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Spatio-temporal analysis of the growth of Calabar metropolis, Cross River State, Nigeria

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Abstract: This study analyzed the spatio-temporal growth of Calabar metropolis, Cross River State, Nigeria. Remote sensing and qualitative techniques were used to examine the extent, magnitude, rate, pattern, determinants and effects of the spatial growth of Calabar metropolis from 1987 to 2018. Landsat 5 TM of 1987, 1997; Landsat 7 ETM+ of 2008 and Landsat 8 OLI of 2018 with spatial resolution of 30 meters respectively were obtained from United State Geological Survey platform (USGS). Supervised classification was performed using maximum likelihood classification (MLC) algorithm to classify the imagery into various LULC classes. Data on the determinant and the effects of the spatial growth of Calabar metropolis was derived using question and in-depth interview while Relative importance index (RII) was used to analyze and rank the perception of respondents. Results revealed that the extent of built-up land use in 1987 was 32.91 km^2 (12.83%) of the total landmass of the metropolis. In 1997, 2008 and 2018 the built-up land increased to 47.34 km^2 (18.46%); 58.68 km^2 (22.87%) and 59.55 km^2 (23.22%) respectively. The overall percentage increase in built-up area for the 31-year period was 80.98% at a yearly growth rate of 0.86 km² (2.61%). Findings also revealed that the major land use as at the year 1987 was for agricultural purpose while built-up was identified as the major land use in 2018. Finally, the RII on the determinant and effects of the spatial growth of Calabar metropolis revealed that increase in population was the major determinant for the growth of the built-up land-use of the metropolis while increase in the cost of land within the metropolis was the most influenced factor.

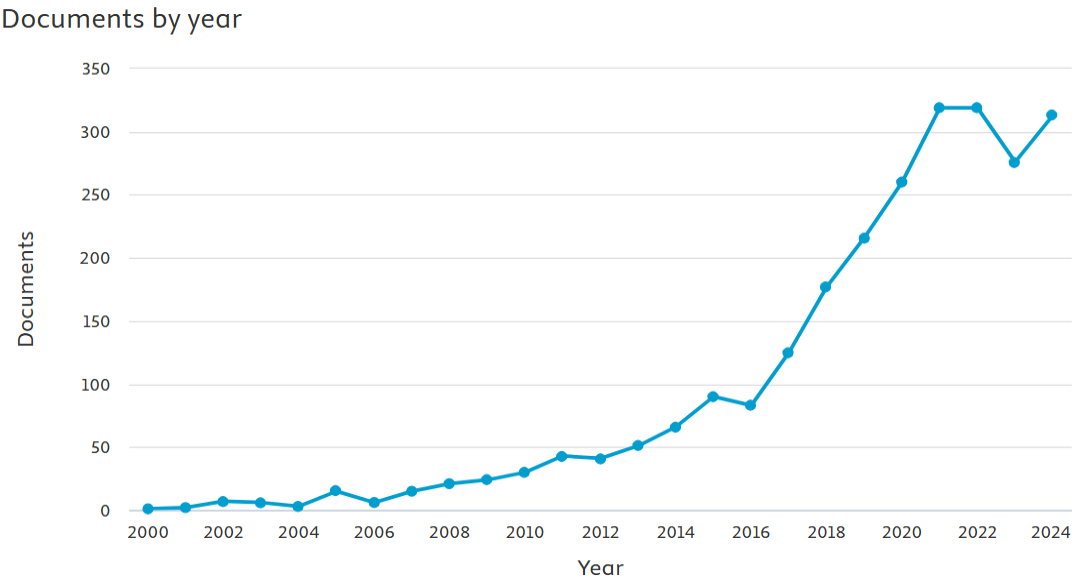
1. Introduction

Urbanization is necessary to sustain growth in developing countries and yield other benefits as well. Over the years, the growth rate of the world's population and several human activities have been of serious concern as no country has ever reached middle-income status without a significant population shift into cities (Michael *et al*. 2009). Rapid increase of human population in urban areas affects adjustment of the structure and arrangement of urban centers globally. The remarkable pace of urban growth has resulted in multiple infrastructure and environmental challenges (Barry and Haack 2006). Urban growth especially in the developing world is one of the crucial issues in the 21st century affecting the physical dimension of cities (Abebe 2013)

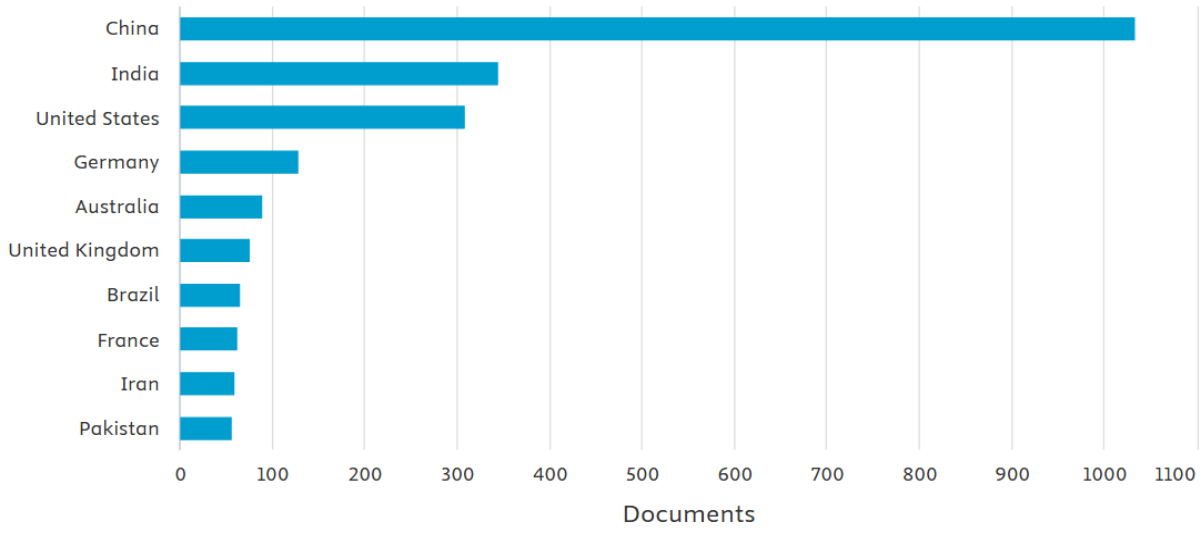
Urban growth denotes a continuous growth of the human population, activities and a corresponding increase of infrastructures that extend to the areas surrounding these cities (Barry and

Haack 2006). Offiong and Eteng (2014) viewed urban growth as the expansion of the urban area outside its borders into the conurbations. Gordon and David (2014) also viewed urban growth as broad-based rural-to-urban transition involving population, land use, economic activity and culture, or indeed any one of these. Thus, it is frequently used to refer to changes in land-use for specific areas (usually on the periphery of urban concentrations) as this land becomes 'urbanized' and is sold and developed for urban use.

