Land Use and Land Cover Changes of Quarry Locations within the Greater Jos, Plateau State, Nigeria

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ABSTRACT

This study examined the spatial distribution of quarry locations and the associated land use and land cover (LULC) changes within the Greater Jos area of Plateau State, Nigeria. The study was motivated by the rapid expansion of quarry since the 1990s, driven by the region's abundant Precambrian granitic deposits, which has altered land use patterns in ways that remain inadequately documented. The study sought to identify and map quarry locations, and to analyse changes in LULC patterns and vegetation cover over a thirty-year period (1994-2024). An integrated geospatial approach involving GPS field survey, Landsat image classification, and NDVI difference analysis was adopted. The findings revealed that quarry sites are spatially clustered around geologically favourable areas with granitic outcrops, particularly along the Jenta-Lamingo and Vom-Shen axes. The LULC analysis showed substantial landscape transformation over the study period, marked by a fourfold expansion of built-up areas (306.29%), a 35.25% net increase in bare land, a 23.52% net decline in farmland, and a 26% reduction in maximum vegetation vigour Normalized Difference Vegetation Index (NDVI). These changes were most pronounced in the immediate vicinity of active quarry locations, providing quantitative evidence that quarry, in combination with urban growth, is a major driver of land use and land cover change in the Greater Jos area. The study recommends the institutionalisation of GIS and remote sensing technologies for continuous LULC monitoring around quarry sites, stricter land-use regulation to protect farmland and vegetation from uncontrolled quarry expansion, and mandatory rehabilitation of bare and degraded surfaces created by quarry operations.

Keywords: Quarry, Land Use and Land Cover Change, Quarry, Remote Sensing and GIS, NDVI.

INTRODUCTION

Land use and land cover (LULC) change is one of the most visible indicators of environmental transformation globally, reflecting the continuous interaction between human activities and natural landscapes (Li, Zhou and Gong, 2022). Extractive activities such as quarrying and mining have been identified as major anthropogenic drivers of LULC change, converting vegetated and agricultural land into bare surfaces and built-up infrastructure (FAO, 2020). The extraction of mineral resources, particularly through open-pit mining and quarrying, often leaves behind large scars on the landscape and alters the vegetation and land cover composition of surrounding areas.

In Nigeria, quarry plays a vital role in the economy by supplying raw materials for the construction industry; however, it also drives significant land use change (Eze, 2020). The country's rapid urban expansion, particularly in cities like Lagos, Abuja, and Jos, has intensified the demand for granite and other aggregates, leading to the establishment of numerous quarry sites across the nation, often with little regard for land use planning or post-quarry land restoration (Ibrahim and Musa, 2021).

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The Plateau region, especially Greater Jos, is one of Nigeria's most prominent quarry zones due to its rich deposits of granite and other solid minerals (Danjuma and Gukas, 2021). Quarry operations in this area have intensified over the decades to meet growing construction needs, and this expansion has coincided with the loss of fertile agricultural land, destruction of vegetation cover, and expansion of bare and built-up surfaces (Maimako and Gwom, 2022). Despite the scale of this transformation, the specific land use and land cover changes associated with quarry locations in the study area have not been adequately mapped or documented (Pam and Nanle, 2023).

This paper is therefore directed at filling this empirical gap by pursuing three specific objectives: (i) to identify and map the spatial distribution of quarry locations within the Greater Jos area; (ii) to analyse changes in land use and land cover (LULC) patterns from 1994 to 2024 in the study area; and (iii) to evaluate the vegetation cover change (NDVI) associated with quarry expansion. Together, these objectives generate a geospatial evidence base that can guide land use planners and quarry operators toward more sustainable land management practices in Plateau State and comparable Nigerian contexts.

