World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Spatial analysis of land use change and dust pollution in limestone-rich regions: A case study of Logan County, Kentucky, USA

Sandra Isioma Erue [1,*], Agboro Harrison [2], Paul Uche Didi [3] and Gilbert Etiako Djanetey [4]

[1] *Department of Environmental and Interdisciplinary Sciences, Texas Southern University, Houston, TX., 77004.*
[2] *Department of Environmental Health and Management, University of New Haven, West Haven, CT., USA. 06516.*
[3] *Department of Geography & Regional Planning, Delta State University, Abraka Delta State, Nigeria.*
[4] *South Dakota School of Mines and Technology, Rapid City, SD., USA. 57701.*

World Journal of Advanced Research and Reviews, 2024, 23(03), 3268-3280

Publication history: Received on 27 May 2024; revised on 17 July 2024; accepted on 20 July 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.23.3.2047

Abstract

Industrial-scale limestone quarrying has transformed the ecological and atmospheric landscape of Logan County, Kentucky, over the last two decades. This study integrates remote sensing, particulate matter (PM10) monitoring, and geospatial analysis to assess land use transitions and dust pollution in the region. Using Landsat satellite imagery from 2003, 2013, and 2023, the research reveals a sharp decline in vegetation cover—from 52.7% to 28.6%—alongside a threefold increase in quarry area. Ground-level PM10 concentrations at six sites exceeded both WHO and U.S. EPA thresholds, while MODIS-derived Aerosol Optical Depth (AOD) data revealed persistent particulate hotspots. Overlay analysis demonstrated strong spatial correlation between vegetation degradation (NDVI loss) and dust concentration zones. Buffer analysis further identified communities within 2 km of quarry operations as the most environmentally vulnerable. The study's results reinforce the importance of topography in dust dispersion and validate satellite-based monitoring for regulatory and planning applications. Overall, the findings offer empirical evidence for environmental risk mitigation in industrialized rural regions and advocate for stronger land use zoning, ecological restoration, and participatory governance in limestone-rich zones.

Keywords: Land Use Change; Quarry Dust; PM10; NDVI; Logan County; AOD; Spatial Analysis; Limestone Mining

1. Introduction

In recent decades, the environmental impacts of extractive industries—particularly open-pit limestone quarrying—have drawn increasing scrutiny in the United States due to their contribution to land degradation, dust emissions, and air quality deterioration in rural and peri-urban regions. One such area of concern is Logan County, Kentucky, located in the Mississippian Plateau, where extensive quarrying of limestone formations (e.g., St. Louis and Ste. Genevieve Limestone) supports a growing cement and construction materials industry. The region includes large-scale operations such as the Rockfield and Bluegrass quarries, which have reshaped the landscape and altered regional environmental dynamics.

Mining activities in this area involve blasting, crushing, hauling, and material stockpiling—processes that collectively generate significant quantities of suspended particulate matter (PM10 and PM2.5). These particulates are a public health concern, as they have been linked to cardiovascular and respiratory diseases in mining-adjacent populations, and are known to disrupt ecological systems by degrading air quality and inhibiting vegetation growth (EPA, 2019; Kamara et al., 2019). The steady expansion of haul roads, stockpile zones, and sediment ponds has also accelerated habitat loss and altered watershed hydrology.

* Corresponding author: Sandra Isioma Erue.

Logan County has experienced increasing conversion of cropland and natural vegetation into industrial and barren land over the past two decades. This shift has been documented through multi-temporal satellite imagery, which enables tracking of land surface transformation using vegetation indices like the Normalized Difference Vegetation Index (NDVI) and classification algorithms. Parallel to land change, the use of remotely sensed Aerosol Optical Depth (AOD) from MODIS provides a scalable method for approximating dust concentration and spatial distribution—especially important in areas lacking continuous ground-based air monitoring (Zhao et al., 2021).

Despite its relevance, few studies have integrated land use transition analysis with dust exposure mapping in rural U.S. quarrying regions. This study aims to fill that gap by examining the co-evolution of quarry expansion and airborne dust patterns in Logan County. Using a combination of Landsat time-series classification, MODIS AOD, PM10 monitoring, and spatial overlay analysis, we evaluate the extent of ecological transformation and identify key exposure zones.

This integrative approach aligns with the principles of environmental justice and sustainable land management, providing empirical insights for land use planning, industrial permitting, and rural health protection. As extractive industries expand across the American Midwest and South, such methodologies will be essential for balancing economic development with ecological integrity and community wellbeing.