The spatio-temporal studies are so frequently in literature and more than 125 thousand documents were found in Scopus. This research may be limited to 2605 when a second key word is added "landsat". So, a bibliometric analysis can be added to show the importance of this field and the authors and countries interested and forming clusters as found in literature (Waltman *et al.*, 2010; N'diyae *et al.*, 2022; Hammouti *et al.*, 2025). **Scheme 1** shows clearly the evolution of the scientific production on "spatio-temporal & landsat" to reach more 300 articles per year last years; and China has the lion part in this field (1033 articles), followed by India, the United States, Germany etc. (**Scheme 2**).

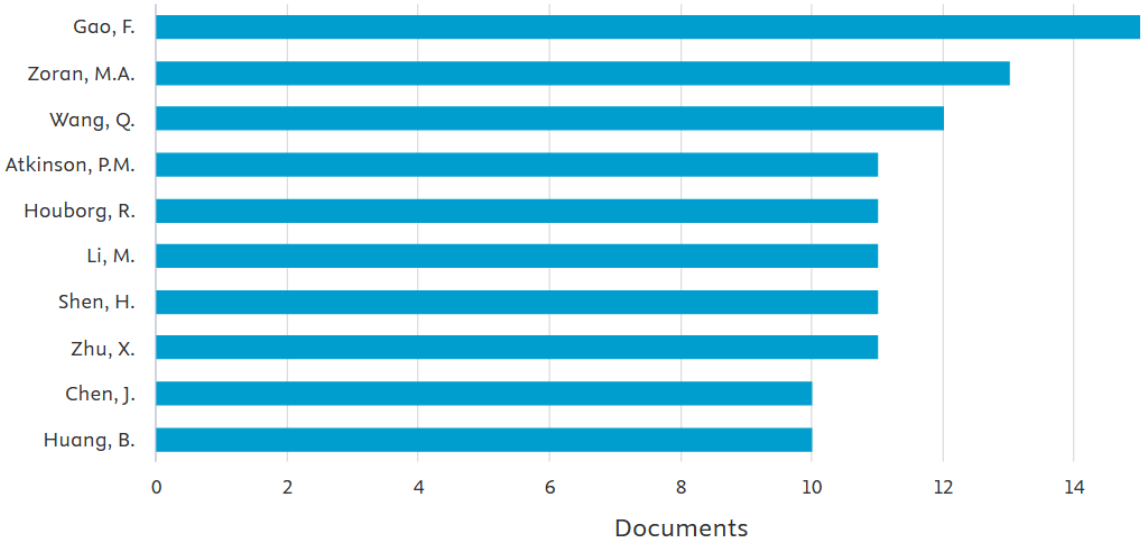


Scheme 1: Increase of the publication's number from 2000 to 2024

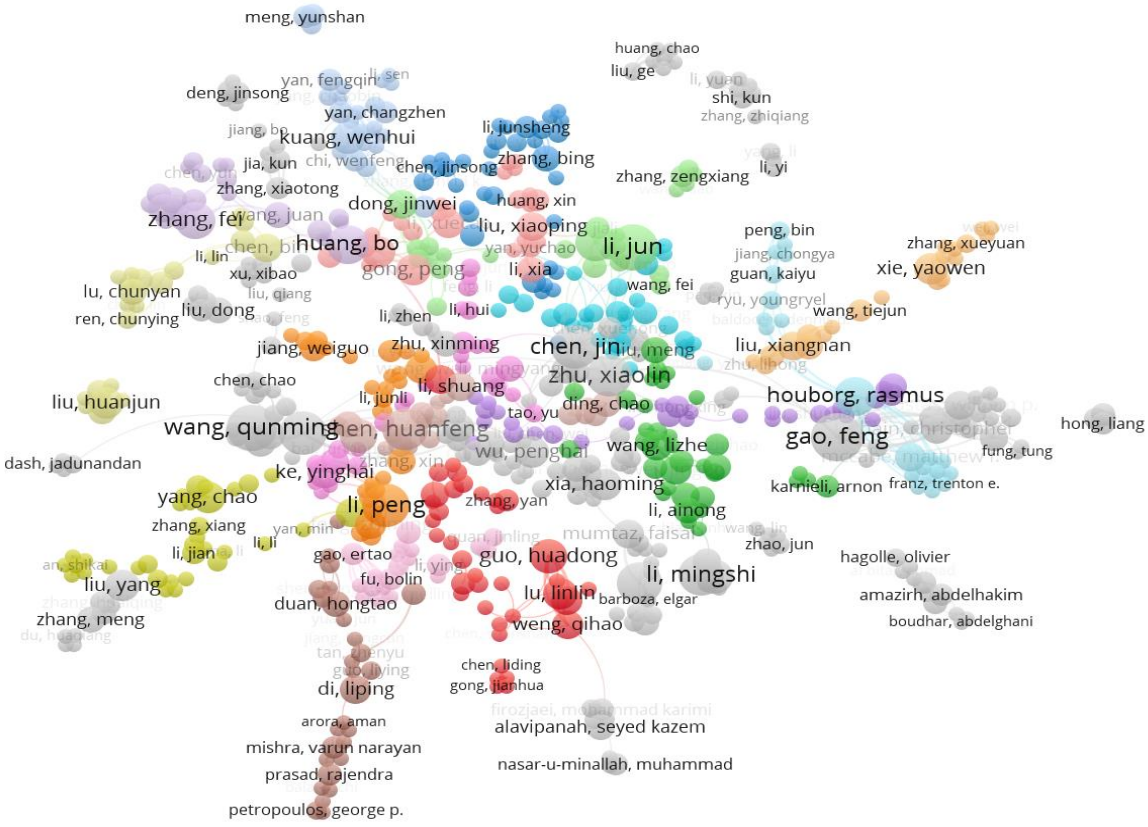


Scheme 2: Increase of the publication's number from 2000 to 2024

We notice also that Gao, F., Beltsville, United States, Scopus ID: 56486548700, published 15 papers, followed by Zoran, Wang, Atkinson etc. having around 10 papers (**Scheme 3**). The scientific production can also be visualized via VOS viewer to show numerous dote with different colors corresponding to authors. The size indicates the number of publication and the same color font shows the collaboration as presented in **Scheme 4**. VOS viewer analysis is used to level authors, institutions, journals, Universities and Countries exploiting the data of papers and citations numbers (Aichouch *et al.*, 2025; Ballesteros-Ballesteros & Zárate-Torres (2025); Lrhoul *et al.*, 2023; Skute *et al.*, 2019; Hammouti *et al.*, 2010).



Scheme 3: Increase of the publication's number from 2000 to 2024



Scheme 4: Network visualization of authors (VOS viewer)

Calabar, the capital of Cross River State of Nigeria over the years has witnessed observable urban growth and expansion, outstandingly the built-up area which burst outward in an explosion of growth that consumed former agricultural land at a break-neck pace. Thousands of hectares of agricultural land have been covered by concrete and asphalt as new roads are created and existing ones are extended. Over 5,200.09 hectares of the former agricultural lands at Ekorinim, EsukUtan, Edim-Otop, Anantigha, and Ikot Efanga areas of the metropolis have been converted to residential, commercial and industrial uses as these areas are merged with the urban areas (Atu *et al*. 2012).

There is therefore a need to study the growth of Calabar metropolis, in order to estimate and understand the spatio-temporal processes, which is crucial for sound planning and resource management. The current study utilized remote sensing techniques and GIS to assess the spatio-temporal growth of Calabar metropolis.

