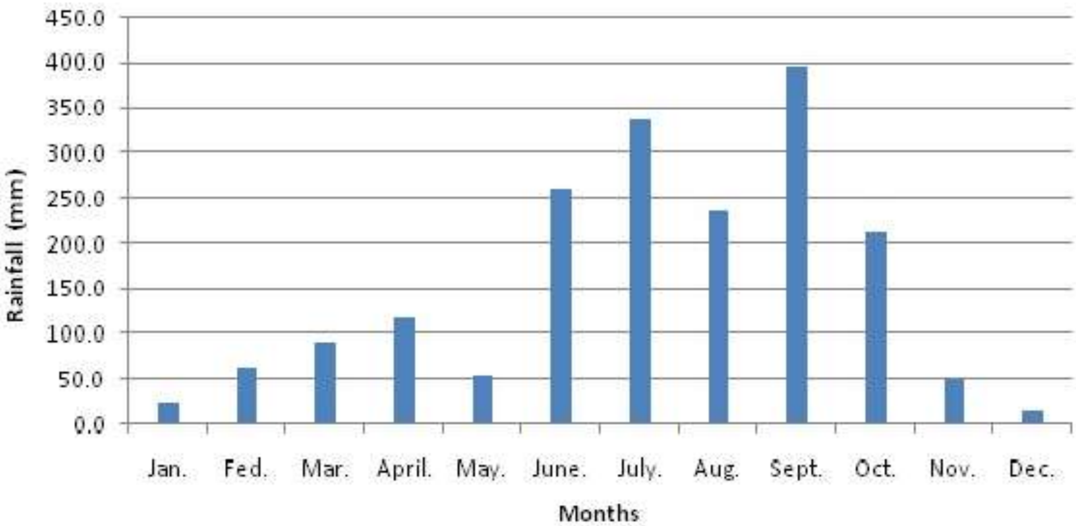

Figure 5. Mean monthly rainfall condition in Awka (1976 – 2015).

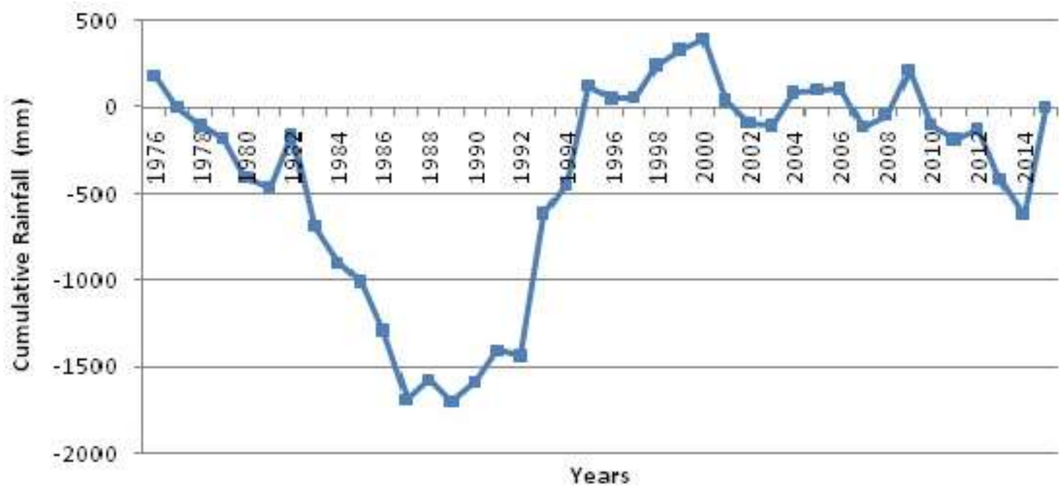

Figure 6. A CUSUM plot of annual rainfall.

rainfall starts in Awka around March/April and terminates in October/November. However, it does appear that periods of onset and cessation of rain are changing with onset of rains occuring more in January and February in the last 10 years and cessation still in October. Similarly, a slight increase in the number of rainy days was observed for Awka, while the relationship between annual rainfall and number of rainy days (Figure 7) was found to yield a positive correlation $r = 0.485$ ($p = 0.05$) with coefficient of determination of $r^2 = 0.24$.

Water balance components

A comparison of the patterns of mean decadal monthl water budget characteristics for Awka as depicted in Figure 8a, b, c, and d shows some differences. The values of PE estimated for the four decades using Thornthwaite's formular were used while soil moisture holding capacity of 250 mm was assumed. These were used to provide estimates of monthly and annual values of actual evapotranspiration (AE), water deficit (D) and water surplus (S) for the four decades under consideration.

The relative amount of water surplus vary amongst the four decades. For example, the 1986 to 1995 had the highest value of water surplus of about 599.3 mm followed by the 1996 to 2005 decade for which 522.8 mm of rainfall occuring as surplus was recorded based on estimation of monthly values. This further validates and supports the assertion made earlier that from around 1988s and early 2000s can be categorised as wet period.

Table 1. Dates of onset and retreat of rains in Awka and the number of rainy days in a year.

Year	Onset	Cessation	Number of rainy days	Year	Onset	Cessation	Number of rainy days
1976	10th February	23rd November	287	1996	11th March	25th October	229
1977	17th March	28th October	226	1997	13th March	10th November	243
1978	22nd February	26th October	248	1198	28th March	27th October	214
1979	30th March	10th November	226	1999	6th March	1st November	241
1980	3rd March	14th November	257	2000	3rd March	24th October	236
1981	23rd March	28th October	220	2001	1st April	20th October	203
1982	18th February	25th October	250	2002	2nd April	29th October	211
1983	19th March	12th October	181	2003	5th March	28th October	238
1984	16th March	22nd October	193	2004	3rd April	30th October	211
1985	7th March	21st October	229	2005	23rd February	25th October	245
1986	11th March	8th November	243	2006	12th March	28th October	231
1987	5th May	25th October	174	2007	5th April	28th October	207
1988	13th March	25th October	227	2008	16th March	28th September	197
1989	7th April	28th October	205	2009	14th January	14th November	305
1990	6th April	1st December	240	2010	21st February	29th October	252
1991	4th March	27th October	238	2011	17th March	29th October	227
1992	11th April	3rd November	207	2012	10th February	31st October	264
1993	8th April	30th November	237	2013	10th March	24th October	229
1994	2nd April	3rd November	216	2014	23rd January	8th November	290
1995	25th January	31st October	280	2015	9th February	3rd October	237

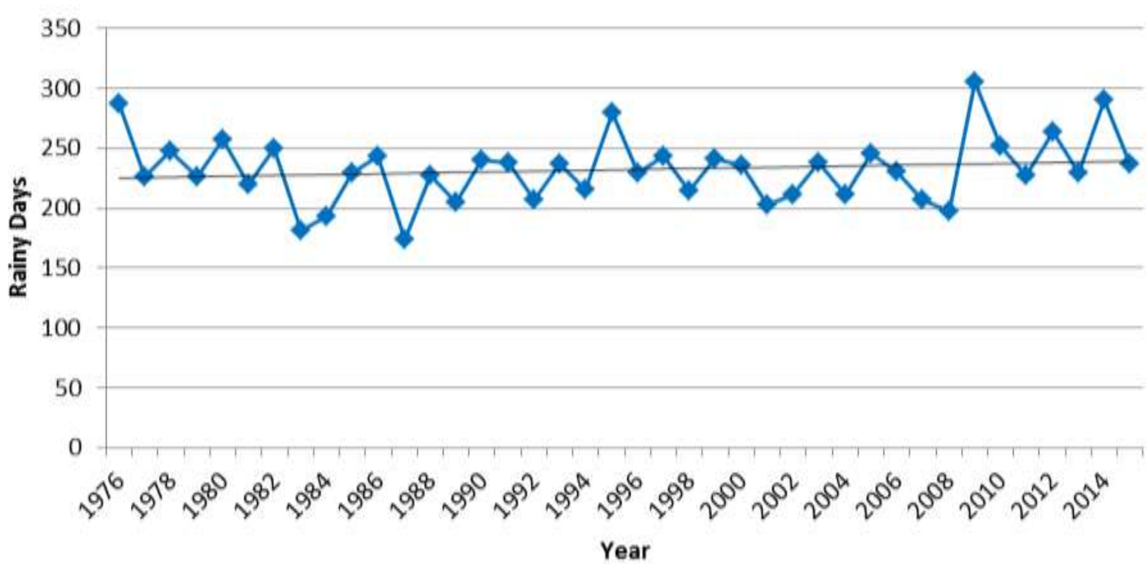

Figure 7. Variations in the number of rainy days in Awka (1976 – 2015).