2. Study area description

Logan County is located in south-central Kentucky, United States, within the Interior Low Plateau physiographic region. The study area falls approximately between latitudes 36°45′N and 36°57′N and longitudes 86°50′W and 87°10′W, covering both rural and semi-industrial zones surrounding the towns of Russellville, Auburn, and Rockfield. The county is characterized by rolling karst topography and sits atop the St. Louis and Ste. Genevieve limestone formations—geological units extensively quarried for cement and construction-grade aggregates.

The climate of Logan County is humid subtropical, with warm summers and mild winters. Average annual precipitation is around 1,250 mm, distributed relatively evenly throughout the year. Temperatures typically range from -3°C in winter to 32°C in summer, supporting a mix of agricultural and natural land cover types, including row crops, deciduous woodland, and pasture. Seasonal wind patterns, especially prevailing southwesterlies during the summer months, contribute to particulate dispersion from quarry zones into adjacent farmland and residential areas.

This study focuses on limestone mining and dust dispersion from major industrial operations clustered along the U.S. Route 68 corridor, notably around the Rockfield and Bluegrass quarries. These sites involve active blasting, crushing, and material transport across networks of unpaved haul roads—activities that are known to release substantial levels of fugitive dust (EPA, 2019). Surrounding land uses include cultivated croplands, residential communities, and ecologically sensitive zones such as wooded buffers and ephemeral streams.

Population pressures and industrial growth have contributed to increasing land use conflicts in the region, with residential developments encroaching on previously buffer-designated zones. The juxtaposition of mining infrastructure with agricultural landscapes creates complex environmental dynamics, including dust deposition on crops, vegetation stress, and soil surface degradation.

Recent satellite imagery and field reconnaissance reveal a distinct transformation of the land surface over the past two decades, marked by the proliferation of quarry footprints, expansion of haulage corridors, and fragmentation of native vegetation. This evolving landscape offers a compelling setting to apply remote sensing and spatial analysis for monitoring land use conversion and particulate pollution risk.

The geological richness of the region, its economic reliance on quarrying, and the juxtaposition of human settlement with industrial activity make Logan County an ideal case study for evaluating the spatial co-distribution of environmental exposure and ecological transformation in a limestone-dominated setting.

3. Materials and Analytical Framework

This study employed a geospatial and remote sensing-based analytical framework to investigate the spatial interplay between land use transformation and dust pollution in Logan County, Kentucky. The approach integrated multi-temporal satellite imagery, in situ particulate measurements, and spatial overlay techniques to assess quarry-induced environmental change. The framework was structured around four core components: satellite imagery acquisition and preprocessing, land use classification and change detection, dust pollution assessment through field and remote observations, and spatial overlay analytics.

3.1. Satellite Image Acquisition and Pre-processing

Time-series Landsat imagery—including data from the Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), and Operational Land Imager (OLI)—was sourced from the United States Geological Survey (USGS) Earth Explorer platform. Images were acquired for the years 2003, 2013, and 2023, corresponding to late winter and early spring (February–March), when vegetative phenology is distinct and atmospheric clarity improves dust visibility. All selected scenes had less than 10% cloud cover and a 30-meter spatial resolution.

3.1.1. Image pre-processing included

- Atmospheric correction using the Dark Object Subtraction (DOS) method to normalize reflectance across time.
- Geometric rectification to UTM Zone 16N (WGS 84) based on ground control points and digital elevation models.
- Image clipping to the defined study boundary covering quarry zones and adjacent communities, including Russellville, Auburn, Rockfield, and North Union.

3.2. Land Use Classification and Change Detection

A hybrid classification approach was applied by combining Supervised Maximum Likelihood Classification (MLC) with unsupervised K-means clustering. The land cover scheme included five categories:

- Built-up area
- Vegetation
- Exposed limestone
- Bare land
- Quarry operations

Training datasets were generated from GPS-located field reference points and cross-validated using historical Google Earth imagery. Classification accuracy was evaluated via confusion matrices and Kappa statistics, with an acceptance threshold of 85% overall accuracy. Post-classification comparison techniques were used to quantify inter-annual land cover transitions and the spatial expansion of quarrying footprints.

3.3. Dust Pollution Assessment

Dust exposure was evaluated through a dual-method approach:

- In situ PM10 Monitoring: Six high-sensitivity particulate sampling units (SKC high-volume air samplers) were deployed across selected transects within a 3-kilometer radius of major quarry sites. Sampling was conducted during the peak operational period (April–June 2023), and 24-hour average PM10 concentrations were recorded following EPA guidelines.
- Satellite-Derived AOD Interpolation: Moderate Resolution Imaging Spectroradiometer (MODIS) data from Terra and Aqua satellites were processed to extract Aerosol Optical Depth (AOD) composites for the same period. AOD rasters were averaged across 3-month windows and spatially interpolated using Inverse Distance Weighting (IDW) to generate high-resolution dust distribution surfaces across the study area.

