Ratio of Land Consumption Rate to Population Growth Rate - A case of Gombe Metropolis, Nigeria

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Abstract: Demographic and socio-economic developments couple with other requirements to satisfy human needs result in rapid urban expansion sometimes with increasing rate of surface extent greater than the rate of growth of population, that result in continuous sealing of ground surface thereby affecting ecosystem services. This study applied remote sensing toward achieving the progress of SDGs and stage to determine the ratio of the rate of land consumption to the rate of population growth of Gombe metropolis. QGIS 2.18 was used for the image processing and classification analysis for the key Landsat ETM+ (Enhanced Thematic Mapper), Impervious Surface Indices and population data to inform on the urban trend and LCR/PGR for the periods 2000-2005, 2005-2010, and 2010-2015. The result appears that the LCR/PGR for the periods of study show split trends. During 2000-2005 the result shows that the study area expanded outward with LCR/PGR of 1.2. The result also indicate that during 2005-2010, the study area densified with little expansion with the LCR/PGR of 0.8. The result further reveals that during 2010-2015 the LCR/PGR reached 1.8. Pointing that the study area expanded outward with the rate of ground sealing getting high.

Keywords: Land consumption, Sustainable Development Goal, population growth, urban area,

1   Introduction

The sustainable Development Goals are blue print to attain distant better and more sustainable future for all. SDGs were embraced at the end of September 2015, amid UN summit in New York, by all Joined together Countries as all inclusive call to activity to put down poverty, ensure the planet and guarantee that all individuals appreciate peace and success by 2030.[1]

Sets of 17 Sustainable Development Goals and 169 targets came into effect in January 2016 and coordinates in a way they recognize that activity in one area will influence the result of the others. These goals are categorized into three grades based on the branch of philosophy that analyses the principles, procedures and availability of data at world level. The SDGs are anticipated to direct and adjust the three attributes of sustainable development comprise of economic, social, environmental approach and investments until 2030.[2] SDG indicator 11.3.1 which aim to determine the "ratio of Land consumption rate to Population Growth Rate".[3]

The contemporary urban transformation rate cause changes in environmental state at different scale, which is closely related to land-use, cover, diversity of plant and animal life, climate and other components of environment.[4] These urban areas are the primary human living space which depend on environmental services to flourish, but they too debilitate the components of the environment through excessive resource-use to contamination that result in land deterioration.[5]

The patterns in these urban areas are energize by few essential variables like: changes in population, economic opportunities and efficiency, good physical and social conditions and presence of empowering policies etc. 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.[6]

This urbanization comes almost through the social, political, economic and cultural dynamic and result within the convergence of human activity in all cities regardless of size. This result in competition on land as request by numerous land uses and ecosystem services rises whereas this urban zones still speak to nowadays a little extent of the Earth's surface,[7,8] but their impacts on hydrology, climate, resource request, utilization, and emissions, for case, 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 determine their characteristics and for better understanding of the cause and effect of this changes. In keeping with the afore objective to accomplish land use efficiency, decision makers, NGOs pressure groups ought to get it 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 moreover open door to make approaches that encourage ideal utilize of urban land effectively securing other land uses. Moreover, to accomplish environmental sustainability, the urban utilization must be coordinated to be in harmony or be underneath what the common environment can give, and the coming about pollutants must not overpower the environment's capacity to supply resources to people and other components of the ecosystem.[9]

According to the study which positions 100 cities worldwide on three attribute of sustainability: people, planet and profit. (They speak to social, environment and economic sustainability). The research appears that cities in and around the world are not balancing these three pillars of sustainability. Instead, many of these cities portray split identities either in people, and planet or profit, but exceptionally few do well in all three, demonstrating the challenge that cities ought to adjust all three needs effectively to guarantee long-term sustainability.[10] As such, analysts and related NGOs, pressure groups emphasize on the role of knowledge of good urban transformation within the setting of urban planning.[11]

The aim of this paper is to monitor the ratio of land consumption rate to the rate of population growth of Gombe metropolis. 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 less than, or greater than, the prevailing rate of population growth, in order to promote sustainable urban expansion.