The mean water surplus for the four decades (40 year period) is 499 mm. The period of soil moisture utilisation in Awka was found to be from January to April and November to December the first two decades, while this was found to have reduced by one month for the last two. Thus, for 1996 to 2005 and 2006 to 2015, the period of soil moisture utilisation was from January to March and November to December. Similarly, annual values of AE was shown to be on the increase (Table 2 and Figure 8). The highest for AE of 1411 mm was estimated for 2006 to 2015 period. Thus, though the number of months for which AE > P has reduced by one, the mean decadal

Table 2. Water balance relations of Awka.

Parameter	1976 – 1985 (mm)	1986 - 1995 (mm)	1996 - 2005 (mm)	2006 - 2015 (mm)
Precipitation	1775.3	1927.4	1897.6	1900.5
PE	1740.2	1776.7	1816.1	1781.4
AE	1340.4	1328.1	1369.8	1411.0
Water deficit	399.8	448.6	445.9	404.7
Water surplus	434.9	599.3	527.8	433.4

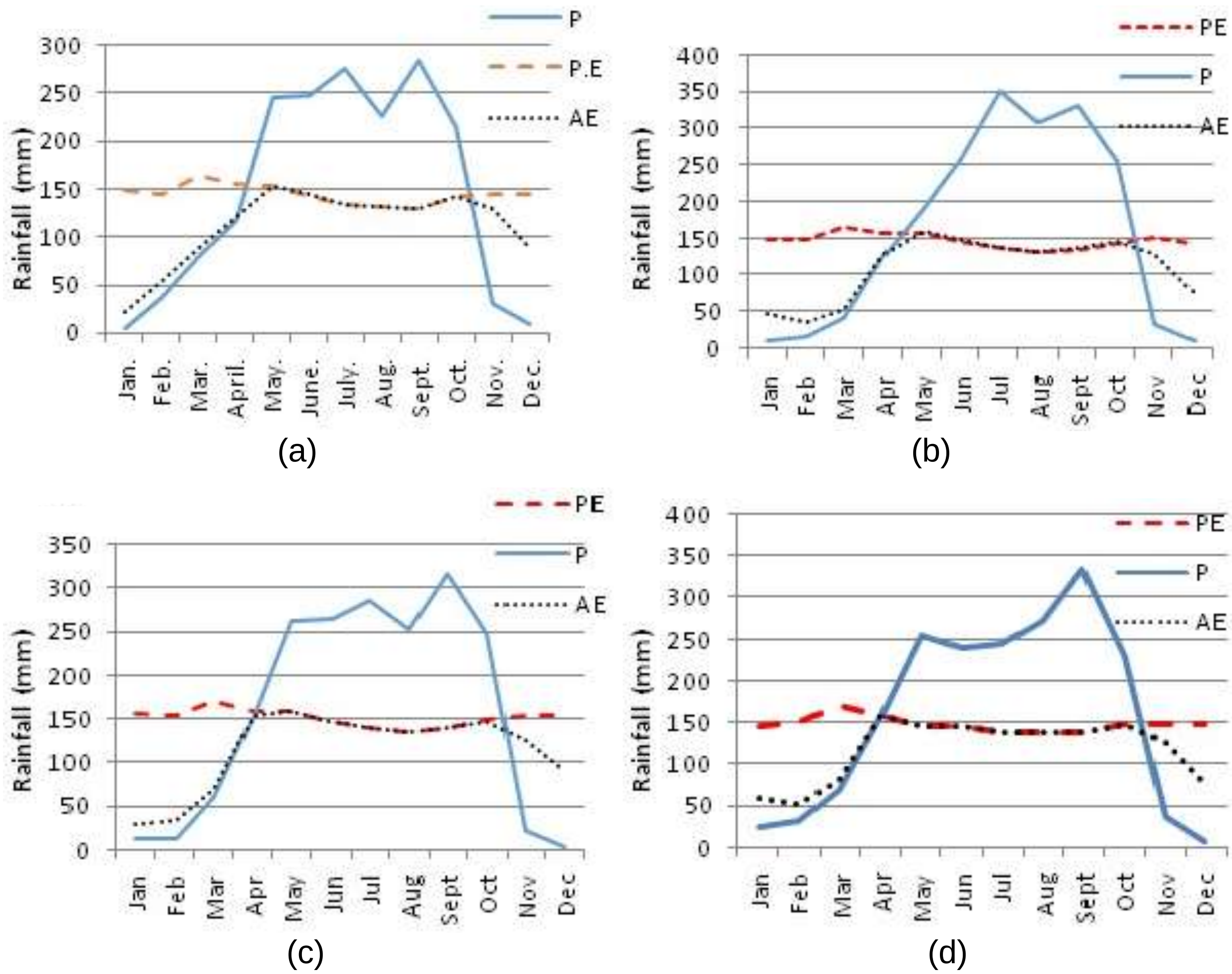

Figure 8. Water Balance Graph for Awka 1976 - 2015.

values of AE for the 40 years period have shown a consistent increase; a stong indication of possible contribution of increasing temperature to increasing evaporation rates (Nzoiwu, 2015) and the possibility of the monthly rates of evapotranspiration becoming more intense.

In the same vein, the period of water deficit (PE > AE) reduced by one month in the last decade, an indication of AE closing in on PE given the available energy and water availability due to increasing rainfall observed for Awka.

Similarly, period of soil moisture recharge before field capacity was discovered to be consistently between May and June for the following periods: 1976 to 1985, 1986 to 1995 and 1996 to 2005, while this was found to be from April to June in the last 10 years following the reduction in the number of months for soil moisture utilization. Water surpluses have been shown to consistently occur from July to October for the whole 40 years period given that the soil reaches its field capacity in July throughout the period in the study area.

DISCUSSION

The annual rainfall in Awka varies from slightly over 1370 mm to more than 2700 mm for the 40 years period under study. The mean annual rainfall for the period is 1900.5 mm, while the standard deviation and coefficient of deviation are 269.8 mm and 14.2%, respectively. It was observed based on the trend plot for rainfall that this climatic variable is changing. The direction of the trend is positive and is evident that rainfall is rising annually given the slope of the regression coefficient. The trend plot (Figure 2) shows that at the start of the studied period (1976 to 2015), rainfall decline was recorded within the first decade (1976 to 1985) until 1987 after which increasing rainfall was noticeable for Awka. This increase was found to be more pronounced between 1988 and early 2000s. A graph of rainfall anomaly (Figure 4) was also shown to give a clearer picture on rainfall condition in Awka and as such a further confirmation of the assertion on the direction of the rainfall trend. The rainfall anomalies relative to the 1976 to 2015 normal provide evidence to a more recent increase in the rainfall trend which was more from the late 1980s.

CUSUM technique showed a similar picture when used to examine the temporal sequence of rainfall in Awka. The CUSUM distribution for the annual rainfall as shown in figure 6 can be treated as consisting of two distinct average rainfall periods. The first period from 1976 to 1987 consisted of a period of less than average rainfall while the second period 1988 to early 2000s is a period of above average rainfall with some uncertainty up to 2015; a further proof that rainfall condition in Awka is experiencing an upward trend. Therefore, the period lasting from 1988 to early 2000s can be classed as the wettest period given that the highest annual rainfall amount recorded during the 40year period occurred in 1993, while the majority of the years has annual rainfall total above average value. The monthly rainfall characteristics of Awka was determined using the available data and is shown (Figure 5) to be bimodal with the first peak occurring in July followed by a second peak in September after which rainfall maintains a downward trajectory for the remainder of the year.

