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Remote Sensing and Gis-Based Assessment of the Spatio-Temporal Dynamics of Urban Vacant Lands in Jos Metropolis, Nigeria.

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ABSTRACT

Urban vacant lands constitute an important but often poorly documented component of rapidly changing urban landscapes. Their spatial distribution and temporal dynamics provide valuable information for understanding urban expansion, land-use efficiency and sustainable physical planning. This study assessed the spatio-temporal coverage of urban vacant lands in Jos Metropolis, Nigeria, using remote sensing and Geographic Information Systems (GIS). Multi-temporal Landsat satellite imagery covering 1994, 2004, 2014 and 2024 was analyzed to classify land use/land cover and determine changes in vacant land over a 30-year period. The study focused on Jos North and Jos South Local Government Areas, which constitute the core of Jos Metropolis. Supervised Maximum Likelihood Classification was applied using ArcGIS, while field observations, GPS ground-truthing and accuracy assessment were used to validate the classification. Six land-use/land-cover classes were identified: built-up area, vegetation, water body, rock outcrop, agricultural land and vacant land. The results showed substantial temporal changes in the spatial coverage of vacant lands. Vacant land increased from 8,406.9 ha (10.3%) in 1994 to 22,795.2 ha (27.9%) in 2004, declined to 19,231.0 ha (23.6%) in 2014 and further declined to 11,694.5 ha (14.3%) in 2024. During the same period, built-up land increased from 2,384.91 ha to 11,083.23 ha, representing approximately 365% growth. Spatial analysis indicated that vacant lands were unevenly distributed and concentrated particularly in peri-urban areas, hilly terrain and environmentally constrained locations. Moran's I of 0.42 ($p < 0.01$) indicated significant positive spatial clustering. The findings demonstrate that vacant land in Jos Metropolis is dynamic rather than static, reflecting processes of urban expansion, land conversion and physical constraints. The study recommends systematic vacant-land inventories, GIS-based monitoring, strategic infill development and integration of vacant-land information into urban development plans.

Keywords: Urban vacant land; Remote sensing; GIS; Spatio-temporal analysis; Land-use change; Jos Metropolis; Nigeria; Urban planning.

1. INTRODUCTION

Urbanization has substantially transformed the spatial structure of cities, particularly in developing countries where rapid population growth and expansion of built-up areas have generated complex land-use patterns. One important but relatively understudied component of contemporary urban landscapes is vacant land. Vacant lands may occur as undeveloped parcels, abandoned or underutilized areas, residual spaces within the urban fabric, or areas awaiting future development. Their existence has important implications for urban development, land-use efficiency, infrastructure provision, environmental management and spatial planning.

Urban vacant lands are not uniformly distributed. Their location and persistence may be influenced by urban expansion, land speculation, land-tenure arrangements, infrastructure availability, environmental constraints and planning practices. Consequently, understanding their spatial distribution and temporal changes is important for urban planners and other land-management stakeholders.

In rapidly urbanizing cities, vacant land can represent both a planning challenge and an opportunity. On one hand, extensive vacant land may indicate inefficient land utilization and fragmented urban development. On the other hand, such land can provide opportunities for affordable housing, public facilities, green infrastructure, urban agriculture and other forms of strategic urban

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redevelopment. The thesis on which this article is based, identifies vacant lands as important elements of urban planning and argues that their accurate identification and mapping can support more efficient and sustainable urban development.

In Nigeria, rapid urban growth has increased pressure on urban land resources. Jos Metropolis has experienced substantial transformation in land use, with the expansion of built-up areas occurring alongside changes in agricultural land, vegetation, rock outcrops, water bodies and vacant lands. However, accurate and up-to-date information on the location, extent and temporal behaviour of vacant lands remains limited.

The study therefore focused on the spatio-temporal assessment of vacant lands in Jos Metropolis using remote sensing and Geographic Information System (GIS). The specific objective addressed in this article is to assess the spatio-temporal coverage of vacant lands in Jos Metropolis, Nigeria.

