Land Degradation Induced by Quarry in the Greater Jos, Plateau State, Nigeria

Shelbut, Nandir Elaine[1], Samaila, I. K.[2], Mahmud, A.[2], Ponsak Emmanuel[3] and Albert Wash[4]

[1]Department of Geography, Faculty of Environmental Sciences, Nasarawa State University, Keffi, and Geosciences Department, National Centre for Remote Sensing, Jos, Nigeria.

[2]Department of Geography, Faculty of Environmental Sciences, Nasarawa State University, Keffi, Nigeria.

[3] Zonal Advance Space Technology Application Laboratory Langtang, NCRS Jos, Plateau state, Nigeria

[4]National Centre for remote Sensing Jos, Plateau State, Nigeria

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ABSTRACT

This paper assesses quarry induced land degradation in the Greater Jos area of Plateau State, Nigeria, using an integrated geospatial framework that brings vegetation condition, terrain modification and soil erosion risk into a single analysis. Landsat imagery was used to derive Normalized Difference Vegetation Index (NDVI) conditions for 1994 and 2024, ASTER Digital Elevation Model (DEM) data supported elevation change analysis, Sentinel 1 Synthetic Aperture Radar supported land subsidence assessment, and the Revised Universal Soil Loss Equation (RUSLE) was applied using soil erodibility, rainfall erosivity and slope related factors. The resulting layers were standardized and integrated through a weighted overlay model. The DEM difference ranged from -22.2548m to +95.9155 m, showing substantial excavation and deposition around quarry zones. Maximum NDVI declined from 0.53 in 1994 to 0.39 in 2024, a reduction of about 26 percent in peak vegetation vigour. The LULC analysis further revealed notable changes in land-cover patterns between 1994 and 2024, providing important land-use context for interpreting quarry-induced vegetation loss and the spatial pattern of degradation. Land subsidence ranged from minus 0.42m to plus 0.04 m. RUSLE estimated soil loss from 918.63 to 1,214.42 t ha^{-1} yr^{-1}, with the highest erosion risk concentrated in the southern and southwestern quarry corridor. The composite map shows moderate to very high degradation clustering around intensive quarry operations, particularly the Vom, Shen and Mararaba Jama'a axis. The convergence of NDVI decline, DEM alteration, subsidence and RUSLE erosion risk demonstrates that quarry induced degradation is a multi-process landscape problem rather than a single indicator phenomenon. The study recommends routine geospatial monitoring, enforced rehabilitation, erosion control and stronger environmental compliance around active and abandoned quarry sites.

Keywords: Quarry; Land Degradation; Vegetation Loss; Soil Erosion and Land Subsidence.

INTRODUCTION

Land degradation is the decline in the productive and ecological capacity of land through natural processes and human activities. Quarry is a particularly intensive driver because extraction begins with vegetation clearing and topsoil removal, continues through drilling, blasting and excavation, and often leaves exposed surfaces, pits, spoil materials and altered drainage. These changes can accelerate erosion, reduce vegetation health and permanently modify terrain. In Nigeria, the growing demand for construction aggregates has increased quarry activity, while environmental management and post extraction rehabilitation remain uneven (Eze, 2020; Ibrahim & Musa, 2021).

Greater Jos is an important quarry zone because of its extensive granitic and basement complex formations. Quarry expansion has been associated with vegetation removal, loss of productive land, abandoned pits,

erosion and visible alteration of the plateau landscape (Danjuma & Gukas, 2021; Maimako & Gwom, 2022). Earlier work has established the usefulness of remote sensing for detecting land cover transitions around extractive sites (O'Donnell, 2024; Romańczukiewicz et al., 2025), but a more convincing assessment requires vegetation, topography and erosion to be interpreted together. A single indicator can misrepresent degradation because vegetation may recover on some abandoned surfaces while erosion or terrain instability remains severe.

The central purpose of this paper is therefore to quantify quarry induced land degradation through three complementary environmental dimensions: vegetation change using NDVI, topographic change using DEM difference and land subsidence, and soil erosion risk using RUSLE. The individual outputs are then integrated in a weighted overlay to show the spatial extent and severity of cumulative degradation. This integrated emphasis is important for identifying priority areas for regulation, rehabilitation and continued monitoring.

Study Area

The study covers the Greater Jos area of Plateau State, central Nigeria, principally Jos North and Jos South Local Government Areas. The area lies on the Jos Plateau at an elevation of roughly 1,200m above sea level and contains extensive Precambrian basement complex rocks, including granites, gneisses and schists. The geology has encouraged the development of numerous quarry operations. The climate has a wet season that generally extends from April to October and a dry season from November to March. Agriculture, trade, construction and quarry related activities form important components of local livelihoods.

