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Assessment of the spatial pattern, nature, and growth drivers in selected peri-urban areas

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ABSTRACT

BACKGROUND AND OBJECTIVES: One of the fascinating and complex realities of global development in the 21st century is urbanization. The present study focused on appraising the spatial pattern, nature, and growth drivers in selected peri-urban areas of Jos Metropolis. Accuracy assessment and classification of Landsat Satellite Images, evaluation of the spatial pattern of growth, the nature of growth, and the driving forces of growth were conducted.

METHODS: Data were collected through field observation and questionnaire administration, use of Remote Sensing and Geographic Information System, Global Positioning System, and camera. Satellite imageries used to identify the classes of LULC from 1999 to 2022 were Thematic Mapper (L5_TM) 1999, Landsat 7 ETM+ 2014, and Landsat 8 ETM+ 2022. GPS was used for Ground Truthing, and IDRISI Taiga software was used for image classification and area calculation. ArcGIS 10.1 used to visualize the satellite images and produce maps.

FINDINGS: Results revealed a definite growth rate pattern and land modification trends in the peri-urban areas over the study period. From 1999 to 2014, fast growth was observed in Farin Gada and Rantya at 42.5% and 35.8% change, respectively; there was slow growth in Sabon-Gari at 7.0% proportion. From 2014 to 2022, growth in Farin-Gada (41.9%), Rantya (35.9%), and Rahowl Kanang (21.9%) proceeded rapidly with Sabon-Gari maintaining the least growth (0.3%). The study observed a linear growth pattern along arterial roads and a dispersed pattern proceeded by land fragmentation as built-ups spread farther from the road corridors. The nature of growth in the peri-urban areas was significantly unplanned, irregular, and disorderly and observed to be massively taking over agricultural land and swallowing up adjoining settlements. The study identified eight drivers that contributed to shaping and propelling growth in the areas.

CONCLUSION: The study recommended that the government should integrate the peri-urban areas into its physical development planning schemes and should enforce an effective Development Control mechanism to manage the spatial growth of these areas. The findings will help planners and policy-makers make informed and unified decisions beyond administrative boundaries. The study also adds to the body of knowledge globally and provides the bases for further research.

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INTRODUCTION

The growth of peri-urban areas across the world is one of the most attractive features of the current research in urban studies (Idowu *et al.,* 2020). The challenges that are manifested in cities due to rapid urbanization are enormous and unsustainable. According to the United Nations Department of Economic and Social Affairs, Population Division (2022) and The World Bank Data (2022), Africa, though one of the least urbanized regions in the world, is second in the top global average annual urban growth rate (1.09%) between 2015 and 2020, and in West Africa, Nigeria is urbanizing at an alarming rate, with an average annual urban population growth rate of 1.65%. However, most of such growth occurs in the major cities, like the Federal Capital city Abuja and the state capitals that are the country's principal administrative, economic, and commercial centers (Iorliam and Ortserga, 2019). From time immemorial, people have constantly been searching for an improved economic and social life for themselves and their families. People are prompted to migrate to urban regions owing to better opportunities (European Parliament, 2020), especially, when the standard of living, economic condition, essential services, security, and climate change in their environment is not favorable and appear at risk of declining further. When there is an increase in the urban population, spatial expansion is prone to occur with consequent impacts on land due to human-connected sustenance activities (Shehu *et al.,* 2023). According to Ibrahim and Hassan (2018), when cities grow, they require more land and resources to sustain such growth. Consequently, the increased demand for land has up-surged land use and land cover alterations (Fikadu, 2022), and heightened the environmental and planning challenges already posing threats in cities of developing countries. Naab *et al.* (2013) and Suwarlan *et al.* (2022) established that the increased population pressure in urban centers is consequent to the proliferation of sprawl growth and the entire built form into peri-urban areas. Several studies have described peri-urban areas as an interface or rural-urban fringe (Varkey and Manasi, 2019; Idowu, 2017; Iorliam and Ortserga, 2019; Tali and Nusrath, 2014). The term rural-urban fringe was first used by Smith, T.L in 1934 to describe a region in an urban setting characterized by the rural and urban population, also referred to as the zone of transition or peri-urban (Maconachie, 2016). The per-urban zone portrays two distinct attributes or phases which are the predominant urban setting and spatial planning challenge of the twenty-first century arguably in developing countries. The two peri-urban phases were identified by Nilsson *et al*. (2013) who established that in developed countries, the peri-urban is a zone of social and economic change and spatial restructuring while Albert *et al.* (2020) recognized the peri-urban regions in developing countries, as a zone of chaotic growth. The zone exhibits a relatively low population density by urban standards, scattered settlements, slums, high transport for commuting, fragmented communities, and a lack of spatial governance (Nilsson *et al.,* 2013). Sahu and Vaidya (2020) described peri-urban areas as regions that go through the process of transformation from rural to urban land use, located between urban and rural areas, and are areas that are predominantly adjacent to urban municipal boundaries. These areas possess the features of urban and rural regions. They have the environment of the rural area with some amenities of urban zones. In the opinion of Ravetz *et al.* (2013) cited in Adedire (2020), what differentiates the rural, peri-urban, and urban is the population, compactness of built-ups, infrastructure, administration, boundaries, and economies. Thou (2013) described a typical spatial morphology of cities and the progression of peri-urban growth to include the urban area (Core area), rural-urban or peri-urban fringe (inner and outer fringes), the urban shadow and rural hinterland which comprises isolated and dispersed settlements (Fig. 1).

The peri-urban settlements provide a means of housing for the urban population and accommodate industrial activities (Acheampong and Anokye, 2013) due to the availability and affordability of land in cities of developing countries. However, Zheng *et al.,* (2022), Akhtar (2016), Shi *et al.,* 2020; Han, 2020, Kapisa, (2022, February), and Ewing *et al.* (2016) cited in Mehriar, *et al.,* (2020), identified problems of peri-urban growth, including un-intensive use of land, low level of services and infrastructure, few job opportunities, untenable development, unplanned patterns of growth, high cost of providing services, lack of clear jurisdictions, and weak planning control, higher air, and water pollution, increased traffic fatalities, jams, and unsustainable transport means, increased carbon emission, segregation of social

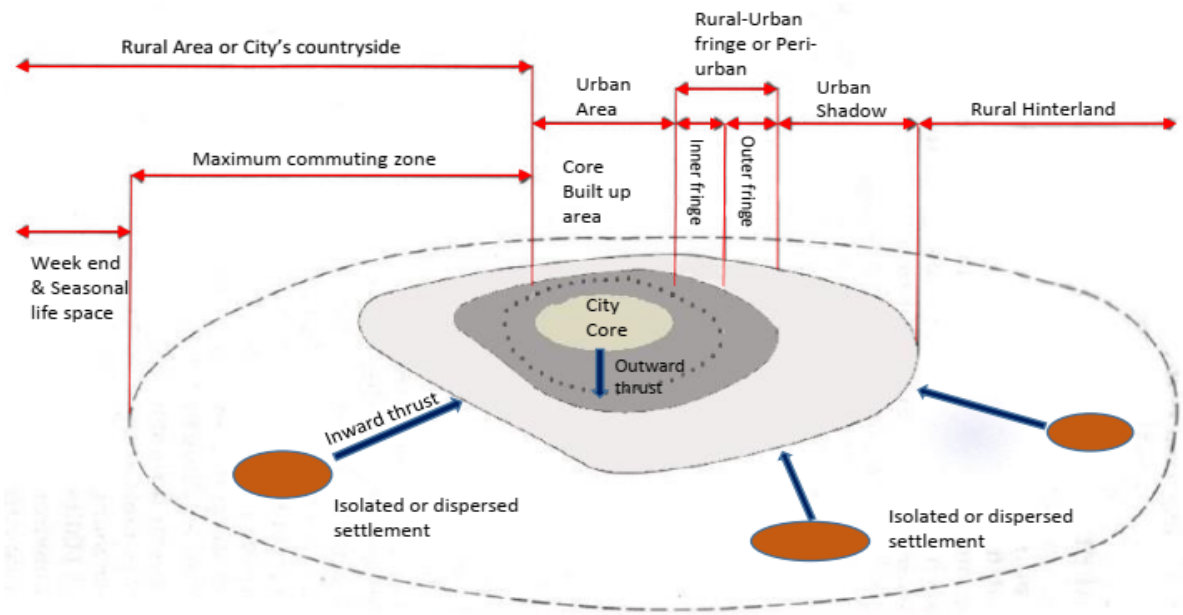

Fig. 1: The rural-urban fringe (Modified from Thou, 2013)