Onset of rains was found to be predominantly in the month of March/April, while cessation was predominantly October/November. It does appear, however, that the period of Onset of rains is changing with this occurring more in January/February in the last 10 years, while cessation of rains remained almost undeterred. Consequently, a slight increase in the number of rainy days was observed (Figure 6) which could be related to the shift in the onset and cessation dates. A correlation analysis performed, using Pearson Product Moment Correlation, to determine relationship between number of rainy days and annual rainfall yielded a positive correlation, r = 0.485 (p = 0.05). Thus, with increasing number of rainy days, annual rainfall total is expected to increase.

Mean estimated water surplus was calculated and yielded a mean value of 499 mm. The periods 1986 to 1995 and 1996 to 2005 had surplus value above the mean value of 599.3 and 522.8 mm, respectively. This further validates and confirms that 1987 to early 2000s were the wettest period in Awka based on the available 40 year record. The period of soil moisture utilization was found to occur from January to April and November to December from 1976 to 1995, while this was found to have reduced by one month for the last two decades 1996 to 2015 as this now occurs from January to March and November to December. Similarly, values of actual evapotranspiration are shown to be increasing (Table 2). The highest actual evapotranspiration value was estimated for 2006 to 2015 period. This shows that though the number of months during which AE > P has reduced by one, the mean decadal value of actual evapotranspiration maintained a continued increase indicating that the monthly rates of evapotranspiration is becoming more intense attributable to climate variability and change. Also, the period of water deficit was found to have reduced by one month in the last decade, a strong indication that actual evapotranspiration is closing up on the potential evapotranspiration given the availability of moisture. In the same vein, the period of soil moisture recharge before field capacity was found to be consistently May to June from 1975 to 2005 while it was found to have increased by one month as it is now April to June due to a reduction in the number of months for soil moisture utilization.

Moreover, a good knowledge of critical values in the series of various climatic elements such as rainfall and some of their derived parameters is of great importance in detecting variability which has implications for various important sectors, such as agriculture, water supply, flood management etc. Moisture plays a vital role in crop growth and development given that it is the main constituent of plant tissue and a reagent in photo-synthesis. The role of moisture in agricultural production is even more spectacular in the tropics especially Nigeria where high temperature prevail throughout the year and rainfall is highly seasonal in most parts and varies from year to year while the growing season is determined by the availability of moisture to meet crop water requirements (Ayoade, 2008). The state of soil moisture is controlled by rainfall, evaporation rate and soil characteristics (Ayoade, 2008). Thus, from agronomic point of view, the supply of soil moisture may vary from wilting point when no water is available for crop use to field capacity when soil is fully saturated with moisture. These conditions ranging from periods of soil moisture utilization or wilting point to soil moisture recharge, to field capacity and deficit have been determined for Awka as described above. In Ayoade (2008), it is noted that growing season in the tropics is determined by rainfall conditions in relation to evapotranspiration rates which are temperature dependent. Other studies such as Stern and Coe (1982) and Nieuwolt (1982) have confirmed that rainfall is the principal controlling element in agriculture given that in the tropics, rainfall is often the only input that varies markedly from year to year; so the predicted variability in crop index or water balance is due only to the variability in rainfall (Odekunle, 2004). The results of this study, therefore, can find further applications in the determination of the length of the growing season in Awka. Several methods abound as to the determination of growing seasons. These range from those that employ critical threshold values of rainfall to the methods based on rainfall and evapotranspiration data on the grounds that the effectiveness of rainfall for agricultural production in the tropics is determined by the prevailing rates of evapotranspiration. The Walter (1967) method utilized in this paper defined onset and cessation of rainfall in Nigeria in terms of a rainfall threshold of 51mm on a monthly basis and this is used to delimit the beginning and end (and by implication length) of the growing season. Thus, the length of the growing season for Awka has been defined in this paper which has equally shown some level of variations from year to year depending on rainfall variability. Given that a slight increase in the number of rainy days has been reported for Awka, it follows that the length of the growing season has equally increased over time in Awka.

More so, the possible changes in precipitation behavior and the associated water balance and hydroclimatic characteristics without doubt have important consequences on planning and development (Ojo, 1990). As noted, precipitation trends in Awka have shown some slight variations with related changes in water budget components. In most tropical cities, severe hydrometeorological phenomena related to precipitation and water balance have frequently occurred and usually cause great damage leading to loss of lives and property and causing great setbacks in development such as the case of recurring flood episodes in Awka and environs which has been related to climatic parameters as part of the casual factors in Ezenwaji et al. (2013). Other important consequences could range from problems relating to water supply in urban areas due to rapidly increasing water demands to issues of irrigation agriculture given the changing patterns in spatial and temporal rainfall due to climate change. This paper is timely given that the rainfall trend plot for Awka has shone light on the possible feedbacks which may result to more cases of flood. The result has equally shone light on the need for relevant authorities and households in Awka to consider rain water harvesting given that with increase in rainfall trend, the city has an ample supply of rainwater that should not be allowed to waste as flood in some instances with its attendant high magnitude that destroys lives and properties (Ezenwaji et al., 2016).

Conclusion

This paper has attempted to determine the trends in rainfall characteristics and associated water budget components and found that rainfall amounts have continued to increase over 29 years out of the 40 years under study from 1987 to 2015, while the water budget components have equally changed. For agricultural purposes, this paper established that periods of soil moisture utilization and deficit have reduced by a month while period of soil moisture recharge and amounts of water surplus have increased. Also, the length of rainy season or the growing season has been shown to increase due to changes in onset periods in Awka and a positive correlation is seen to exist between the annual rainfall amounts and the number of rainy days in a year. Therefore, given the nature of rainfall trend, the possibility of harnessing rainwater by relevant agencies as well as households is encouraged as this could help satisfy levels of water demand in the Awka urban area. This paper without doubt underscores the importance and usefulness of determining trends in hydroclimatic parameters of a region and associated water balance components given their potential contribution in planning and development (Ojo, 1990). However, important linkages have equally been shown to exist between changes in hydroclimatic parameters and how these changes propagates through changes in the frequency of occurrence of water related problems such as flooding, drought due to changes in periods of soil moisture recharge and utilization and as such should be of concern.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Predicting urban sprawl and land use changes in Akure region using markov chains modeling

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This study makes use of Markov chains modeling to predict sprawl and pattern of land use change in Akure region. Efforts were made to examine the trend of the expansion using Aerial Imagery Interpolation (AII). It focuses on overlaying of Landsat TM imageries of 1986, 2002, 2007 and 2014 to determine the land use changes and extent of expansion between 1985 and 2014. The land use were classified and displayed in colors for better visualization. With the aid of Markov chain modeling, the study made a projection of possible land use area and extent of expansion by the year 2034. Findings revealed continuous expansion in the growth of the city as evident in percentage increase of the built-up area. There were incompatible conversions in land uses and unguided expansions leading to undue encroachment into green areas at the suburbs. It was observed that without appropriate attention to adequate planning for effective measures, the trend of changing agricultural and forested lands to built-up areas will continue to increase with attendant effects on regional environment. Consequently, the study suggests effective zoning strategy and sustainable monitoring measures by different stakeholders in urban planning to check indiscriminate urban expansion in the study area.

Key words: Urban sprawl, land-use pattern, markov chains, landsat TM imageries, Aerial Imagery Interpolation (AII).

INTRODUCTION

Changes in Land Use and Land Cover are urbanization induced which are mainly incited by many factors, such as: human activities, culture, economy, policy making, planning and environment (Houghton, 1994; Chellasamy et al., 2015; Mirkatouli et al., 2015). Rapid pace of urbanization is believed to be a global problem that has led to dramatic change in land use practices in most developing nations of the world. Such expansion has encouraged residential development, leading to urban sprawl and consequently damaged the environment. Balogun et al. (2011) submitted that urban populations in developing countries have grown by 40% between 1900 and 1975. The trend will continue adding approximately 2 billion people to the urban population of the presently less developed nations for the next 30 years.