2. STUDY AREA

The study was undertaken in Jos Metropolis, Plateau State, Nigeria. The research specifically focused on Jos North and Jos South Local Government Areas, which constitute the core urban area examined in the study. The broader Jos Metropolis comprises six (6) Local Government Areas, while Jos North and Jos South were selected for detailed analysis because of their urban characteristics and extensive development layouts.

The study area covers approximately 816.44 km² according to the research framework, while the detailed study scope identifies the urban area as the focus of the vacant-land investigation. The area is characterised by varied topography, including relatively flat areas, valleys, hills and rocky terrain. These physical characteristics are important to the distribution and development potential of vacant lands.

The Digital Elevation Model used in the study indicates elevations ranging from approximately 886 m to 1,514 m, with Jos South recording the highest elevation. The terrain therefore constitutes an important spatial characteristic in understanding vacant-land distribution.

3. MATERIALS AND METHODS

3.1 Research Design

The study adopted a mixed-methods approach, although the analysis presented in this article is primarily focused on the quantitative geospatial component of the research. The broader research integrated remote sensing, GIS, field observations, interviews, questionnaires and documentary evidence. The mixed-methods design allowed spatial information to be validated through field observations and ground-truthing.

3.2 Satellite Data

Multi-temporal Landsat imagery was used to examine land-use/land-cover changes over a 30-year period. The selected years were: 1994, 2004, 2014, and 2024.

The imagery had a spatial resolution of approximately 30 m and was obtained from satellite data archives and processed at the National Centre for Remote Sensing (NCRS), Jos.

The use of multi-date Landsat imagery provided a consistent basis for comparing land-use conditions over time.

3.3 Image Processing and Classification

The satellite images were subjected to geo-correction, geo-referencing, image compositing and subsetting to the study area. ArcGIS was used for image processing, classification and spatial analysis. Supervised Maximum Likelihood Classification was employed to classify the imagery into six major land-use/land-cover categories:

i Built-up area
ii Vegetation
iii Water body
iv Rock outcrop
v Agricultural land

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vi Vacant land

The classification procedure was specifically designed to identify and quantify vacant land within the wider land-use/land-cover system.

3.4 Ground Truthing and Accuracy Assessment

Ground-truthing was undertaken using GPS and field observations, with KoboCollect also used for mobile data collection. The field information was used to validate the interpretation and classification of satellite imagery.

The study reports classification accuracy assessment using confusion matrices and Kappa statistics, with Kappa values exceeding 0.87 for the analyzed years. This indicates a high level of agreement between classified imagery and reference information.

3.5 Spatial Analysis

GIS-based spatial analysis was used to determine the location, extent and pattern of vacant lands. Trend analysis was applied to compare vacant-land coverage between the four observation years. Spatial autocorrelation and hotspot analysis were used to examine whether vacant lands were randomly distributed or spatially clustered.

Moran's I was employed to assess spatial autocorrelation. Digital Elevation Model data were also incorporated to examine the relationship between vacant land and topography.

4. RESULTS

4.1 Land-Use/Land-Cover Composition

The classification identified six major land-use/land-cover classes in Jos Metropolis. These comprised built-up areas, vegetation, water bodies, rock outcrops, agricultural land and vacant land.

The analysis demonstrates considerable transformation of the landscape between 1994 and 2024. Built-up areas expanded substantially, while agricultural and vacant lands generally declined over the longer period.

Table 1. Land-Use/Land-Cover Distribution in Jos Metropolis, 1994–2024

Year	Built-up (ha)	Vegetation (ha)	Water body (ha)	Rock outcrop (ha)	Agricultural (ha)	Vacant land (ha)
1994	2,384.91	6,696.36	879.93	22,452.12	40,824.81	8,406.90
2004	3,145.23	10,243.26	989.28	19,094.13	25,503.84	22,795.20
2014	5,256.09	9,665.64	896.13	18,682.56	27,913.59	19,231.02
2024	11,083.23	11,083.77	2,216.70	18,557.82	27,009.00	11,694.51

Source: Author's Fieldwork (2025).