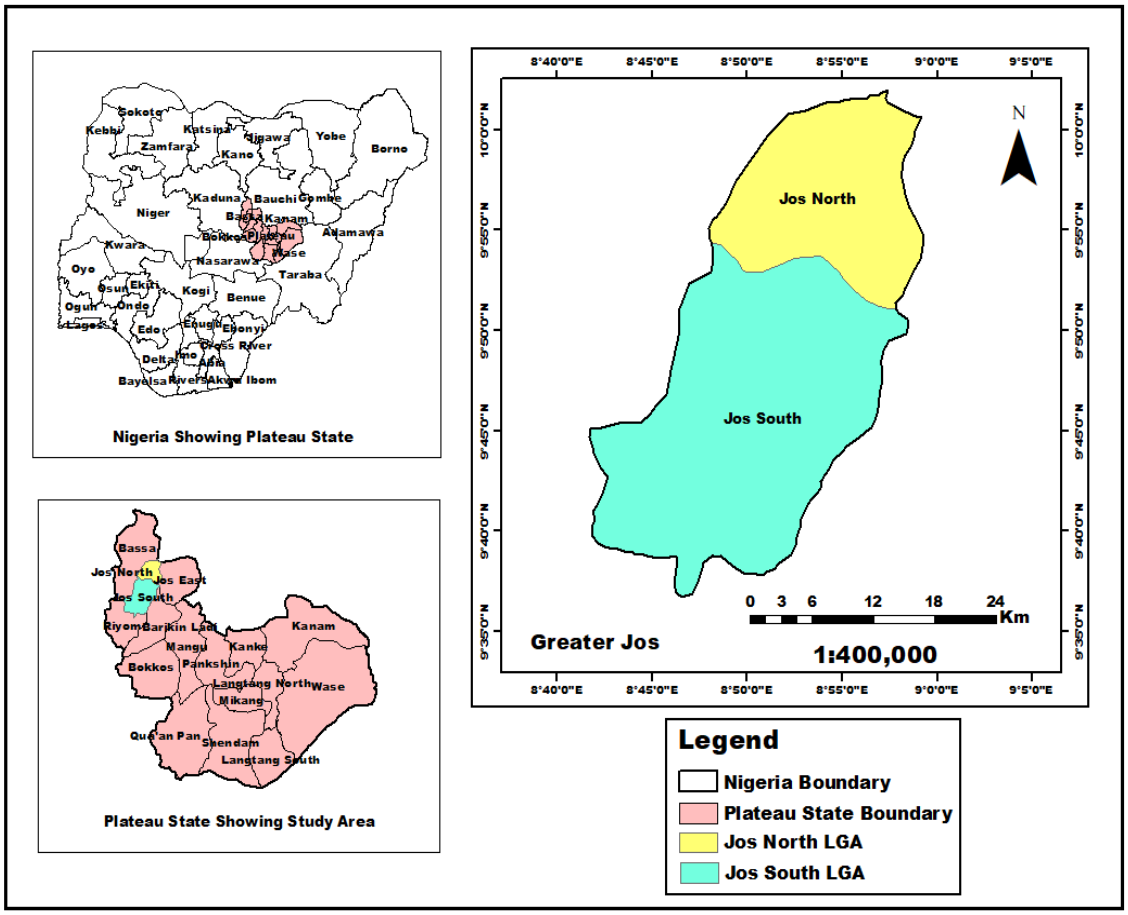


Figure 1. Location of the study area within Plateau State and Nigeria

Source: Author's computation, 2025

MATERIALS AND METHODS

Data and geospatial processing

The study used Landsat imagery, ASTER DEM, Sentinel 1 SAR, FAO soil data, MODIS rainfall data and field

GPS coordinates. Landsat scenes for 1994, 2004, 2014 and 2024 were processed at 30m resolution. The classified imagery achieved an average kappa coefficient of 0.994 and an overall accuracy of 99.5%. For the degradation analysis reported in this paper, the 1994 and 2024 endpoints were emphasized to provide a thirty years comparison. ASTER DEM at 30m resolution was used for terrain and DEM difference analysis, while Sentinel 1 SAR at 10m resolution supported land subsidence assessment. Soil data were used to generate the RUSLE soil erodibility factor and rainfall data were used to derive rainfall erosivity.

Dataset	Purpose	Resolution / period
Landsat imagery	NDVI and LULC change	30m; 1994 to 2024
ASTER DEM	Elevation difference, slope and terrain	30m
Sentinel 1 SAR	Land subsidence	10m
FAO soil data	Soil erodibility, K factor	Soil thematic data
MODIS rainfall	Rainfall erosivity, R factor	4 km
Field GPS	Quarry location validation	2025 field survey

Table 1. Principal datasets used in the integrated degradation assessment

NDVI analysis

NDVI was calculated from near infrared and red surface reflectance as NDVI = (NIR − RED) / (NIR + RED). The 1994 image represented the baseline condition and the 2024 image represented the current condition. NDVI difference was calculated as NDVI 2024 minus NDVI 1994. Negative change indicates a reduction in photosynthetic vegetation, while positive change indicates improvement. The difference surface was interpreted together with mapped quarry locations to identify areas where vegetation decline coincided with extraction activity.

DEM difference and land subsidence

ASTER elevation surfaces were processed to derive terrain characteristics and a DEM difference layer representing elevation change between the study endpoints. Negative values were interpreted primarily as terrain lowering or material removal, while positive values represented elevation gain that can include spoil deposition and other surface changes. Sentinel 1 SAR was processed for land subsidence to provide an independent measure of terrain stability. The two outputs were compared spatially with the ten identified quarry sites.

RUSLE soil erosion model

Potential soil loss was estimated using the Revised Universal Soil Loss Equation, $A = R \times K \times LS \times C \times P$, where A is annual soil loss, R is rainfall erosivity, K is soil erodibility, LS represents slope length and steepness, C is cover management and P is support practice. Quarry disturbance influences several of these components by removing vegetation, exposing soil and rock, steepening local slopes and redirecting runoff. RUSLE therefore provides an erosion risk surface that complements NDVI and DEM evidence.

Integrated weighted overlay

The NDVI difference, RUSLE erosion risk, DEM difference, land subsidence and reclassified LULC layers were standardized to a common scale and combined using a weighted overlay. The composite index followed $LD = \Sigma(Wi \times Xi)$, where LD is the land degradation index, Wi is the assigned weight and Xi is the normalized value of each environmental criterion. NDVI difference and RUSLE were assigned 30%, DEM difference 20%, land subsidence 15% and LULC 5%. The weighting gives greatest emphasis to direct evidence of vegetation loss and soil erosion while retaining terrain modification and land use context.

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RESULTS

Spatial distribution of quarry sites

Ten operational and non-operational quarry sites were identified across Jos North and Jos South. Their distribution reflects the availability of granitic outcrops and access corridors. The mapped pattern places several intensive operations in the southern and southwestern part of Greater Jos, including PW Quarry at Vom, Afrimines Quarry and Mararaba Jama'a Quarry, while Jolex Construction Company, J S Quarry and Shere Hills Quarry occur farther north. This spatial framework is important because the degradation indicators can be compared directly with known extraction locations.