groups along income or economic discrimination. Besides, the challenges of peri-urban areas in developing countries are similar, most developing countries have a spontaneous nature and pattern of peri-urban development phenomenon rather than planned growth, and land development takes place without conforming to planning regulations. Likewise, due to the high demand for land, marginal lands in low-lying areas, hills, and infrastructural setbacks are being filled up for development purposes without considering any environmental impact. Similarly, Amoateng *et al.,* (2013) and Drabkin (1977) established that the peri-urban areas are unplanned physical growth characterized by an unregulated pattern of physical development, resulting in complex organic urban growth and predominantly expanding with horizontal developments. Though peri-urban growth is a global challenge, its nature and growth pattern vary (Idowu *et al.,* 2020). In many cities of Nigeria, peri-urban areas have been observed to exhibit a nature and pattern of growth that is undesirable, uncontrolled, poorly organized, and environmentally unsustainable. The situation has been a constraint leading to the proliferation of informal settlements and slums and causes a twofold problem; first, its high consumption of agricultural land, and second, the degeneration of the environment (Union of International Association, 2020; Noor and Rosni, 2013). There is a growing body of studies on peri-urban zones worldwide (Dung-Gwom, 2008; Idowu *et al.,* 2020; Johnson, 2001; Neisiani *et al.,* 2016; Sale, 2018; Amoateng *et al.,* 2013; Nilsson *et al.,* 2013; Akhtar, 2016; Othow *et al.,* 2017; Appiah *et al.,* 2015; Mehdipour *et al.,* 2017), particularly in developing countries due to emerging challenges in these regions, ranging from environmental consequences, ecological footprint, spatial, and land use and land cover(LULC) transformation, to social, economic, and planning challenges. Though in developing countries, the peri-urban areas differ in origin, history, and functions, they tend to portray similar attributes (Emankhu and Ubangari, 2015). Thus, the views, methods, and techniques used in the previous studies have been reviewed and used in the present study. Jos metropolis is one of the fast-growing cities in Nigeria that are undergoing rapid urbanization since their emergence as the administrative capital and economic hub of the various states. The city continues to witness unprecedented growth that has seen many of the vast surrounding villages engulfed in the city's fabric resulting in peri-urban growth. The peri-urban areas grow organically with little or no coordination

and are characterized by a deteriorated environment. These areas has become constraints to sustainable and environmental management, and little has been done to address the problems in this direction. Poor implementation of the provision of the two planning policies (Doxiadis Master Plan 1975-2000, and Fola Konsult Greater Jos Master Plan 2008-2025) which were meant to shape and guide the development of the metropolis by the previous state governments contributed hugely to the prevailing decay in the core urban area and the seeming uncoordinated growth in the peri-urban regions of the fast-growing metropolis. It was reported that 75% of Doxiadis Master Plan provisions were unimplemented after a period of 47 years from the time when the plan was established and adopted by the state government, and only 25% were partially implemented. The Fola Konsult Master Plan was prepared and submitted to the state government in 2008, yet, 12 years later, 84.62% of the plan has not been implemented, only 7.69% of the policies were implemented and 7.69% partially implemented. The participation of the local community in the process of plan preparation and subsequent implementation efforts has been insignificant (Amine, 2021; Musa and Dung-Gwom, 2020; Wapwera, 2018). Thus, the present study sought to evaluate the growth of peri-urban regions from 1999 to 2022. The study assessed the accuracy of the Landsat images used and identified the various classes of LULC from 1999 to 2022 and examined the spatial pattern, nature, and growth drivers in selected peri-urban areas. The current study was conducted in Jos metropolis, Plateau State, Nigeria, in 2022.

MATERIALS AND METHODS

Study Area

Jos Metropolis is located in the middle belt zone of Nigeria. It is the administrative and commercial hub of Plateau State. The metropolis lies between latitude 9º55'0" N to 9º47'40" N and Longitude 8º57'20" E to 8º50'0" E. It is bordered to the North West by Bassa Local Government, North-East by Bauchi state, southwest by Bassa and Riyom Local government, and to the South East by Barkin Ladi Local Government areas, respectively (Hassan, 2015). The city is unique to beautiful rock formations scattered across the grasslands, with altitudes ranging from 1,200 meters (about 4000 feet) to a peak of 1,829 meters above sea level. It is characterized by a near-temperate climate with an average temperature between 18°C and 22°C and a record annual rainfall varying from 131.75 cm to 146 cm (Plateau State ICT Development Agency, 2021). The growth of Jos is associated with the mining of tin ore and the construction of railway lines linking the metropolis to the southern region of Nigeria, thus, transforming it into the hub of the world economy. The tin mining which started since 1904 (Shehu *et al.* 2023), unveiled opportunities leading to massive migration, majorly from the northern and southern parts of the country, and the Europeans who formed more than half of the city's population, making it highly cosmopolitan (Dung-Gwom and Bashir, 2022; Dung-Gwom and Rikko, 2009). In 2009, the Greater Jos Master Plan reported the Jos Metropolitan population at 987,185, and estimated to house a population of 1,563,193 in 2022. The influx of migrants, coupled with the existence of administrative functions in the city, led to its expansion, engulfing surrounding areas (Fig. 2).

Method of Data Collection and Sources

The data collection methods employed in this study include pre-field schedule, reconnaissance study, hardware and software used, image classification and trend analysis, sampling techniques, and confidence level. Data were acquired from primary and secondary sources. The secondary sources were information obtained from relevant text, official documents (Doxiadis Master Plan 1975-2000, and Fola Konsult Greater Jos Master Plan 2008-2025), and locational maps (Nigeria, Plateau State, and the metropolis). The primary data were obtained through field observation, questionnaire administration, Global Positioning System (GPS), and Remote Sensing and Geographic Information System (GIS). The authors organized the questionnaire, vetted by the department of urban and regional planning at the University of Jos, Nigeria. The respondents were strictly household heads and community stakeholders. However, participation was voluntary. The image data used in this research were Landsat. The images were obtained from the United States Geological Survey's (USGS) spatial portal. The images were from three different epochs; the first epoch (1999) was collected from Thematic Mapper (TM) Sensors with Seven Bands in Geotiff format, 2014 epoch was from LANDSAT 7, with Enhance Thematic Mapper Sensor (ETM+), and 2022 was from LANSAT 8 ETM+ sensors (Table 1). Major landmark

