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Monitoring urban growth and changes in land use and land cover: a strategy for sustainable urban development

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ABSTRACT

BACKGROUND AND OBJECTIVES: Recently, Jos Metropolis, Nigeria is witnessing a strong trend toward urban growth and expansion. This phenomenon has impacted Land Use/Land Cover and efficient management of land. This paper evaluated urban growth and changes in Land Use /Land Cover and examined the land use efficiency of the metropolis. Land Use and Land Cover changes were established from 1999 to 2022; Land consumption rate and population growth rate were determined, and computation of the SDG 11.3.1 framework was done to examine the efficiency of land use.

METHODS: Data were collected through official documents, the use of remote sensing, and, geographic information systems. Satellite imageries used to determine the classes and changes in Land Use/Land Cover changes were Landsat 5 TM (1999), Landsat 7 ETM+ (2004, 2009, and 2014), and Landsat 8 ETM+ (2018 and 2022). Global positioning system was used for ground-truthing, IDRISI Taiga software was used for image classification, and ArcGIS was used for map visualization. Four classes of Land Use and Land Cover were identified: Built-up, Meadows, Mountain/Vegetation, and Water bodies.

FINDINGS: Results revealed that built-up area increased consistently from 3494.007 hectares in 1999 to 16995.360 ha in 2022 leading to a substantial reduction in other land use and land cover. The study confirmed a burgeoning population growth from 780,000 in 1999 to 1,563,193 in 2022. This growth had a significant impact on urban land use management, consuming a large proportion of land from 3494.007 hectares to 16995.36 hectares in 1999 and 2022 respectively. Results revealed a high land consumption rate of 0.0962 and 0.0884 during 2018-2022 and 1999-2004. A high population growth rate (0.0414) was recorded during 2018-2022. These dynamics intensified the rate of land acquisition for urban development. The average value of the SDG 11.3.1 framework was 2.3 which is higher than 1, indicating that urban expansion is moving away from land use efficiency.

CONCLUSION: The paper recommended the establishment of a Growth Management Monitoring system by the state government for effective and efficient management of land resources through a spatial plan for the metropolis. This study has provided insight into the dynamics of Jos metropolitan LULC and land use efficiency management which could be useful to policymakers, urban planners, and researchers in initiating sustainable urban development strategies and inclusive structure for its planning and management.

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INTRODUCTION

The dynamic nature of urban areas the world over suggests that the future of planet earth is an urban one. Urban areas all over the world are in a state of flux, especially in less developed countries, and a strong trend toward urban growth and expansion has been observed (Rikko, 2016). The United Nations predicted that by the year 2030, more human population will live in urban than in rural regions, majorly in Asia and Africa, which presently are the slightest urbanized parts of the globe (Abdulkadir *et al.* 2019, Sustainable Development Solutions Network, 2012). In Sub-Saharan Africa, Nigeria has the highest proportion (52.764%) of the urban population (The World Bank Data, 2022; Rowland, 2016). This unprecedented increase in population has a significant impact on the land due to human-associated sustenance activities, such as shelter, infrastructure development, food production, and extraction of natural resources. However, land resources are becoming increasingly scarce on a global scale, as a result of continued exploitation and mismanagement (Fikadu, 2022; Gessese, 2018). The rapid increase in urban population derived several cities globally into having high land consumption due to increased demand, which is evidenced in city boundaries often extending to further peripheries (Nicolau *et al.,* 2019; UN-Habitat, 2018; Seto *et al.,* 2011). This development according to Mustard *et al.* (2012) changes the entire spatial distribution of Land Use and Land Cover (LULC) of cities. The rapid changes in LULC, are one of the major forces of environmental change globally and are focal to the sustainable development debate. These changes in LULC, include the rampant conversion of agricultural land to urban development due to urban growth, and environmental degradation (Hegazy and Kaloop, 2015; Tsegaye, 2014). It is, therefore, crucial to evolve approaches that monitor and measure urban growth and LULC change for sustainable and efficient land management. The present study area is witnessing rapid population growth coupled with haphazard and unguided expansion occurring in the metropolis which has accelerated due to international crises, environmental changes, and urbanization. The expansive nature of growth and the change occurring in the LULC of the metropolis is unsustainable. This growth has serious environmental challenges ranging from loss of agricultural land (d'Amour *et al.,* 2017; Pandey and Seto, 2015), poor/lack of infrastructure, and growing sprawl/squatter settlements (Wang *et al.,* 2021), urban greenhouse gas emission (IPCC, 2014), habitat fragmentation and biodiversity loss (Cameron *et al.,* 2021; McDonald *et al.*, 2020; Guneralp *et al.,* 2013). Interestingly, UN-Habitat, (2018) posits that more than half of the area expected to be urban in 2030 has yet to be built. Thus, there is a great chance to make the future city more productive and sustainable, and cities that have the potential to improve the lives of half the world's population today, and 80% by 2030 (UN-Habitat and UNEP, 2013). However, most cities are forfeiting these advantages, growing spatially faster than their population and haphazardly absorbing land needed for agriculture and ecosystem services (UN-Habitat, 2018; UN DESA, 2022). Given the increasing environmental challenges posed by urban growth, growth monitoring techniques have been reviewed. The United Nations Human Settlements Programme proposed the adoption of a framework for urban growth monitoring, titled "ratio of Land Consumption Rate to Population Growth Rate" (UN-Habitat, 2018). This framework is also known as SDG 11.3.1, because it is associated with Sustainable Development Goal 11 which is aimed at "making cities inclusive, safe, resilient and sustainable", and, more specifically with the target 11.3 that envisages "enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries" by 2030 (UN-Habitat, 2018, Nicolau *et al.,* 2019). The framework SDG 11.3.1 is intended to understand the relationship between population shifts and urban land (Sharma *et al.,* 2012). It informs and enables policymakers and urban planners to monitor and manage urban land efficiently and ensure cities that are productive and environmentally sustainable (Sustainable Development Solutions Network, 2012). The framework SDG 11.3.1 has been grouped as grade II due to its universally proven technique for its calculation, even though, the data for its establishments are not often produced by nations (Nicolau *et al.,* 2019). In the foregoing, experts view the formula suggested for working out of framework 11.3.1 as inadequate because it ends with uncertain values. The discussion on the method and accessibility of datasets for the calculation of the framework has been limited to a set of scholars working together with the UN for this reason. In line with (Nicolau *et al.,* 2019; Abdulkadir *et al.*, 2019) that this framework aims to examine the extent of areas occupied by urban settlements relative to population increase. There is a lack of clarity regarding the standard definition and measurement of what constitutes the category of land referred to by the framework. However, scholars assume the category of land referred to by the framework is the urban spatial extent which includes the entire built-up areas of the target regions or cities (UN-Habitat, 2018, Abdulkadir *et al.,* 2019). Global Human Settlement Layer (GHSL), has been used in a variety of urban studies to source data on built-up areas and the population of regions within a given period which is crucial in determining the relationship between the spatial extent and population increase of an area. For instance, Abdulkadir *et al.,* (2019); Freire and Pesaresi (2015), acquired data on built-up area and population densities from the GHSL in the development of the framework SDG 11.3.1. The results calculated in the framework have been useful in monitoring Land Use Efficiency (LUE) in the respective regions. However, data obtained from the GHSL may not be always correct, sometimes the built-up areas may be falsely detected, being that some settlements are not detected because of their size or material used for construction or they were below a dense tree canopy (Cai *et al.,* 2020). Other open data sources like satellite images, such as Thematic Mapper (TM), Enhanced Thematic Mapper (ETM+), and Operational Land Imager (OLI) from Landsat satellites, with a spatial resolution of 30 meters, have been reliable in providing substantial data for geographical studies (Chen and He, 2018), especially on LULC including built-ups and changes that have occurred in the environment. Remote Sensing and Geographic Information Systems (GIS) have been widely used and can provide scientifically reliable data on urban spatial extent and detection of changes in the LULC (Hossain and Moniruzzaman, 2021; Chen *et al.,* 2020; Rimal *et al.* 2018; Wang *et al.* 2020; Mohamed, 2017). Remote sensing data particularly Landsat images provide a suitable possibility for LULC change monitoring, particularly for developing countries where geospatial technologies are not well developed (Adepoju *et al.* (2006) cited in Leta *et al.* 2021). Geographic Information Systems provide maps, geographically referenced spatial analysis, and tabular information on the extent and changes in LULC (Kotaridis and Lazaridou, 2018). Pieces of literature on LULC have been reviewed (Agarwal *et al.,* 2002; Ochuka *et al.,* 2019; Bashir, 2012; Minale, 2013; Hegazy and Kaloop, 2015; Rikko, 2016; Farrell, 2017; Yohanna*, et al.* 2015; Mahmoud *et al.*, 2016; Fikadu *et al.,* 2022; Arifeen *et al.*, 2021; Hassan and Nazem, 2016; Liping *et al.*, 2018). These studies have generated credible information on the extent and changes in LULC, which can provide better decision-making for sustainable development in various areas. Studies conducted in Jos south Local Government Area of Plateau State Okafor *et al.,* (2014), mapped out land use and land cover between 1993 and 2013 using remote sensing and GIS, and Adzandeh *et al.,* (2015) analyzed urban growth agents in Jos metropolis. The studies revealed significant transformations in LULC. However, the previous studies concentrated on LULC changes and the identification of growth agents, in certain areas. The extent of land consumption to the population growth rate of the region has not been considered. This study fills the knowledge gaps. The present study employed remote sensing and GIS techniques to determine the LULC areal extent and changes of the entire metropolis and applied the framework SDG 11.3.1 to measure the rate of land consumption to the population growth rate of the region. The present study focused on the evaluation of the spatial changes in LULC along with the relationship between the extent of built-up areas and population growth rate from 1999 to 2022 in Jos metropolis. Statistics of LULC and changes and location of change were established, land consumption and population trend of the metropolis were determined, and computation of SDG 11.3.1 which determines the LUE was carried out. In the end, the computed value of the SDG 11.3.1 framework determines whether the extent of land consumption is higher or lower than the rate of population growth. The current study have been carried out in Jos Metropolis, Plateau State, Nigeria in 2022.