4.2 Temporal Trend of Vacant Land

The results reveal a distinct fluctuation in vacant-land coverage.

In 1994, vacant land covered approximately 8,406.9 ha, representing about 10.3% of the classified study area. By 2004, vacant land had increased dramatically to 22,795.2 ha (27.9%).

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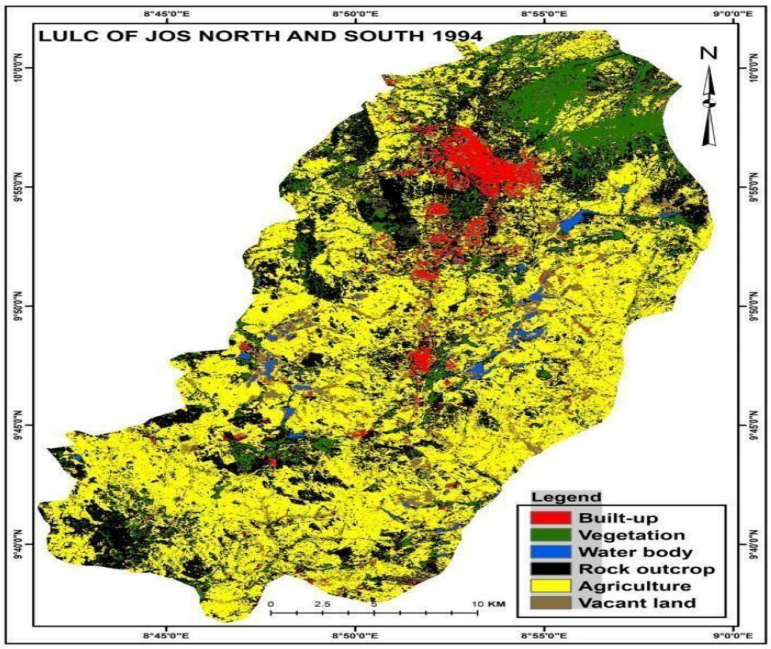


Figure 1 Land Use Land Cover Classification of Jos Metropolis (1994)
Source: Author's fieldwork (2025)

The increase between 1994 and 2004 represents approximately a 171% increase in the mapped vacant-land class.

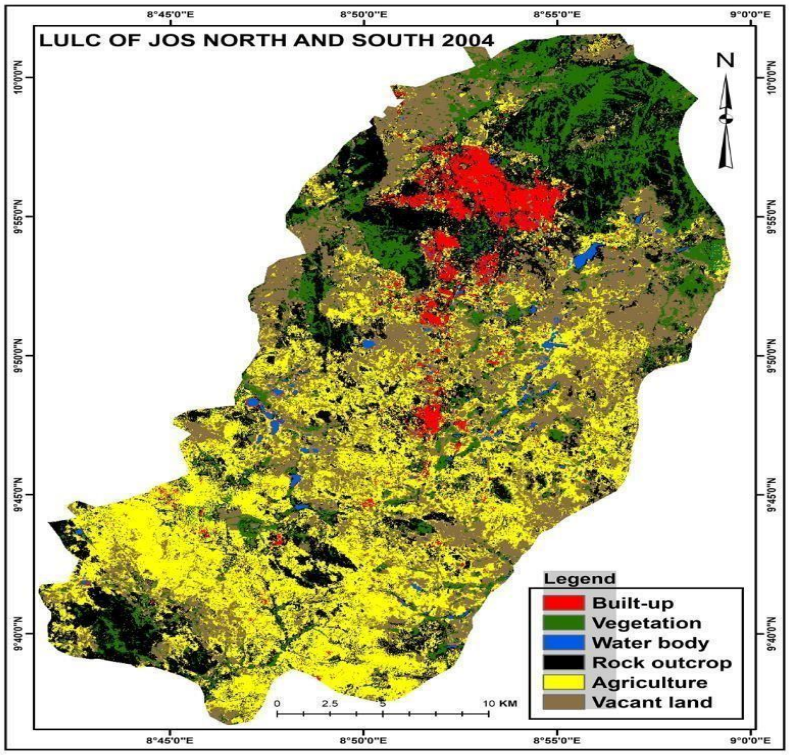


Figure 2 Land Use Land Cover Classification of Jos Metropolis (1994 - 2004)
Source: Author's fieldwork (2025)

Between 2004 and 2014, however, vacant land declined to 19,231.02 ha (23.6%). By 2024, it had declined further to 11,694.51 ha (14.3%).