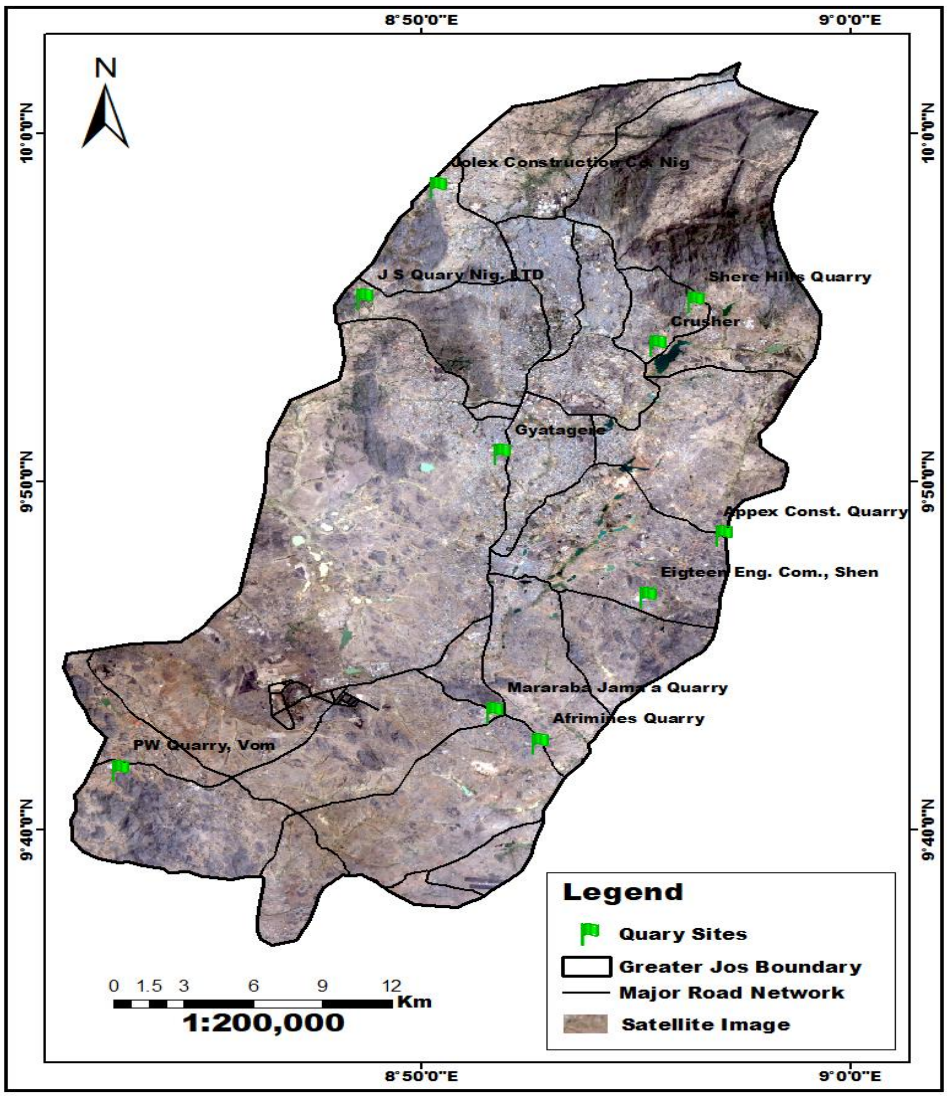


Figure 2. Spatial distribution of quarry sites in the Greater Jos area

Source: Author's computation, 2025

DEM difference and terrain modification

The DEM difference analysis shows pronounced topographic change between 1994 and 2024. Elevation differences range from -22.2548m to +95.9155m. Negative values identify areas where the surface has been lowered, consistent with excavation and removal of rock materials. Positive values identify elevation gains that can reflect overburden and waste deposition as well as other terrain changes. The strongest changes occur around major quarry locations, indicating that quarry has substantially modified local relief rather than simply changing surface cover. The result is particularly important in a plateau environment because newly created faces, benches and spoil surfaces can alter runoff pathways and increase erosion susceptibility.