2. Study Area

Calabar Metropolis lies between Latitudes 4°54′ 00″ N to 5°04′ 00″ N and Longitudes 8°18′ 00″ E to 8°24′ 00″ E and it is bounded at Calabar River, to west, Kwa River to the East, Odukpani L.G.A to Northern flank, and the creeks of the Atlantic Ocean in the south (Figure 1). The metropolis covers a land area of 256.51km². Calabar is the capital city of Cross River State, southern Nigeria. It comprises of Calabar Municipality and Calabar South Local Government Areas (LGAs). There are 22 political wards in both LGAs, 10 in the later and 12 in the former; numbers are used as the name the wards in the study area.

The climate of the area is largely controlled by the two major air masses, which are tropical maritime and tropical continental air masses. Under the Koppen's climate classification, the metropolis features a tropical monsoon climate with a lengthy wet season spanning 8-9 months that starts from April to October, Calabar experience a double maximal of rainfall in the month of July and September with an average annual rainfall of 2000-3000mm and experiences a short dry season covering the remaining 3-4 months. (Benedict *et al*. 2016) The harmattan that significantly influences weather in West Africa is noticeably less pronounced in the city.

Temperatures are relatively constant throughout the year, with average temperatures usually ranging from 27°C to 35°C. (Benedict *et al*. 2016). The favorable climate of tropical humid, dry and wet seasons gives rise to rich agricultural lands, thus encouraging both perennial and annual crop cultivation which is one of the drivers of population growth as well as the growth of the city.

The vegetation of the Calabar is a mixture of mangrove and rainforest. The rainforest is further subdivided into the lowland rainforest and the freshwater swamp forest. The mangrove swamp is found in the southern fringe of the area and stretches from the freshwater limits to the ocean beaches. The rich and luxuriant vegetation of the area has been subjected to severe degradation due to anthropogenic activities primarily driven by urbanization (Eni *et al*. 2012) However, patches of forest can still be found at the fringes of the city.

3. Methodology

3.1 Types of data

The data required for the study include:

i. Landsat 5 Thematic Mapper (TM) of 1987 and 1997 with spatial resolution of 30 m
ii. Landsat 7 Enhanced Thematic Mapper (ETM+) of 2007 with spatial resolution of 30 m
iii. Landsat 8 Operational Land Imager and Thermal Infrared Sensor (OLI/TIRS) of 2017 with spatial resolution of 30 m