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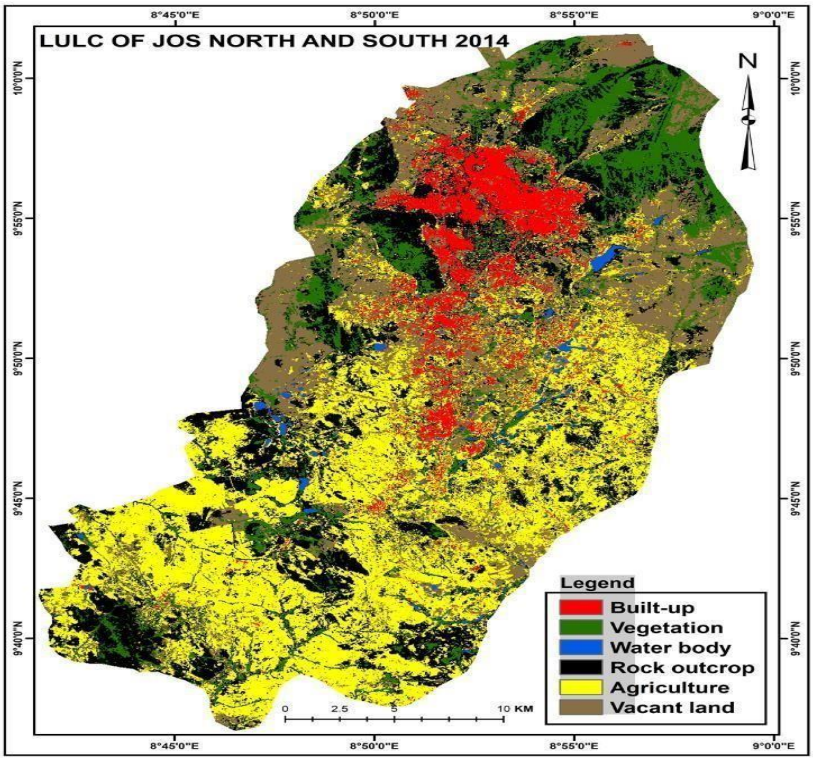


Figure 3 Land Use Land Cover Classification of Jos Metropolis (2004 - 2014)
Source: Authors fieldwork (2025)