Study Area

Jos, the capital city of Plateau State in central Nigeria, is strategically located on the Jos Plateau, approximately between longitude 8º 50′ E to 9º 00′ E and latitude 9º 55′ N to 10º 5′ N, at an elevation of about 1,200 metres above sea level. This elevated position gives the city a relatively temperate climate compared to most other Nigerian cities and contributes to its fertile volcanic soils, which support agriculture. The Greater Jos is administratively divided into Jos North and Jos South Local Government Areas (LGAs). The study area covers a land area of approximately 3,564 km^2 encompassing these two LGAs, delineated as the Region of Interest (ROI) within the coordinates of longitude 8º 42′ E to 9º 00′ E and latitude 9º 42′ N to 10º 01′ N.

Jos Plateau is geologically significant, underlain predominantly by basement complex rocks of Precambrian origin, including granites, gneisses, and schists, with pockets of volcanic and sedimentary formations. These geological attributes make the Greater Jos area particularly attractive to quarry operators, and consequently susceptible to quarry-induced land use and land cover change. The climate features two main seasons: a wet season from April to October and a dry season from November to March. The population of the Greater Jos metropolitan area was estimated at approximately 970,000 in 2023, representing a 2.97% increase from the previous year (NPC, 2023). Agriculture, informal trade, and quarry-related activities constitute major livelihood sources for the diverse ethnic groups inhabiting the area.

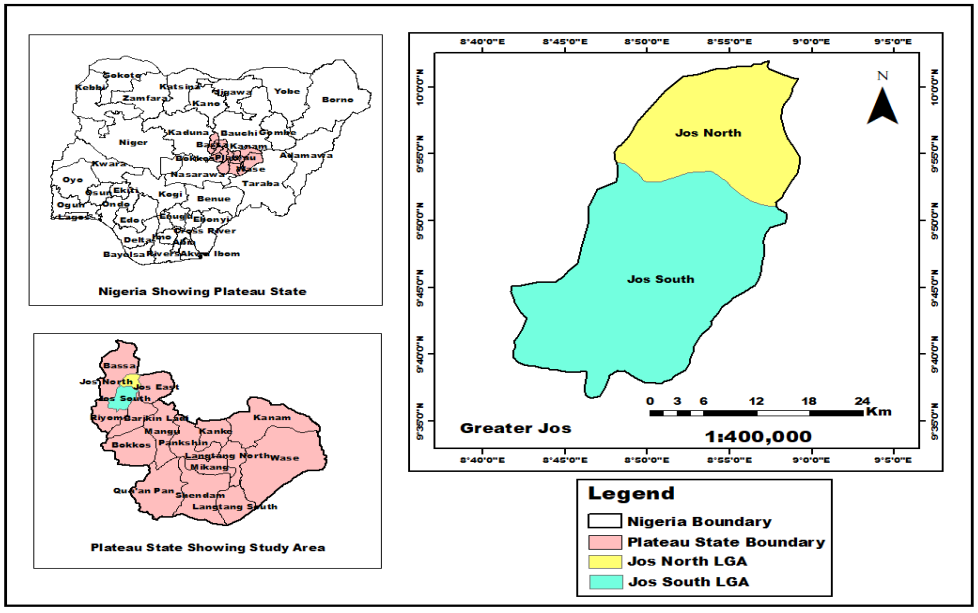

Figure 1: The Study Area Location (Greater Jos, Plateau State, Nigeria)

Source: Plateau State Ministry of Lands and Survey, Author's Compilation 2025

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Theoretical Framework

This paper is grounded in two interconnected theoretical frameworks that together provide a lens for interpreting the relationship between quarry location and land use and land cover change.

Environmental Determinism Theory, associated with Ratzel (1897) and Semple (1911), posits that physical environmental factors such as landforms and natural resources are primary determinants of human economic activity. In the context of the Greater Jos area, this framework helps explain how the region's rich granitic geologic formation has historically attracted and concentrated quarry operations, providing a basis for understanding why quarry-related LULC change is spatially concentrated in geologically favourable zones.

Human-Environment Interaction Theory, developed through the contributions of Sauer (1925), Steward (1955), and Vidal de la Blache (1926), emphasises the reciprocal modification of environment by human agency and vice versa. This theory captures the feedback dynamic between quarry and land cover change: quarrying reshapes vegetation, soil exposure, and built-up expansion, which in turn alter agricultural viability and the ecological character of the surrounding landscape (Turner et al., 1990).