In a similar way, Arnfield (2003) (cited in Owoeye and Ibitoye, 2016) observed that the world is becoming increasingly urbanized with 45% of the population already living in the urban areas in the year 2000; with a

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projection that half of the world will live in urban areas by 2007. It was also estimated that by the year 2025, 60% of the world's population would live in cities (UNPF, 1999). Akure is not in any way going contrary to this prediction, as the population has been more than triple of what it used to be before it became the administrative headquarters of the state and local governments. Presently, the estimated population is about 476159 compared with 71,106 in 1963, 239,124 in 1991 and 360,268 in 2006 (NPC, 1991 and 2006). Unfortunately, the trend of development in the study area is not reducing in any way, but rather increasing at alarming rate. The thrust of this paper, however, is to use Markov chain model to predict possible impact of urban sprawl on land use changes in Akure region with a view to providing information that will aid policy formulation towards the physical development of the region.

LITERATURE APPRAISAL

Rapid urbanization in developing countries has been a major cause of environmental change (Oyinloye and Popoola, 2015). Urban encroachment and land use/land cover changes around fast-growing cities in the developing world has drawn considerable attention from urban geographers as well as city and regional planners (Rahman, 2016). According to Balogun et al. (2011), they are urbanization induced. Rahman (2016) further stressed that population growth in terms of increased population density is seen as the key factor directly inducing Land Use changes and Urban Sprawl. Land use and land cover change is as a result of high rate of urban growth which according to Yohanna, et al. (2015) is a major phenomenon in our contemporary era. According to Vitousek, (1992), it is a vital key to global change and has significant implications for many international policy issues. Several studies have shown that uncoordinated urban expansion and unplanned land use changes due to urbanization have become a major problem in many urban areas (Chellasamy et al., 2015). Sankhala and Singh, (2014) opined that although urban sprawl is a worldwide phenomenon, the rate of urbanization is very fast especially in the developing countries and further stressed that it is mainly driven by unorganized growth, increased immigration and rapidly increasing population.

Much of this explosive growth has been unplanned. It is quite obvious that most cities in the developing countries have been unprepared for the expansion currently witnessed. These cities are envisaged to double their urban population in the next thirty years, and possibly triple the land area (Angel et al., 2010). The land use/land cover pattern of a region is an outcome of natural and socio-economic factors and their utilization by man in time and space. The term 'sprawl' is basically another word for urbanization which refers to movement of population from populated city centres to lower density areas. Therefore, rapid population growth is a key factor inducing Urban Sprawl as well as changes in land use and land cover. According to Tofowomo (2008), Urban Sprawl is characterized by unplanned and uneven pattern of growth driven by multitude of processes and leading to inefficient resource utilization. Urban Sprawl has its threshold limits. At the lowest end of the spectrum, a city remains uniform and vulnerable to change while rapid unplanned Urban Sprawl exceeding its maximum threshold limit creates chaos and deteriorates the quality of city transportation and utility services (Rahman, 2016).

Urban Sprawl is not only visually unattractive but also not sustainable. An organized and planned Urban Sprawl is essential to build a socially, economically, and environmentally sustainable society. Urban Sprawl has both positive and negative impacts; however, the negative impacts are generally highlighted because sprawl is as a result of unplanned and uncoordinated development. Bhatta (2010) highlighted some of the consequences to include increase in cost of infrastructure and public service cost, impact on wildlife and ecosystem, loss of farmland, increase in temperature, flooding, poor air and water quality, ugly and monotonous suburban landscapes among others. However, many shifting land use patterns driven by a variety of social causes, result in land cover changes that affects biodiversity, water and radiation budgets, trace gas emissions and other processes that come together to affect climate and biosphere (Riebsame, et al., 1994). The rapid growth of the Akure city, particularly within the last few decades, has made it one of the fastest growing metropolitan cities in the South Western Nigeria (Balogun and Samakinwa, 2015). Hence, studies have revealed that Akure just like any other fast growing state capital has been witnessing rapid developmental changes in terms of physical landscape, urban growth and Urban Sprawl (Balogun et al., 2011).

This according to Tofowomo (2008), Oduwaye (2015), Owoeye and Ibitoye (2016) is as a result of population growth, rise in house hold income, ineffective land use, and excessive growth among others. Other major consequences include flooding, poor air and water quality, urban growth, soil erosion, and desertification, etc. The uncontrolled growth of urban development of Akure has adversely affected its ecosystem which has the potency to indirectly reflect on weather parameters with eventual local climate modification (Akinbode et al., 2007; Balogun et al., 2009). In this regard, Kufoniyi (1998), Oyinloye (2010), Olofin (2012), Rimal (2013), Oduwaye (2015) and Owoeye and Ibitoye (2016) opined that there is hardly can we find any vegetation that has not been affected or altered by man in the world.

The emerging consequences of these uncontrolled growth and development on the lives and properties of

Figure 1. Ondo state in the national setting; Source: Dept. of Surveys, Federal Ministry of Works, Abuja (2014).

urban dwellers is becoming an issue that demands attention. In order to mitigate these effects, an organized and planned urban sprawl is essential to build a socially, economically, and environmentally sustainable society. This can be done by formulating policies, plans and programs that are environmentally sustainable and guide development in a way that it will not damage the environment for the incoming generations. The essence of this is to balance environmental protection with economic and social needs. This can be achieved by managing and planning on a sustainable basis through sustainable practices, which can therefore be made possible by examining the dynamics of land use and land cover changes and assessing the rate of urban sprawl that has occurred in the city in recent times. It is on this premise, therefore, that the study is set to investigate changes in Akure urban land use since the past three decades. It adopts Markov chain model to predict the extent of future changes and expansion with a view to providing information that will aid policy formulation towards the physical planning of the region.

MATERIALS AND METHODS

The research locale

The study focuses on Akure city and its adjoining settlements that made Akure region as shown in Figures 2 and 3. Akure is a notable city in the South-western Nigeria which became the capital of Ondo State on February 3rd, 1976. It is located between Latitudes 7^o 15^1 and 7^o 17^1 North of the Equator and between Longitudes 5^o 14^1 and 5^o 15^1 East of the Greenwich Meridian. It is about 204 km east of Ibadan, capital of Oyo state; 168 km west of Benin City, capital of Edo state; 311 km north-east of Lagos; and 323 km south-west of Abuja, the Federal Capital Territory of Nigeria. Akure town spreads over an area of about 15,500 km^2 in about 370 m above the sea level. Its population figure by the National Population Census (NPC, 1963) was just 71,106. With the influx of public servants into the town consequent upon state creation in 1976, the population rose to 239,124 and 360,268 in 1991 and 2006, respectively (NPC, 1991 and 2006) with a projection of 476,159 to year 2014 (on 3.18 annual growth rate) when this study was carried out (Figure 1).

The database

Data collection for this study was essentially through Aerial Imagery Overlay (AIO) with the aid of GIS, RS and personal observations.