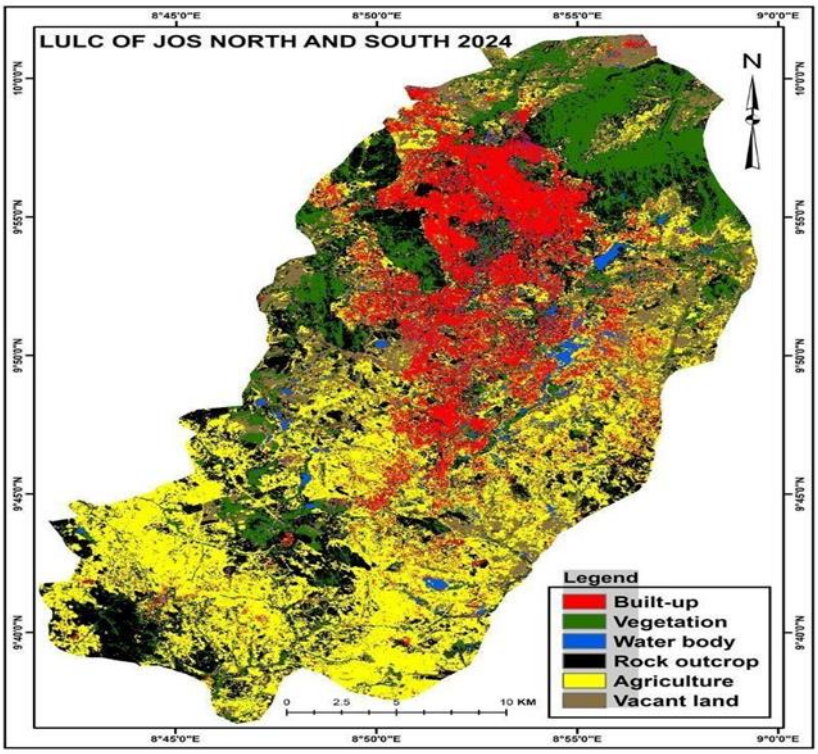


Figure 4 Land Use Land Cover Classification of Jos metropolis (2014 - 2024)
Source: Author's fieldwork (2025)

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Thus, the temporal trajectory can be summarized as:

1994 → Increase → 2004 peak → Decline → 2014 → Further decline → 2024

This represents a boom-and-decline pattern, rather than a continuous increase or decrease.

Table 2. Temporal Change in Vacant Land

Period	Vacant land (ha)	Percentage	Change
1994	8,406.90	10.3%	—
2004	22,795.20	27.9%	+14,388.30 ha
2014	19,231.02	23.6%	−3,564.18 ha
2024	11,694.51	14.3%	−7,536.51 ha

The results indicate that the largest concentration of vacant land occurred in 2004, after which a substantial proportion was reabsorbed into other land-use categories.

4.3 Expansion of Built-Up Land

The increase in built-up land provides important context for interpreting the decline in vacant land.

Built-up land increased from 2,384.91 ha in 1994 to 11,083.23 ha in 2024, representing an increase of approximately 8,698 ha or 365%.

This substantial increase demonstrates the intensity of urban expansion during the study period. The inverse relationship between the growth of built-up land and the later decline of vacant land suggests that portions of previously vacant areas were absorbed into the expanding urban fabric.

4.4 Spatial Distribution of Vacant Land

The GIS analysis indicates that vacant land was not uniformly distributed throughout Jos Metropolis. Rather, vacant lands occurred in clustered, fragmented and sporadic patterns.

The analysis identified concentrations in:

i Peri-urban areas;
ii Hilly terrain;
iii Environmentally constrained locations;
iv Areas with relatively poor accessibility; and
v Selected inner-city/brownfield locations.

The spatial pattern was particularly evident in Jos South, where vacant lands occurred in association with relatively high elevations and difficult terrain.

4.5 Spatial Autocorrelation and Hotspot Analysis

Spatial autocorrelation analysis produced a Moran's I value of 0.42 ($p < 0.01$). This indicates statistically significant positive spatial autocorrelation and demonstrates that vacant lands were spatially clustered rather than randomly distributed.

The clustering was particularly associated with areas having elevations of approximately 1,200–1,514 m and slopes exceeding approximately 12°.

The result suggests that the physical geography of Jos is an important component of vacant-land distribution.

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4.6 Relationship Between Vacant Land and Topography

The DEM analysis revealed elevations ranging from approximately 886 m to 1,514 m. Jos South contained the highest elevation zones.

The study found that steeper areas remained relatively undeveloped because of construction challenges, erosion risks, poor accessibility and higher development costs. In contrast, flatter and more accessible areas had experienced greater conversion to housing, markets and institutional uses.

This spatial pattern demonstrates that vacant land should not be considered simply as unused land. Some vacant areas are associated with physical constraints that limit their immediate development potential.

5. DISCUSSION

The results demonstrate that urban vacant land in Jos Metropolis is a dynamic component of urban land-use change. Rather than following a simple linear trajectory, vacant land experienced a substantial increase between 1994 and 2004 before declining considerably between 2004 and 2024.

The increase from 8,406.9 ha in 1994 to 22,795.2 ha in 2004 may reflect the transitional nature of land at the urban fringe. The thesis associates such patterns with processes including land clearance, fallowing, land speculation and transitional development.

The subsequent decline in vacant land corresponds with significant expansion of built-up areas. Built-up land increased by approximately 365% during the 30-year period, indicating intense urbanization.