METHODOLOGY

Research Design

The study on quarry locations and land use and land cover change in the Greater Jos adopted a research design combining quantitative and descriptive approaches. The quantitative component involved the systematic acquisition and processing of Landsat imageries for LULC classification and NDVI difference analysis over thirty years at ten-year intervals (1994-2024). A descriptive approach was used to characterise the spatial distribution of quarry locations through field GPS survey and geospatial data analysis, supported by Average Nearest Neighbour (ANN) statistics computed in QGIS software (Shelbut, 2025).

Spatial Distribution Mapping

A hand-held Global Positioning System (GPS) was used to collect coordinate points of quarry locations during field surveys. The GPS coordinates were imported into GIS software to generate a point layer representing specific quarry locations and to produce a quarry site location map of the Greater Jos area. Average Nearest Neighbour (ANN) analysis was subsequently performed in QGIS to statistically characterise the spatial distribution pattern of the identified quarry sites.

LULC Change Analysis

High-resolution Landsat imageries for four different years (1994 Landsat 5, 2004 Landsat 7 ETM+, 2014 Landsat 8 OLI, and 2024 Landsat 8 OLI) were acquired from the United States Geological Survey (USGS) Earth Explorer portal. Images underwent preprocessing for geometric and radiometric correction. Supervised classification using the Maximum Likelihood method was applied to derive six LULC classes: Farm Land, Rock Outcrop, Bare Land, Vegetation, Built Up Area, and Water Body. Classification accuracy was validated through confusion matrices, achieving an average Kappa coefficient of 0.994 and an overall accuracy of 99.5% (Shelbut, 2025). NDVI difference maps were generated by subtracting the 1994 NDVI from the 2024 NDVI, calculated using the formula NDVI = (NIR minus RED) / (NIR + RED), where NIR is surface reflectance in the near-infrared band and RED is surface reflectance in the red band.

Table 1: Data Types and Sources Used for the Study

Data	Name	Date	Format	Source	Resolution
LULC	Landsat Imageries	1994/2004/2014/2024	GeoTIFF	usgs.gov	30 m

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Geology	Geological Map	1965	JPG	Nigeria Geological Survey Agency	1:250,000
Field Data	GPS Coordinates	2025	Text	Field Survey	Lat/Long

Source: Author's Computation, 2025

RESULTS AND DISCUSSION

Spatial Distribution of Quarry Locations within the Greater Jos Area

The field GPS survey identified ten quarry sites distributed across Jos North and Jos South LGAs of the Greater Jos area. Figure 2 presents the exact coordinates of the ten mapped quarry sites, which provide important insight into their locational tendencies.