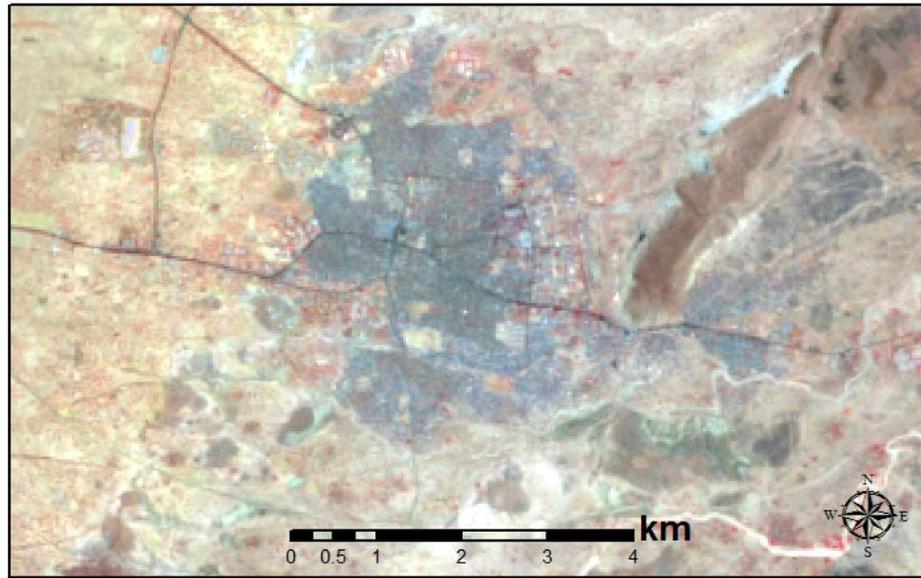
2   Materials and Methods

2.1   *Study Area*

Gombe metropolis is the seat of government of Gombe state, situated in the northern part of Nigeria. It was created from the then Bauchi state on 1st October, 1996. It is located between lat. 10º 0' to 10 º 20'N and log, 11º 01' to 11º 19'E. It is bounded to the north by Kwami local government area, to the south and west by Akko, and to the East by Yamaltu-Deba.[13] It has a projected population of about 400,000 in 2010.[14] (Fig. 1) show Landsat satellite scene of the study area in near infrared, red and green. The urban areas can be seen in light-medium or dark blue colors, undeveloped surfaces in light brown-yellow, vegetation in red, roads in black, and geological outcrop in brown. Previous research reported that due to the reflection of the roofs of corrugated iron sheets, most African towns seen from space, appear in blue luminosity. And the spectral attributes of these metal roofs differ with age, which is an important peculiarity allowing the differentiation of the urban structure and the monitoring of its development.[15]

2.2   Method

2.2.1   Materials

This research require datasets in Table 1 that cover the entire study area for the period between 2000 and 2015. The changes for each sub-indicator can be assessed during three periods over the time frame at interval of 5 years.

Source: Landsat, Reference scene ID of 186-053; on 07-04-2000.
Fig. 1 Satellite image of Gombe Metropolis

Stage 1 Establishing factor of annual urban extent:

Annual land consumption rate $= \dfrac{\ln (U_{t2}/U_{t1})}{nY}$ (1)[12]

ln is natural logarithm
U_{t1} is the surface area extent of study area for initial period;
U_{t2} is the surface area extent of study area for final period;
nY is years difference

Stage 2 Establishing factor of annual population increase:

Annual population growth rate $= \dfrac{\ln (P_{t2} / P_{t1})}{nY}$ (2)[12]

ln is natural logarithm;
P_{t1} is the population of study area initial period;
P_{t2} is the population of study area for the final period;
nY is years difference.

