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Monitoring the Ratio of Land Consumption Rate to Population Growth Rate in Gombe Metropolis, Nigeria

Abdulkadir I[1], SathishKumar[2]

[1] Geography Unit, School of Basic and Remedial Studies, Gombe State University, Gombe, Gombe State, Nigeria

[2] Department of Civil Engineering, SRM institute Science and Technology, Chennai, India

Email: [1] abdish@ymail.com, [2] sathishj1@srmist.edu.in

ABSTRACT

Rapid urban expansion causes a continuous ground sealing, sometimes with increasing rate of surface extent greater than population growth rate that jeopardize some ecosystem services. It is in this context that the paper sets out to apply remote sensing techniques to assess the ratio of land consumption rate to population growth rate (LCR/PGR) in Gombe metropolis. QGIS was used in analyzing Landsat, impervious surface and population datasets to assess the urban trend and LCR/PGR between 2000 and 2015. The result appears that LCR/PGR show split trends, during 2000-2005 LCR/PGR stood at 1.2, indicating that the metropolis expanded outward. During 2005-2010 LCR/PGR stood at 0.8, indicates that the Gombe metropolis became more compacted with little expansion. During 2010-2015 the LCR/PGR reached 1.8, indicates that, the metropolis expanded outward with the rate of ground sealing getting higher. The study therefore recommends vertical urban growth depending on the metropolis's social, economic, and environmental traditions for better ecosystem services.

Keywords

Sustainable Development Goals, Land Consumption, Population Growth, Urban area

Introduction

In 2016 a global initiative (SDGs) was constituted as a unified road sign to establish a state of equilibrium between the present needs and for the yet unborn [1]. One of the indicators of this initiative calls to assess the "*ratio of land consumption rate to population growth rate"* to maintain a sustainable urban growth. Urban areas are the main human living space, they are dynamized by some essential variables like: changes in population, economic opportunities, presence of empowering policies, good physical and social conditions etc. which result the convergence of human activity regardless of size. However cities change, adjust, expose to certain variations with rising patterns, some of the time grow, or shrivel depending on the size of afore specified variables. The contemporary urban transformation rate cause changes in environmental state, as a result of land request for numerous land uses and in turn jeopardize ecosystem services. In the foregoing these urban zones still speak to nowadays a little extent of the Earth's surface [2], but their impacts on environment are progressively felt from territorial to mainland, and indeed worldwide.

It becomes crucial to measure and monitor how urban areas consume surface area against the rate at which population increases and also to determine their characteristics for better understanding of the cause and effect of these changes. In keeping with the afore mentioned objective to accomplish land use efficiency, decision makers, NGOs pressure groups ought to get at how quick their urban zones are developing, and in which course. This will not only help to understand the development patterns and viably address demands for the fundamental services but will also open doors to make approaches that encourage ideal utilization of urban land effectively, and help to secure other land uses. Furthermore, to accomplish environmental sustainability, the urban utilization must be coordinated to be in harmony or be underneath what the common environment can give, so that coming about pollutants will not overpower the environment's capacity to supply resources to people and other components of the ecosystem [3]. As such, analysts and related NGOs, pressure groups emphasize on the role of knowledge of good urban transformation within the setting of urban planning [4]. The paper is intended to answer the question of whether the remaining undeveloped urban land of the study area is being

consumed at a rate that is greater than, or less than, the prevailing rate of population growth, in order to promote sustainable urban expansion.

Materials And Methods

A. Study Area

Gombe metropolis is the seat of government of Gombe state, situated in the northern part of Nigeria. It overlaps into Akko, Kwami and Yamaltu-Deba local government areas [5]. The metropolis is situated in Sudan savannah belt, and marked with wet (April to October) and dry (November to March) yearly seasons. It has mean maximum monthly (March – May) temperature of about 34^0C and mean minimum monthly (December – February) temperature of about 18^0C [6]. It is located within guinea savanna woodland vegetation characterized by unevenly distributed grasses, shrubs and trees [7]. However the natural vegetation has either completely disappeared as a result of gully erosion [8], or has greatly modified by various human activities such as urban land consumption, bush burning, cultivation, and grazing [7].