iv. Population of the area

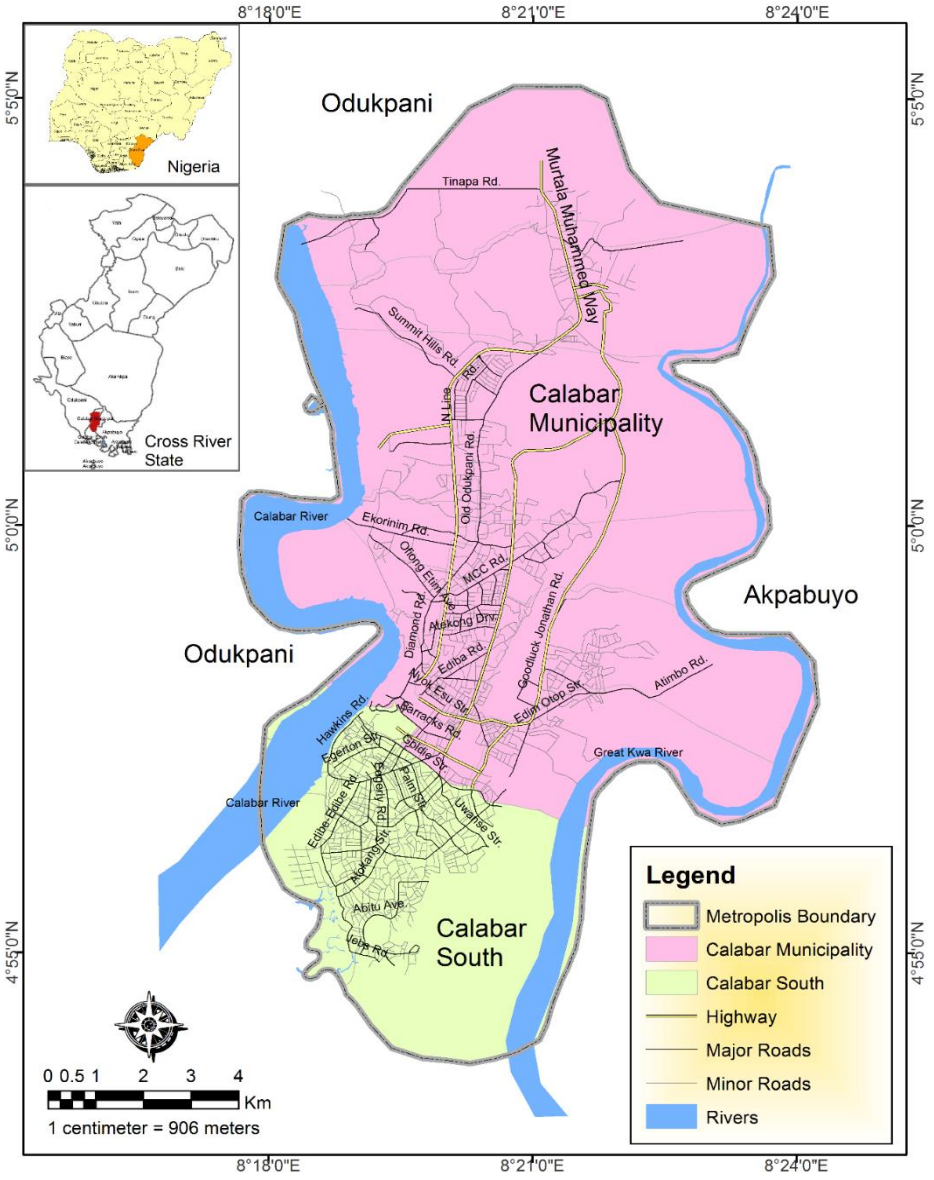


Figure 1: Calabar metropolis

3.2 Sources of data

Landsat 5 TM of 1987 and 1997, 2007 Landsat 7 ETM+ and Landsat 8 OLI of 2018 were obtained from United State Geological Survey website (USGS). The images were used to determine the rate, pattern and extent of urban expansion through land use/ land cover change detection analysis. Topographic map of the study area was obtained from the office of the Surveyor General, Calabar, while the population of the area was obtained from the National Population Commission, Calabar. Data on determinants of urban expansion in the area and effect of urban expansion in the metropolis was gotten through the administration of a well-structured questionnaire and interview.

3.3 Sample size and techniques

The sample frame of the study is the population of Calabar metropolis which was projected to 2018 using the 1991 population figure. The use of 1991 population data is due to the non-availability of the 2006 NPC population data at ward level. In order to determine the sample population, the population of the twenty-two (22) wards comprising both Calabar- municipality and Calabar south was

projected to 2018 using the exponential growth model with an annual growth rate of 2.54 percent. As a result, 384 copies of questionnaire were administered to ascertain the determinants of urban growth and the effects of urban growth in the metropolis. The sampling of respondents was done using purposive sampling technique.

3.4 Data processing techniques

The satellite imageries acquired from the United State Geological Survey (USGS) LandLook platform were already otho-rectified, thus there was no need for geo-referencing. Calabar metropolis which is the area under study was subset from each large scene of the satellite imagery by using the extract/clip tools in ArcGIS 10.4 software. This was done using vector boundary data of Calabar metropolis to clip the imageries, extracting the extents within the boundary of the imageries which is the area of interest (AOI)

4. Results and Discussion

4.1 Extent of Built-Up Land Use in Calabar Metropolis from 1987-2018

The extent of the built-up land in Calabar metropolis from 1987 to 2018 was assessed and results presented in **Table 1** and **Figure 2** to **Figure 5.**

Table 1: Percentage Distribution of Built-Up Land use Extent

Year	Built-up Area in km²	Percentage
1987	32.91	12.83
1997	47.34	18.46
2008	58.68	22.87
2018	59.55	23.22