Stage 3: determine the ratio of annual land consumption to annual population growth

$LCRGR = \dfrac{ALCR}{APGR}$ (3)[12]

LCRPGR is Land consumption rate Population growth rate;
ALCR is annual land consumption Rates;
APGR is annual Population Growth Rates.

Table 1 Data and Source

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

2.2.2   *Estimating Population for each year of study*

The number of people living within the Gombe metropolis for the period of this study is being established through Gridded population of the world (GPWv4). The built-up area of the metropolis is being used to estimate the distribution of the count and densities on a continuous raster surface with the aid of grid cells based method that estimate the population both for the dispersed and dense areas, and each grid cell bear a unique value, depending on the location, quantity of the built-up area and land use classes.

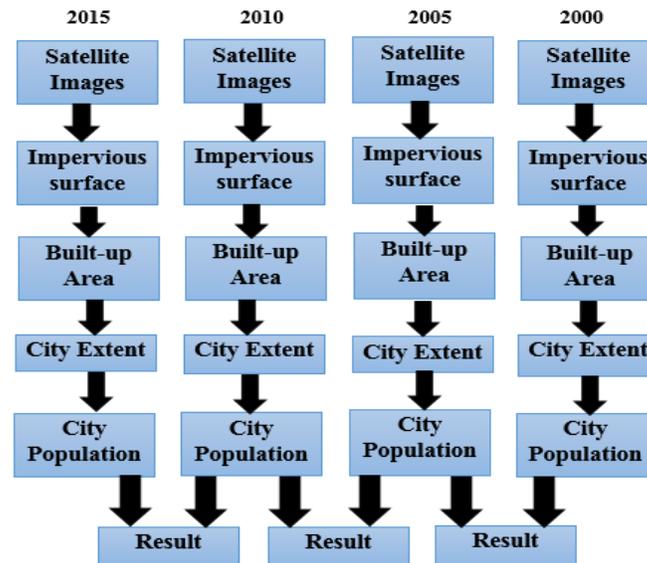



Fig. 2 Flow-chart showing technical process for computation of ratio of land consumption rate to the population growth rate

2.2.3   *Estimating Land Consumption Rate*

Land consumption rate is estimated through image classification technique where three classes were employed in the analysis included: built-up/sealed areas (urban, suburban and road network), undeveloped areas and vegetation, for the period of 2000, 2005, 2010 and 2015. Three parameters were used to influence the process:

- **Impervious Surface Index ISI:** In estimating impervious surfaces, 15% is being applied to cover both the compacted and disperse areas at the periphery of the study area**.**
- **Night Time Lights Index NTL:** In estimating the night time light for the impervious surfaces, 15% is being used to cover both the compacted and disperse areas of the study area**.**
- **Water Frequency Index WFI**: In the absence of large water body in and around the study area, this is index is being selected as default.

This data is been converted to binary representations which determine surface area occupied by buildings within the squares of the Gombe metropolis area.

2.2.4   *Computation of Ratio of Land Consumption Rate to the Population Growth Rate*

Trends.Earth Plugin for Quantum GIS is employed for the analysis. Multi-dated images for key land changes are being computed using the work flow in (Fig. 2) and track the relationship between consumed land surfaces to population increase of the study area for the period of 2000-2015 at the interval of 5 years. Maps and tables are produced for interpretation.

3   Result and Discussion

3.1   *Estimated Population*

The population of Gombe metropolis can be traced to 1900 to 1952 when the inhabitants were 800 to 18,500 and in 1964 to 1991 the population stand at 47,000 to 138,000. In 1996 when Gombe became the seat of government the number of inhabitants increased to 169,894. However the result obtained from this study (Table 2) reveals a progressive population increase. In 2000 the number of inhabitants reached 262,226 and during 2005 the population estimated at 321,278 inhabitants, with an increase of 59,052 inhabitants. In 2010 the population reach 402,885 inhabitants with an increase of 81,607 inhabitants. In 2015 the population the number of inhabitants reached 495,000, with an increase of 92,115 inhabitants.