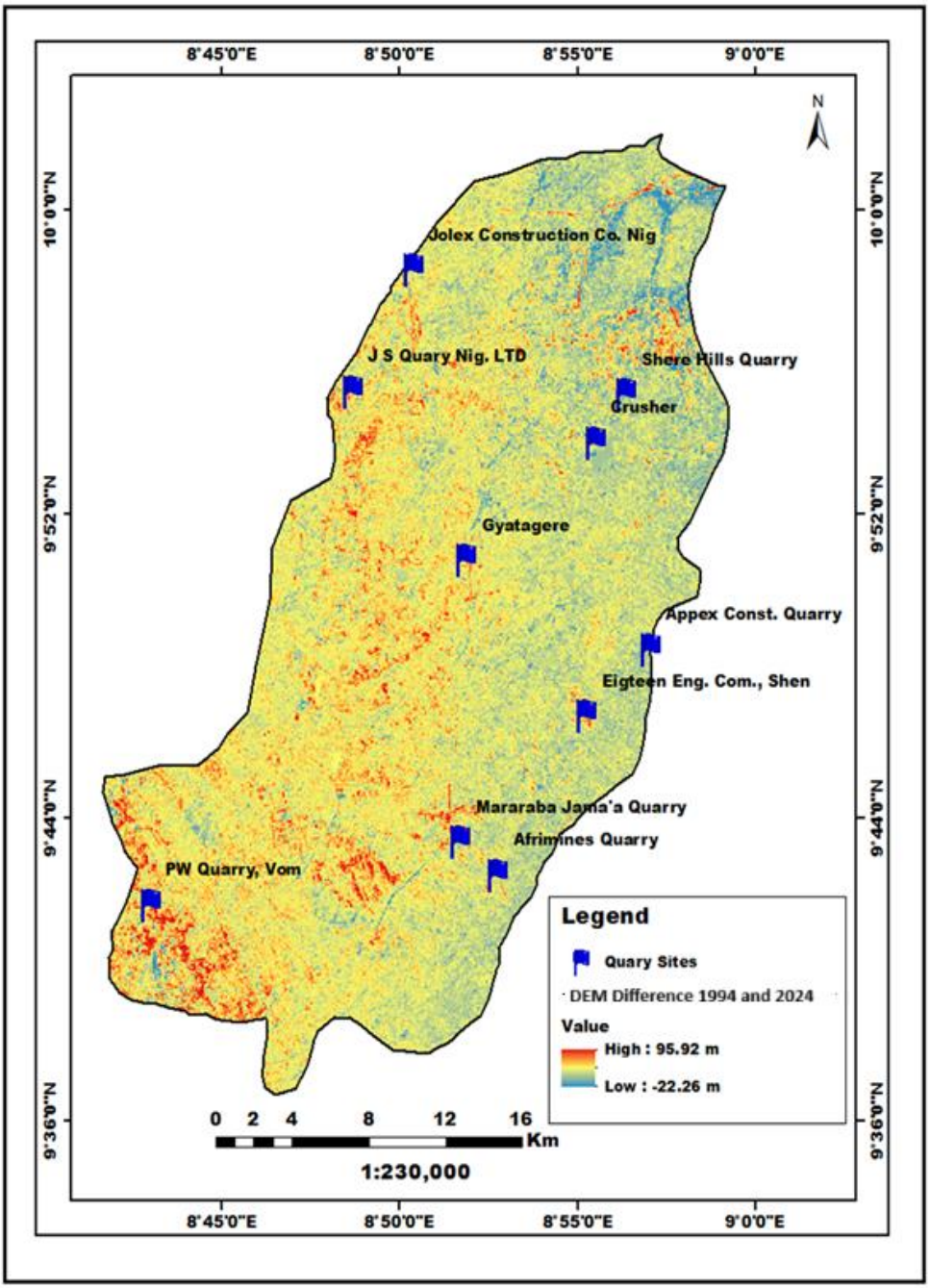


Figure 3. DEM difference between 1994 and 2024 showing topographic change

Source: Author's computation, 2025

NDVI change and vegetation degradation

The 1994 NDVI surface ranged from +0.53 to -0.54. Values around 0.3 to 0.5 represented relatively healthy vegetation, while negative values were associated with water, exposed rock or already degraded surfaces. By 2024, the range had contracted to 0.39 to - 0.25. The decline in maximum NDVI from 0.53 to 0.39 represents a 26.42% reduction in peak vegetation vigour. The 2024 map also contains larger zones of low NDVI near identified quarry sites, indicating increased soil and rock exposure and reduced photosynthetic cover.

Indicator	1994	2024	Change
Maximum NDVI	0.53	0.39	−26.42%
Minimum NDVI	−0.54	−0.25	Range contracted

Table 2. NDVI summary for the Greater Jos area

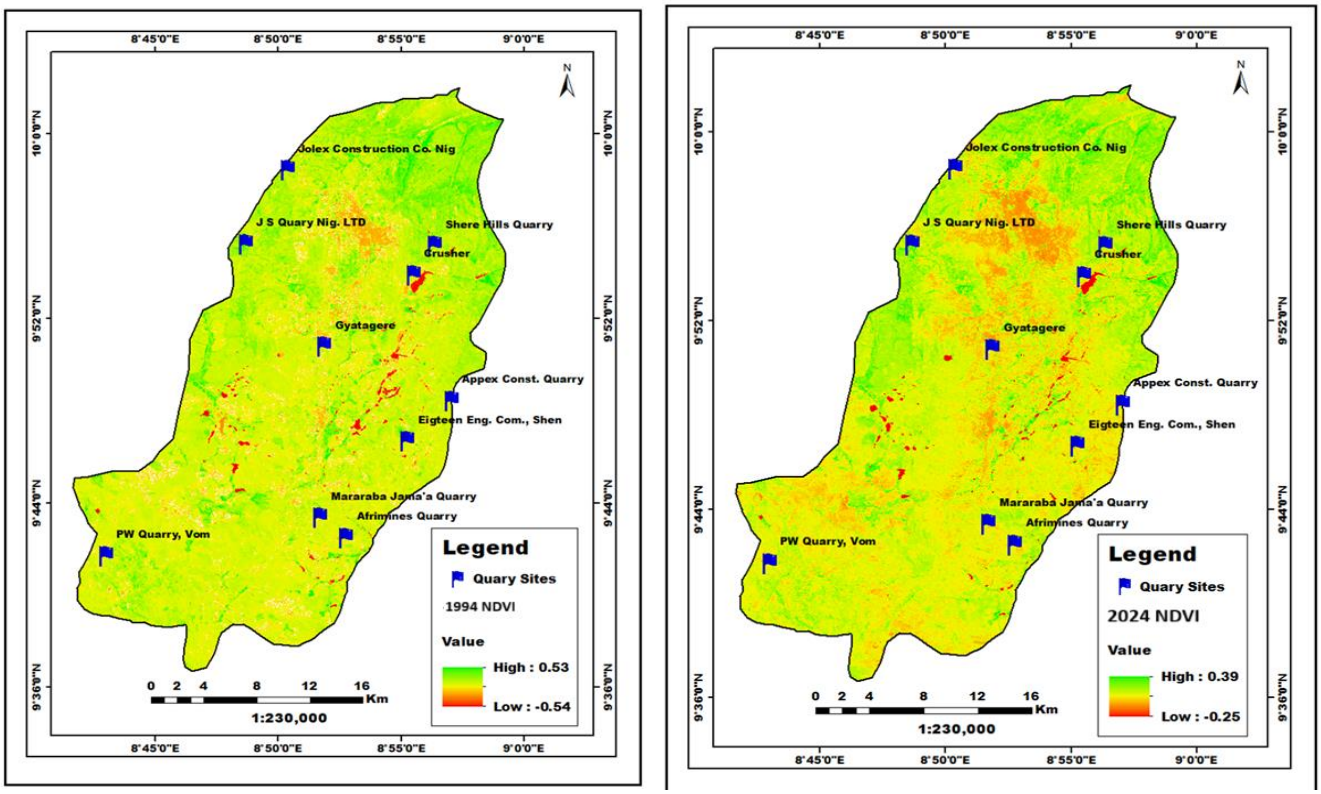


Figure 4. NDVI conditions in 1994 (left) and 2024 (right)

Source: Author's computation, 2025

The NDVI difference surface provides a more direct representation of change. Extensive negative values occur around Jolex Construction Company, J S Quarry, Shere Hills Quarry and the southern quarry corridor. At active extraction surfaces, vegetation has been replaced by exposed rock, processing areas and stockpiles, causing NDVI values to approach zero or become negative. Moderate decline also extends beyond immediate quarry boundaries, which is consistent with indirect stress associated with dust deposition, drainage modification and habitat fragmentation. These findings agree with remote sensing studies that identify quarry expansion as a driver of vegetation and land cover change (Chaurasia et al., 2023; O'Donnell, 2024).