MATERIALS AND METHODS

The Study Area

Jos Metropolis is the administrative and commercial hub of Plateau State. Located in north-central Nigeria, it is about 288 kilometers from Abuja the federal capital territory. The metropolis lies between latitude 9º55'0" N to 9º47'40" N and

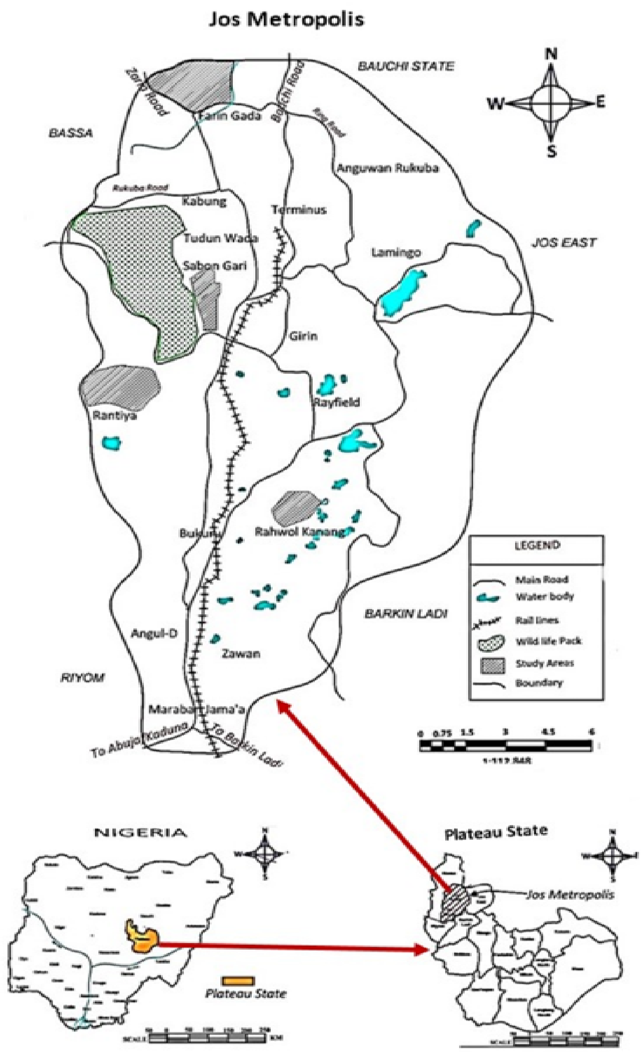

Fig. 1: Jos Metropolis.

Longitude 8º57'20" E to 8º50'0" E (Hassan *et al.* 2015). It is bordered to the North-West by Bassa Local Government, North-East by Bauchi state, the South-West by Bassa and Riyom Local government, and the South-East by Barkin Ladi Local Government areas respectively (Fig. 1). The metropolis existed as a small mining city in 1904, demand for tin ore paved way for its fast urban population, consequently physical expansion (Dung-Gwom and Rikko, 2009; Wapwera *et al.,* 2015).

Methodology

The flow chart (Fig. 2) outlines the procedures involved in this study.

Data Sources

In this research, data were collected through the application of Remote Sensing and GIS tools. The image data used were Landsat images. These images were acquired from the United States Geological Survey's (USGS) spatial portal. The images were from six different epochs; the first epoch (1999) was collected from Thematic Mapper (TM) Sensors with Seven Bands in Geotiff format. The other collections were that of LANDSAT 7, with Enhance Thematic Mapper Sensor (ETM). As shown in table 1, 2004, 2009, and 2014 images are from LANSAT 7 ETM sensors; while 2018 and 2022 were from LANSAT 8 ETM sensors (Table 1). Key land-cover modification