Metropolis Gombe during the period of this study experienced demographic, socioeconomic and surface area, transformations. These changes pointed to large influx of migrants. The compacted and dense populated areas are found especially in and around the old town of Gombe, and the dispersed (sub-urban) areas towards periphery. Number of previous studies reported that the population of the Gombe metropolis is projected to reach about 219,946[16] and 400,000[14] in 2000 and 2010 respectively. Another research reported that the 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.[17]

Table 2 Estimated population of the study area

Years	Population
2000	262,226
2005	321,278
2010	402,885
2015	495,000

Source: Gridded population of the world (GPWv4).

Demographic development is one of the driving agents for urban dynamics and pattern of development within the squares of the study area. Growth of 4% was recorded during 2000-2005. The growth remained consistent and increased to 4.5% during 2005-2010. But during 2010-2015 the growth drop to 4.1% when compared with the previous growth recorded. The population growth influence various land use to provide for its needs. This is consistent with the previous studies 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.[17] Research also 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.[18] Another study also reported that as human population within Gombe Metropolis rise, more land is cleared of its available natural vegetation and replace it with impervious surfaces leading to low infiltration-runoff ratio.[19]

Table 3 Population Growth Rate

	Population Growth Rate	%
2000-2005	0.0406	4.0
2005-2010	0.0452	4.5
2010-2015	0.0411	4.1