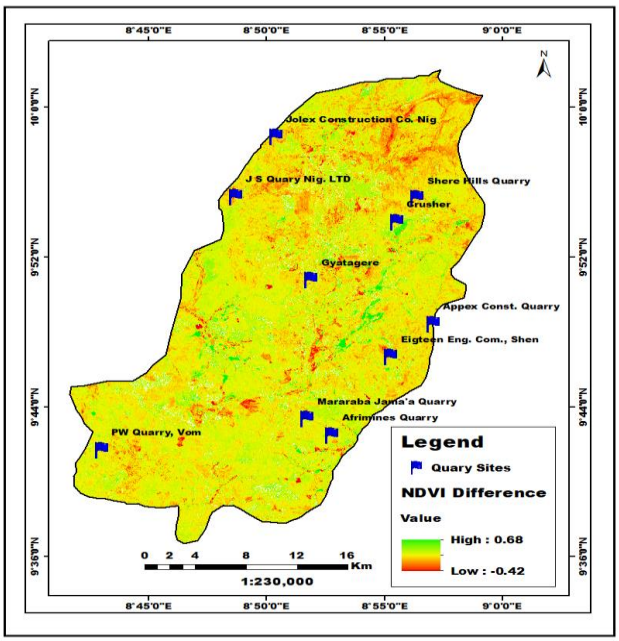


Figure 5. NDVI difference, 2024 minus 1994, showing the spatial extent of vegetation change

Source: Author's computation, 2025

Land subsidence

The land subsidence analysis ranges from -0.42m to +0.041m. The most pronounced subsidence signatures are concentrated in the southern and southwestern parts of Greater Jos and align with quarry sites including PW Quarry, Mararaba Jama'a Quarry and Afrimines Quarry. Values in the most affected corridor commonly exceed 0.30m. Intermediate subsidence of about -0.15m to -0.25m also occurs between quarry locations, suggesting that terrain instability can extend beyond the excavated footprint. The subsidence result reinforces the DEM difference analysis because both independently identify substantial terrain modification in the principal quarry corridor.

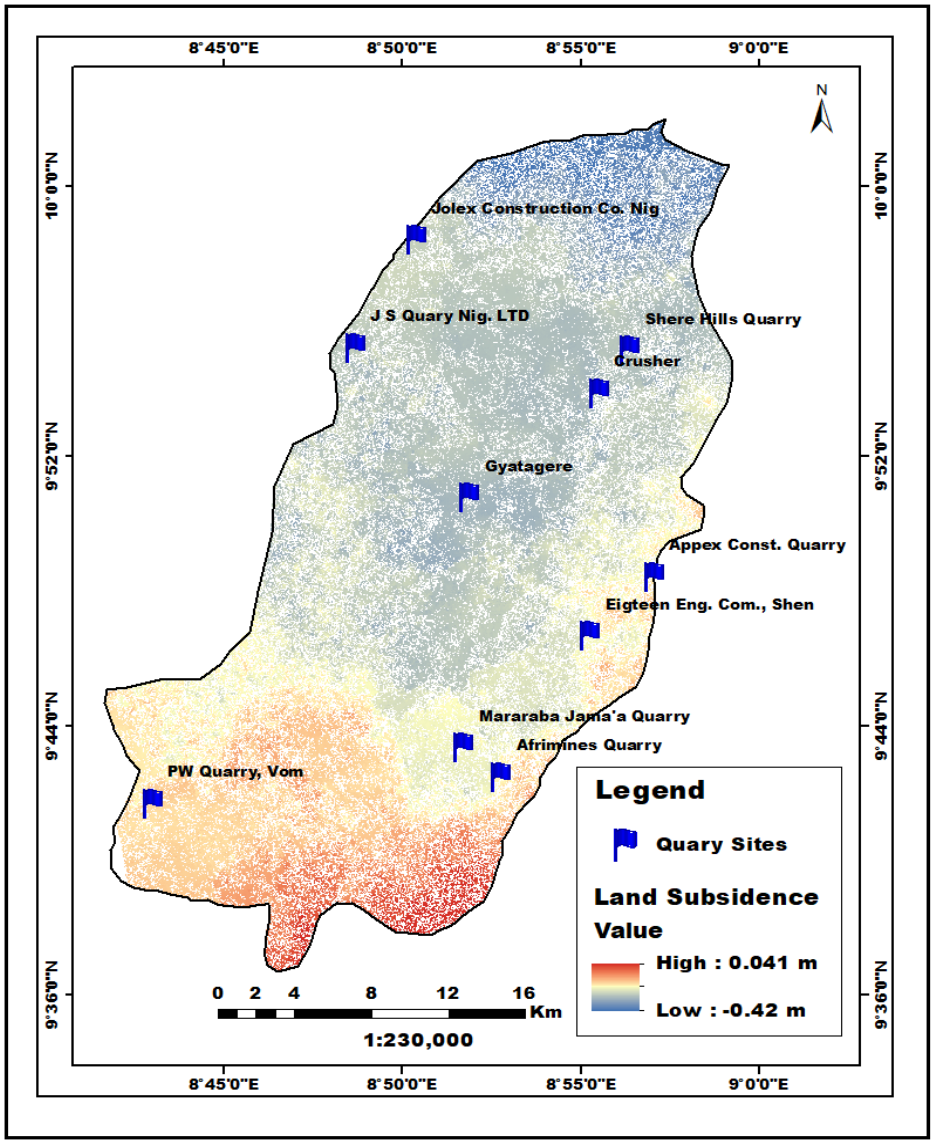


Figure 6. Land subsidence pattern in the Greater Jos area

Source: Author's computation, 2025

RUSLE erosion risk

Three principal soil groups occur in the study area. Ferric Acrisols cover approximately 651.35km² and host many quarry operations. Lithosols cover about 148.61km² and are shallow soils over bedrock, making them particularly vulnerable to removal and exposure. Gleyic Luvisols occupy approximately 27.92km² and occur in more poorly drained settings. Quarry activity increases erosion vulnerability by removing protective vegetation, disturbing soil structure and creating steep, unvegetated slopes. The K factor map shows several quarry sites in zones of moderate to high soil erodibility.