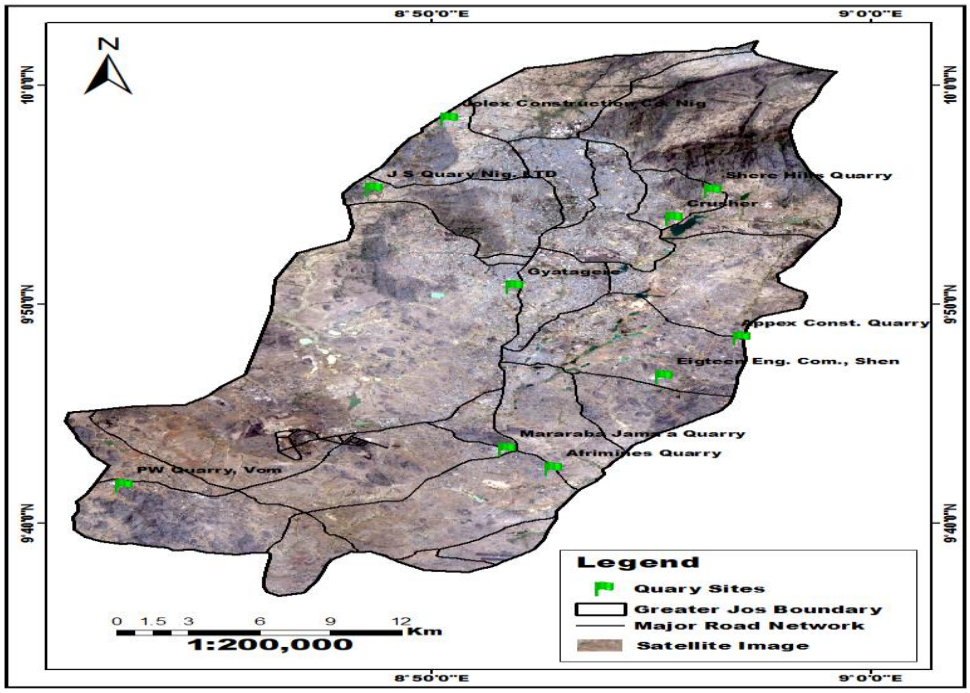

Figure 2: Spatial Distribution of Quarry Sites within the Greater Jos Area

Source: Author's Computation, 2025

The spatial distribution of quarry sites in the Greater Jos, as shown in Figure 2, reveals a clear pattern of clustering around areas characterised by extensive basement complex rocks and granitic outcrops. For example, Jolex Construction Co. Nigeria, Zaria Road at longitude 8.838314 and latitude 9.975421, and J S Quarry Nigeria Ltd. Agingi at longitude 8.809936 and latitude 9.921877, are both situated toward the northern section of the study area, forming a noticeable concentration of quarry around the Jenta-Lamingo axis. In the southern section, quarries such as PW Quarry Vom, Afrimines Quarry Bisichi junction, and Mararaba Jama'a Quarry are positioned along the Vom-Shen axis where bedrock exposures are more prominent, thereby reducing extraction costs.

Statistical Validation of Spatial Distribution

The results from the Average Nearest Neighbour (ANN) analysis presented in Table 2 further support the observed spatial clustering pattern. The ANN ratio of 1.458808, accompanied by a significant z-score of 2.775632 and a p-value of 0.005509, provides statistical confirmation that the quarry sites are not randomly distributed but exhibit a clustered spatial pattern, reflecting underlying geological controls and infrastructural factors such as road accessibility.

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Table 2: Average Nearest Neighbour Summary Statistics

Parameter	**Value**
Observed Mean Distance (m)	5,823.6464
Expected Mean Distance (m)	3,992.0579
Nearest Neighbour Ratio	1.458808
Z-score	2.775632
P-value	0.005509
Interpretation	Clustered (significant at 99% CI)

Source: Author's Computation, 2025

The spatial distribution additionally highlights land use planning concerns. The proximity of several quarries to residential neighbourhoods in Shen, Vom, and Lamingo suggests that land use conflicts may intensify as extraction activities expand. Quarry sites located near settlements, such as PW Quarry Vom, Eighteen Engineering Company Shen, and J S Quarry Agingi, fall within zones that experience rapid built-up expansion.

Changes in Land Use and Land Cover (LULC) Patterns over Time

The temporal analysis of LULC classification from 1994 to 2024 reveals dynamic landscape transformations driven by quarry, socio-economic, and demographic factors. Multi-temporal Landsat imageries at four epochs (1994, 2004, 2014, and 2024) were classified into six LULC categories: Farm Land, Rock Outcrop, Bare Land, Vegetation, Built Up Area, and Water Body. The analysis achieved an average Kappa coefficient of 0.994 and an overall accuracy of 99.5%, confirming the reliability of the classification (Shelbut, 2025).

1994 LULC Classification

The 1994 LULC classification reveals a landscape predominantly characterised by agricultural activities and natural features. Farm Land constituted the dominant land use category, occupying 408.20 km^2, reflecting the region's strong agrarian economy during the mid-1990s. Rock Outcrop emerged as the second most prominent feature, covering 245.28 km^2, characteristic of the Jos Plateau's geological composition. Vegetation accounted for 124.30 km^2. Built-up areas occupied only 23.53 km^2, indicating limited urban expansion during this period. Bare Land occupied 21.16 km^2, likely associated with early-stage Dquarrying or fallow agricultural fields. Water Bodies represented the smallest land cover category at 7.15 km^2.