Source: Author's analysis 2020

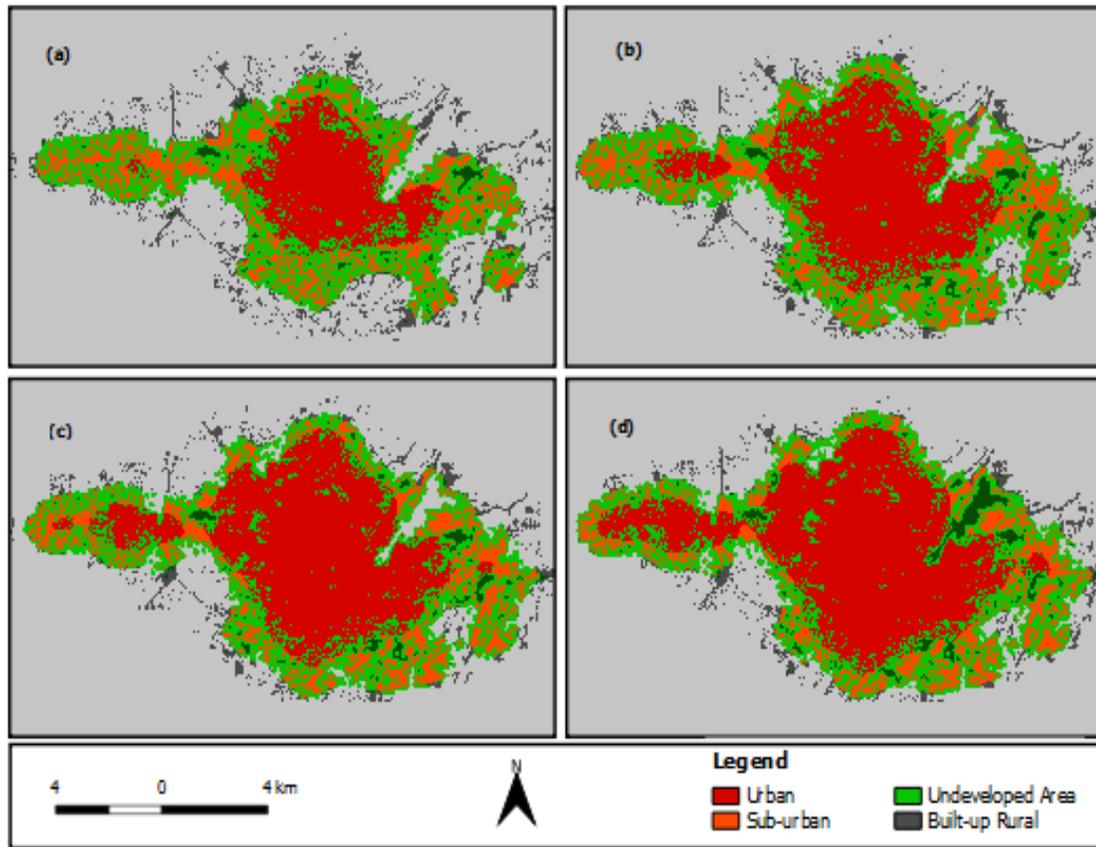
3.2   *Land Consumption Rate*

Source: Author's analysis 2020

Fig. 3 surface area occupied by Gombe Metropolis.

Surface area occupied by study area for the period of this study is presented in Figure 5: (a) 2000, (b) 2005, (c) 2010 and (d) 2015.

The surface extent of the study area (Fig. 3) is being classified into:

- Urban: a class of built-up area which represent the compacted areas and can be seen at the central part of the study area especially in and around the old town of Gombe. Though Tumfure area to the western part (Fig. 3), shows an extension of this form and indicating progressive urban transformations during 2005, 2010, 2015. This class is defined as urban area for having greater than 50% built-up in 500m radius of that pixel.
- Suburban: a class of built-up area which represent the peri-urban areas where buildings are separated with undeveloped plot of land (Fig. 3). This class is defined as Suburban area for having the range of 25-49% built-up in 500m radius of that pixel.
- Undeveloped areas: represent plot of land own by individuals that are not developed. This class can be seen especially in and around suburban areas and at the periphery of the study area (Fig. 3). Undeveloped class is defined as area that is less than 100m from urban and suburban.

- ▪ Built-up Rural: represent the rural areas around the study area (Fig. 3). This class is classified as built-up rural area for having less than 25% built-up in 500m radius of that pixel. This class does not constitute surface area of the study area.

Table 4 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	30.1	49.7	72.1

Source: Author's analysis 2020

The study area in 2000 occupied surface area of 31.8 sq.km. Out of this surface area 9.7 sq.km constitute the built-up/sealed areas with 30.5% of the total area, and the other classes put together stand at 22.1 sq.km (Table 4). In 2005 the surface area stand at 41.2 sq.km. Out of this figure 11.4 sq.km is built-up/sealed area with 27.7% of the total surface area and the other classes are 29.8 sq.km. In 2010 the surface area occupy 49.6 sq.km. Out of this area 16.6 sq.km is built-up/sealed areas with 33.5% of the total surface area and the other classes stand at 33.0 sq.km. In 2015 the study area occupied surface area of 72.1 sq.km. Out of this area 22.4 sq.km is built-up/sealed areas with 30.1% of the total land area covered and the other classes stand at 49.7 sq.km.

Nearly one-third of ground surface of the study area is being sealed with impervious materials which affect water cycle and encourage other environmental problems: (1) rainwater cannot be absorbed to supply the soil, (2) no supply to maintain a certain level of groundwater below, (3) decrease the infiltration rate and cause an accelerated surface run-off through gullies, (4) flooding can occur especially when there is heavy rainfall over prolonged period.