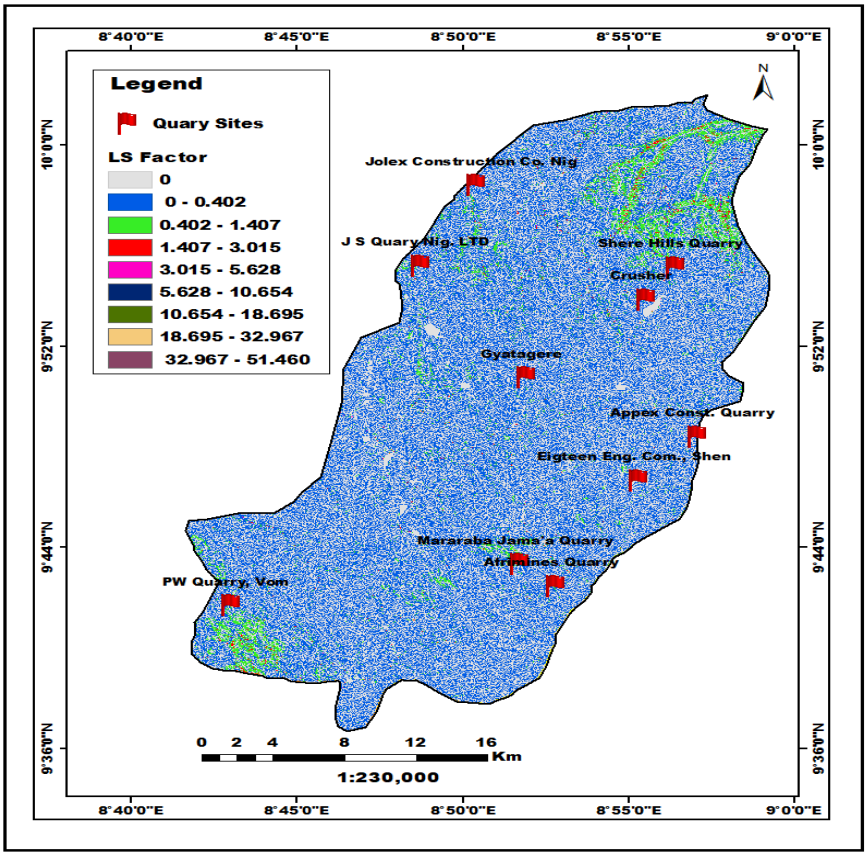


Figure 7a. RUSLE component surfaces : slope LS

Source: Author's computation, 2025

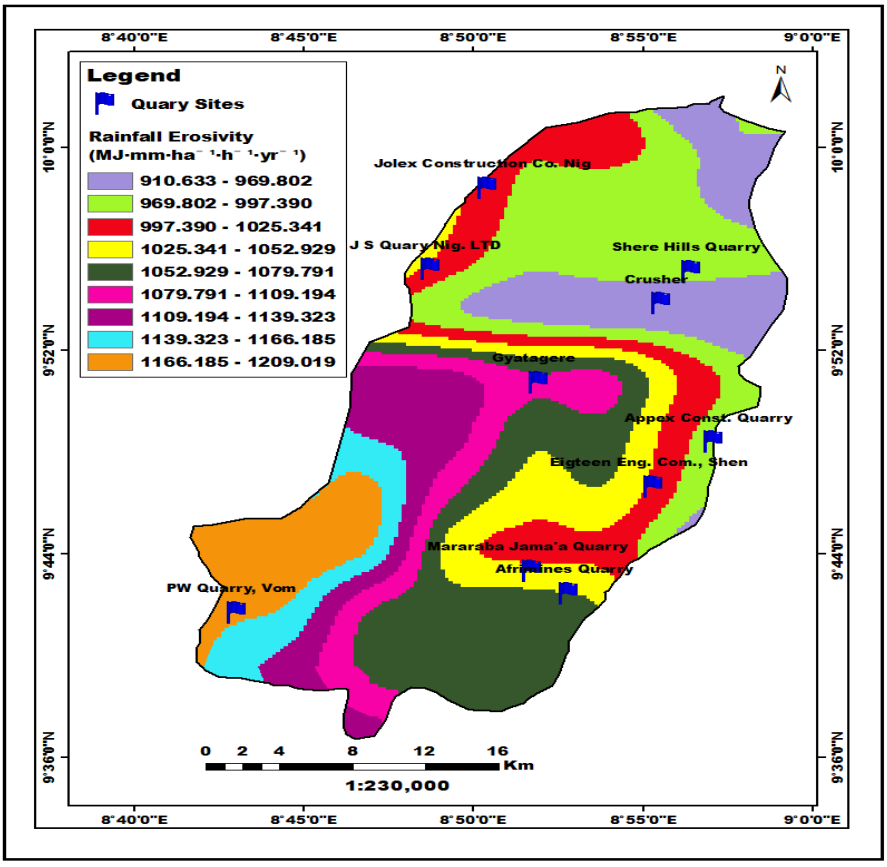


Figure 7b: RUSLE component surfaces: rainfall erosivity R

Source: Author's computation, 2025

Quarry operations have also altered slope conditions by creating faces, benches, haul roads and disturbed surfaces. Rainfall erosivity is highest in parts of the southwest, where values reach approximately 1,166.19 to 1,209.02 MJ mm ha^{-1} h^{-1} yr^{-1}. The combination of erosive rainfall and exposed quarry surfaces intensifies runoff and sediment transport. The integrated RUSLE result estimates soil loss between 918.63 and 1,214.42 t ha^{-1} yr^{-1}. The highest class, approximately 1,170.34 to 1,214.42 t ha^{-1} yr^{-1}, is concentrated in the southwestern sector around PW Quarry, Vom, Afrimines and Mararaba Jama'a. Localized hotspots also occur around northern quarry sites. The pattern supports the interpretation that quarry modifies the controls of erosion through vegetation removal, slope creation and drainage concentration.