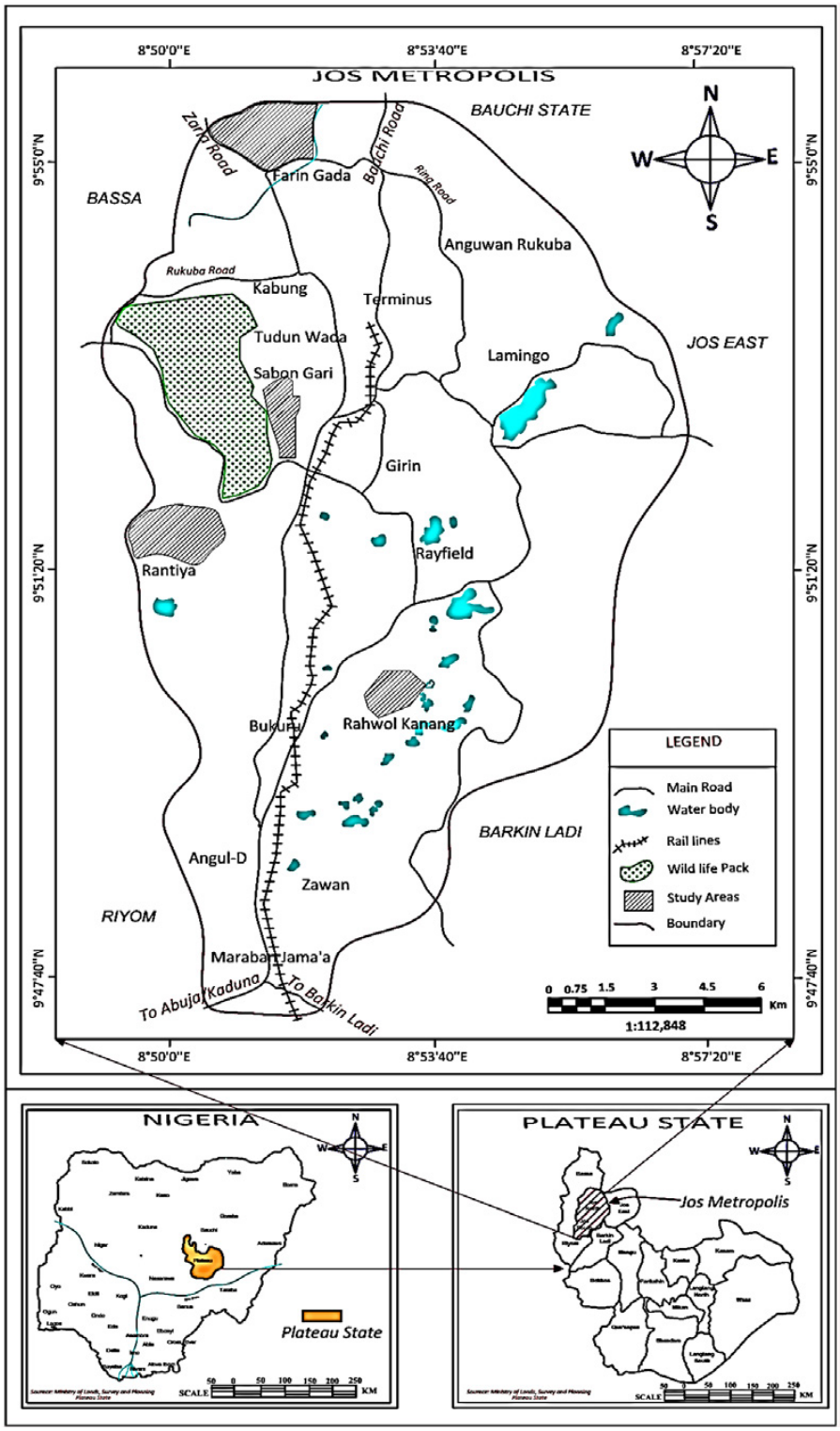

Fig. 2: Jos metropolis

Table 1. Image data used

Data type	Acquired dates	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+	26/12/2014	7	6378137.000000, 6356752.314200	188/53	008	USGS
LANDSAT 8 ETM+	05/02/2022	11	6378137.000000, 6356752.314200	188/53	036	USGS

information such as road networks, and railways, was gathered using GPS during the reconnaissance survey. The image processing procedures, composite image creation, and creation of training samples were all conducted.

Image classification and trend Analysis

The land use and land cover of the area was performed in the image classification toolbar of ArcGIS, thus yielding four major land cover maps: Built-up areas, Meadows, Mountain Vegetation, and Water bodies. The built-up area comprised commercial areas, residential, roads, impervious features, industrial, railway networks, parking lots, sports and leisure facilities, schools, government offices, hospitals, religious centers, etc. The meadows consisted of farmland, undeveloped plots, organize open spaces, and or grasslands, while the Mountain Vegetation covered trees, orchards, rocks/hills, and forests, and the Waterbody included dams, rivers, and abandoned mining ponds. The overall classification accuracy was assessed using a dendrogram. The Post-classification comparison technique produced a LULC map in ArcGIS 10.1. The resultant land cover maps were then visually compared, and change areas were simply those areas that were not classified the same at different times. Following this method, maps were produced to show the land use and land cover trends in each subsequent year (i.e. 1999, 2014, and 2022). The LULC magnitude and trend were computed using Eq. 1 and 2.

a) Magnitude

$$m\Lambda = \alpha 2 - \alpha 1 \quad (1)$$

b) *Trend*

$$Tq = \left(\frac{m\Lambda}{\sum m\Lambda}\right) \times 100 \quad (2)$$

Where: Tq= Trend; mΛ= Magnitude of change; $\alpha 1 and \alpha 2$ = Areal extent of the previous and later years; ∑mΛ = Total sum of the magnitude of change.

Sampling Technique and Sample size

Following the data obtained from the field survey, there are thirty-nine (39) peri-urban neighborhoods in Jos metropolis, comprising seventeen (17) in Jos North local government area (LGA) and twenty-two (22) in Jos South LGA. This study used systematic sampling techniques to select its study areas. Four (4) sample peri-urban areas were selected systematically after the areas were organized in alphabetical order. The fourth (4^{th}) and eighth (8^{th}) peri-urban neighborhoods in Jos North and the fifth (5^{th}) and eleventh (11^{th}) in Jos South LGA were systematically chosen, including Farin-Gada, Sabon-Gari, Rantya, and Rahowl-Kanang. According to the information acquired from the official documents, the four selected peri-urban areas has a total estimated population of 191,728. To attain the purpose and objectives of this research, the present study used a sample size of 0.16% based on the argument of Krejcie and Morgan (1970) that the larger the population the smaller the sample size. Thus, three hundred and seven (307) sample population was drawn and were administered questionnaires randomly across the four selected areas, and 282 (92%) were retrieved (Table 2).