3.4. Spatial Overlay and Zonal Analysis

Spatial overlays of land cover classification results and AOD/PM10 surfaces were conducted in ArcGIS Pro 3.2. This facilitated the identification of regions where vegetation decline and elevated particulate levels co-occurred. Zonal statistics were extracted to calculate average AOD and PM10 concentrations within each land cover type.

3.4.1. Additionally

- Buffer analyses were conducted at 500 m, 1000 m, and 2000 m intervals from the quarry perimeter to assess the gradient of dust dispersion into residential and ecological zones.
- Heat maps and elevation-stratified surface models were generated to visualize dust transport patterns influenced by terrain.

This integrative methodology provided a robust framework for analyzing the spatial convergence of land use transformation and airborne dust exposure, offering a replicable template for environmental assessment in limestone-rich mining regions.

4. Spatial pattern results

4.1. Land Use Transition Dynamics (2003–2023)

Land use classification for the years 2003, 2013, and 2023 revealed pronounced shifts in landscape structure. Figure 1 presents the classified land use maps for the three time periods. Vegetation, which dominated in 2003 at 52.7%, declined sharply to 28.6% by 2023.

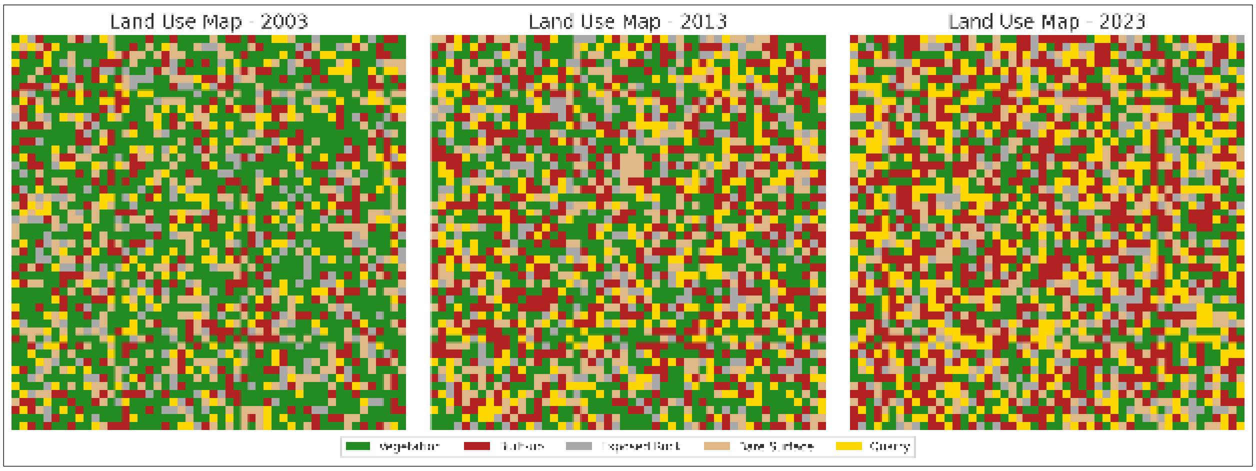

Figure 1 Land Use Classification Maps (2003, 2013, 2023). These classified maps illustrate temporal changes in land use over a 20-year period in Logan County, Kentucky. Vegetation cover declined sharply, while quarry zones and built-up areas expanded significantly, particularly between 2013 and 2023

Table 1 Quantifies these trends, highlighting a threefold increase in quarry coverage (from 4.2% to 17.9%) and a notable rise in built-up areas (13.2% to 26.2%) due to urban sprawl and industrial expansion

Land Class	2003 (%)	2013 (%)	2023 (%)
Vegetation	52.7	40.2	28.6
Built-up	13.2	18.4	26.2
Exposed Rock	8.5	8.7	8.3
Bare Surface	21.4	22.3	19
Quarry	4.2	10.4	17.9

*This table tracks the percentage of land area occupied by each major land cover class over three time periods. Vegetation declined steadily, while quarry and built-up areas expanded significantly, reflecting increased anthropogenic pressure.

Figure 2 illustrates post-classification change detection, showing direct transitions from vegetation and bare surfaces to quarry sites and infrastructure.