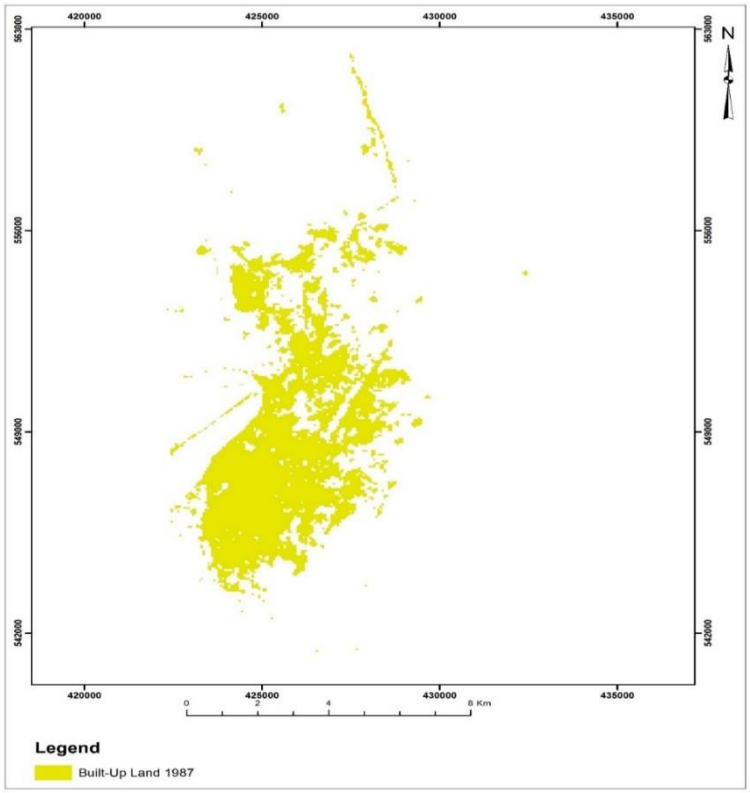


Figure 2: Extent of built-up land use in 1987

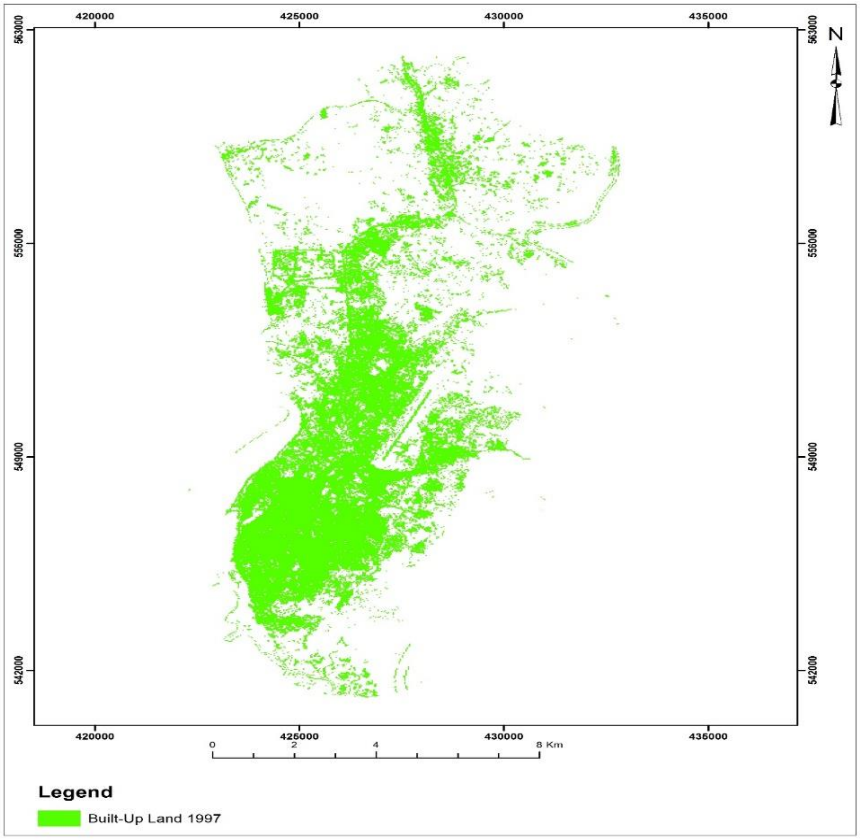


Figure 3: Extent of built-up land use in 1997

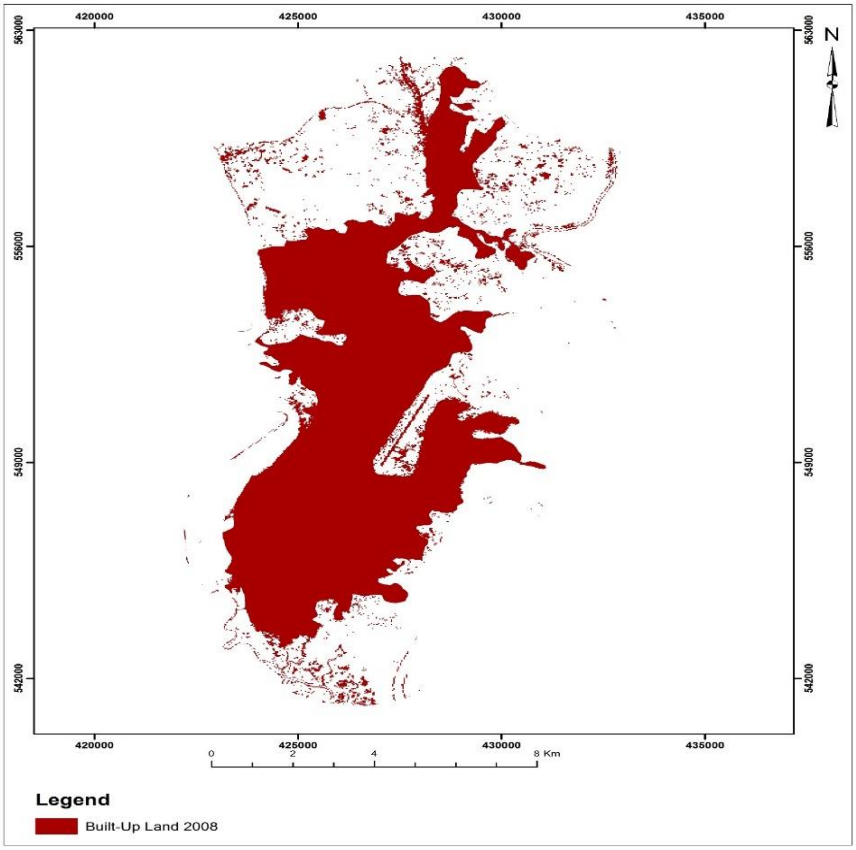


Figure 4: Extent of built-up land use in 2008

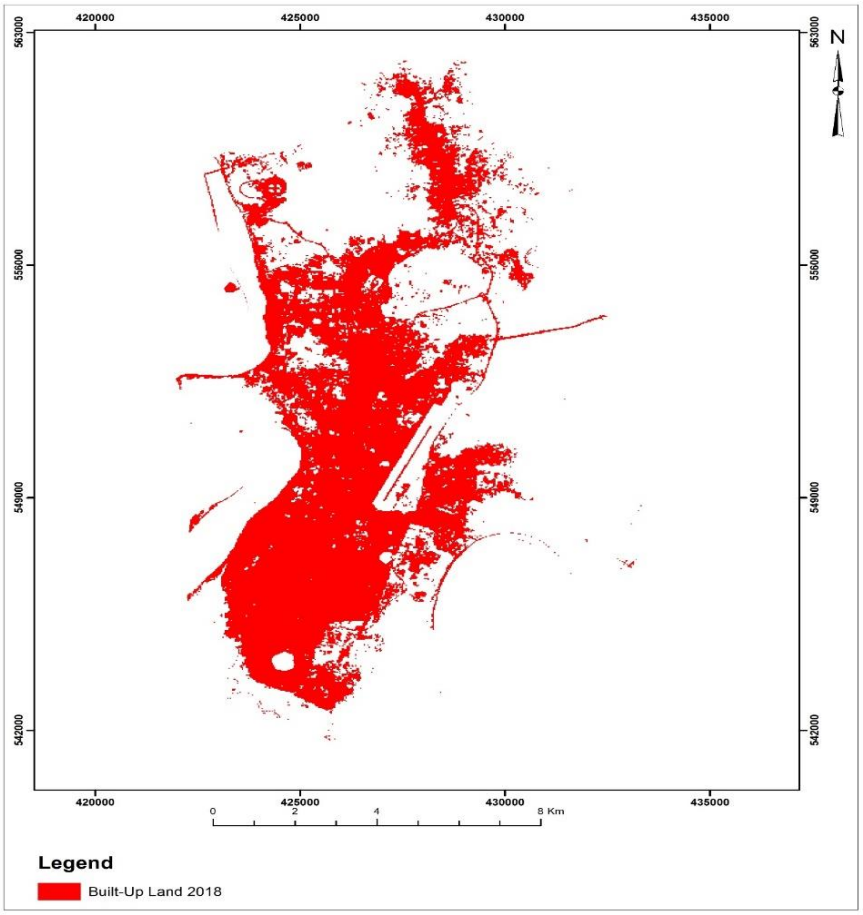


Figure 5: Extent of built-up land use in 2018

Table 1 revealed that the extent of built-up land use in 1987 which is the base of the study was 32.91 km² of land that accounts for 12.83% of the total landmass of the metropolis while in 2018 the built-up landmass increased to 59.55 km² that accounts for 23.22% of the total landmass of the metropolis. It can be deduced from the result that there has been a steady increase in the built-up area of Calabar metropolis which shows that the city has not been static in its infrastructural developmental processes. This result is in agreement with the findings of Ade and Afolabi (2013) who in their study stated that urban built-up of any city or country is never static that it changes per time and as days and years go by, they affect the structural topography of the urban areas.

4.2: Magnitude and Rate of Growth of Calabar Metropolis from 1987 to 2018

The magnitude and rate of the growth of the built-up area from 1987 to 2018 was determined and results tabulated as seen in **Table 2.** The data analysis in **Table 2** revealed that the magnitude of built-up land use in the metropolis between 1987 and 1997 increased by 14.43 km² (43.85 %) at the rate of 1.44 km²/year (4.38 %/year), while the magnitude of built-up land use in the metropolis between 2008 and 2018 increased by 0.87 km² (1.48 %) at the rate of 0.1 km²/year (0.17 %/year). From the above results it can be seen that the metropolis experienced the highest spatial growth between 1987 and 1997. This is attributed to the rapid infrastructural developmental processes experienced during the period as being the first decade Calabar became the capital of the new Cross River State. Further analysis revealed that within the period under study, the built-up land increased by 26.64 km² (80.98%) at the rate of 0.86 km² (2.61%) of the landmass is being taken over by urban development annually.

Table 2: Magnitude and rate of growth between 1987 and 2018

Urban Built-up			Magnitude of Growth		Rate of Growth	
Period	Year	km²	km²	%	km²/Year	%/Year
1987-1997	1987	32.91	14.43	43.85	1.44	4.38
10 years	1997	47.34				
1997-2008	1997	47.34	11.34	23.95	1.03	2.18
11 years	2008	58.68				
2008-2018	2008	58.68	0.87	1.48	0.1	0.17
10 years	2018	59.55				
1987-2018	1987	32.91	26.64	80.95	0.86	2.61
31 years	2018	59.55				

However, when one compare Calabar to some other Nigerian cities, it can be inferred that Calabar metropolis is not expanding significantly. For instance, Onyebuchi *et al*. (2016), indicated that the extent of the built-up area coverage of Ibadan in 1984 was 118.45 km² and 2014 to be 529.57 km². This implies that the built-up area in Ibadan increased by 347% within 30 years. In the case of Calabar metropolis, an 80.98% increase in the built-up area in 31 years means the city is expanding in an arithmetic, rather than a geometric progression. This is due to the fact that Calabar is impasse which is bounded by Calabar River, Kwa River, and the estuaries of the Atlantic Ocean. The land in Calabar has been put to different uses as shown in **Figure 6.**