Confidence level

To express the reliability of this study's results, particularly in assessing the driving forces of growth, the confidence level approach was adopted from Kleemann *et al.,* (2017) and Jacobs *et al.,* (2015). They used a combination of agreement and evidence level to evaluate confidence in the validity of a finding. The approaches in the previous studies were modified to fit into the present study. Thus, the level of agreement was defined differently for the respective variables. There is high agreement if more than 60%

Table 2: The selected peri-urban areas

Ward	Population	Selected areas	Questionnaire administered	Retrieved
Naraguta B	79,580	Farin Gada	92	82
Kabong/Tudun-wada	72,159	Sabon Gari	93	84
Du	18,438	Rahwol Kanang	61	57
Gyel A	21,551	Rantya	61	59
Total	191,728		307	282

Table 3: Agreement levels for findings modified from Kleemann *et al*. (2017)

Symbol	Level of Agreement	Interpretation
xxx	High Agreement	If more than 60% of the respondent confirm the variable.
Xx	Medium Agreement	If 25-60% of the respondent confirm the variable.
X	Low Agreement	If less than 25% of the respondent confirm the variable.
–	No	If no data or information is provided

Table 4: Accuracy Assessment of the classified Landsat images

LULC Categories	1999 (year)		2014 (year)		2022 (year)	
	UA	PA	UA	PA	UA	PA
Built-up Area	0.977778	0.956522	0.900000	0.991453	1	1
Meadows	0.984127	0.953845	0.983051	0.967033	0.995261	1
Mountain Vegetation	0.984334	0.994722	0.989324	0.985816	1	0.994950
Water Body	1	0.909091	0.956522	0.818182	1	1
Overall Accuracy (OA) (%)	98.40		98.00		99.80	
Kappa Values (KV)	0.959747		0.966482		0.996921	

of respondents confirm the variable, and medium agreement is defined if 25-60% of respondents confirm the variable. The low agreement is provided if less than 25% of the respondent confirm the variable, and No (-) if no data or information is provided (Table 3).

RESULTS AND DISCUSSION

Accuracy Assessment and Classification of the LULC.

The present study used the supervised classification method to analyze the Landsat images of the selected peri-urban settlements (Farin Gada, Sabon Gari, Rantya, and Rahowl Kanang). Each of the epochs was matched to reference data to gauge the accuracy of the classification. Five hundred (500) stratified random sample points were selected for the validation of the classified images for each epoch. Accuracy assessment for the four (4) land use and land cover categories was generated as regards the user accuracy (UA), producer accuracy (PA), overall accuracy (OA), and the Kappa values (KV) for 1999, 2014, and 2022 (Table 4). The overall accuracy of the LULCs for the years 1999, 2014, and 2022 were 98.4%, 98.0%, and 99.8% respectively. While the kappa values for the three years were within the range of 0.959747 and 0.996921. According to Mahmoud *et al.*, (2016) and Mango *et al.,* (2010), an overall accuracy from 60% to 90% is acceptable for remote sensing image-based analysis. Likewise, Manomani and Suganya (2010) and Maingi and Marsh (2002) cited in Wang *et al*. (2021) classified kappa values into six broad groups: <0 indicates no agreement, 0 - 0.2 as slight, 0.2 - 0.41 as poor, 0.41 - 0.60 as moderate, 0.60 - 0.80 as significant, and 0.81 - 1.0 as almost perfect agreement. The average OA and KV of this study surpassed 90% and 0.81, implying, the accuracy is within the permissible range.

An actual growth rate and land modification trend pattern were observed in the peri-urban areas, and this trend was confirmed by image classification and a growth pattern. Fig. 3 - 6 displays the classification of LULC that has evolved in the areas through the study period. The four classes of land use and land cover were built-ups, meadows, mountain vegetation, and water body. However, this study has keenly focused on built-up areas in the various peri-urban regions

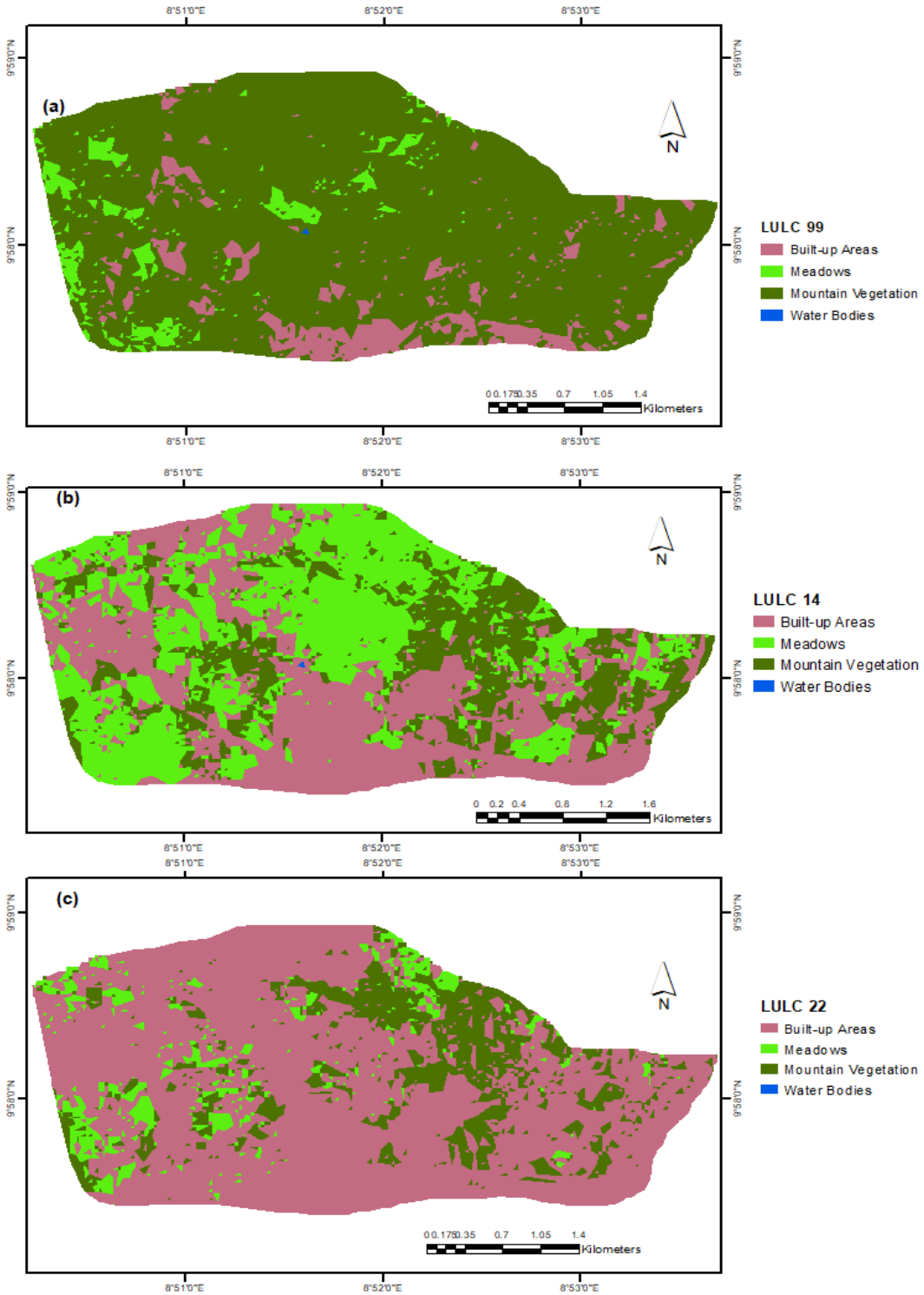

Fig. 3: Farin-Gada LULC (1999-2022)