Gombe Metropolis indicates a great rate of growth of built-up areas in and around the undeveloped metropolis land and that it is fast becoming more compacted, especially in the central part where population densities reach about 260 persons per square hectare [9]. It has a projected population of about 400,000 in 2010 [10]. Fig.1 Show urban land changes of the metropolis. Black color represents built up areas before 2001, red color for built up areas between 2001 and 2005, orange color represents built up areas between 2006 and 2010, yellow color represents built up areas between 2011 and 2015.

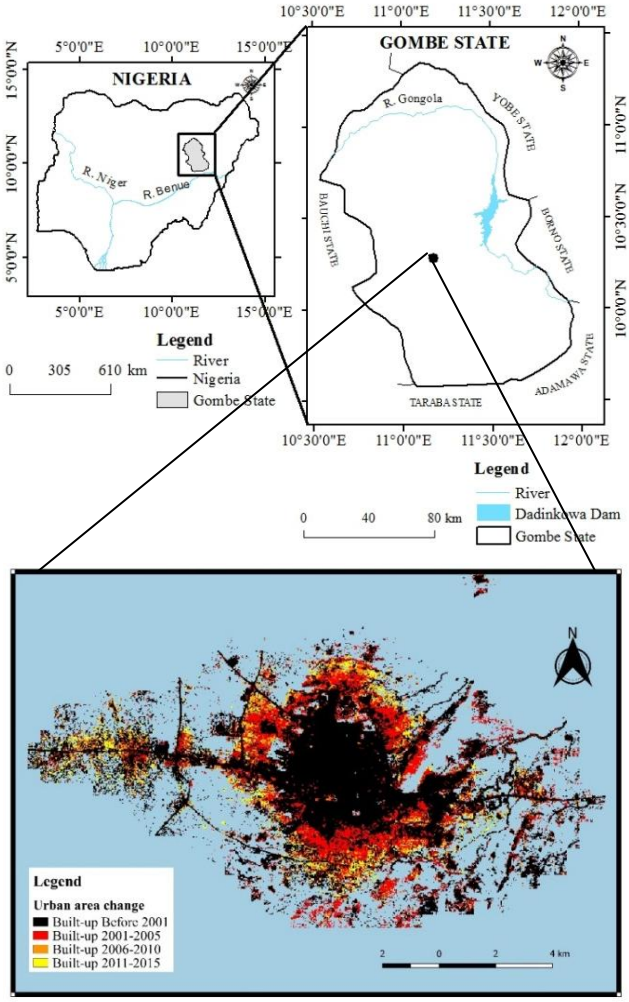

Fig 1: Study area Gombe Metropolis

B. Methods

This research employed datasets in table 1 between 2000-2015, and assessed the LCR/PGR of Gombe metropolis using Quantum GIS and one of its extensions (Trends.Earth) in a cloud based method.

Table 1 Data and Source

Data	Source	Requirements
Impervious surface data	Global Man-made Impervious surface	Impervious surface indices
Landsat ETM+	USGS Earth Explorer	Built-up area, surface extent
Population data	Gridded population of the world	Population estimate

i. Land Consumption Rate

Impervious surface and night time lights indices at 15% were applied to assess the built-up area (both compacted and disperse areas at the periphery) of Gombe metropolis on Trends.Earth urban Mapper:(https://geflanddegradation.users.earthengine.app/view/trendsearth-urban-mapper) Landsat available at 30 m resolution was used to assess the surface extent of the study area at an interval of 5 years (2000, 2005, 2010 and 2015). The surface extent was later categorized based on the built-up density into: urban (more than 50%), suburban (25-49%), built up rural (less than 25%)