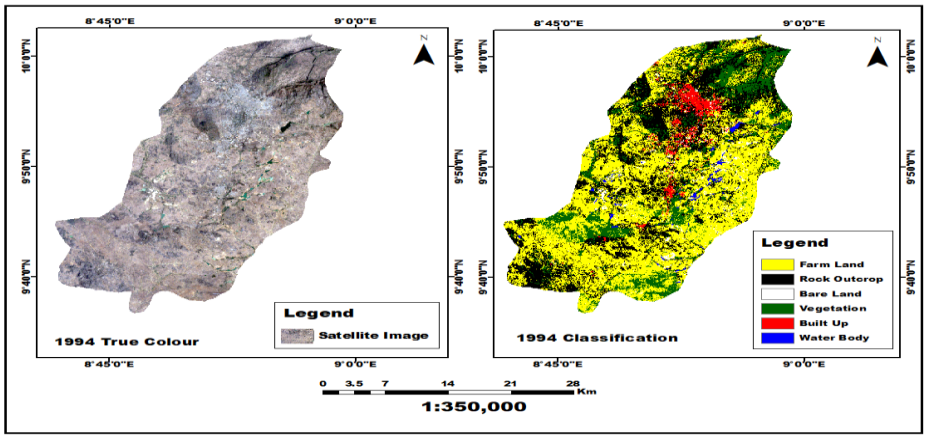

Figure 3: 1994 LULC Classification Map of the Greater Jos Area

Source: Author's Computation, 2025

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2024 LULC Classification

The 2024 LULC classification presents the contemporary land use configuration of the Greater Jos region. Farm Land showed recovery to 312.21 km^2 compared to the 2014 trough of 287.18 km^2, though this represents a net decline of 23.52% from the 1994 baseline. Rock Outcrop remained relatively stable at 222.28 km^2. Most notably, Built Up areas experienced dramatic growth to 95.58 km^2, representing a fourfold increase since 1994, consistent with rapid urbanisation. Bare Land declined to 28.62 km^2, its lowest extent across all study periods. Vegetation declined from its 2014 peak to 165.00 km^2, a loss of 53.33 km^2 over a decade. Water Bodies declined to their lowest extent at 5.92 km^2, raising concerns about water resource sustainability.