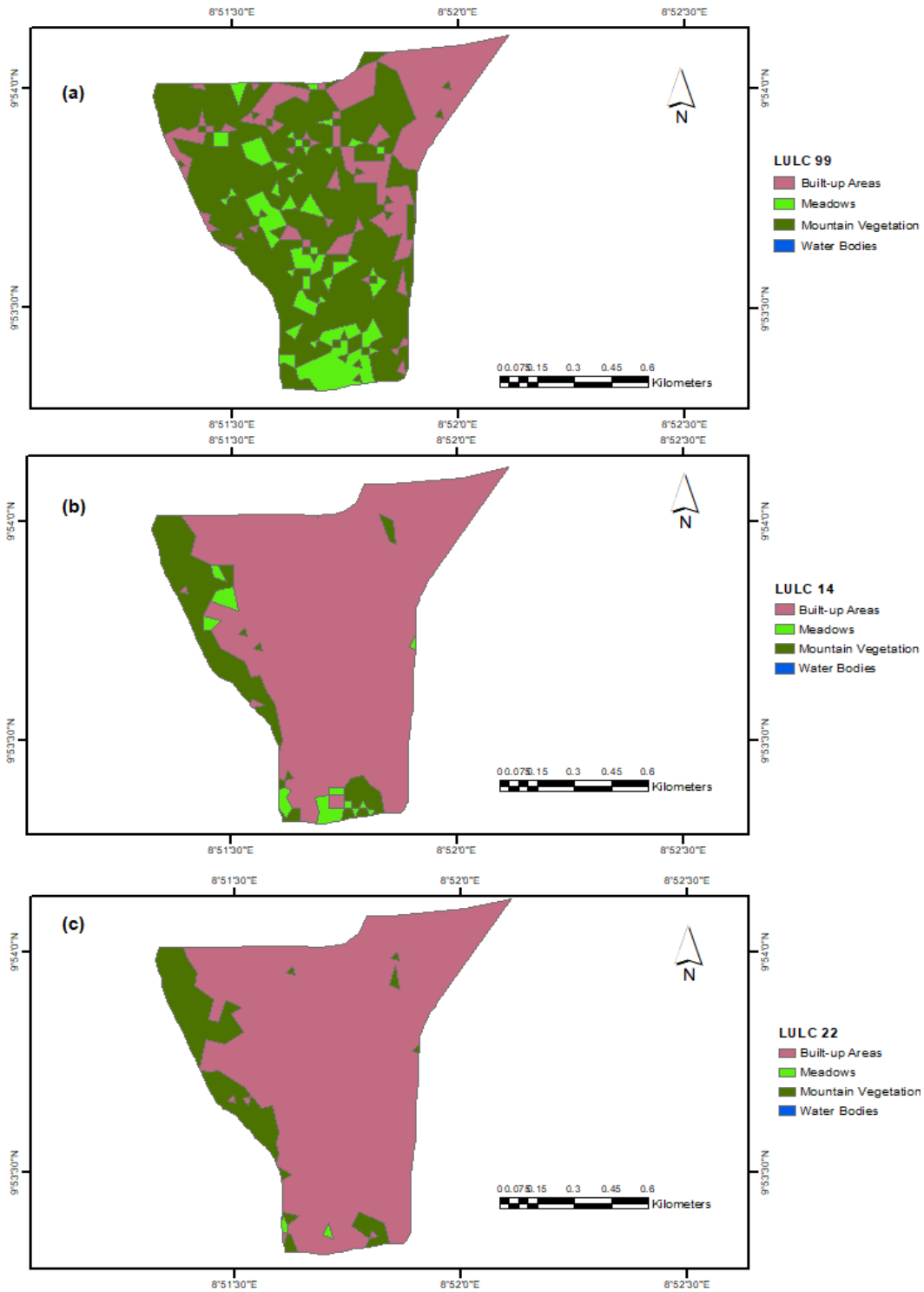

Fig. 4: Sabon-Gari LULC (1999-2022)

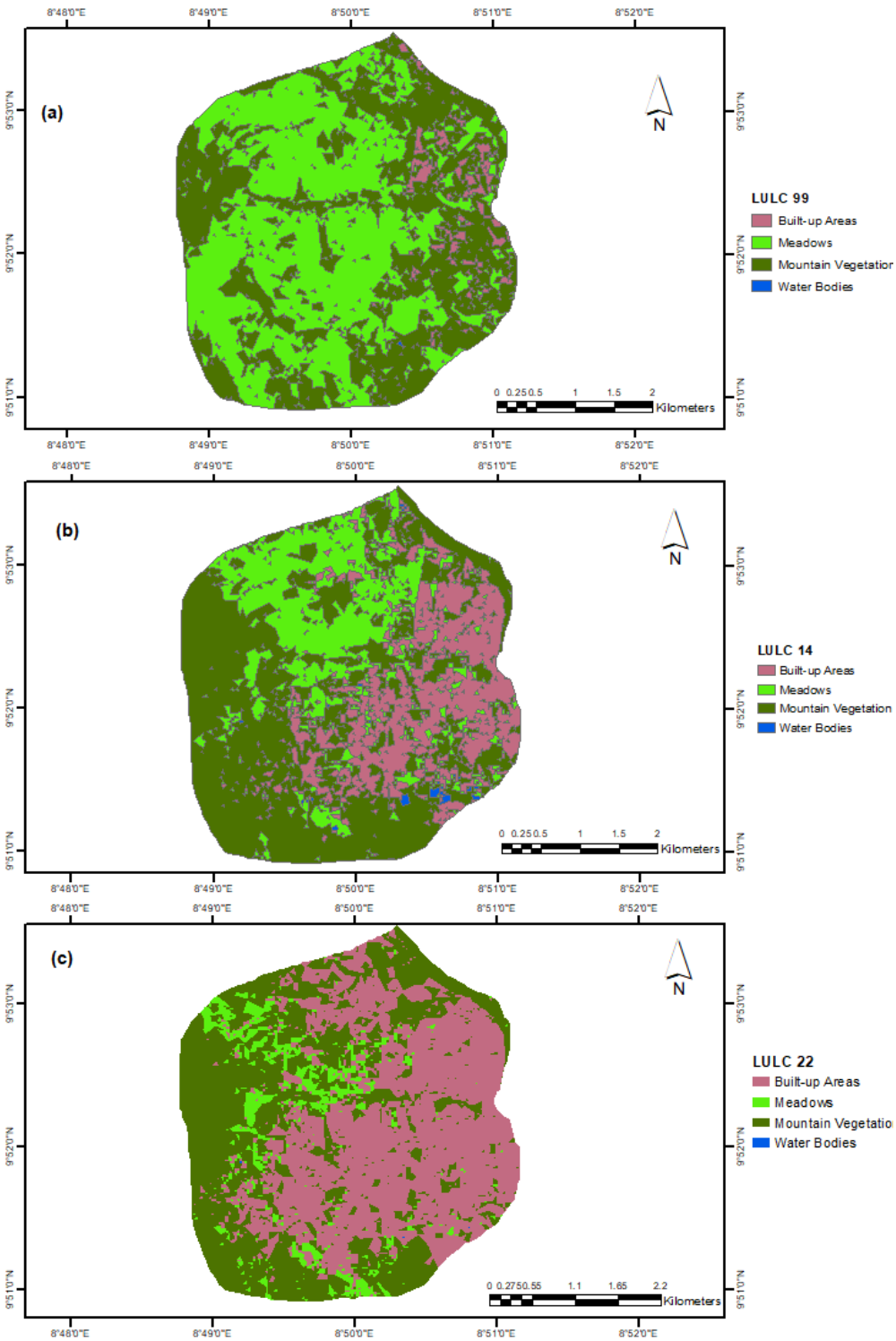

Fig. 5: Rantya LULC (1999-2022)