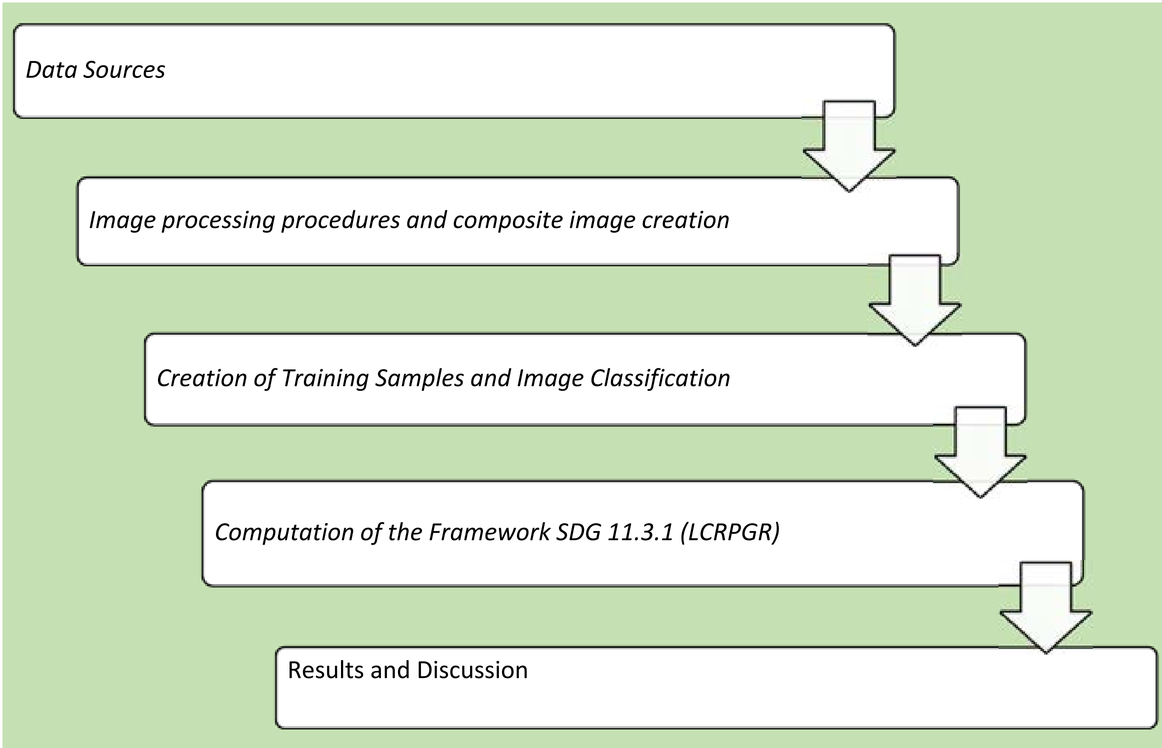

Fig. 2: Flow method Chart Modified from Yohanna *et al.* (2015).

information and road networks were gathered using Global Positioning System (GPS) during the field visit and field confirmation operations.

Image processing procedures and composite image creation

All the image collections downloaded for the three epochs fall under WRS_PATH = 188, and WRS_ROW = 53. This means that the images spanned beyond the Jos metropolis, thereby requiring a means of being clipped to fit the study area. The image analysis, processing, classification, and analysis of the images were concentrated on the metropolis. Therefore, some secondary administrative data with the help of Google Earth were used to delineate the Jos Metropolis. These shapes in Google.klm formats were converted in ArcGIS' ArcMap to ESRI shapefiles as polygonal features. These features represented the areal extent of Jos Metropolis which was subsequently used in Clipping or extracting Jos Metropolis from the images. The researcher used a combination of three clean bands for each epoch for the creation of composite images. A strand of the band in an image collection comes stretched in black and white; therefore composite mapping is geared towards combining a minimum of three bands to achieve an RGB color combination using sensors reflectance. In ArcMap, in the Toolbox, Create Composite tool was used in the Raster Data Management section. Three clean bands for each epoch were selected after which composite maps were created respectively.

Creation of Training Samples and Image Classification

The clarity of the images used by the researcher warranted the adoption of the Supervised Classification Method. With the researcher's firsthand knowledge of the study area, and the help of Google Earth Imagery software, a ground truth exercise was conducted to ascertain the different land uses in the study area and equally compare them with the spectral signatures of the composite images. The training samples were proportionally registered

Table 1: Data type and sources

Data type	Acquisition date	Number of bands	ELLIPSOID AXES	WRS PATH/ROW	EPHEMERIS EPOCH DAY	Source
Thematic Mapper (L5_TM)	18/11/1999	7	6378137.000000, 6356752.314200	188/53	322	USGS
LANDSAT 7 (ETM)	22/01/2004	9	6378137.000000, 6356752.314200	188/53	008	USGS
LANDSAT 7 ETM+	08/11/2009	9	6378137.000000, 6356752.314200	188/53	322	USGS
LANDSAT 7 ETM+	26/12/2014	7	6378137.000000, 6356752.314200	188/53	008	USGS
LANDSAT 8 ETM+	09/01/2018	11	6378137.000000, 6356752.314200	188/53	009	USGS
LANDSAT 8 ETM+	05/02/2022	11	6378137.000000, 6356752.314200	188/53	036	USGS

Table 2: Land use and land cover classification

LULC Categories	Description
Built-up	Urban, peri-urban and rural settlements, commercial areas, government offices, industrial zones, royal palaces, road networks, airports, and all public services including hospitals, schools, colleges, worship centers, etc)
Meadows	Bare/farmlands, undeveloped plots, organize open spaces, and orchards.
Mountain Vegetation	Bare rocks, hills, tree coverage, and or scattered and spare forest.
Water Bodies	Rivers, ponds, dams, and reservoirs.

using the respectful composite images for four land uses and land covers in the metropolis, namely: Built-up area, Mountain Vegetation, Meadows, and Water bodies (Table 2). Having the training sample registered, and the signature files for each epoch created, a supervised classification scheme was utilized. The classification of land use and land cover of Jos Metropolis was performed in the Image classification toolbar of ArcGIS thus yielding four major LULC categories. The overall classification accuracy was assessed using a dendrogram.

Computation of the Framework SDG 11.3.1 (LCRPGR)

The main data applied in the calculation of SDG 11.3.1 comprised the metropolitan population data for the period of study acquired from the National Population Commission and Greater Jos Master plan, and the metropolitan area extent extracted from the LULC statistical data. The population data were the census of the registered household population in the spatial unit of the metropolis. Due to rapid urbanization, movement or increasing population is a common occurrence, so it is hard to get the permanent population of a unit area that meets the requirements of the time series data (Cai, *et al.,* 2020). Thus, this study used the estimated population obtained from the National population commission and the Greater Jos Master Plan for the computation of the SDG framework (Table 3). According to the SDG 11.3.1 monitoring framework, the metropolitan area, or the urban agglomeration can be measured as the built-up land (UN-Habitat, 2018). Thus, the built-up area (herein referred to as the "metropolitan area") has been used in the computation of the framework. The mathematical equation recommended for defining the relationship between the metrics of the framework is presented in Eqs. 1, 2, and 3.

$$LCRPGR = \left(\frac{\text{Land Consumption Rate}}{\text{Population Growth Rate}} \right) \quad (1)$$

$$LCR = \frac{In\left(mt|m\varepsilon\right)}{n} \quad (2)$$

$$PGR = \frac{In\left(pt|p\varepsilon\right)}{n} \quad (3)$$

Where:

LCRPGR = Ratio of land consumption rate and Population growth rate; LCR = Land consumption rate; PGR = Population growth rate; In = Natural logarithm;

Table 3: Population data of Jos Metropolis

Year	Population Figure
1999	780,000
2004	877,500
2009	987,185
2014	1,130,325
2018	1,324,741
2022	1,563,193

mt = Metropolitan area at the final year;

$m\varepsilon$ = Metropolitan area at the initial year; pt = Population of metropolitan area at the final year;

$p\varepsilon$ = Population of the metropolitan area at the initial year; n = Number of years between the two-time intervals.