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undeveloped (less than 100m from urban or suburban) [11]. Land consumption rate was computed using equation (1):

$$\text{Land consumption rate} = \frac{Ln\ (Urb_{(t+n)} / rb_t)}{Y} \ldots (1)$$

Where, Ln is natural logarithm
$Urb_{(t+n)}$ is surface extent of study area for initial period;
Urb_t is surface extent of study area for final period;
Y is year's difference

ii. Estimating Population of the study Area

The population of Gombe metropolis in the period under study was obtained through Gridded population of the world (GPWv4). The surface extent of metropolis was used and estimated the population both for dense and dispersed areas at the periphery. Population growth rate was computed using equation (2):

$$\text{Population growth rate} = \frac{Ln\ (Pop_{(t+n)} / Pop_t)}{Y} \quad (2)$$

Where
Ln is natural logarithm;
$Pop_{(t+n)}$ is the population of study area initial period;
Pop_t is the population of study area for the final period;
Y is year's difference.

iii. Ratio of land consumption rate to population growth rate

The ratio of land consumption rate to population growth rate was computed using the equation (3):

$$LCR/PGR = \frac{LCR}{PGR} \quad (3)$$

Where
LCR/PGR is ratio land consumption rate population growth rate;
LCR is land consumption Rates;
PGR is Population Growth Rates.

Result and Discussion

A. Surface Extent of Gombe Metropolis

The surface extent of the metropolis in fig. 2 was classified into:

1) Urban: a class of built-up areas which represents the compacted areas, found at the central part of Gombe metropolis especially in and around the old town of Gombe. Having population densities reach about 260 persons per square hectare [9]. Though Tumfure area to the west shows an extension of this form and indicates progressive urban transformations during the year 2005, 2010, and 2015.

2) Suburban: a class of built-up area which represents the peri-urban areas where buildings are separated with undeveloped plots of land.

3) Undeveloped areas: represents plots of land that are not developed. This class can be seen especially in and around suburban areas and at the periphery of the study area.

4) Built-up Rural: represents the rural areas around the study area. This class does not constitute surface area of the study area.

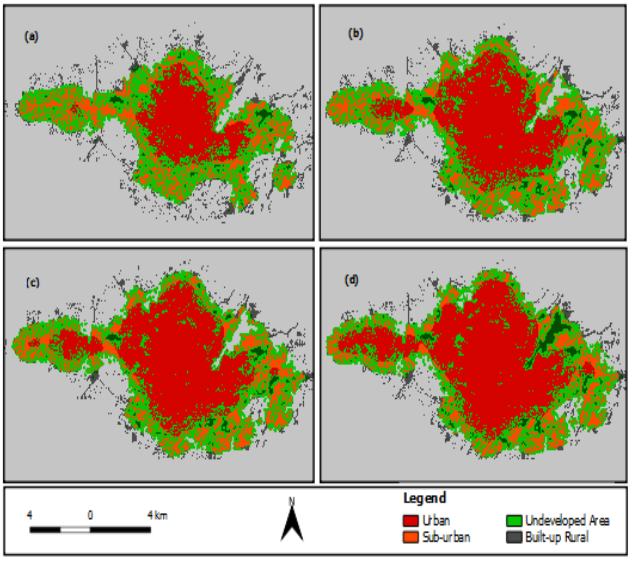

Fig.2 Classified Image of Gombe Metropolis.
(a) 2000, (b) 2005, (c) 2010 and (d) 2015

Table 2 Surface Area and Sealed Areas

Years	Built-up/ Sealed Areas (sq.km)	%	other classes (sq.km)	Surface Area (sq.km)
2000	9.7	30.5	22.1	31.8
2005	11.4	27.7	29.8	41.2
2010	16.6	33.5	33.0	49.6
2015	22.4	31.1	49.7	72.1