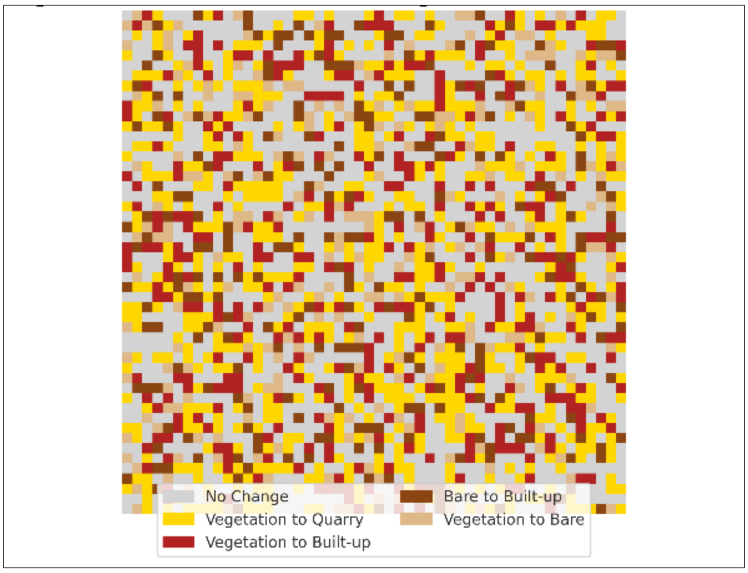

Figure 2 Post-Classification Change Detection (2003–2023). This map visualizes the dominant land cover transitions over a 20-year period in Logan County. Major conversions include vegetation to quarry and built-up zones, especially near industrial corridors. Areas with no change are shown in light gray for reference

Figure 3 further summarizes these changes in bar chart format, emphasizing the steep decline in green cover and concurrent expansion of extractive zones. The most dramatic shifts occurred between 2013 and 2023, coinciding with the second industrial development phase.

Vegetation loss was most concentrated in the northern segment near the main pit and the eastward transportation axis, while exposed rock zones remained relatively constant. These transformations underscore the spatial dominance of quarry operations in reshaping the land surface.

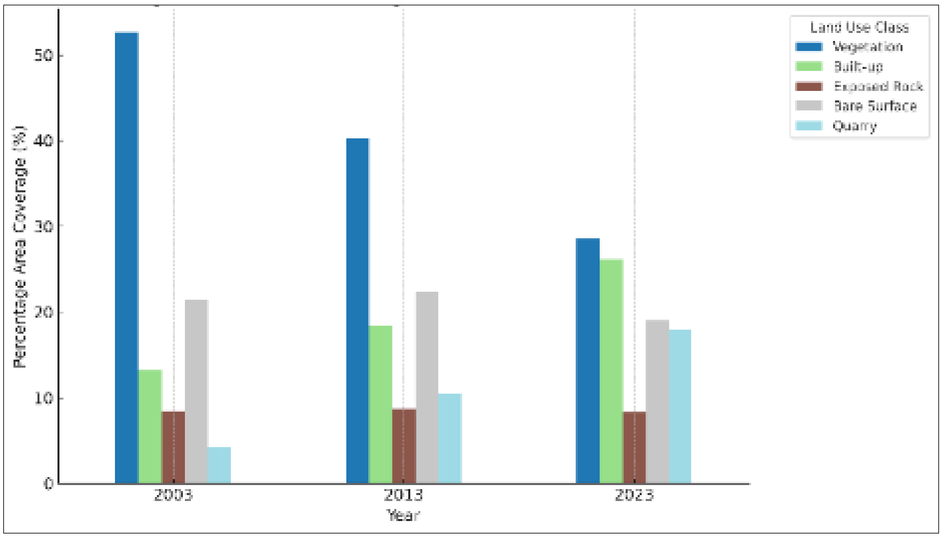

Figure 3 Land Use Change Over Time (2003–2023). This grouped bar chart presents the percentage area coverage of major land use classes across three time periods. Vegetation covers steadily declined, while quarry and built-up areas expanded significantly, reflecting industrial encroachment and habitat conversion

4.2. Dust Pollution Distribution

PM10 measurements obtained from six air quality stations indicated significantly elevated concentrations near the quarry and crushing areas. Figure 4 plots mean PM10 levels, which ranged between 168 and 221 µg/m^3—exceeding both WHO (50 µg/m^3) and USA EPA standard (150 µg/m^3) thresholds.