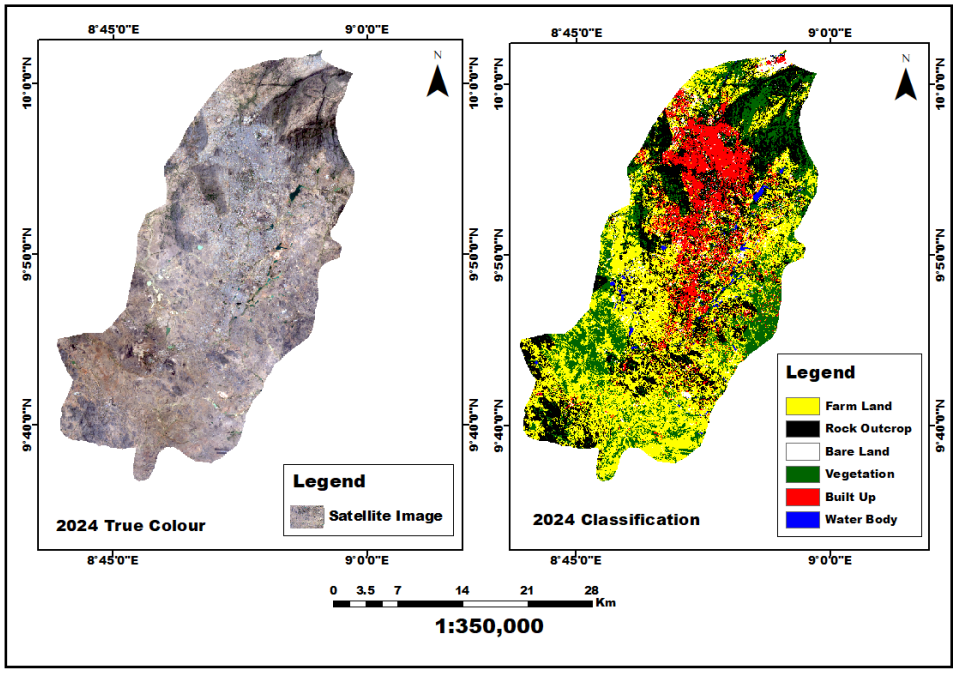

Figure 4: 2024 LULC Classification Map of the Greater Jos Area

Source: Author's Computation, 2025

Comprehensive LULC Change Analysis (1994-2024)

Table 3 presents the LULC area statistics across all four temporal epochs, while Table 4 presents the corresponding percentage changes. These data enable systematic comparison of land use trajectories over the full thirty-year study period.

Table 3: LULC Area Statistics for the Greater Jos Area (1994-2024)

Class Name	1994 (km^2)	2004 (km^2)	2014 (km^2)	2024 (km^2)
Farm Land	408.20	477.34	287.18	312.21
Rock Outcrop	245.28	150.82	225.62	222.28
Bare Land	21.16	68.91	35.09	28.62
Vegetation	124.30	88.50	218.33	165.00
Built Up	23.53	35.45	56.47	95.58
Water Body	7.15	8.03	6.93	5.92

Source: Author's Computation, 2025

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The percentage change analysis reveals several critical patterns. Farm Land exhibited the most volatile trajectory, increasing by 16.93% between 1994 and 2004, followed by a dramatic 39.84% decline by 2014, before recovering modestly with an 8.71% increase by 2024. The overall net decline of 23.52% over the three-decade period indicates significant contraction of agricultural land, potentially driven by urbanisation pressures and quarry expansion (Foley et al., 2005). Rock Outcrop experienced a substantial 38.51% decrease between 1994 and 2004, likely attributable to intensive quarry operations, with subsequent partial recovery suggesting either reduced extraction activity or improved classification accuracy.

Table 4: Percentage Change in LULC Classes (1994-2024)

Class Name	**1994-2004 (%)**	**2004-2014 (%)**	**2014-2024 (%)**	**Overall (%)**
Farm Land	+16.93	-39.84	+8.71	-23.52
Rock Outcrop	-38.51	+49.62	-1.48	-9.37
Bare Land	+225.66	-49.08	-18.43	+35.25
Vegetation	-28.80	+146.72	-24.42	+32.75
Built Up	+50.66	+59.30	+69.25	+306.29
Water Body	+12.31	-13.70	-14.58	-17.20

Source: Author's Computation, 2025

The most alarming single-period change was the 225.66% expansion in Bare Land between 1994 and 2004, rising from 21.16 km^2 to 68.91 km^2. This explosion in exposed surfaces directly coincides with the documented intensification of quarrying on the Jos Plateau during that decade. Subsequent declines in Bare Land to 35.09 km^2 in 2014 and 28.62 km^2 in 2024 may reflect partial natural regeneration, though the net 35.25% increase over the full study period confirms persistent land cover disturbance. The most consistent and dramatic trend is observed in Built Up areas, which exhibited continuous growth across all periods at 50.66%, 59.30%, and 69.25% respectively, producing a cumulative increase of 306.29%. Water Bodies experienced a consistent declining trend, reaching their lowest extent of 5.92 km^2, a total reduction of 17.20%, raising concerns about hydrological change in quarry-affected catchments.