RESULTS AND DISCUSSION

Land Use and Land Cover Change and Location of Change

The LULC classification from 1999 to 2022 is shown in Fig. 3 and the trend of changes based on the interval of five years has been examined (Tables 4 and 5). From 1999 to 2004, a remarkable increase was observed in built-up areas and meadows, and a drastic decline in mountain vegetation and water bodies. The built-up area increased by 1942.6 hectares (ha) from 3494.007 ha to 5436.57 ha. The meadowland use including farmlands, undeveloped plots, organize open spaces, and orchards increased rapidly by 7066.6 ha from the initial 4968.9 ha to 12035.5 ha. These sharp alterations affected other LULCs, in which mountain vegetation and water bodies recorded a loss of 9006.5 ha and 2.7 ha respectively to meadows and built-up areas. Between 2004 and 2009, an increase in the built-up area and water bodies and a drop in meadows and mountain vegetation occurred during this period. The built-up area progressively increased by 1454.0 ha from 5436.57 ha to 6890.538 ha and water bodies expanded by 2.3 ha. The sudden decline in meadows and vegetation was due to the conversion of 894.5 ha and 561.8 ha respectively to built-up land. The expansion of water bodies could be attributed to increased mining activities in the region resulting in the proliferation of more mining ponds and ditches. The period from 2009 to 2014 witnessed a continuous increase in built-up land and a rise in vegetation cover and a decline in meadows and water bodies. Built-up areas expanded by 2538.3 ha from the initial 6890.538 ha to 9428.859 ha and a sharp rise of vegetation cover by 1350.8 ha from 21247.0 ha to 22596.3 ha. The increase in vegetation cover was a positive development owing to the ailing surge in environmental challenges and a call for the protection of the biodiversity and promotion of sustainable development (UN-Habitat and UNEP, 2013; UN DESA, 2022). Intense pressure upon undeveloped and farmlands resulted in a devastating drop of the meadow land cover by 3890.9 ha from 11140.96 ha to 7250.047 ha. The huge loss of meadows was evident in the increased expansion of settlements. In the period 2014 to 2018, the trend of the built-up area increased and a sharp decline across meadows, mountain vegetation and waterbodies occurred in this period. The built-up area increased by 2136.5 ha from 9428.859 ha to 11565.35 ha. This change affected the mountain vegetation cover, meadows land cover, and waterbodies by 1069.7 ha, 939.5 ha, and 127.3 ha respectively. The increased expansion of built-up areas was evident in the massive conversion of farmlands, vegetation, and hills into residential settlements. Due to the rapid expansion of built-ups, hill-tops and rocky areas have been converted into residential settlements in the Zinariya, Kabong, Sabon-gari, and Tudun Wada neighborhoods of the Jos metropolis. From 2018 to 2022, the continuous expansion of built-ups and meadows and a decline in vegetation and waterbodies were the main changes that occurred during this period. Built-up areas and meadows expanded highly by 5430.0 ha and 597.9 ha respectively. These transformations culminated in the conversion of 5876.2 ha and 151.7 ha of mountain vegetation cover and water bodies into urban settlements and farms, parks, and organized open spaces. The continued decrease of water bodies could be attributed to the season of the

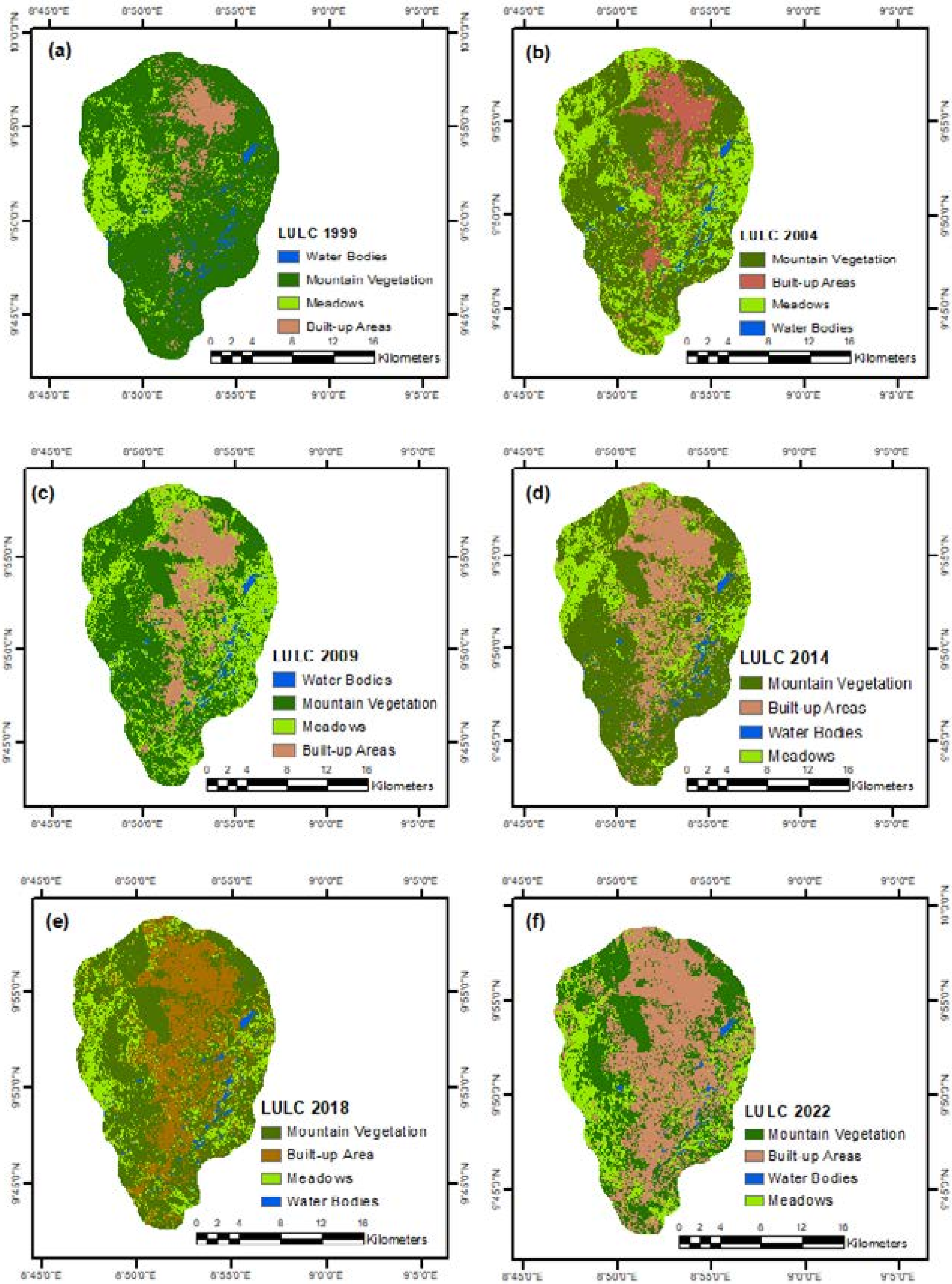

Fig. 3: LULC of Metropolitan Jos from 1999 to 2022.