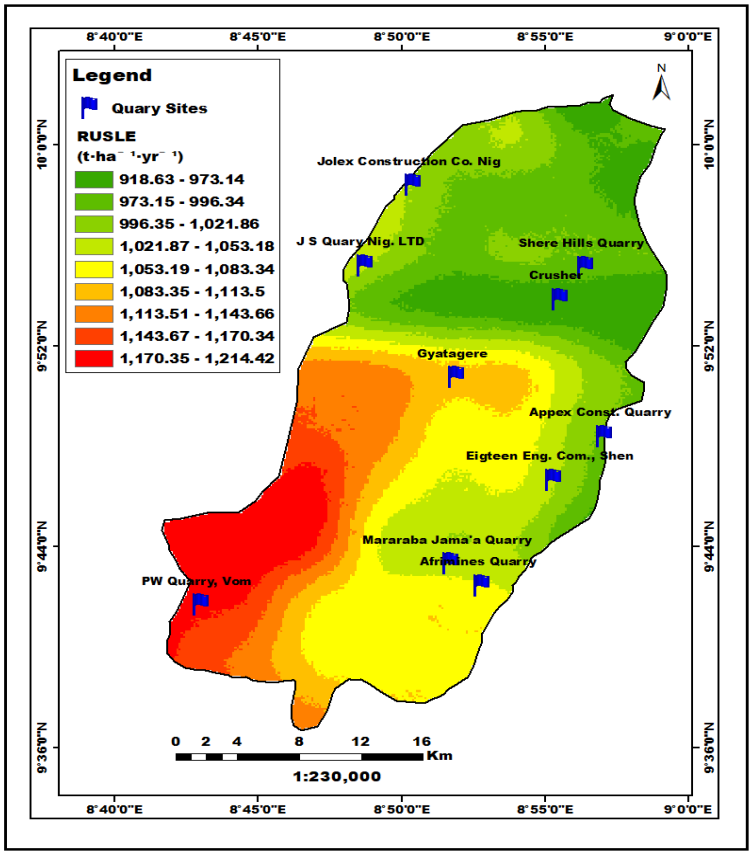


Figure 8. RUSLE estimated soil loss across the Greater Jos area

Source: Author's computation, 2025

Composite extent of quarry induced land degradation

The strongest evidence emerges when the indicators are interpreted together. NDVI identifies vegetation loss, DEM difference captures excavation and deposition, land subsidence identifies terrain instability, and RUSLE quantifies erosion risk. Their weighted integration produces a degradation gradient from very low to very high. High and very high classes cluster strongly in the southern and southwestern portions of Greater Jos, coinciding with intensive quarry operations, especially PW Quarry at Vom and Mararaba Jama'a Quarry. Northern areas farther from the principal quarry concentration are more commonly classified as low or very low degradation, although local hotspots remain around individual sites.

Layer	Weight (%)	Role in degradation assessment
NDVI difference	30	Vegetation loss
RUSLE erosion risk	30	Soil erosion
DEM difference	20	Topographic modification
Land subsidence	15	Terrain stability
LULC	5	Land use context

Table 3. Weights used for the composite land degradation assessment

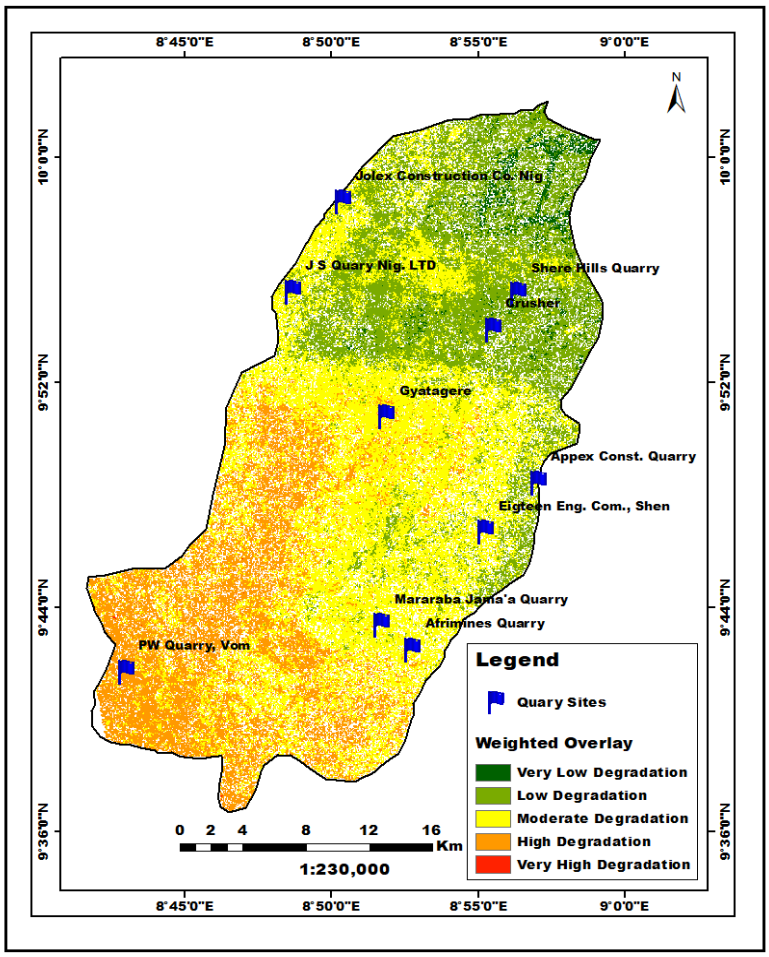


Figure 9. Composite land degradation map showing the cumulative extent and severity of degradation

Source: Author's computation, 2025

DISCUSSION

The combined results demonstrate that quarry induced land degradation in Greater Jos operates through linked physical and ecological pathways. The DEM difference indicates direct reshaping of the terrain, while the subsidence surface shows that instability extends beyond the most obvious excavation zones. These terrain changes are environmentally significant because they alter slope geometry and runoff pathways. The observed concentration of terrain change around quarry sites is consistent with studies that associate quarry with landscape modification and reduced land stability in Plateau State and comparable environments (Danjuma & Gukas, 2021; Kafu-Quvane et al., 2024).