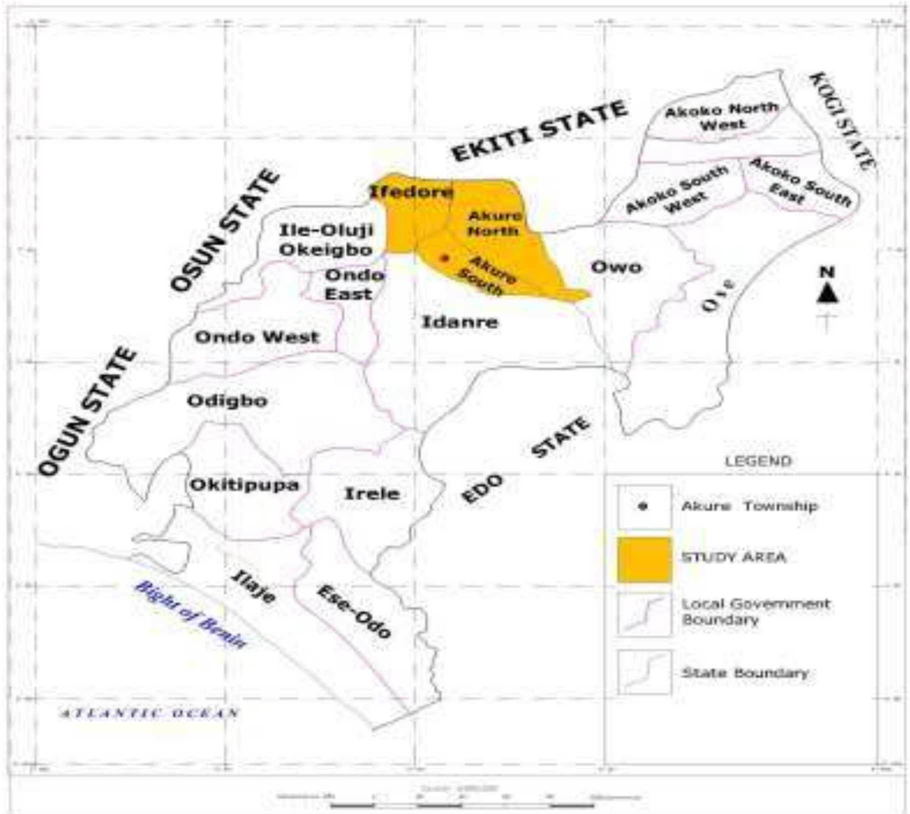


Figure 2. Ondo State and its Eighteen Local Govt. Areas Source: Ondo State Ministry of Lands and Housing, Akure (2014).

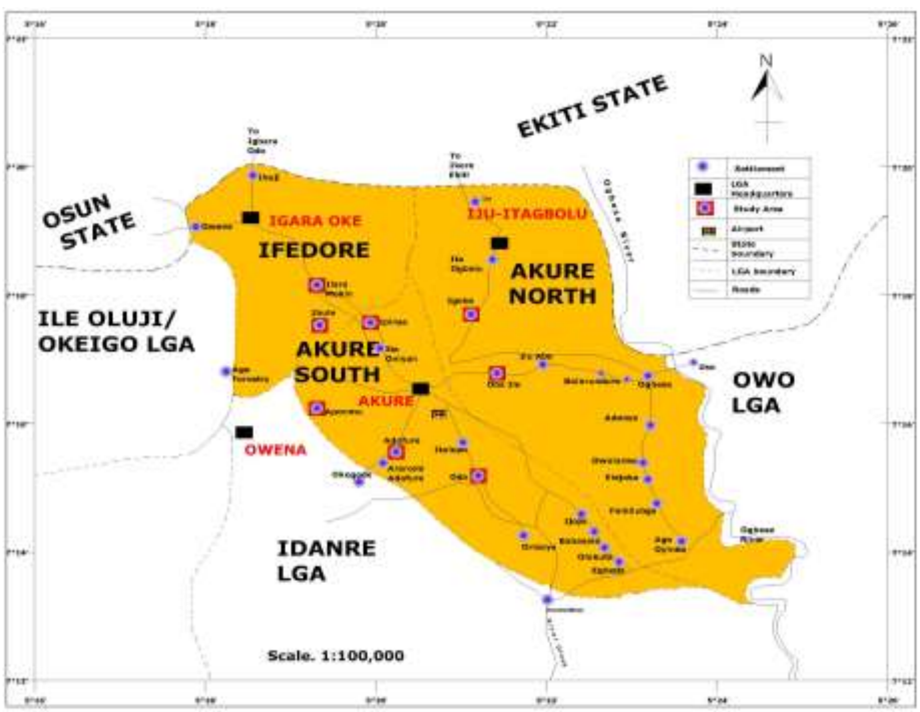


Figure 3. Locational Map of the Study Area in Regional Setting Source: Ondo State Ministry of Lands and Survey, Akure (2014).

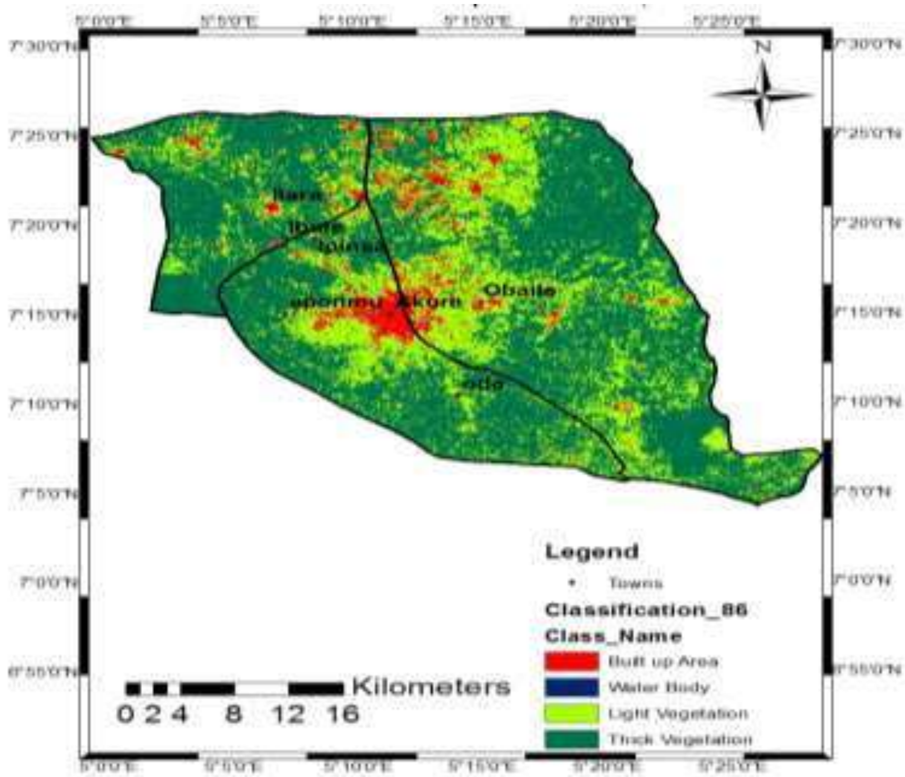


Figure 4. Land Use Classification of Akure as at 1986 Source: Landsat 4 Thematic Mapper (TM) Imagery (1986).

Other sources include government ministries and establishments for historical milieu of the area as well as base maps and population data used for the study. Internet facilities were equally explored for relevant information. The study area has a total (projected) population of 476,159 in 2014 with a total land expanse of 125,212 hectares. The main approach used in this study was mainly post-classification comparison analysis of satellite imageries of Akure obtained at three different decadal variations: 1985 to 1994, 1995 to 2004 and 2005 to 2014. This helps to show the direction and extent of growth in the study area from one period to the other. The land use for the study area is classified into four categories, which include: the built-up area (involving residential, commercial, industrial, recreational and educational land uses); thick vegetation (forested land areas); light vegetation (cultivated land areas), and the water bodies (Rivers, streams, etc).

FINDINGS AND DISCUSSION

Akure Urban sprawl and land use classifications-1986 to 2014

This study has discovered that lager proportion (80,796 ha.) of the study area were covered with thick vegetation as at 1986, which accounted for 64.53% of the land area while 37,977 hectares (30.33%) were cultivated and covered with light vegetation. Only about 5.1% was developed and used either for residential, commercial, recreational, industrial or educational purposes. This occupied just about 6,384 hectare (5.1%) land area while only about 56 hectares (0.04%) were covered by water. This situation expresses the low level of development as at 1986 with a small compact urban area as shown in Figure 4. In 2002, as revealed in Figure 5, the percentage of built-up area had increased from 5.1% (in 1986) to 16.63% (20,885 ha.). The cultivated land area (that is, light vegetation) also increased from 30.33 to 55.06% (68,940 ha.) while the area covered by thick vegetation reduced drastically from 64.53 to 26.34% (32,978 ha.). This shows there was much development and sprawling in cities and major towns in the region through building constructions and provision of public utilities through which much of the thick vegetation were depleted.