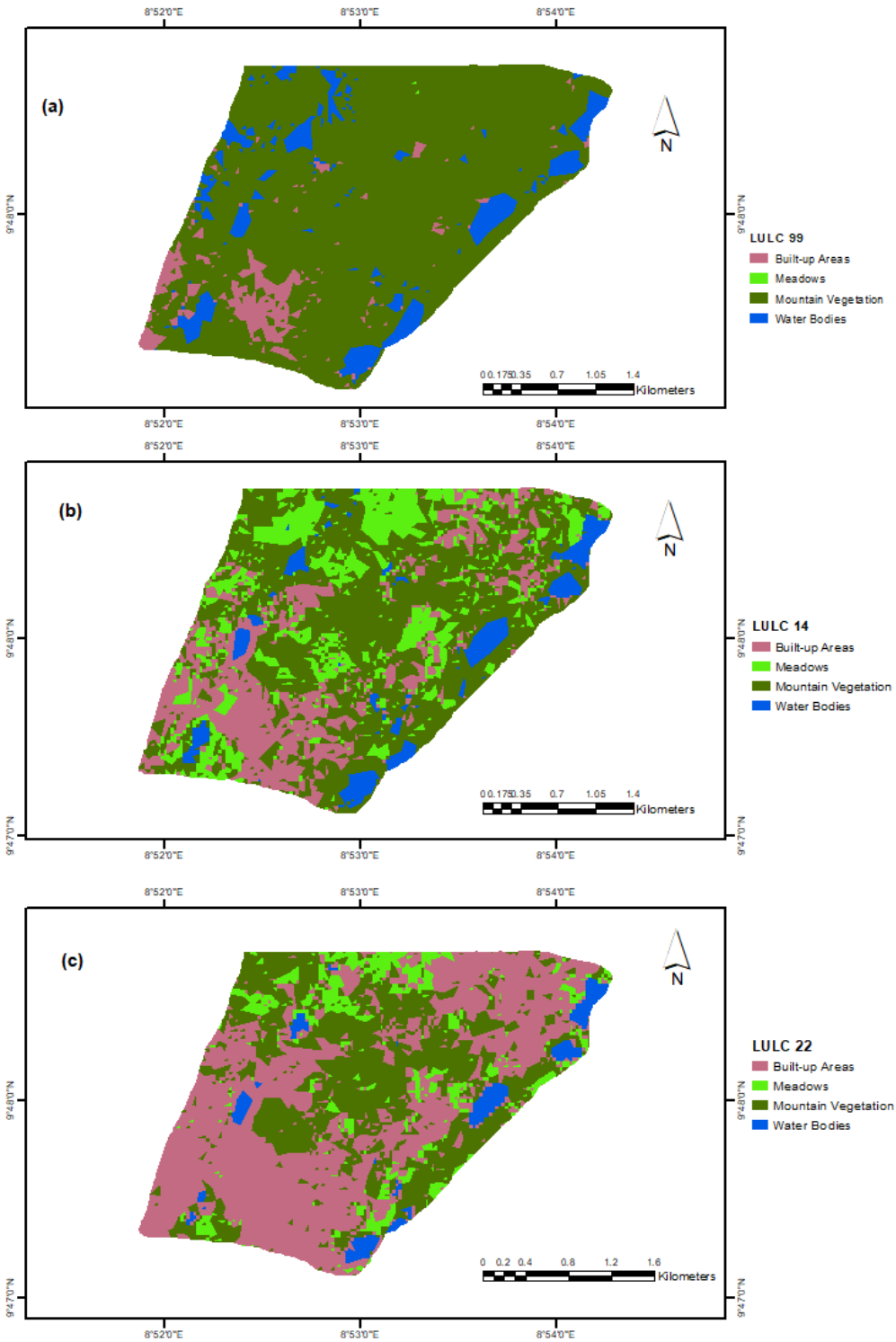

Fig. 6: Rahwol Kanang LULC (1999-2022)

to examine the spatial pattern, nature, and drivers of growth.

The spatial pattern of growth

From 1999 to 2014, an all-round massive development was observed in the regions (Table 5). Highest wave of growth proceeding toward Farin Gada and Rantya was observed with a large proportion change of 42.5%, and 35.8% respectively. At the same time, considerable growth occurred in Rahowl Kanang and Sabon-Gari, with a significant magnitude of 141.23 hectares (ha) at 14.7% rate of change and 67.12 ha at 7.0% rate. The rapid spatial growth pattern could be attributed to the presence of infrastructure majorly in Farin Gada and the extension/construction of service roads in Rantya and Rahowl Kanang. A large expanse of developable lands and the existence of health, educational and institutional services in these areas also contributed to the rapid growth. In Sabon-Gari, slow growth was witnessed. The presence of Jos Wildlife Park which is located behind the settlement may have deterred further expansion.

From 2014 to 2022, Farin Gada, Rantya, and Rahowl Kanang maintained the highest rate of growth, with the former having a magnitude of 475.49 ha at 41.9%, 406.23 ha at 35.9%, and the later with a magnitude of 247.94 ha at a percentage change of 21.9%. The unprecedented growth in Farin-Gada, Rantya and Rahowl Kanang cannot be far from the factors discussed previously coupled with the relative peace witnessed in the later years after the previous crises and unrest of 2010/2011 experience in Jos as reported in previous studies (Krause, 2011; Shehu *et al.* 2023). Sabon-Gari maintained the most nominal growth, due to constraints posed by the Wildlife Park, and rugged terrain. This has restricted the expansion of the settlement.

A critical study of the images revealed considerable growth and land fragmentation in all the areas. In the early years (1999-2014), the spatial growth patterns in the peri-urban areas depicted a ribbon and linear growth, with extensive growth proceeding along arterial roads. These patterns occurred along Jos Zaria road, Rukuba road, Tudun Wada, Sabon-Gari, Donkat Bali road, Rantiya-High cost road, and Gura top – Rahowl Kanang road, where lands adjoining these corridors witnessed rapid growth. The finding accords with Webster and Muller (2009) notion that the pattern of peri-urbanization is often determined initially by the routes of newly built highways. In the later years (2014-2022), dispersed/isolated growth patterns were observed as built-ups spread farther from the major road corridors. Land fragmentation and scattered small settlements were observed around unguwan Jarawa in Farin-Gada, towards, Gura-top, Du, and Zawan in Rahowl Kanang and Mado settlements around Tudun Wada, Sabon-gari, and Rantya. This result also confirmed the findings by Shehu *et al.* (2023) who observed an outward pattern of growth from the city core to peripheral regions of the Jos metropolitan area. A similar pattern of growth

Table 5: Spatial growth of the study area from 1999 to 2014

Peri-urban areas	1999 (year)	2014 (year)	Change (1999-2014)	
	Growth extent (Ha)	Growth extent (Ha)	Magnitude (Ha)	Trend (%)
Farin-Gada	126.17	533.39	407.22	42.5
Sabon-gari	26.81	93.93	67.12	7.0
Rantya	49.95	393.17	343.22	35.8
Rahwol Kanang	53.78	195.01	141.23	14.7
Total	256.71	1215.50	958.79	100

Table 6: Spatial growth of the study area from 2014 to 2022

Peri-urban areas	2014 (year)	2022 (year)	Change (2014 - 2022)	
	Growth extent (Ha)	Growth extent (Ha)	Magnitude (Ha)	Trend (%)
Farin-Gada	533.39	1008.88	475.49	41.9
Sabon-Gari	93.93	97.29	3.36	0.3
Ranya	393.17	799.40	406.23	35.9
Rahwol Kanang	195.01	442.95	247.94	21.9
Total	1215.50	2348.52	1133.02	100

was observed in Tamale (Karg *et al.,* 2019), Kumasi (Simon *et al.,* 2004), Minna (Idowu *et al.,* 2020), and Bauchi (Sale, 2018) were according to these studies, growth of settlements was faster along the service roads that linked the core area and other cities than in areas not served by roads. Settlements in the peri-urban regions of the metropolis continued to erupt in uncoordinated and unregulated patterns. These growth are massively submerging agricultural land and swallowing up adjoining settlements growing into a large "uncontrolled conurbation of slums".