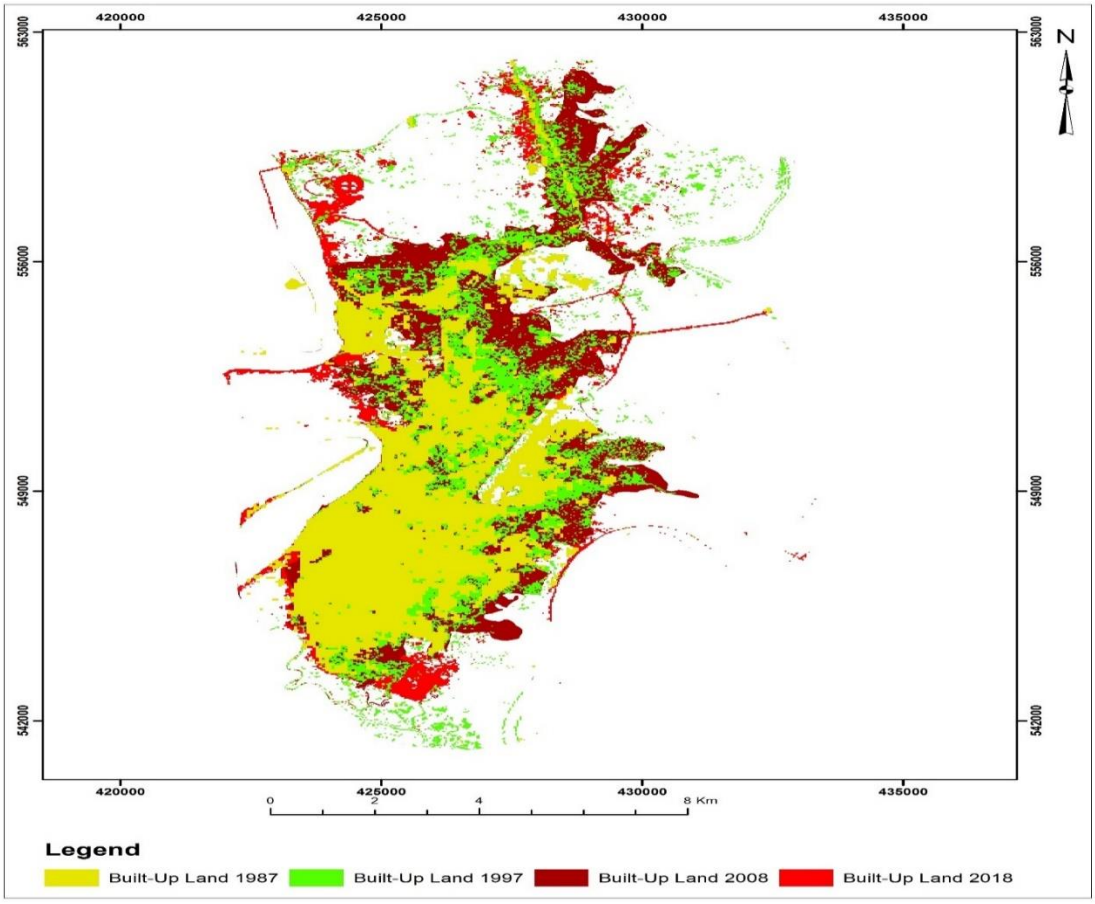


Figure 6: Overlay of the built-up Land use of Calabar Metropolis From 1987-2018

It revealed that over time other land use classes such as Agriculture and forest land which were the major land use type as at the year 1987 have been converted to urban built-up. It can be deduced that urban growth in Calabar metropolis can be attributed to several factor outside being the capital of Cross River State. Population increases through natural birth and immigration, presence of educational institutions, government parastatals, military barracks, and industries as well as a home to tourist with several tourism support facilities.

4.3: Perception of Respondents on the Determinant of the Spatial Growth of Calabar Metropolis Land Use in Calabar as at 1987

An assessment of the perception of respondents on the land use scenario as at the year 1987 in Calabar metropolis is presented in Figure 7.

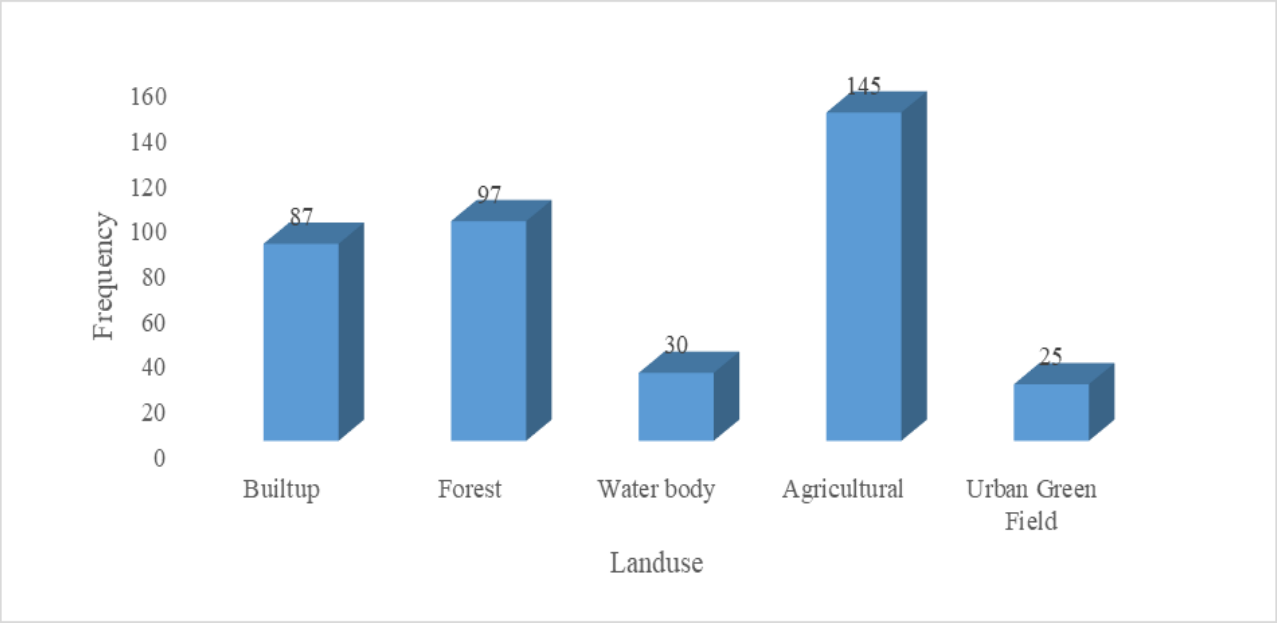


Figure 7: Land use scenarios as at 1987

Figure 7 showed that 37.7% of the total respondents perceived that the major land use in Calabar as 1987 was agricultural land use. The findings also revealed that agricultural land use was the major land use type back then in 1987. This might be attributed to the fact that majority of the dwellers in the metropolis then use to be farmers. This result is in agreement with the findings of Chete *et al*. (2014) stated that Agriculture used to be integral part of the nation's economy providing food and employment for the populace, raw material for the nascent industrial sector among others.

4.3.1: Land use state

The study showed that 100% of the respondents affirmed that the land use in the study area has changed. This has been attributed to increase in population in the metropolis due to government presence. This result is agreement with the study of Oka (2009); Offiong and Eteng (2014), stated that Calabar has witness a speedy urban growth that has led to alteration of several land uses. This result conforms to the in-depth interview conducted in the study area as all the respondents agreed that the land use has changed noticeably.

4.3.2: Land use in Calabar in 2018

An assessment of the perception of respondents on the current land use in Calabar metropolis is presented in Table 3.

Table 3: Land Use in Calabar in 2018

Land Use in Classes	Frequency	Percentage
Builtup	311	81.1
Forest	37	9.6
Water body	9	2.3
Agricultural	13	3.4
Urban Green Field	14	3.6
Total	**384**	**100**

Table 3 showed that majority of the respondents which accounts for 81.1% of the total respondents perceived that the major land use now is the Built-up land use. The findings as revealed in Table 4 shows that built-up land use is the major land use type. This might be due to increase in population as a result of Government presence in the metropolis. This is in agreement with the findings of Atu *et al.* (2012), who in their study revealed that built-up area has busted outward in an explosion of growth that consumed former agricultural land at a break-neck pace, and thousands of hectares of agricultural land are covered by concrete and asphalt as new roads are created and existing ones are extended. This result conforms to an in-depth interview conducted in the study area. All the respondents agreed that built up land use has taken over other land uses.