In 2007, the built-up area further increased to about 22,985 hectares (18.36%) as well as light vegetation cover to 82,415 hectares (65.82%). But land areas covered by thick vegetation and water body reduced to 19,002 hectares (15.18%) and 811 hectares (0.64%) respectively. This is well illustrated in Figure 6. While the land use for the built-up area continue to increase, those covered by thick and light vegetation as well as water bodies reduces in 2014. As revealed in the Figure 7,

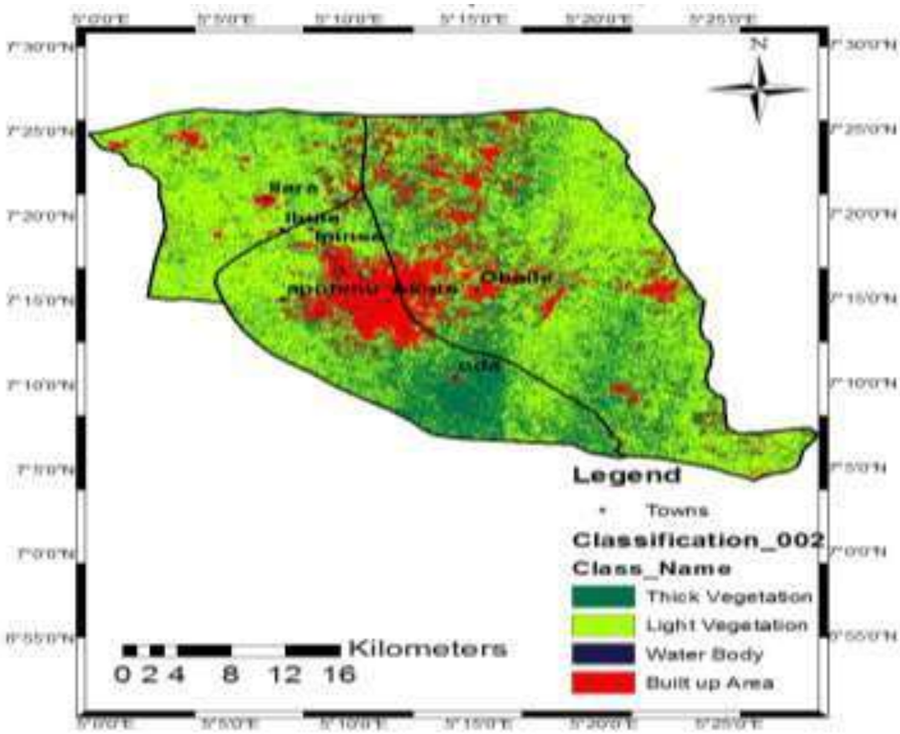


Figure 5. Land Use Classification of Akure as at 2002; Source: Landsat 7 Enhanced Thematic Mapper (ETM^+) Satellite Imagery (2002).

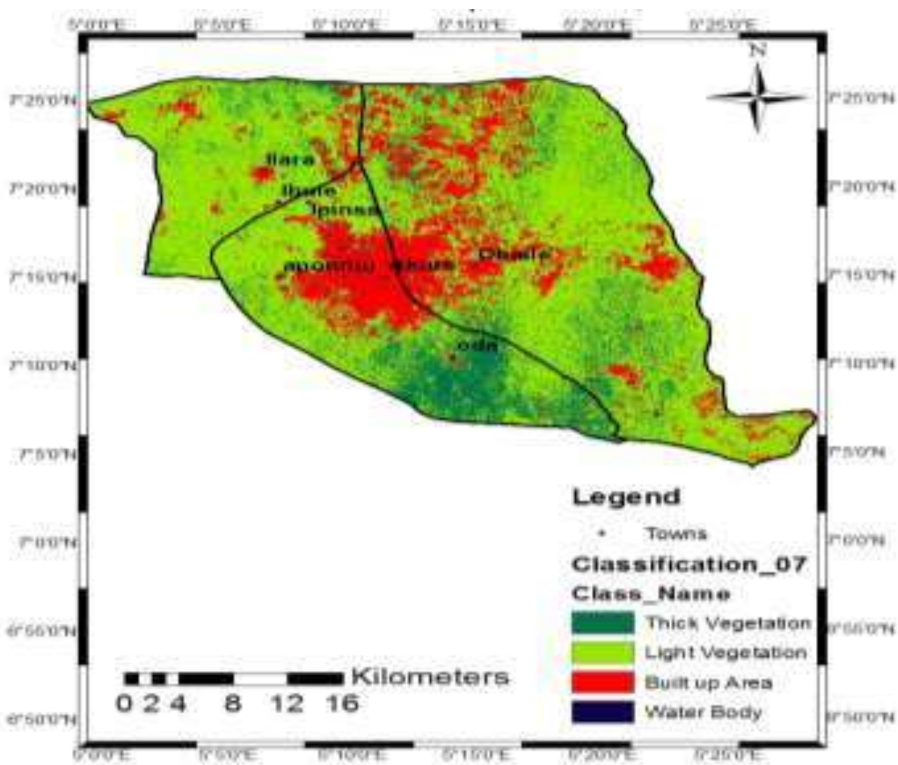


Figure 6. Land Use Classification of Akure as at 2007; Source: Landsat 7 Enhanced Thematic Mapper (ETM^+) Satellite Imagery (2007).

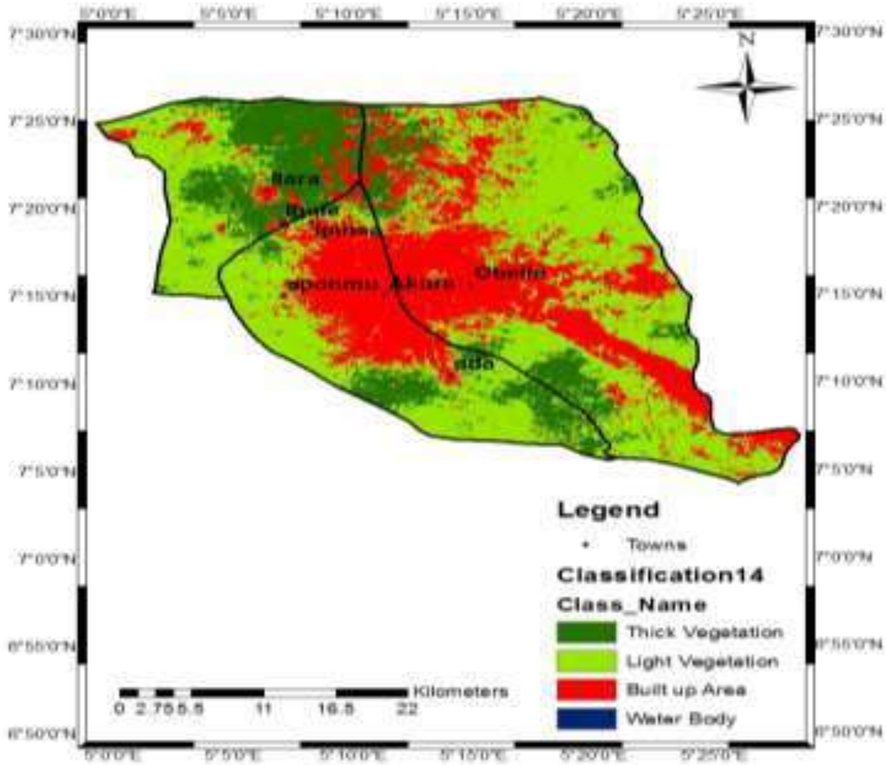


Figure 7. Land Use Classification of Akure as at 2014; Source: Landsat Operational Land Imager (OLI) Satellite Imagery (2014).

land use for built-up area had increased from 22,985 hectares (18.36%) in 2007 to 34,303 hectares (27.40%) in 2014 while light vegetation (the cultivated area) reduced from 82,415 hectares (65.82%) in 2007 to 72,675 hectares (57.51%) in 2014. The reason for this might be due to drastic reduction in number of farmers since majority of people working on the farms had been taken over by urbanization while some land areas meant for cultivation were acquired for provision of public utilities.