Normalized Difference Vegetation Index (NDVI) Difference Analysis

The 1994 NDVI baseline for the Greater Jos area recorded values ranging from a maximum of 0.53 to a minimum of -0.54, reflecting a diverse landscape mosaic of intact vegetation, farmland, and scattered bare surfaces. By 2024, the NDVI range had contracted to 0.39 to -0.25, with the maximum value declining by 26% from 0.53 to 0.39. This substantial reduction in peak vegetation vigour signals widespread deterioration of vegetation cover across the landscape, extending beyond the immediate quarry boundaries to affect surrounding land cover.

The NDVI difference map (2024 minus 1994) revealed extensive areas of negative vegetation change concentrated in proximity to major quarry sites including Jolex Construction Co. Nigeria Zaria Road, J S Quarry Nigeria Ltd Agingi, Shere Hills Quarry Lamingo, PW Quarry Vom, and Afrimines Quarry Bisichi Junction. These zones of maximum vegetation loss exhibited NDVI values approaching zero or negative, indicating removal of photosynthetic cover and replacement by exposed rock faces, processing facilities, and stockpiles. The spatial correlation between low NDVI areas and documented quarry locations provides direct quantitative evidence of the contribution of quarry to vegetation cover loss in the Greater Jos area, consistent with findings by O'Donnell (2024) and Romańczukiewicz, Nowak and Wojcik (2025) in comparable sub-Saharan contexts.

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Table 5: NDVI Summary Statistics for the Greater Jos Area

Year	Maximum NDVI	Minimum NDVI	Change in Max NDVI (%)
1994 (Baseline)	0.53	-0.54	N/A
2024 (Current)	0.39	-0.25	-26.42%