Table 4: Land Use-Land Cover Statistics

LULC Category	1999 Area (Ha)	2004 Area (Ha)	2009 Area (Ha)	2014 Area (Ha)	2018 Area (Ha)	2022 Area (Ha)
Built-Up	3494.007	5436.57	6890.538	9428.859	11565.35	16995.36
Meadows	4968.9	12035.5	11140.96	7250.047	6310.579	6908.504
Mountain/Vegetation	30825.21	21798.81	21247.0	22596.3	21526.64	15650.46
Water bodies	668.8048	665.9288	668.2215	666.3864	539.0864	387.3464

Table 5: LULC change detection from 1999 to 2022

LULC Category	1999 – 2004 Change (Ha)	2004 – 2009 Change (Ha)	2009 -2014 Change (Ha)	2014-2018 Change (Ha)	2018 -2022 Change (Ha)
Built-Up	+1942.6	+1454.0	+2538.3	+2136.5	+5430.0
Meadows	+7066.6	-894.5	-3890.9	-939.5	+597.9
Mountain/Vegetation	-9006.5	-561.8	+1350.8	-1069.7	-5876.2
Water bodies	-2.7	+2.3	-1.8	-127.3	-151.7

NB: Ha indicates Hectares, the (+) sign indicates an increase and the (–) sign indicates a decrease in a different time frame

year when the images were taken in the dry season when the volume of water is low in all waterbodies and seasonal streams dry up due to the absence of rain and excessive usage for irrigation/dry season farming. Also, observed, drying up and disappearing of some mining ponds around Rahowl Kanang and Gura-top around Bukuru/Rayfield and Du, Zawan toward Hiepang due to reclamation activities. Further, unsustainable disposal of solid waste were observed in Farin-Gada and Dilimi River leading to obstruction and shrinking of the water ways. Unless drastic measures are taken such rivers may cease to exist. It is quite evident, from the result that the Jos metropolitan area (built-ups) has been growing progressively at an alarming rate over the last two decades owing to the rapid rate of urbanization and global crises leading to an increase in population and economic activities. The favorable climate, and the incessant crises and insecurity that have ravaged the entire nation and particularly the rural areas and the entire northern part of Nigeria aggravated the immigration of people into the metropolis of Jos. These results corroborate the findings of Rimal *et al.,* (2018); Hegazy and Kaloop (2015); Rikko (2016); Appiah *et al.,* (2015); Mahmoud *et al.,* (2016), and Dung-Gwom (2008). Uncontrolled urban expansion presents particular challenges to the sustainability of cities such as the high cost of planning and service provision and environmental challenges as established (Zhao *et al.,* 2018; Rikko, 2016).

Critical observation of the image maps from 2009 to 2022, there seems to exist a growth away from the city center following the concentric zone model of city growth postulated by Ernest Burgess, discussed in Planning Tank, (2020). From 1999 to 2009, there was all-round growth occurring majorly in the fringes of the metropolis evident around Farin-Gada sprawling into Unguwan Jarawa, Naraguta, ECWA Staff, Army engineer, and Mista Ali along Zaria road to the north while state low-cost and Rantya engulfing surrounding villages toward Wildlife Park to the southwest and around the Bukuru axis, Gura-top, Rahowl Kanang, Du, Zawan, Hiepang and Shen dam toward southern part and Rayfield, Kwang, Gwarandok, Rikkos, Eto-Baba, and Bauchi bye-pass toward the southeast of the metropolis. This development may not be far from the reasons discussed earlier and the fact that people build houses close to their places of work. From 2013 to 2018, the growth tended majorly toward the south, east, and southwestern parts of the metropolis. This could be attributed to the improvement and development of infrastructure and services such as roads as witnessed in Rantya, Gura-top, and Rahowl Kanang (Fig 3).

Land Consumption and Population Trend

Table 6 presents the land consumption of Jos metropolis and the trend of the population within the span of the study. It is quite evident, from the result that the metropolitan area has been expanding increasingly at an alarming rate over the last two decades. The table revealed that during the year 1999,

Table 6: The Metropolitan Land Consumption and Population statistics.

Years	Metropolitan Spatial Extent (Ha)	Estimated Population
1999	3494.007	780,000
2004	5436.570	877,500
2009	6890.538	987,185
2014	9428.859	1,130,325
2018	11565.350	1,324,741
2022	16995.360	1,563,193

Table 7: The Ratio of Land Consumption Rate and Population Growth Rate.

Interval (Years)	Land Consumption Rate (LCR)	Population Growth Rate (PGR)	LCRPGR
1999-2004	0.0884	0.0236	3.75
2004-2009	0.0474	0.0236	2.01
2009-2014	0.0627	0.0271	2.31
2014-2018	0.0511	0.0397	1.29
2018-2022	0.0962	0.0414	2.32

the metropolitan area consumed 3494.007 ha of land and unremittingly expanded to occupy 16995.360 ha in 2022. The increase in land consumption is associated with an increase in urban population and economic activities. The table indicated a rapidly burgeoning population, from 780,000 in 1999 to 1,563,193 in 2022. This frequent upsurge in the metropolitan population has contributed to the increasing rate of land consumption in efforts to meet its need. The growth trend of the Jos metropolis population is a thing of serious concern to sustainable development. This is because the alteration of the environment due to human-associated activities such as urban development can have far-reaching consequences on land. It was observed that population growth depletes resources and could trigger a social or economic catastrophe if it is not contained. Moreover, the rising population put swelling demand on land and, generate contaminations, such as air and water pollution and greenhouse gas emission along with increasing quantities of waste as already manifested in Dilimi, Gangare, Rikos, Unguwan Rogo, Nasarawa-Gwom, Sabon-layi, Unguwan Rukuba, Kongo-Rosha, Jenta and Tudun-Wada areas of the metropolis. This result settles with Sharma *et al,* (2012), where population growth in Bhagalpur played a crucial role in the environmental destruction of the city: from cultivation to land depletion or modification, increasing solid waste leading to nuisance, foul smell, and water pollution, and increased social and economic turmoil, hunger, migration, and conflict. The case of Tanzania, (UNFPA, 1991; Green, 1992 cited in Gwani and Galadima, 2015), where many areas especially around Dar es Salam and Mwanza witnessed environmental degradation due to increased demand for housing and other infrastructure development and arable land, to the extent that it could not support ecological balance and the provision of necessary resources to the present and future population. The incidence of rapid urban growth is likened to the situation in Indian cities, the cities are subject to an influx of over 38,000 new residents every day as India continues to urbanize at a rapid rate (Metropolis, 2011). Although the case of Indian cities is overwhelming compared with the situation in Jos, the resultant effect of rapid urban growth could be devastating if no measures are put in place to cater to the rising population and the associated challenges such as inadequate infrastructure and social services, increase in crime and insecurity, poverty and hunger, environmental pollution, susceptibilities to natural and man-induced hazard, and the proliferation of slums and informal settlements as already the case in the metropolis.