The nature of growth

The nature of growth in the peri-urban areas was mainly unplanned, irregular, and disorderly. Results in Fig. 7 identified a significant proportion (78%) of respondents who indicated their settlement was unplanned. In comparison, 13% indicated partially planned, and 9% revealed their settlement was planned. Growth in most parts of these areas was proceeding in a sporadic and uncoordinated manner, with little or no space for roads leading to narrow roads with no pavement and poor or no drainage. A visit to Farin-Gada and Sabon-Gari, a visible disorderly growth was observed, primarily unpaved roads, poor drainages, and sporadic medium to low-density housing (Fig. 8). This could be attributed to the expansion of these areas beyond the urban boundaries of planning regulation. This result aligned with the Union of International Association (2020), where unplanned and poorly managed growth contributes to environmental challenges manifesting in the chaotic pattern of land use and incoherent nature of development. The partially or relatively planned areas were found in parts of Bukuru high cost/Rantya and Rahowl Kanang. These are areas that were partly planned and are regulated by the Jos Metropolitan Development Board in efforts to actualize the provisions of the Greater Jos Master Plan (Musa and Dung-Gwom, 2020).

Drivers of growth in the peri-urban areas

The study identified the drivers that led to the rapid growth in Farin-Gada (FG), Sabon-Gari (SG), Rantya (RT), and Rahowl Kanang (RK) (Table 7). These drivers were assessed based on people and community perceptions using agreement-level evaluation. Table 7 cited forces of peri-urban growth, including population increase, Market (trade and economy), provision of services, mining, Security challenges, tourism and recreation, physical constraint, increased demand/affordability of land, and customary land tenure system.

In Table 5, a high confidence level was accorded to rapid population as the major driving force of growth, confirmed by the respondent in Farin-Gada, Sabon-Gari, and Rantya with more than 60% proportion in high agreement; in Rahowl Kanang, about 50% of respondents confirmed so with the medium agreement. The reason for the population growth could be propelled by natural increase and migration of people from rural areas due to

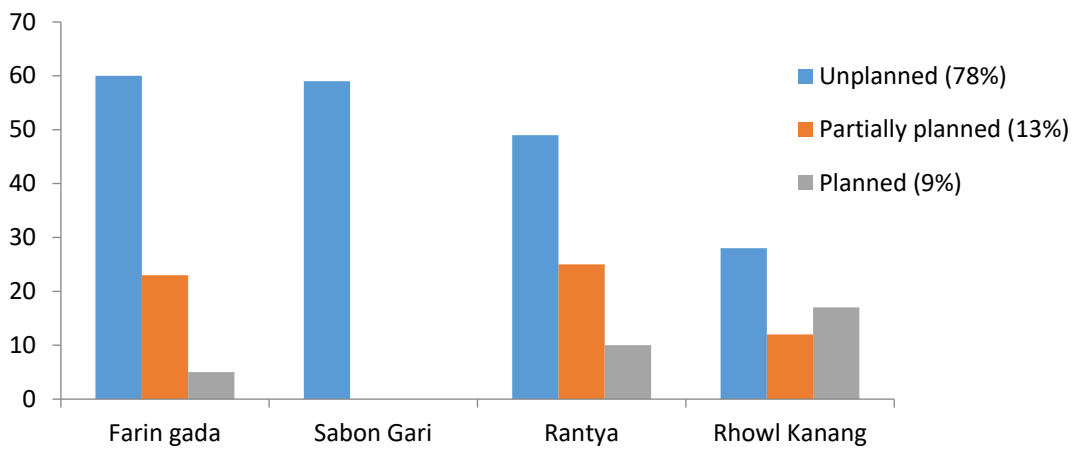

Fig. 7: The nature of growth in peri-urban areas of Jos metropolis

a. Farin-Gada (unguwan Jarawa) b. Sabon-Gari

c. Rantya d. Rahowl Kanang

Fig. 8: Sporadic nature of growth in peri-urban areas of Jos

Table 7: Drivers of growth in Jos peri-urban areas

Drivers of Growth	Peri-urban areas				Confidence Level			
	FG	SG	RT	RK	FG	SG	RT	RK
Population increase	xxx	xxx	xxx	xx	High	High	High	Medium
Market (trade & economy)	xxx	x	xx	-	High	Low	Medium	No
Provision of services	xx	x	xxx	xxx	Medium	Low	High	High
Mining activities	-	-	x	xx	No	Low	Medium	No
Security challenge	x	xxx	xxx	xx	Low	High	High	Medium
Tourism and recreation	x	xxx	xxx	xxx	Low	High	High	High
Physical constraints	-	xxx	-	xx	No	High	No	Medium
Demand/affordable land and customary land tenure system	xx	x	xxx	xxx	Medium	Low	High	High

Agreement level: xxx = high agreement (>60%); xx = medium agreement (25-60%); x = low agreement (<25%); — = no data.
FG = Farin-Gada; SG = Sabon-gari; RT = Rantya; RK = Rahowl Kanang

employment opportunities in the city, and more recently, due to insecurity in the rural areas. This is a common phenomenon, mostly in cities of developing countries. The result affirmed the study conducted by Abdulai *et al.* (2021); Azandeh *et al.* (2015); Appiah *et al.* (2014); Kleemann *et al.* (2017), and Salem *et al.* (2018), who identified natural increase and migration as driving forces for peri-urban growth. Market (trade and economy) was identified to be an agent of growth in Farin-Gada, with more than 60% proportion confirmed in high agreement. While respondents in Sabon-Gari and Rantya confirmed a low and medium