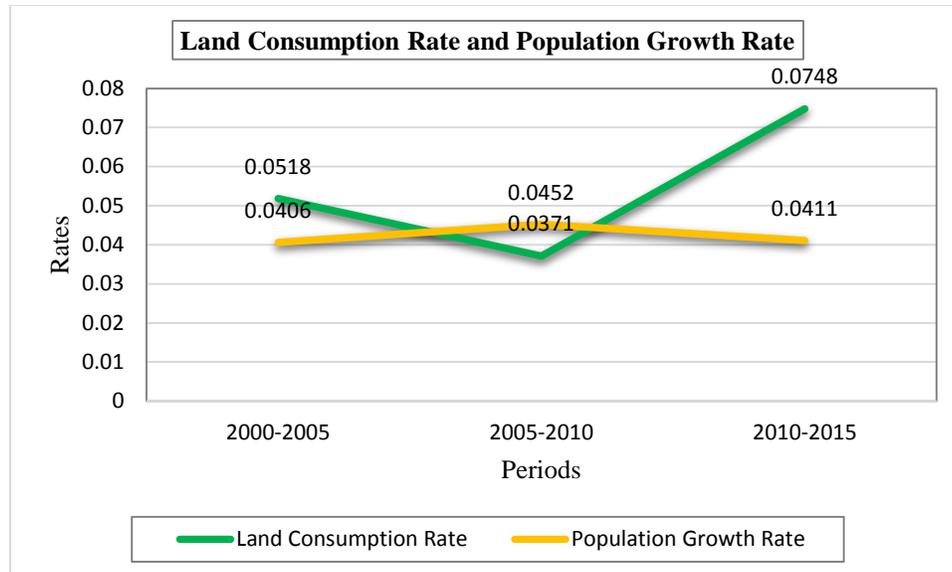
One of the above findings (Table 4) matches the result reported by previous study which indicated that the development in Gombe metropolis result in the unification of the traditional settlements and peri-urban areas in the 1990s to form a single body which reach the size of 30 sq.km in 2000. Out of this figure approximately 10 sq.km constitute (built-up area and ground for traffic) the sealed surface.[17] The sealing of ground surface is more experienced especially in and around the compacted areas of the study area than in the dispersed areas at the periphery. Another result also reported that the highest sealing rate of 75% can be found in the old town of Gombe whereas the marginal wards, containing more new buildings, reach sealing rate between 20 and 50%.[17]

Table 5 Land Consumption Rate

	Land Consumption Rate	%
2000-2005	0.0518	5.2
2005-2010	0.0371	3.7
2010-2015	0.0748	7.5

Source: Author's analysis 2020

The land consumption rate (Table 5) during the periods of 2000-2005 is 0.0518. During 2005-2010 has the rate stand at 0.0371. The consumption rate during the periods of 2010-2015 stand at 0.0748.

This consumption result into conversion of the outlying land/farmland in and around the study area into residential, commercial, educational, administrative, road network or any developed land use. The land consumption rate (Fig 4) between the three periods of study of varies. This variation can be affected by certain factors among which include: (1) economic development, (2) increase income affect living standard and living space and mobility, (3) social developments, (4) increase in population, (5) Price of land and other building materials, (6) extension of infrastructures (e.g. highways, power plants etc.).

Source: Author's analysis 2020
Figure 4: Land Consumption Rate and Population Growth Rate**.**

3.3   *Ratio of Land Consumption Rate to Population Growth Rate*

Table 6 Difference between land consumption rate and population growth rate

	Population Growth Rate	**Land Consumption Rate**	**Difference**	**%**
2000-2005	0.0406	0.0518	0.0112	1.1
2005-2010	0.0452	0.0371	0.0081	0.8
2010-2015	0.0411	0.0748	0.0337	3.4