Computation of the SDG 11.3.1

The study reveals that the land consumption rate for the period 1999-2004, 2004-2009, 2009-2014, 2014-2018, and 2018-2022 is 0.0884, 0.0474, 0.0627, 0.0511, and 0.0962 respectively (Table 7). It was high from 2018-2022 and 1999-2004 but dropped in the period 2004-2009 and slightly increased from 2009 to

2018. The decrease observed during the years 2004 to 2009, could be attributed to the 2001, 2008, and 2010/2011 Jos crises that devastated parts of the metropolis leading to the displacement of people to other regions (Krause, 2011), and the fact that most of the population concentrated within the urban core. The increase in land consumption lately, suggests that during the period (2009 to 2022), people dispersed towards the peripheries of the metropolis for better living in an open space away from the densely populated area due to the relative peace restored. Thus, the rate at which lands were acquired for built-up development heightened. This situation poses a negative impact on the urban region because of the associated complications of land depletion, increased environmental pollution, and climate change. The Jos metropolitan population growth rate during the period 2018-2022 and 2014-2018 was high with a growth rate of 0.0414 and 0.0397 respectively. This proportion has been connected with the rapid increase of migration from within the Plateau State, the country, and other parts of the world owing to the moderate weather, economic improvement in the metropolis, and the disturbing insecurity that has devastated the entire northern region of Nigeria and Africa. This growth uses land resources for several land use to provide for its needs. This then suggests that the more the population in a given urban area, the more meadows and vegetation cover are lost to development (McDonald *et al*. 2010).

In computing the framework SDG 11.3.1, two main metrics are basic; Land Consumption Rate (LCR) and Population Growth Rate. The framework intends to monitor and achieve urban expansion effectively to encourage LUE. Thus, the framework (LCRPGR) is calculated at a five-year interval in this study. Based on the LCRPGR results, the average speed for the metropolitan area development is about 2.3 times faster than the population growth. According to the United Nations Human Settlements Programme, if the framework value is above or greater than one (1), it means that Land consumption is higher than the population growth rate or urban expansion is moving away from LUE (UN-Habitat, 2018), as such peri urbanization is the order of the day and result into uncontrolled physical expansion, physical infrastructure deterioration, greenhouse gas emission, environmental contamination among others. Abdulkadir, *et al.,* (2019) posits that efficient consumption of land is key to sustainable land use and management. In the present research, the framework exposed that the rate of consumption of land during the period of studies is higher than the population growth rate because the resultant ratio stands at greater than one (1). It then implies that the expansion of Jos metropolis is moving away from land use efficiency (LUE). This result can be compared with the case in Scotland, England and France metropolitan areas where a high LCRPGR was recorded (UK Office for National Statistics, 2018; Ministère de la Transition Écologique et Solidaire, 2018). The result differs from the situation in Wales where the population growth rate surpassed land consumption rate (UK Office for National Statistics, 2018).

CONCLUSION

This study evaluated the changes that occurred in the land use and land cover, the land consumption and population growth rate and determined the urban land use efficiency of Jos metropolis in the past two decades using population data, remote sensing and GIS techniques, and computation of the SDG 11.3.1. Overall, this study established that there has been a phenomenal transformation in land use and land cover throughout the study. The built-up area experienced a maximum and consistent increase in the spatial extent from 3494.007 ha in 1999 to 16995.360 ha in 2022 leading to a substantial reduction in other land use and land cover. There was a drastic loss in vegetation cover from 30825.21 ha in 1999 to 15650.46 ha in 2022. Meadows increased from 4968.9 ha in 1999 to 6908.504 ha in 2022 and a decrease in water bodies from 668.8048 ha in 1999 to 387.3464 ha in 2022. The modification in LULC is linked to the increase in population and economic activities, manifested in the rapid spread of housing development, commercial development, and the construction of infrastructures. Concerning the location of change, this study observed an all-around growth majorly occurring in the fringes of the metropolis witnessed in the proliferation of slums and informal settlements. The study confirmed a burgeoning population growth in the metropolis from 780,000 in 1999 to 1,563,193 in 2022. This growth had a significant impact on urban land use management, consuming a large proportion of land from the initial 3494.007 ha in 1999 to 16995.36 ha in 2022. To ensure sustainable urban development and efficient management of urban land use, the study evaluated the ratio of land consumption rate and population growth rate (LCRPGR). The study revealed a high urban land consumption rate of 0.0962 and 0.0884 during the period 2018-2022 and 1999-2004. The metropolitan population growth rate was high during 2018-2022 and 2014-2018 with a growth rate of 0.0414 and 0.0397 respectively. These dynamics intensified the rate of land acquisition for urban development. The average value of the SDG 11.3.1 framework was 2.3 which is higher than 1, indicating that urban expansion is moving away from land use efficiency. Thus, it is inferred that Jos metropolis is an urban settlement where the land consumption is greater than the population growth. A scenario like this leads to peri-urban development and results in spontaneous and uncontrolled urban expansion, slum development, depletion of infrastructure, increased crime and insecurity, hunger and poverty, and environmental pollution.

Thus, the study recommends that:

1 There should be a Growth Management Monitoring System (GMMS) using Geographic Information System technology to monitor and assess land use and land cover changes as well as periodic mapping and production of spatial and temporal models. The system should include the integration of GIS techniques, planning, population data, or socio-economic data to manage urban growth. This could be spearheaded by PlaGIS (Plateau Geographic Information Services) and the Ministry of Lands, Survey, and Town Planning.

2 There is a need to promote urban greeneries. This may include checking the conversion of agricultural land into urban land use by introducing land-saving construction designs and enhancing the effective utilization of inner-city land and protecting and developing greeneries.

3 There is a need for the state government to know the absolute population change each year. This includes the number of newcomers (by birth or in migration) needing housing and public services. This is crucial in determining and managing land consumption.

4 Policymakers and planning authorities should promote efficient use of urban land and sustainable growth through renewing existing urban land and urban infill. This is better than extending the occupied land encroaching into farmland.

This study has provided insight into the dynamics of Jos metropolitan LULC and land use efficiency management which could be useful to policymakers, urban planners, and researchers in initiating sustainable urban development strategies and inclusive structure for its planning and management. Universally, this study also adds the literature to lay the grounds for effective management of urban land and development policy relating to Jos Metropolis and maybe cities of developing countries. Furthermore, the findings could pave the way for further investigations on the spatial pattern, nature, and drivers of growth in peri-urban areas of the metropolis as well as the provision or adequacy of services in the peri-urban areas.

AUTHOR CONTRIBUTIONS

P. Shehu performed the review of related literature, designed the procedures for carrying out the research, collected and computed data, produced maps, analyzed and interpreted the data, designed the graphical abstract, and prepared the manuscript text and editing. L.S. Rikko supervised the research work and assisted in the review of the literature and the manuscript. M.B. Azi assisted in the data collection and collation and editing of the manuscript.

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CONFLICT OF INTEREST

The authors have no conflict of interest to be declared concerning this review paper. Also, the authors have checked all the ethical affairs comprising duplicates, misconduct, data making, informed consent, and plagiarism.