agreement with less than 25% and 52%, respectively. Respondents in Rahowl Kanang were not sure. Undoubtedly, small and medium-scale businesses has contributed tremendously to the rapid growth of the settlements, much more noticeable in Farin-Gada and Rantya. This result agrees with Salem *et al.* (2018), who stated that economic factors contribute to the expansion of peri-urban areas. Also, the provision of services was identified as one driver of growth in the study area. This was confirmed in high agreement by the respondent in Rantya, and Rahowl Kanang, while Farin-Gada responded with a medium confidence level. This result confirms the study by Dung-Gwom (2008) who established that the construction of road networks, the establishment of schools, the Nigerian National Petroleum Corporation (NNPC) depot at Mista Ali, and health facilities had played significantly in the rapid expansion of the city along the Jos-Bukuru-Barkin Ladi Road axis; the Jos-Bauchi axis, the Jos-Zaria Road, and the Jos-Rukuba Road. Also, the findings agreed with Salem *et al.* (2018), where connectivity to roads and railways contributed to the expansion of peri-urban areas of the Greater Cairo Region. In the study, a large part of the urban expansion was observed to occur adjacent to roads and railways attractive to residents and businesses in the northeast, north, and northwest axis. Mining activities as a growth driver were rated with a medium and low confidence level in Rantya and Sabon-Gari. Undoubtedly, tin ore mining was significant in the expansion of settlements in Jos due to the available economic or employment opportunities; thus, it attracted expatriates and local labour into the region. Conversely, the finding contradicts Wapwera *et al.* (2015) who validates that mining areas in Jos have been left derelict. Further, identified reasons that may have restricted development from the areas, including the presence of radioactive substances, including alpha/beta and gamma radiation. In addition, the determination of the level of these substances shows the environment is not habitable. However, respondents in Farin-Gada and Rahow Kanang indicated nil. Similarly, Security challenges such as the communal crisis of 2001, 2010, and 2011 were rated with high confidence in Sabon-Gari and Rantya and a medium agreement in Rahowl Kanang. Undoubtedly, the security challenges contributed to the segregation of residential settlements and the dispersal of the population to perceived areas of safety. This finding harmonized with Aliyu *et al.* (2015); Krause (2011); Shehu *et al.,* 2023, and Dung-Gwom and Rikko (2009). They asserted that the communal crisis had created fear and mistrust among people, particularly between the indigenes and the settlers (migrants), leading to the relocation and residential development alongside socio-cultural and religious inclination. Thus, there was an outthrust of the population from the city core into the peri-urban axis. Tourism and recreation were rated highly by the respondents in Sabon-Gari, Rantya, and Rahowl Kanang, and low confidence levels in Farin-Gada. The development of tourism and recreational services around state low-cost, Rahwol Kanang and Sabon-Gari, including hotels, Solomon Lar Amusement park, and Jos wildlife park, has created a variety of entertainment and contributed to the growth of settlements in the areas the services were located. This finding aligned with Wapwera *et al.* (2015) who argued that the establishment of the famous Wildlife Parks, the game reserves, Mado Tourist Village, and Rayfield Resort, amongst others, have been instrumental in the expansion and development of peri-urban areas in Jos. Physical constraints were observed to contribute to the growth of peri-urban areas. The respondent confirmed this in Sabon-Gari and Rahowl kanang with a high and medium confidence level, respectively. This finding accords with Dung-Gwom (2008) and Wapwera *et al.* (2015), where rocky outcrops, streams, and abandoned mining ponds significantly influenced physical developments in Jos which has tended to frog-leap to avoid areas that are difficult to develop. A Visit to Sabon-Gari and Farin-Gada confirmed this as development was frog-leaping toward adjoining settlements of Sabon-Gari, Mado, Tudun-Wada, Jenta Adamu, Jenta Mangoro, Kabong and Unguwan Jarawa in Farin-Gada forming a conurbation of slums. Given the result (over 60% confirmed), increased demand/affordable land and customary land tenure system were identified to contribute to the growth of peri-urban areas with high confidence in Rantya and Rahowl Kanang areas; a medium confidence level in Farin-Gada, and a low in Sabon-Gari. Furthermore, the respondent attributed the high cost of land and residential rent in the city core to pushing them to the fringes. This finding is similar to the fact that peri-urban area provides accommodation for people seeking to settle in the areas due to their proximity to the city and relatively

low land affordability. This result is in agreement with Abdulai *et al., (*2021) in their study of livelihood diversification among indigenous peri-urban women in the Wa municipality, Ghana, where high rent in the urban core areas of Wapaani, Sokpayiri, Kabanye, and others compelled tenants to acquire land in peri-urban areas to build their own houses instead of renting. Also, the present study indicated that the customary land tenure system significantly influenced the growth of peri-urban areas. This result parallels Wapwera (2014), who observed that land tenure has immensely instigated people to acquire land for development in peri-urban areas. The rapid growth of peri-urban areas in the metropolis could not be complete without the influence of one or two of the forces identified in the present study.

CONCLUSION

This study evaluated the spatial pattern of growth, nature, and drivers of growth in peri-urban areas of Jos Metropolis. The results revealed a definite growth rate pattern and land modification trends observed in the peri-urban areas over the study period. From 1999 to 2014, fast and massive growth was observed in Farin Gada, Rantya and Rahwol Kanang, and a slow in Sabon-Gari. This spatial growth pattern may have been influenced by the presence of public services and the extension of service roads coupled with a large expanse of developable lands in the areas. From 2014 to 2022, continued rapid growth occurred in Farin-Gada, Rantya, and Rahowl Kanang. Sabon Gari maintained the lowest growth because of the constraints of the rugged terrain and the location of the Wildlife Park. Findings revealed considerable growth, land fragmentation, and scattered small settlements in all the areas. In the early years (1999-2014), the growth depicted the ribbon and linear pattern, with extensive growth proceeding along major roads. In the later years (2014-2022), a dispersed/ isolated growth pattern was observed as built-ups spread farther from the road corridors. The nature of growth in the peri-urban areas was generally unplanned, irregular, and disorderly and observed, converting agricultural land to urban settlements and swallowing up adjoining communities. The study identified eight significant growth drivers that have propelled the unprecedented growth witnessed in the areas. These include; population increase (natural and migration), markets (trade and economy), service development, mining activities and security, tourism/recreation, physical constraints, and demand/affordable land and customary land tenure.

Based on the findings, the study recommends:

i. That the government should integrate these areas into its physical development planning schemes. Efforts should be made to promote local participation and law enforcement through adopting participatory land-use planning with critical adaptation to and emphasis on sectoral planning. Such a bottom-up approach to planning could propel the incorporation of the development of local plans at the local and state levels into the respective regional spatial development frameworks;

ii. There should be an effective Development Control mechanism to manage the spatial growth of these areas. This requires the enactment of laws and forming enforcement agencies in collaboration with Jos metropolitan Development Board and Plateau state Geographic Information Services with necessary incentive/penalties structures. While the incentives are expected to encourage systematic growth of urban areas, the penalties will curb illegal development;

iii. There should be a dynamic approach that promotes sustainable and orderly growth of the peri-urban areas, including the provision and improvement of essential services. This should involve incorporating spatial planning to control growth in peri-urban areas. The primary role of spatial planning is the integration of various LULCs, strategic and urban infrastructure development, and improvement in local governance. Such an effort is necessary to facilitate the rational use of land resources on a sustained basis in the long run;

iv. There should be a proper capacity-building and awareness campaign to be established by the State Government in collaboration with NGOs to disseminate information about the adverse effects of sprawl or peri-urbanization on various socio-economic and environmental aspects;

v. There is a need for the Government of Plateau state to establish a policy that regulates artisanal mining and promotes land reclamation. The areas should be established within the control of the planning authorities at the state and local government levels to regulate artisanal mining

activities to prevent similar occurrences in other areas.

The findings in this study will help planners and policy-makers make informed and unified decisions beyond administrative boundaries. The study also adds to the body of knowledge globally and provides the bases for further research.

AUTHOR CONTRIBUTIONS

P. Shehu performed the conceptualization, reviewed the relevant literature, designed the methodology, conducted data collation and analysis, prepared, reviewed, and edited the manuscript, and produced the graphic abstract. L.S. Rikko supervised the research and reviewed the manuscript. B.A. Musa assisted in the collection of data and computation and reviewed the manuscript. D.B. Bawa carried out the image visualization, and mapping as well as the review of the manuscript. A.Y. Taimako, contributed financially during the collation of data, and reviewed and edited the manuscript.

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CONFLICT OF INTEREST

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

ABBREVIATIONS (NOMENCLATURE)

α1 and α2	*Areal extent of the previous and later years*
Eq.	*Equation*
ETM	*Enhance Thematic Mapper*
FG	*Farin-Gada*
Fig.	*Figure.*
GIS	*Geographic Information System*
GPS	*Global Positioning System*
Ha	*Hectare*
KV	*Kappa Value*
LULC	*Land Use and Land Cover*
m∧	*The magnitude of change.*
∑m∧	*Number of years*
N	*Total population of the wards*
NGO	*None Governmental Organization*
OA	*Overall Accuracy*
PA	*Producer Accuracy*
RK	*Rahowl Kanang*
RT	*Rantiya*
SG	*Sabon-Gari*
Tq	*Trend*
UA	*User Accuracy*
USGS	*United States Geological Survey*
xxx	*High agreement (>60%)*
xx	*Medium agreement (25-60%)*
x	*Low agreement (<25%)*
—	*No (no data)*

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