The spatial clustering identified through Moran's I further demonstrates that vacant land distribution is not random. The concentration of vacant lands in peri-urban and hilly areas suggests an interaction between urban growth and physical geography.

The relationship with topography is particularly important in Jos because steep slopes, erosion risk, poor accessibility and development costs can discourage construction. The thesis reports that areas exceeding approximately 12° slope tend to remain less developed, while flatter areas have experienced greater development pressure.

From an urban planning perspective, these findings have two major implications. First, declining vacant land indicates increasing pressure on available urban land. Second, the remaining vacant land cannot automatically be regarded as immediately developable because a considerable proportion is located in physically constrained environments.

Therefore, planning interventions should distinguish between developable vacant land and environmentally or physically constrained vacant land.

6. PLANNING IMPLICATIONS

The findings have several implications for sustainable urban planning in Jos Metropolis.

6.1 Development of a Vacant-Land Inventory

The study demonstrates the usefulness of remote sensing and GIS for establishing a spatial database of vacant lands. A regularly updated vacant-land inventory would allow planning agencies to monitor changes in vacant parcels.

6.2 Strategic Infill Development

The decline in vacant land alongside substantial built-up growth suggests increasing pressure for urban expansion. Planning authorities should therefore encourage appropriate infill development where vacant land is physically suitable and adequately serviced.

6.3 Protection of Environmentally Constrained Areas

Not all vacant lands should be targeted for development. Areas affected by steep slopes, erosion and other environmental constraints should be assessed carefully before development approval.

6.4 Integration of Remote Sensing into Urban Planning

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The 30-year analysis demonstrates that satellite imagery can provide an effective basis for monitoring urban land transformation. The research used Landsat imagery at 30-m resolution, GIS classification and field validation to establish temporal changes.

6.5 Regular Monitoring

Given the dynamic nature of vacant land, periodic monitoring should be incorporated into metropolitan planning systems. A five-year or annual monitoring framework using current satellite imagery could provide planners with timely information about emerging vacant areas and land conversion.

7. CONCLUSION

This study assessed the Spatio-temporal coverage of urban vacant lands in Jos Metropolis, Nigeria, using multi-temporal Landsat imagery and GIS. The results demonstrate substantial changes in the spatial coverage of vacant land between 1994 and 2024.

Vacant land increased markedly from 8,406.9 ha (10.3%) in 1994 to 22,795.2 ha (27.9%) in 2004, before declining to 19,231.02 ha (23.6%) in 2014 and 11,694.51 ha (14.3%) in 2024.

At the same time, built-up land expanded from 2,384.91 ha in 1994 to 11,083.23 ha in 2024, representing approximately 365% growth.

The spatial analysis revealed significant clustering of vacant lands, with Moran's $I = 0.42$ ($p < 0.01$). Vacant lands were particularly associated with peri-urban areas, hilly terrain, higher elevations and locations affected by physical development constraints.

The study concludes that urban vacant land in Jos Metropolis is a dynamic spatial phenomenon influenced by urban expansion and physical characteristics. Consequently, effective management requires continuous GIS-based monitoring, appropriate land-use classification, strategic infill development and protection of environmentally constrained areas.

8. RECOMMENDATIONS

Based on the findings, the study recommends that:

i. Jos Metropolitan planning authorities should establish a digital vacant-land inventory based on GIS and remote sensing.
ii. Multi-temporal satellite imagery should be used periodically to monitor changes in vacant-land distribution.
iii. Vacant parcels suitable for development should be prioritized for strategic infill development rather than indiscriminate outward urban expansion.
iv. Steep slopes and environmentally sensitive vacant areas should be protected through appropriate zoning and development controls.
v. Vacant-land information should be integrated into metropolitan master plans and development-control systems.
vi. Ground-truthing and field verification should remain an important component of remote-sensing-based vacant-land mapping.
vii. Future studies should incorporate higher-resolution satellite imagery and parcel-level cadastral information to improve the identification and management of small vacant parcels.

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