The study area in year 2000 occupies surface area (Table 1) of 31.8sq.km; out of this surface area, 9.7sq.km constitutes the built-up/sealed areas with 30.5% of the total area, and the other classes put together stand at 22.1sq.km. In year 2005 the surface area stood at 41.2sq.km, out of which 11.4sq.km is built-up/sealed area with 27.7% of the total surface area and the other classes are 29.8sq.km. During the year 2010 the surface area occupies 49.6sq.km, out of this area 16.6sq.km is built-up/sealed areas with 33.5% of the total surface area and the other classes stood at 33sq.km. In year 2015 the study area occupied surface area of 72.1sq.km, out of this area 22.4sq.km is built-up/sealed areas with 31.1% of the total land area covered and the other classes stand at 49.7sq.km. Nearly one-third of ground surface of the study area is being sealed with impervious materials that affect water cycle and encourage other environmental problems, they include: (1) rainwater cannot be absorbed to supply the soil, (2) no supply to maintain a certain level of groundwater, (3) decrease the infiltration rate and cause an accelerated surface run-off through rivulet and gullies, (4) flooding can occur especially when there is heavy rainfall over prolonged period.

One of the above findings (Table 1) matches the results found by [8] which indicate that the development in Gombe metropolis results in the unification of the traditional settlements and peri-urban areas in the 1990s to form a single body which reached the size of 30 sq.km in year 2000. Out of this figure approximately 10sq.km constitutes (built-up area and ground for traffic) the sealed surface. Balzerek *et al*., [8] also reported that the sealing of ground surface is more experienced especially in and around the compacted areas/old town of Gombe (with highest sealing rate of 75%) than in the dispersed areas at the periphery containing more new buildings (with sealing rate between 20 and 50%).

B. Land Consumption Rate

The rate of conversion of outlying/farmlands in and around the study area for urban land use stood at 5.2% during the year 2000 and 2005 (Table 2) and during the year 2005 and 2010 the rate falls to about 3.7% and the rose to 7.5% in the year 2010 and 2015, showing the need for land has risen more than the two periods recorded previously. The consumed land areas are being converted from outlying/farmland into residential, commercial, educational, administrative, road network or any related land use. The variation in the rate of land consumption between the three periods of study was influenced by certain factors which include: (1) economic development, (2) increase income, (3) living standard influence living space and mobility,(3) social developments, (4) increase in population, (5) Price of land and other building materials, (6) extension of infrastructure (e.g. roads, pipe borne water, power plants etc). [8] Reported that the expansion of the urban area in respect to the stages and the corresponding number of inhabitants as indicated by the area size of the adjacent circle diagrams, describe the dynamic of the urbanization process. [12] Indicated that open space/outlying land lost to urban areas is related to changes in population especially those areas with greater increase in population losing more space. [13] Reported that as human population within Gombe metropolis rises, more land is cleared of its available natural vegetation and replaced with impervious surfaces leading to low infiltration-runoff ratio.

C. Population of the Study Area

The population of Gombe metropolis can be traced in [13] to the year 1900 to 1952 when the inhabitants were 300 to 18,500 and in year 1964 to 1991 the populations stood at 47,000 to 138,000. In year 1996 when Gombe became the seat of government, the number of inhabitants increased to 169,894.

However the result obtained from this study reveals a progressive population increase. In year 2000 the number of inhabitants reached 262,226 and during year 2005 the population estimated at 321,278 inhabitants, with an increase of 59,052 inhabitants. In year 2010 the population reached 402,885, with an increase of 81,607 inhabitants. In year 2015 the number of inhabitants estimated at about 495,000, with an increase of 92,115 inhabitants when compared with the previous period. This demographic development creates room for more transformations especially in socio-economic activities and urban surface area growth. These developments are makers to a significant influx of migrants from the neighboring states and have been one of the drivers of urban dynamics and patterns within the squares of Gombe metropolis. [8] Reported that demographic development of Gombe metropolis is mainly based on dynamic intra and inter-regional migration and significantly indicates the development of the economy, predominantly the tertiary sector.

D. Population Growth Rate of the Study Area

Gombe metropolis recorded population growth of 4% during the year 2000 and 2005 (see Table 2). The growth increased to about 4.5% during the year 2005 and 2010. But drop to about 4.1% between the year 2010 and 2015 when compared to the previous growths recorded.