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ABBREVIATIONS (NOMENCLATURE)

Eq.	Equation
ETM	Enhance Thematic Mapper
GIS	Geographic Information System
GMMS	Growth Management Monitoring System
GPS	Global Positioning System
Ha	Hectare
In	Natural logarithm
LCR	Land consumption rate
LCRPGR	The ratio of land consumption rate and Population growth rate
LUE	Land use efficiency
LULC	Land Use and Land Cover
$\mathring{m}$	Metropolitan area at the initial year
mt	Metropolitan area at the final year
	Number of years between the two-time intervals
OLI	Operational Land Imager
$\mathring{p}$	The population of the metropolitan area in the initial year
PGR	Population growth rate
PlaGIS	Plateau Geographic Information Services
pt	The population of the metropolitan area in the final year
SDG	Sustainable development goal
TM	Thematic Mapper
USGS	United States Geological Survey

REFERENCES

Abdulkadir, I.; Kumar, J.S.; Noon, M., (2019). The ratio of land consumption rate to the population growth rate-A case of metropolitan Gombe. Preprints. Org., 47(1): 1-17 (**17 pages**).

Adzandeh, E.A.; Akintunde, J.A.; Akintunde, E.A., (2015). Analysis of urban growth agents in Jos Metropolis, Nigeria. Int. J. Remote Sens., 4(2): 41-50 **(10 pages).**

Agarwal, C.; Green, G.M.; Grove, J.M.; Evans, T.; Schweik, C.M., (2002). Review and assessment of land-use change models: dynamics of space, time, and human choice. General Technical Report NE-297. Newton Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Center Station **(61 pages).**

Appiah, D.O.; Schröder, D.; Forkuo, E.K.; Bugri, J.T., (2015). Application of geo-information techniques in land use and land cover change analysis in a peri-urban district of Ghana. Int. J. Geog. Inf. Sci., 4: 1265-1289 **(25 pages).**

Arifeen, H.M.; Phoungthong, K.; Mostafaeipour, A.; Yuangyai, N.; Yuangyai, C.; Techato, K.; Jutidamrongphan, W., (2021). Determine the land-use Land-cover changes, urban expansion, and their driving factors for sustainable development in Gazipur Bangladesh. Atmosfere, 12: 1353 (**19 pages**).

Bashir, M., (2012). The impact of land-use change on the livelihoods of rural communities: a case study in Edd Al-Furssan locality, South Darfur State, Sudan. Ph.D. Thesis, Technische University Dresden.

Cai, G.; Zhang, J.; Du, M.; Li, C.; Peng, S., (2020). Identification of urban land use efficiency byIndicator-SDG 11.3.1. PLoS ONE 15(12): e0244318 (**14 pages**).

Cameron, C.; Maharaj, A.; Kennedy, B.; Tuiwawa, S.; Goldwater, N.; Soapi, K.; Lovelock, E.C., (2021). Landcover change in mangroves of Fiji: Implications for climate change mitigation and adaptation in the Pacific. Environ. Challenges, 2(2021): 1-11, (**11 pages**).

Chen, J.; He, C.W., (2018). Global land cover mapping and its application for SDGs, National Geomatics Center of China, May 30, 2018, Copenhagen.

Chen, J.; Peng, S.; Chen, H.; Zhao, X. S.; Ge, Y.J.; Li, Z.L., (2020). A comprehensive measurement of progress toward local SDGs with geospatial information: methodology and lessons learned. ISPRS Int. J. Geo-Info., 9(9): 552 (**19 pages**).

d'Amour, C.B.; Reitsma, F.; Baiocchi, G.; Barthel, S.; Güneralp, B.; Erb, K.H.; Haberl, H.; Creutzig, F.; Seto, K.C., (2017). Future urban land expansion and implications for global croplands. Proceedings of the National Academy of Sciences of the United States of America. 114(34): 8939-8944 (**6 pages**).

Dung-Gwom, J.Y. (2008). Nature of peri-urban development in Jos, Nigeria. World Congress on Housing, National Housing Programme—New Vision XXXVIIAHS. Kolkata, India.

Dung-Gwom, J.Y.; Rikko, D.S.L., (2009, September). Urban violence and emerging housing markets in Jos, Nigeria. International Sociological (ISA) Housing Conference. Glasgow, GB.

Farrell, K., (2017). The rapid urban growth traid: a new conceptual framework for examining the urban transition in developing countries. J. Sustain., 9(8): 1-19 **(19 pages).**

Fikadu, G., (2022). Impact of land use land cover change using remote sensing with the integration of socio-economic data on rural livelihoods in case of Nashe Watershed, Ethiopia. Res. Square, 1-12 **(12 pages).**

Freire, S.; Pesaresi, M., (2015). GHS population grid, derived from GPW4, multi-temporal (1975, 1990, 2000, 2015). European Commission, Joint Research Centre, 2015.

Gessese, B., (2018). Impact of land use/land cover change on rural community's livelihood of Ethiopia. Res. Rev. J. Ecol. Environ. Sci., 6(1): 8-15 **(8 pages).**

Güneralp, B.; Seto, K.C., (2013). Futures of global urban expansion: uncertainties and implications for biodiversity conservation. Environ. Res. Lett. 8(1): 014025 (**10 pages**).

Gwani, J.; Galadima, A., (2015). Population. In Egunjobi, L., (Eds.), Contemporary concepts of physical planning. Department of Urban and Regional Planning, University of Ibadan, Ibadan, Nigeria. 894-914 (**21 pages**).

Hassan, A.; Raji, B.; Malgwi, W.; Agbenin, J., (2015). The basaltic soils of Plateau State, Nigeria: properties, classification, and management practices. J. Soil Sci. Environ. Manage., 6(1): 1-8 **(8 pages).**

Hassan, M.M.; Nazem, M.N.I., (2016). Examination of land use/land cover changes, urban growth dynamics, and environmental sustainability in Chittagong city, Bangladesh. Environ. Dev. Sustain., 18(3): 697-716 (**20 pages**).

Hegazy, R.I.; Kaloop, R.M., (2015). Monitoring urban growth and land-use change detection with GIS and remote sensing techniques in Daqahlia Governorate Egypt. Int. J. Sustainable Built. Environ., 4(1): 117-124 **(8 pages).**

Hossain, F.; Moniruzzaman, M., (2021). Environmental change detection through remote sensing technique: A study of Rohingya refugee camp area (Ukhia and Teknaf sub-district), Cox's Bazar, Bangladesh. Environ. Challenges, 2: 1-11 (**11 pages**).

Leta, M.K.; Demissie, T.A.; Tränckner, J., (2021). Modeling and prediction of land use land cover change dynamics based on land change modeler (LCM) in Nashe Watershed, upper Blue Nile Basin, Ethiopia. Sustainability, 13(7): 3740 (**24 pages**).

Liping, C.; Yujun, S.; Saeed, S., (2018). Monitoring and predicting land use and land cover changes using remote sensing and GIS techniques—A case study of a hilly area, Jiangle, China. PLoS ONE, 13(7): e0200493 (**24 pages**).