4.3.3: Perception of land use change

Respondents' perception on how the land use has changed from one type to another is presented in Table 4. The result showed that a vast majority of the respondents which represent 62.5% stated that the land use has change from agricultural to residential. This might be as a result of urbanization and several governmental projects and development like establishment of tertiary institutions, military barracks and housing estates among others. This result agrees with the findings of Atu *et al.* (2012), who in their study revealed that built-up area has busted outward in an explosion of growth that consumed former agricultural land at a break-neck pace, and thousands of hectares of agricultural land are covered by concrete and asphalt as new roads are created and existing ones are extended. This result also agrees with an in-depth interview conducted in the study area.

Table 4: Perception of Land use Change

Land use classes	Frequency	Percentage
Agricultural to Residential	240	62.5
Residential to Industrial	37	9.6
Urban Green Field to Residential	63	16.4
Agricultural to Industrial	44	11.5
Total	384	100

4.3.4: Perception on the pace of land use

The processes in which the land use has changed in the metropolis is presented in Table 5.

Table 5: Perception on the Pace of Land use Change

Change	Frequency	Percentage
Gradual	203	52.9
Rapid	181	47.1
Total	384	100

As seen in Table 5, 52.9% of the respondents affirmed that the process in which one land use was converted to another land use type was gradual while 47.1% of the respondent stated that the process was rapid. This is due to the fact that development is a gradual process as it does not happen overnight. This agrees with the findings of Ade and Afolabi (2013) In Nigeria, all cities apart from Abuja are organic in their origin and developed gradually over a long period of time as they build on existing precolonial urban centers. In which Calabar is not an exception.

4.4: Determinant of the spatial growth of Calabar Metropolis

The results of the *RII* on the determinant of the spatial Growth of Calabar Metropolis is presented in Table 6. It was observed as shown in Table 6 that the 384 of the respondents stated that the spatial growth of Calabar metropolis is being influenced by some of the factors as shown. Population increase had the highest ranking (1st) which suggests that it is the most significant factor that is influencing the spatial growth of the metropolis.

Table 6: Relative Important Index (*RII*) on the Determinant of the Spatial Growth of Calabar Metropolis

	Rating (W)							
Factors	1	2	3	4	5	∑W*N	*RII*	RANK
Presence of social Amenities	3	4	8	109	260	1771	0.922	6th
Topography	0	6	17	135	226	1734	0.903	7th
Presence of Tertiary institution	0	0	15	81	288	1809	0.942	4th
Creation of Satellite towns	0	0	0	69	315	1851	0.964	2nd
Tourism	0	0	9	53	322	1849	0.963	3rd
Availability of Industries	0	10	18	59	297	1795	0.934	5th
Population Increase	0	0	9	25	350	1877	0.977	1st
Access to Health Facility	0	4	66	181	133	1595	0.830	8th

Access to Health Facility had least ranking of 8th, topography had a ranking of 7th and both tourism and Creation of Satellite towns was ranked 2nd and 3rd respectively, However, increase in the number of industries was ranked 5th while presence of social amenities was ranked 6th. This agrees with the findings of the in-depth interview conducted which suggested that increase in population is the major determinant of urban growth where all the interviewees unanimously quoted population increase

as the major determinant of the spatial growth of the study area. This result is in agreement with the findings of Ade and Afolabi (2013) who in their study identified that population dynamics are the underlying drivers of development and environment changes in any city. However, the result from the interview conforms to land use land cover analysis which showed that built-up has consumed a substantial part of other land use in the study area. This is as a result of the increase in population. Because land scape transformation in urban environment throughout space and time are mainly dominated by anthropogenic activities and are greatly influenced by the spatial expansion of built up land.

Table 7: RII of the Effects of the Spatial Growth of Calabar Metropolis

	Rating (W)							
Factors	1	2	3	4	5	∑W*N	*RII*	RANK
Availability of skilled jobs	2	4	6	105	250	1702	0.925	4th
Conversion of urban Fringes to urban area	2	2	30	105	229	1660	0.902	5th
Conversion of Farm lands residential within and fringes of the metropolis	0	2	25	220	121	1564	0.850	10th
Forest depletion at the fringe of the metropolis	0	17	21	114	216	1633	0.887	7th
Environmental pollution	1	13	26	113	215	1632	0.886	8th
High rate of crime	0	5	23	118	222	1661	0.902	5th
Pressure on road	2	5	33	132	196	1619	0.879	9th
Poor state of housing	0	3	38	119	208	1636	0.889	6th
Pressure on land within the metropolis	0	0	0	115	353	1725	0.937	2nd
Increase in the cost of land within the metropolis	0	0	3	107	258	1727	0.938	1st
Increase in the cost of house rent	0	0	31	64	274	1715	0.932	3rd
Erosion	9	25	58	130	147	1488	0.808	11th
Traffic congestion within the metropolis	15	7	121	129	96	1388	0.754	12th

Interestingly, Table 7 shows that an increase in the cost rent was ranked 3rd and Pressure on land within the metropolis has the second highest ranking of 2nd and availability of skilled job had a ranking of 4th while erosion and traffic congestion within the metropolis had a ranking of 11th and 12th respectively. The Table revealed that the growth of Calabar metropolis has high influence on all of the factors. The result agrees with the findings of Raphael and Morgan (2014) which revealed that the urban infrastructures such as roads/streets, electricity, water supply system and waste management system are depreciating and this has compounded the way the cities are sprawling far beyond the range for which the facilities were planned and projected.

Conclusion

Based on the findings of the study, it was observed that there has been a steady and sluggish increase extent and annual growth rate of the built-up land use of the metropolis, with the period

between 1987 and 1997 having the highest growth rate within the period under study which was the first decade Calabar became the capital of the new cross river state. Also, the result of the Shannon entropy showed the pattern of growth of the urban built-up to be disperse and expanding towards the northern part of the metropolis. However, increase in population was seen to be the major determinant of the spatial growth of the metropolis while increase in the cost of land has been highly influenced by the spatial growth of the metropolis.

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Compliance with Ethical Standards: This article complied with all the ethical standards.

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