The inference that can be deduced from this analysis is the effect of the sprawling incidence on land cover as illustrated by the continuous expansion of the built-up area throughout the studying period. The drastic reduction in the percentage of thick vegetation shows there was a remarkable growth within the studying period. For instance, as shown in Table 1, the built-up area increased by 22.3% between 1986 and 2014 as well as light vegetation (that is, the cultivated land areas) by 27.71% while thick vegetation and water bodies reduced by 50.47 and 0.45%, respectively. This is the result of massive encroachment into the thick vegetation, rocky and undulating land areas through building construction, quarry, blasting and mining activities that were carried out in the region. It was equally discovered that economic situation in the state in the early 2000s encouraged individuals, government and various establishments to embark on various developments that lead to massive depletion of the vegetation. For example, in 2002 various projects were embarked upon consequent upon the discovery that the state falls within the mineral endowed region, which accounted for tremendous increase in the built-up areas in various parts of the state, including Akure region. Again, Akure gained much influx of people seeking greener pastures being the state capital while the discovery of bitumen in the state attracted much investor and other immigrants within the studying period. Its administrative status and concentration of several establishments like government ministries, housing estates, Ondo State Oil Producing Area Development Commission (OSOPADEC) secretariat, Federal University of Technology, Akure (FUTA) and various other institutions higher learning contributed to this attraction.

Pattern of land use land cover (LULC) changes in Akure region between 1986 and 2014

The LULC of Akure region was classified into four and examined in three decadal variations: 1986 to 2002, 2002 to 2007 and 2007 to 2014. The change detection analyses are presented in Table 1 and Figure 8. Results indicate that the percentage increase of built-up

Table 1. LULC Change Detection Analysis in Akure for the year 1986-2014.

The LULC	2002-1986		2007-2002		2014-2007		1986-2014
	Difference in area (ha.)	**Difference in area (%)**	**Difference in area (ha.)**	**Difference in area (%)**	**Difference in area (ha.)**	**Difference in area (%)**	**Percentage difference (%)**
Built-up Area	14441	11.53	2160	1.73	11318	9.04	22.3
Thick Veg.	-47818	-38.19	-13976	-11.16	-1379	-1.11	-50.46
Light Veg.	30963	24.73	13475	10.76	-9740	-7.78	27.71
Water Body	2413	1.93	-1658	-1.33	-199	-0.15	0.45

Sources: Landsat Satellite Imageries (1986, 2002, 2007 and 2014).

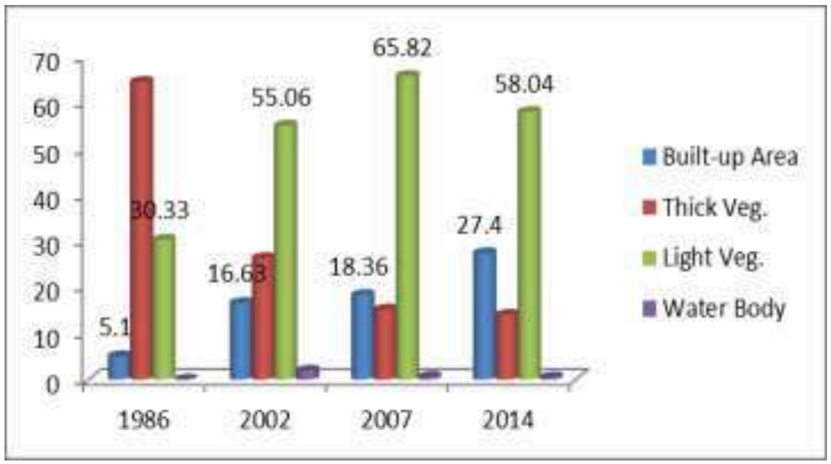


Figure 8. LULC Classification and Change Detection in Akure Urban Land Use (1986-2014); Sources: Landsat Satellite Imageries (1986, 2002, 2007 and 2014).

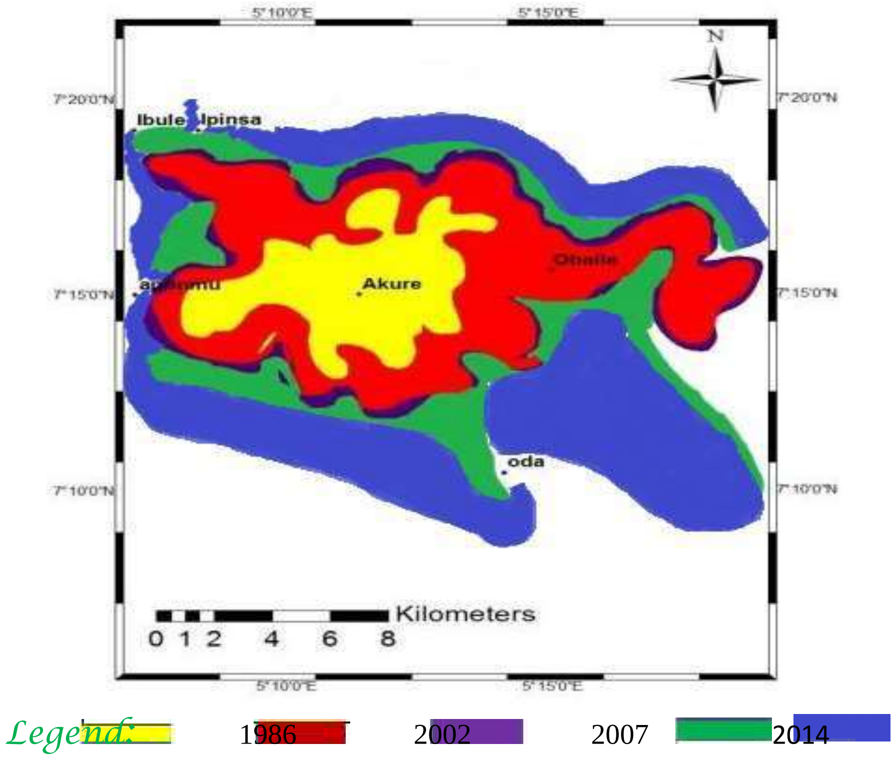
area, light vegetation (that is, cultivated land areas) and water body was higher between 1986 and 2002 than between 2002 and 2007. The percentage difference in built-up area was much higher between 2007 and 2014 while other land classifications have negative index.

This is due to the continuous depletion of vegetal cover occasioned by the rapid growth and development witnessed in the region in recent time.

Thus, thick and light vegetation were rapidly depleted and taken over by built-up land uses in the form of building constructions and provision of public utilities.

Analysis of urban built-up change detection and predictive modeling for future expansion

The spatial analysis of sprawling pattern observed in Akure region between 1985 and 2014 is expressed in Figures 4 to 7 and 9. The figures clearly express the direction and extent of



Year of growth	Growth area (ha.)	Cumulative area (ha.)	Percentage area (%)
1986	6383.65	6383.65	5.10
2002	20825.33	27208.98	16.63
2007	22984.57	50193.55	18.36
2014	32969.15	83162.70	26.33
2034 (Projected)	66881.02	150043.72	53.41

Figure 9. Built-up Change Detection Analysis for Akure Urban Land Use (1985 – 2034); Source: Field Survey, 2014.

growth in the period examined. For instance; as shown in Figure 9, the growth navigates towards the northern and the eastern parts of the region between 1985 and 2002 more than any other direction. These areas were earmarked for the construction of Government Residential Areas (GRAs) and most of government ministries. Besides, the area was the location of Ijapo estate, a notable residential estate in the Akure city that serves as object of attraction to much influx of people into the area. According to Oyinloye (2010), the construction of Ilesha-Akure-Owo express route which passes through the north-eastern part of the city was a notable factor that play prominent role of attracting people to the area. However, the direction of growth thereafter diffused to other directions, probably due to congestion in the north-eastern part and availability of cheap lands which might attract people to other parts of the city. The location of Federal University of Technology, Akure (FUTA) in the north-western part of the region has attracting influence on huge population of people into the area. Most staff of the institution and students live and build houses around the institution, thereby making the growth institutional attraction. Currently, the growth around this institution has almost captured Ipinsa and Ibule (the two nearest settlements) as high percentage of students of the institution find cheaper accommodation there as well as cheaper lands for staff and people from Akure to build residential buildings and hostel accommodation for students. These important developments that parade the city revealed significant difference in stages of expansion and land uses within the studying periods. These findings corroborate the work of Oyinloye (2010) and Balogun (2011) who observed significant difference in stages of development and growth in Akure since its inception as a state capital. Future expansion of the study area and possible change pattern in land use was modeled using Markov chain to guide policy makers in the management of land use activities in Akure and its environs. Adopting the 3.6% growth rate used in

Oyinloye (2010) for Akure, future expansion of built-up area in the region for a period of 20 years (2014 to 2034) was predicted using Markov Chains modeling. This was estimated at 68,793.41 hectares as shown in Figure 9. It means by 2035, the built-up area would occupy about 53.41% land area of the region. By then, Akure would have become a full-grown conurbation and subsumed many of its adjoining communities.