E. Difference between Land Consumption rate and Population Growth rate

The result presented in table 2 indicates that during the periods of year 2000 and 2005 the rate of land consumption grew at the rate of 1.1% greater than the population. Table 2 also shows that the rate of population growth increased at 0.8%, greater than the rate at which the undeveloped urban land of the study area was consumed during the year 2005 and 2010. The result further reveals that in the year 2010 and 2015 the remaining undeveloped urban areas were consumed at the rate of 3.4% greater than the rate of population growth. Fig. 3 also presents disparities between the sub-indicators. The above findings are consistent with those of the previous research which showed that the expansion of Gombe metropolis has led to the intrusion into the peri-urban environs far beyond the original town borders and is followed by a significant change in land use which has increased the sealed surface thereby reducing infiltration rate of rain water [8].

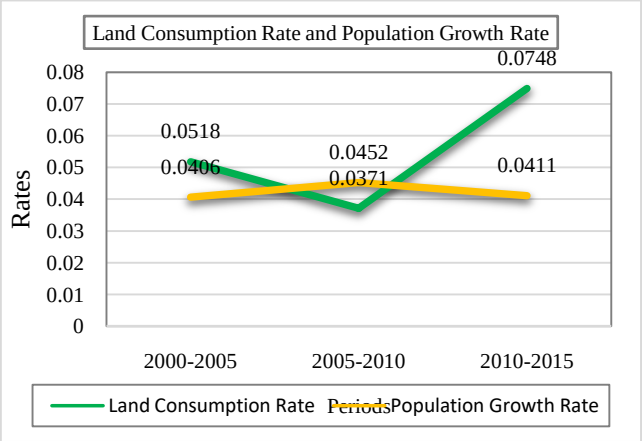

Fig 3: Land Consumption Rate and Population Growth Rate.

F. Ratio of Land Consumption Rate to Population Growth Rate

Table 3 LGR/PGR of Gombe Metropolis

	Population Growth Rate	%	Land Consumption Rate	%	Difference	%	LGR/PGR
2000-2005	0.0406	4.1	0.0518	5.2	0.0112	1.1	1.2
2005-2010	0.0452	4.5	0.0371	3.7	0.0081	0.8	0.8
2010-2015	0.0411	4.1	0.0748	7.4	0.0337	3.4	1.8

The LCR/PGR for the periods under review are not consistent as presented in table 3. Rather they reveal split characteristics. The LCR/PGR during the period of year 2000 and 2005 stood at 1.2, showing that the study area expanded outward. During year 2005 and 2010 the LCR/PGR was 0.8. This ratio shows that the study area became more compacted with little expansion, a trend of this nature if maintained in a relative manner, will make the study area to become compacted and

likely to function in a way, that activities and services are within the reach of people so reduce ground sealing and other environmental problems. The LCR/PGR during the period of year 2010 and 2015 reached 1.8. The LCR/PGR indicates that the study area expanded outward with rate of sealing getting higher. When land consumption rate over sweep the rate of population growth and without proper monitoring, it will result into (1) uncontrolled physical expansion over peri-urban areas, (2) continuous sealing of urban surfaces, (3) physical infrastructural deterioration, (4) high energy consumption, (5) CO^2 emissions, (6) Imbalance between growth of labor force and urban population among others. One of the previous studies reported that the spatial and temporal analysis of Gombe urban layout disclosed centrifugal growth, building densification and urban layout modification [8].

Conclusion

The paper concludes that the study area expanded outward during the year 2000 and 2005, while between the year 2005 and 2010, it became more compacted with little expansion. However, the rate of ground surface sealing was higher than the rate of population growth in the year 2010 and 2015. Therefore, the LCR/PGR pattern in periods under review indicates split trends.

Recommendations

The paper therefore recommends vertical urban growth. This form of growth will not only host vast amounts of people in a relative footprint but also conserve land and natural resources, reduce ground surface sealing, and emissions of CO^2 for better ecosystem services, depending upon the economic, social and environmental tradition of the study area.

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