Kotaridis, I.; Lazaridou, M., (2018). Environmental change detection study in the wider area of lignite mines. Civil. Eng. Archit., 6(2):108-114 (7 pages).

Krause, J., (2011). A deadly cycle: ethno-religious conflict in Jos, Plateau State, Nigeria. Geneva Declaration. **(68 pages).**

McDonald, R.I.; Mansur, A.V.; Ascensao, F.; Colbert, M.; Crossman, K.; Elmqvist, T.; Gonzalez, A.; Güneralp, B.; Haase, D.; Hamann, M.; Hillel, O.; Huang, K.; Kahnt, B.; Maddox, D.; Pacheco, A.; Pereira, H.M.; Seto, K.C.; Simkin, R.; Walsh, B.; Werner, A.S.; Ziter, C., (2020). Research gaps in knowledge of the impact of urban growth on biodiversity. Nat. Sustain., 3(1): 16-24 (**9 pages**).

McDonald, R.I.; Forman, R.T.T.; Kareiva, P., (2010). Open space loss and land Inequality in United States Cities, 1990–2000. PLoS ONE 5(3): e9509 (**7 pages**).

Mahmoud, I.I.; Duker, A.; Conrad, C.; Thiel, M.; Ahmad, H.S., (2016). Analysis of settlement expansion and urban growth modeling using geo-information for assessing potential impacts of urbanization on climate in Abuja city, Nigeria. Remote Sens., 8(3): 1-24 **(24 pages).**

Metropolis, (2011). Managing urban growth. Barcelona. Commission 2 Report **(86 pages).**

Minale, A.S., (2013). Retrospective analysis of land cover and use dynamics in Gilgel Abbay Watershed by using GIS and remote sensing techniques, Northwestern Ethiopia. Int. J. Geosciences, 4(7): 1003-1008 **(6 pages).**

Ministère de la Transition Écologique et Solidaire (2018). Observation et Statistiques. Indicateurs Nationaux de Suivi de la Transition Écologique vers un Développement Durable (2015–2020): Artificialisation des Sols.

Mohamed, M.A., (2017). Monitoring of temporal and spatial changes in land use and land cover in metropolitan regions through Remote Sensing and GIS. Nat. Resources, 8: 353-369 (**17 pages**).

Mustard, J.F.; Defries, R.S.; Fisher, T.; Moran, E., (2012). Land-use and land-cover change pathways and impacts. In Gutman et al. (eds). Land change science. Remote Sensing and Digital Image Processing, Springer, Dordrecht, 6: 411-429 (**19 pages**).

Nicolau, P.; David, J.; Caetano, M.; Pereira, J.M.C., (2019). Ratio of land consumption rate to population growth rate—Analysis of different formulations applied to mainland Portugal. Int. J. Geo-Inf. 8(10): 1-21 **(21 pages).**

Ochuka, M.; Ikporukpo, C.; Mijinyawa, Y.; Ogendi, G., (2019) Land use/land cover dynamics and anthropogenic driving factors in Lake Baringo catchment, Rift Valley, Kenya. Nat. Resour. J., 10(10): 367-389 **(23 pages).**

Okafor, C.; Lekwot, E.; Baji, J.; Yakubu, A., (2014). An appraisal of urban land use and land cover changes in Jos South Local Government area of Plateau State, Nigeria using remote sensing and GIS. Academia.

Pandey, B.; Seto, K.C., (2015). Urbanization and agricultural land loss in India: comparing satellite estimates with census data. J. Environ. Manage., 148: 53–66 (**14 pages**).

PlanningTank, (2020). Concentric zone model by Ernest Burgess: Burges Model. Settlement Geography.

Rikko, L.S., (2016). Urban Growth and the planning challenges of the Greater Karu urban area (Gkua), Nasarawa State. Lambert Academic publishing.

Rimal, B.; Zhang, L.; Keshtkar, H., Haak, B.N; Rijal, S.; Zhang, P., (2018). Land use/land cover change dynamics and modeling of urban land expansion and land use and land cover change by the Integration of cellular Automata and Markov chain. Int. J. Geo-Info., 7(4): 154 (**21 pages**).

Rowland, E.A., (2016). City growth: issues and challenges of urban sustainability in Nigeria. The 46th Annual Conference of the Nigerian Institution of Estate Surveyors and Valuers. Transcorp Hilton Hotel, Abuja, Nigeria.

Sharma, L.; Pandey, P.C.; Nathawat, M.S., (2012). Assessment of land consumption rate with urban dynamics changes using geospatial techniques. J. Land Use Science, 7(2): 135-148 (**14 pages**).

https://planningtank.com/settlement-geography/concentric-zone-model-burgess-model

Seto, K.C.; Fragkias, M.; Güneralp, B.; Reilly, M.K., (2011). A Meta-Analysis of global urban land expansion. PLoS ONE, 6(8): e23777 (**9 pages**).

IPCC, (2014). Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. (**16 pages**).

Sustainable Development Solutions Network, (2012). Ratio of land consumption rate to population growth rate, at comparable scale: Indicators and monitoring frameworks.

Tsegaye, L., (2014). Analysis of land use and land cover change and its drivers using GIS and remote sensing: The case of West Guna Mountain, Ethiopia. Int. Res. J. Earth Sci., 3: 53-63 (**11 pages**).

The World Bank Data, (2022). Nigeria - urban population (% of total) - actual values, historical data, forecasts, and projections. Data World Bank.

UK office for national statistics (2018). Using innovative methods to report against the sustainable development goals.

UN DESA (2022). World Population Prospects 2022: Summary of Results. UN DESA/POP/2022/TR/NO. 3.

UN-Habitat, (2018). SDG Indicator 11.3.1 Training Module: Land Use Efficiency. United Nations Human Settlement Programme (UN-Habitat), Nairobi.

UN-Habitat and UNEP, (2013). TST Issues Brief: sustainable cities and human settlements.

Wang, S.W.; Gebru, B.M.; Lamchin, M.; Kayastha, R.B.; Lee, W.K., (2020). Land use and land cover change detection and prediction in the Kathamandu district of Nepal using remote sensing and GIS. Sustainability, 12(9): 122 (**18 pages**).

Wang, S.W.; Munkhnasan, L.; Lee, W., (2021). Land and land cover change detection in Bhutan's high altitude city of Thimphu, using cellular automata and Markov chain. J. Environ. Challenges, 2(2021): 1-11 (**11 pages**).

Wapwera, S.D.; Ayanbimpe, G.M.; Odita, C.E., (2015). Abandoned Mine, Potential Home for the People: A Case Study of Jos Plateau Tin-Mining Region. J. Civ. Eng. Archit., 9(2015): 429-445 **(17 pages).**

Yohanna, P.; Bulus, L.G.; Alfred, D.M., (2015). Landuse/landcover change detection of Mubi metropolis, Adamawa State, Nigeria. Sky J. Soil Sci. Environ. Manage., 4(6): 070-078 **(9 pages).**

Zhao, M.; Cheng, W.; Zhou, C.; Li, M.; Huang, K.; Wang, N., (2018). Assessing spatiotemporal characteristics of urbanization dynamics in Southeast Asia using time series of dmsp/ols nighttime light data. Remote Sens., 10(1): 47 (**20 pages**).

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