Vegetation change provides a second line of evidence. Although LULC statistics show that vegetation can fluctuate through natural regeneration, land abandonment and classification transitions, the NDVI endpoint comparison shows a clear decline in peak vegetation vigour from 0.53 to 0.39. More importantly, the NDVI difference map spatially connects the strongest negative changes to known quarry sites. This distinction is important because a regional increase in the mapped area of a vegetation class does not necessarily imply improved vegetation condition at quarry affected locations. NDVI measures vegetation greenness and vigour, while LULC classification measures the area assigned to a class. The two indicators therefore answer different questions and should be interpreted together rather than treated as contradictory.

The RUSLE output further explains why vegetation removal and terrain modification matter. Once quarry surfaces are cleared, the loss of cover reduces protection from rainfall, artificial slopes increase the LS component, and altered drainage can concentrate runoff. The highest RUSLE values occur where these conditions overlap with high rainfall erosivity. This spatial coincidence is consistent with the wider literature on quarry related soil erosion and land degradation (Okafor & Anselm, 2020; Umar & Musa, 2023). The

estimated soil loss values are extremely high and should be interpreted as modelled erosion risk rather than direct sediment yield measurements at every location.

The composite map provides the clearest representation of extent because no single variable captures all dimensions of degradation. Weighted overlay integrates direct vegetation loss, soil erosion risk, topographic modification, terrain stability and land use context. The concentration of high and very high degradation in the Vom, Shen and southwestern corridor shows that quarry impacts are cumulative. Vegetation removal increases erosion exposure, excavation modifies slopes, subsidence reduces terrain stability and erosion can further inhibit vegetation recovery. This reinforcing sequence explains why heavily worked quarry landscapes may remain degraded even after extraction intensity declines. The use of multicriteria spatial integration is consistent with the value of GIS based decision support for environmental prioritization (Malczewski, 1999).

The results have direct implications for land management. Areas where high RUSLE risk overlaps negative NDVI change and substantial DEM alteration should receive priority for erosion control and progressive rehabilitation. Active sites require slope management, runoff control and staged revegetation, while abandoned sites require stabilization and land use plans that reflect residual terrain hazards. Remote sensing offers a practical basis for repeated monitoring because the same indicators can be recalculated at defined intervals and compared with licence boundaries and rehabilitation commitments (Nwafor et al., 2022; O'Donnell, 2024).

CONCLUSION

This study establishes that quarry is a major driver of cumulative land degradation in the Greater Jos area. Between 1994 and 2024, DEM difference values ranged from -22.2548m to +95.9155m, indicating substantial terrain lowering and deposition. Maximum NDVI declined from 0.53 to 0.39, while the NDVI difference surface showed pronounced vegetation loss around quarry locations. Land subsidence reached minus 0.42 m in the most affected areas. RUSLE estimated soil loss of 918.63 to 1,214.42 t ha^{-1} yr^{-1}, with the highest erosion risk concentrated in the southern and southwestern quarry corridor. When these indicators were integrated, high and very high degradation classes coincided with the most intensive quarry zones. The findings demonstrate that the extent of degradation is best understood through the combined interpretation of vegetation condition, erosion risk and terrain modification rather than through any one indicator alone.

RECOMMENDATIONS

1. Environmental regulators should institutionalize periodic NDVI, DEM and RUSLE based monitoring of active and abandoned quarry sites in Greater Jos, with results linked to compliance inspections and rehabilitation requirements.

2. Quarry operators in high and very high degradation zones should implement progressive rehabilitation, including slope regrading, topsoil replacement, revegetation, drainage control and stabilization of spoil surfaces.

3. Buffer zones should be enforced around erosion prone slopes, drainage channels, agricultural land and settlements, particularly in the southern and southwestern quarry corridor.

4. Rehabilitation priorities should be based on integrated hotspot mapping. Sites where severe NDVI decline overlaps high RUSLE values, significant elevation change and subsidence should receive first attention.

5. Future monitoring should use consistent seasonal imagery and field validation so that vegetation recovery, erosion control and terrain stability can be measured objectively through time.

REFERENCES

1. Chaurasia, R., Jain, K., & Singh, P. (2023). Monitoring quarry-induced land use and land cover change using multi-temporal satellite imagery and GIS techniques. Environmental Monitoring and Assessment, 195(7), 1-18.

2. Danjuma, A. P., & Gukas, A. B. (2021). Effects of quarrying on land use patterns and environmental sustainability in Plateau State, Nigeria. Nigerian Journal of Geography and Environmental Research, 9(2), 66-79.
3. Eze, V. C. (2020). Environmental degradation and quarrying activities in Nigeria: Challenges and prospects. Journal of Environmental Science and Technology, 14(2), 87-98.
4. Ibrahim, Y. M., & Musa, A. U. (2021). Socio-economic and environmental impacts of quarrying activities in Nigeria. Journal of Sustainable Development Studies, 19(1), 23-41.
5. Kafu-Quvane, T., Ndlovu, P., & Dube, S. (2024). Geomorphological transformations in quarry-dominated regions: A remote sensing analysis. International Journal of Environmental Monitoring, 15(2), 89-104.
6. Maimako, N. M., & Gwom, J. Y. (2022). Land degradation and quarrying in Jos Plateau: An environmental perspective. Journal of Environmental Studies and Policy, 8(1), 34-49.
7. Malczewski, J. (1999). Visualization in multicriteria spatial decision support system. Geomatica, 53(2), 139-147.
8. Nwafor, S. O., Umeh, C. N., & Nnaji, C. C. (2022). Application of GIS and remote sensing in assessing quarry-induced land degradation in Southeast Nigeria. Geo-Environmental Research Reports, 5(2), 54-67.
9. O'Donnell, K. (2024). Remote sensing and land degradation: Mapping quarry expansion and LULC transitions in sub-Saharan Africa. Journal of Environmental Remote Sensing, 18(2), 112-130.
10. Okafor, C. C., & Anselm, E. I. (2020). Environmental implications of quarry activities in Jos Plateau, Nigeria. International Journal of Environmental Studies, 17(3), 115-129.
11. Romańczukiewicz, G., Nowak, M., & Wójcik, K. (2025). Assessing the impact of open-pit mining on land cover change and landscape fragmentation using Sentinel-2 imagery. Land Degradation & Development, 36(1), 221-236.
12. Umar, H., & Musa, M. (2023). Topsoil erosion and land degradation in quarry-dominated landscapes of Jos Plateau. Nigerian Journal of Geography and Environment, 25(3), 100-115.