Source: Author's analysis 2020

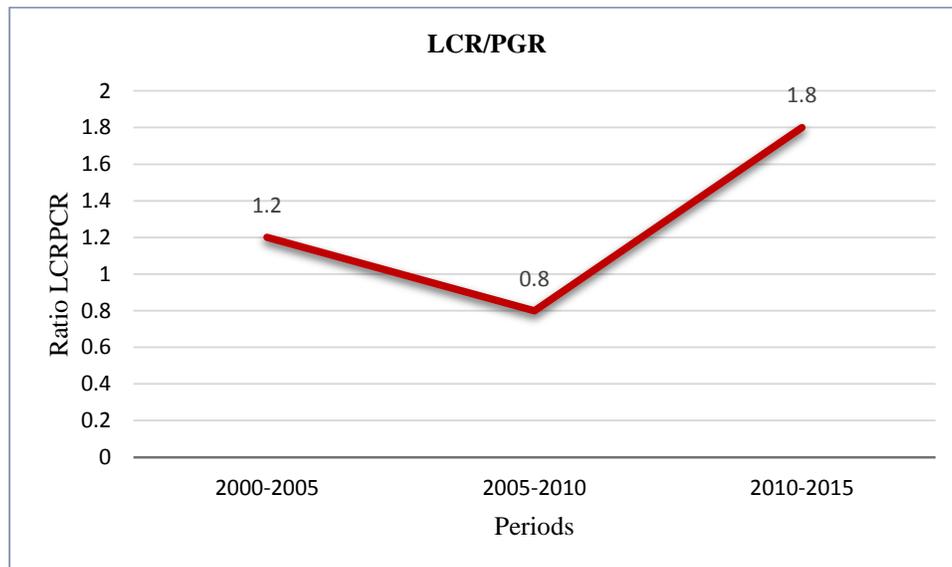
The studies indicates that during the periods of 2000-2005 the rate of land consumption grow at the rate of 1.1% greater than the population. (Table 6) also shows that the rate of population growth increases at 0.8%, greater than the rate at which the undeveloped urban land of the study area were consumed during 2005-2010. The result further reveals that during 2010-2015 the remaining undeveloped urban areas were consumed at the rate of 3.4% greater than the rate of population growth. The above findings is consistent with previous research which reported 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 increase the sealed surface thereby reducing infiltration rate of rain water.[17]

Table 7 Ratio of land consumption rate to the population growth rate

	Population Growth Rate	**Land Consumption Rate**	**Ratio LGR/PGR**
2000-2005	0.0406	0.0518	1.2
2005-2010	0.0452	0.0371	0.8
2010-2015	0.0411	0.0748	1.8

Source: Author's analysis 2020

The LCR/PGR for the period of study are not consistent. Rather they reveal split characteristics. The LCR/PGR during the period of 2000-2005 stood at 1.2, showing that the study area expanded outward. During 2005-2010 the LCR/PGR was 0.8. This ratio shows that the study area densified with little expansion, and a trend of this nature if maintain in relative manner, the study area will become compacted

and likely to function in a way that activities and services are within the reach of people and reduce ground sealing and other environmental problems. The LCR/PGR during the period of 2010-2015 reached 1.8. The LCR/PGR indicates that the study area expanded outward. When land consumption rate over sweep the rate of population growth and without proper monitoring then 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.[17]

Source: Author's analysis 2020
Fig. 5 LGR/PGR

5   Conclusion

This research demonstrated methods, and advanced tool and answered the question of whether the remaining undeveloped urban land of the Gombe metropolis is being consumed at a rate that is less than, or greater than, the prevailing rate of population growth, to promote sustainable urban expansion. The result obtained appears that the LCR/PGR for the periods of this study indicate split trends, during 2000-2005 the result shows that the undeveloped urban areas were consumed at the rate of 1.1% greater than the rate of population growth, indicating that the study area expanded outward. The result also shows that during 2005-2010 the rate of population growth increases at 0.8%, greater than the rate at which undeveloped urban land of the study area were consumed, showing the study area densified with little expansion. But during the period of and 2010-2015 the result shows that the undeveloped urban areas were consumed at the rate of 3.4% greater than the rate of population growth, indicating that the rate of sealing of ground surface was getting high.

6   Recommendations

This paper recommend vertical urban growth, depending on the economic, social and environmental tradition of the study area. This form of growth is being employed by the state government in education section (both primary and secondary schools) to host growing number of students within the available school land area. This form of growth will not only host vast amounts of people in a relative

footprint, but conserving land and natural resources, reduce sealing of ground surface, and also reduce the emissions associated with cars.

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