SUMMARY OF FINDINGS AND POLICY IMPLICATION

The pattern of land use in the region elucidates an unguided expansion in the growth of Akure into the suburb. There were incompatible conversions of land use and undue encroachment into green areas in adjoining towns and villages. This is due to favorable economic situation in the state in the early year of the millennium. Between 2000 and 2005, for example, Akure gained much influx of people being the state capital and, most importantly, due to the discovery of bitumen in the state which attracted much investor and other immigrants in quest of greener pastures and job opportunities. The administrative status and concentration of establishments in the city were the key factors for this attraction. This prompted massive encroachment into thick vegetation which consequently leads to further developments and expansion of the city into various surrounding communities. Meanwhile, the regional setting of the area has naturally influenced the direction of the expansion. Based on major findings in the study, some policy recommendations were proffered to address salient issues. Firstly, the unguided nature of physical expansion and development with consequence effects on land use pattern in the study area needs quick attention. The check on this should commence with land acquisition and allocation procedures for various uses to guide against incompatibility errors and chaos. It is therefore recommended that ministries of Land and Survey, Housing and Urban Development who handles land issues in the state should employ resourceful control measures over private and public land uses through effective zoning strategy. In view of this, the Development Control Department (DCD) in the Ministry of Urban Development and Physical Planning should be reinforced with strong tools to carry out their duties, particularly in the area of effective monitoring for sustainable development.

The existing land use in the study area is more of residential, most of which are aged and dilapidated. In some parts of the city, especially at the urban core, there are series of ongoing redevelopment and building restructuring. In the course of changing some of these buildings, the usages are always at variance with compatibility standard. They constitute nuisance rather than complementing the planning and environmental standards. In this regard, it is recommended that adequate monitoring be made by DCD and other stakeholders in urban planning, right from plan approval stage to erection of structures to forestall such occurrences with a view to achieving a sustainable and virile livable environment. Besides, property rehabilitation strategy should be adopted on degraded landed properties rather than arbitrary removal and rambling replacements. This should involve improving the existing infrastructural facilities as well as providing new ones with a view to making their services functional and accessible to all. To reduce the level of encroachment into natural vegetation in the course of expansion, the study suggests vertical expansion in the form of storey buildings and high scrappers in place of lateral growth and expansion. It is believed that this will reduce the rate of land consumption and as well improve the structural quality and aesthetic value of the environment. The existing Master plan of Akure was produced in 1980 and has become inactive, old and superseded. There is need for a more comprehensive one as well as a Regional Plan to guide the development and spatial growth of the region. These plans are to be administered by a constituted board, which is to be saddled with responsibility to maintain an orderly and aesthetic environment in the region. The board is to be made responsible for the preparation and implementation of planning schemes as well as local, area and structural plans in conformity with the state and regional plans. This will go a long way to assist in regulating land use policies for sustainable development in the area.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper. The founding sponsors had no role in the design of the study as far as the collection, analyses, or interpretation of data is concern either in the writing of the manuscript or in the decision to publish the results.

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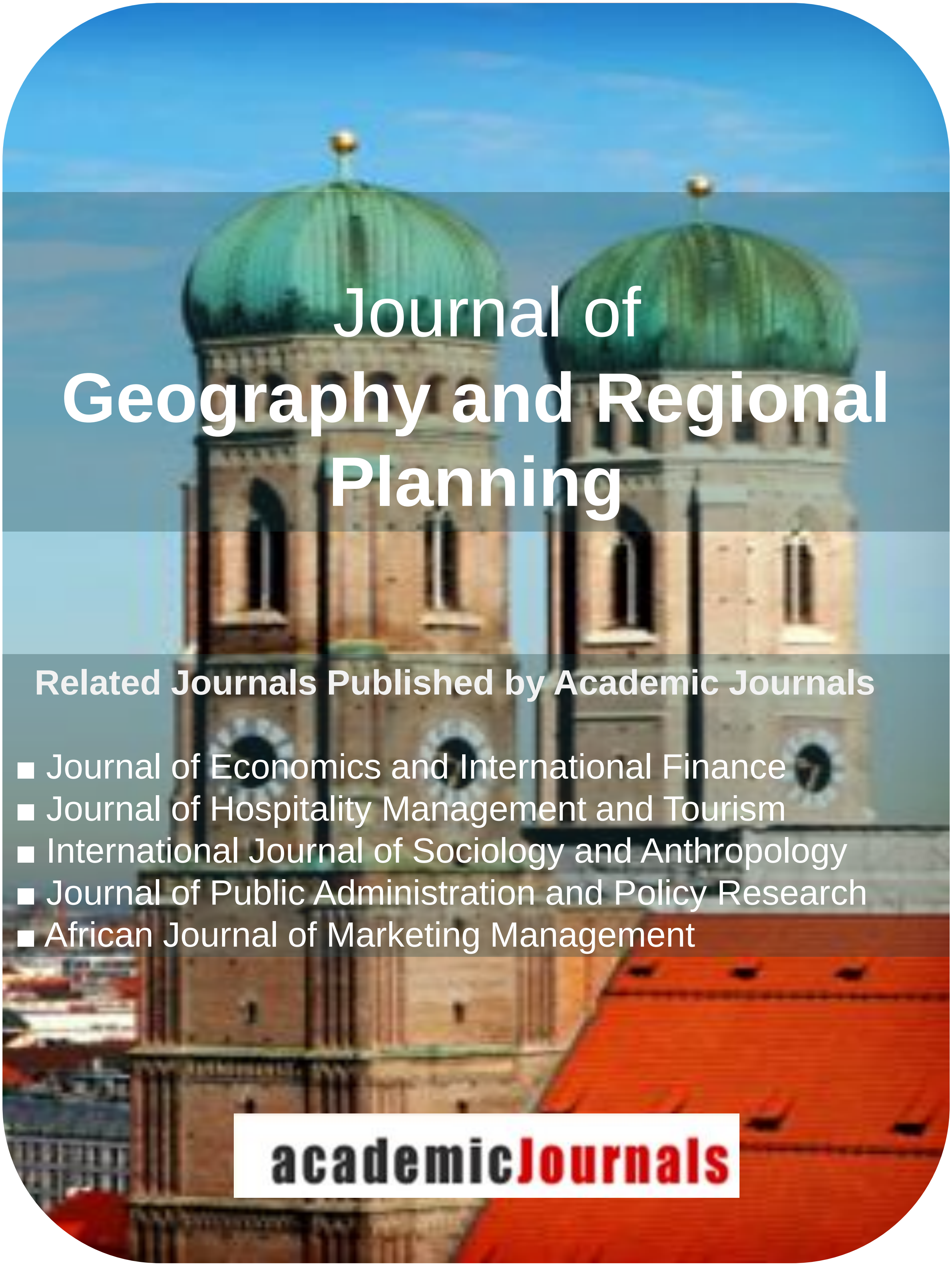

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