Source: Author's Computation, 2025

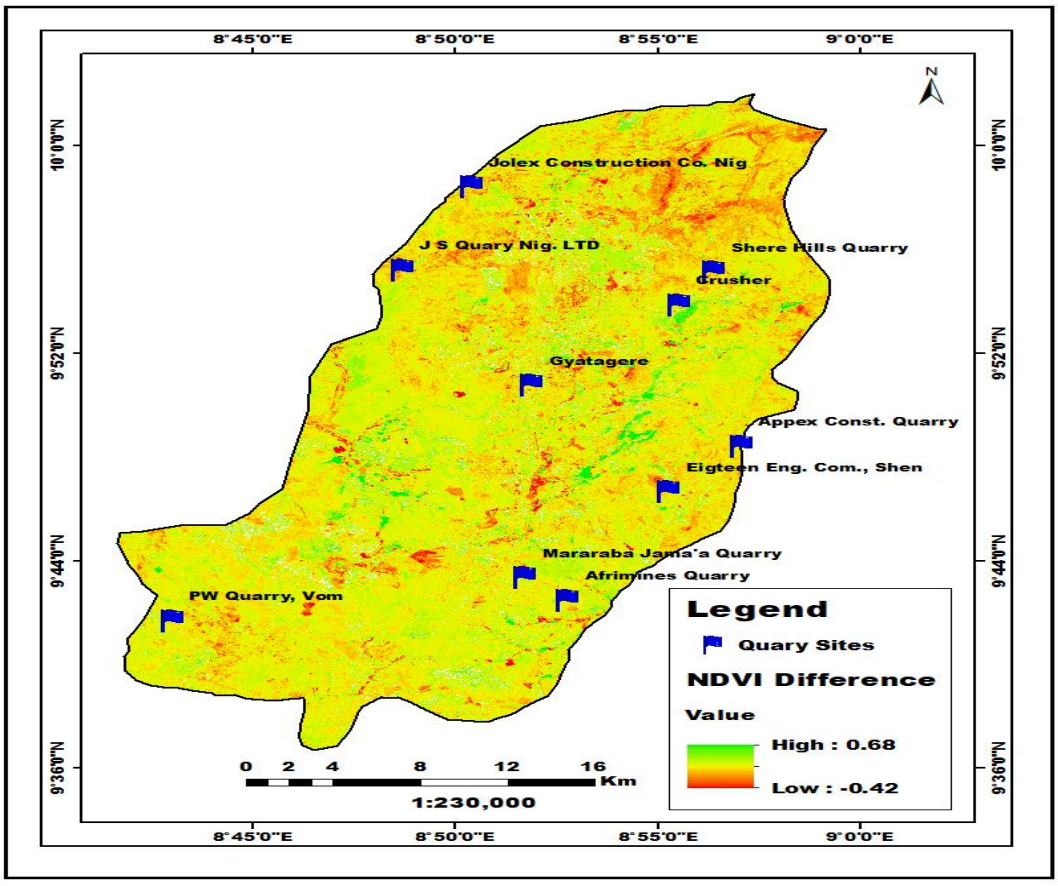

Figure 5: NDVI Difference Map of the Greater Jos Area (2024-1994) Showing Areas of Vegetation Change

Source: Author's Computation, 2025

DISCUSSION

The findings of this study provide compelling evidence that quarry location is a major driver of land use and land cover change in the Greater Jos area. The spatial distribution of quarry sites reveals that operators preferentially locate their activities in areas with favourable geological formations, particularly where basement complex granites are abundant. This clustering has concentrated land cover disturbance within relatively limited portions of the landscape, intensifying cumulative impacts on surrounding vegetation and farmland. This finding agrees with the observations of Carabia-Sanz et al. (2024) and Okafor and Anselm (2020), who reported that quarry activities are largely controlled by geological characteristics and tend to produce concentrated land cover pressures in resource-rich regions.

The land use and land cover analysis demonstrates that quarrying, combined with rapid urban expansion, has significantly altered the landscape of the Greater Jos area over the past three decades. The continuous conversion of agricultural land and natural vegetation into built-up areas and exposed bare surfaces reflects increasing demand for construction materials associated with urban growth. Similar observations have been reported by

Adedeji, Tope-Ajayi and Olusola (2020), who found that unregulated quarry expansion in southwestern Nigeria resulted in extensive land cover modification and reduced agricultural productivity. The corresponding decline in NDVI values around active quarry locations further reinforces the conclusion that quarrying is a dominant factor shaping vegetation cover change within the study area, consistent with sub-Saharan comparisons by O'Donnell (2024).

The persistence of these LULC changes also points to gaps in land use monitoring and regulatory enforcement. Although Nigeria has established institutional frameworks for environmental oversight of the quarry sector, the continued expansion of bare land and built-up surfaces around quarry sites suggests that monitoring of quarry-induced land use change remains inadequate (Nigerian Mining and Geosciences Society, 2022; Pam and Nanle, 2023). Strengthening geospatial monitoring of LULC around quarry locations therefore remains essential for balancing the economic benefits of quarry with the protection of agricultural land and vegetation cover.

CONCLUSION

This study has established that quarry locations are a major driver of land use and land cover change in the Greater Jos area of Plateau State, with quarry sites clustered around geologically favourable granitic zones along the Jenta-Lamingo and Vom-Shen axes. Over the thirty-year study period, the study area experienced a fourfold expansion of built-up land, a net increase in bare surfaces, a net decline in farmland, and a marked decline in vegetation vigour as measured by NDVI, with the most pronounced changes concentrated around active quarry locations. The study demonstrates the value of geospatial technologies, particularly Landsat-based classification and NDVI difference analysis, as effective tools for mapping and monitoring quarry-related land use and land cover change. Beyond providing an empirical account of LULC dynamics in the Greater Jos area, the methodological approach developed in this study offers a practical and replicable framework for monitoring land use change around quarry locations in other parts of Nigeria.

RECOMMENDATIONS

In line with the findings of the study, the following are recommended:

i. The Government and relevant stakeholders should institutionalise GIS and remote sensing technologies for continuous monitoring of land use and land cover change around quarry locations in the Greater Jos area.

ii. Land use planning authorities should enforce stricter zoning regulations to restrict quarry expansion into farmland and vegetated areas, thereby limiting further conversion of productive land to bare land and built-up surfaces.

iii. Quarry operators should be mandated to undertake rehabilitation and revegetation of bare and disturbed land identified through LULC monitoring, as part of quarry licensing requirements.

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