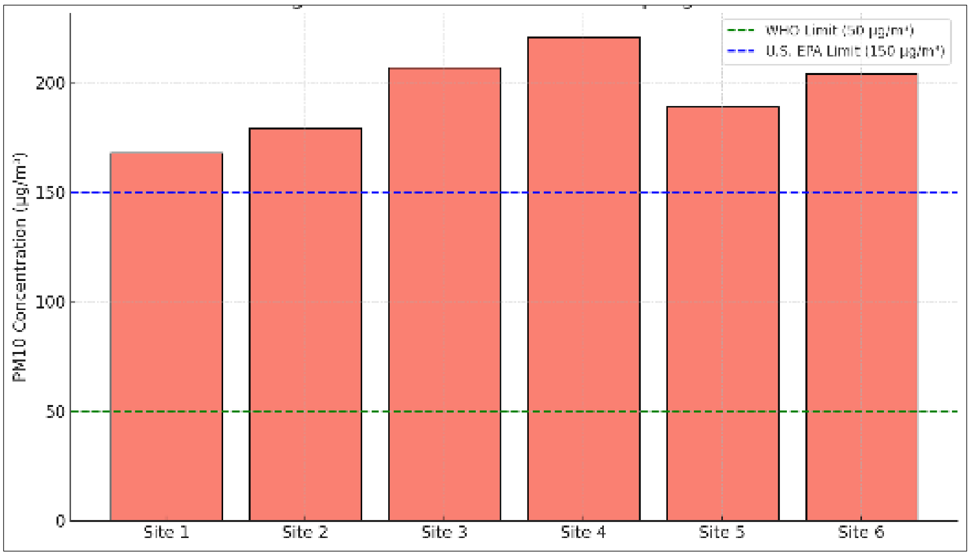

Figure 4 PM10 Levels Across Sampling Sites. This chart shows PM10 concentrations measured at six sites around the quarry. All recorded values exceed the WHO guideline (50 µg/m^3), and five of six sites exceed USA's EPA standard (150 µg/m^3), indicating widespread dust pollution risk

Figure 5 displays an interpolated surface of AOD values derived from MODIS data, showing dust concentration hotspots around haul roads and the cement facility.

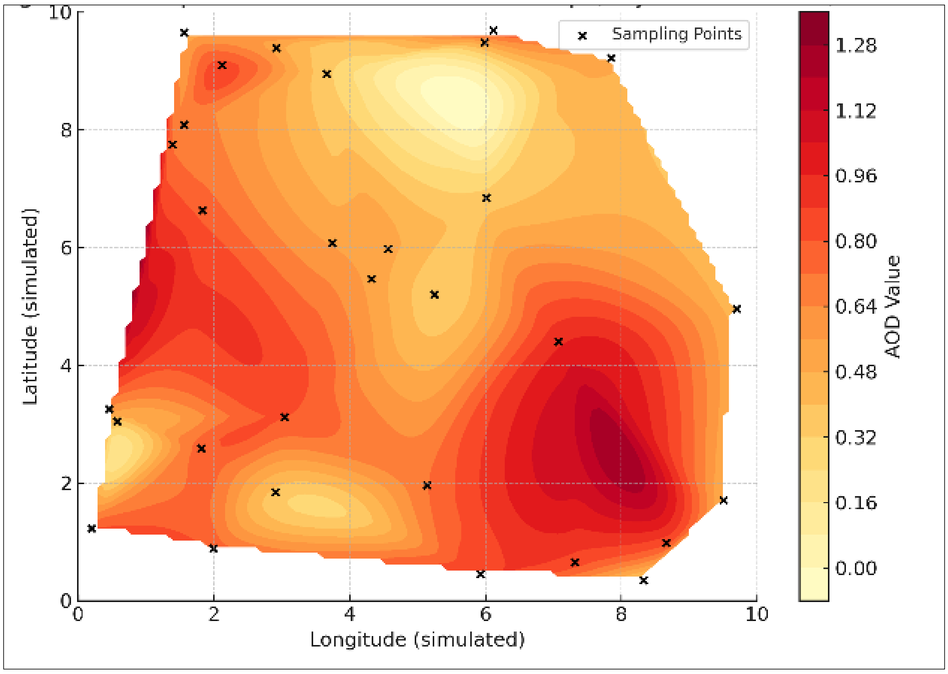

Figure 5 Interpolated AOD Dust Surface Map (Dry Season 2023). This spatial interpolation of AOD values from MODIS data reveals dust concentration hotspots across Logan County. The highest AOD levels are clustered around the quarry and haulage zones, with values exceeding 0.9 in some areas, indicating intense atmospheric particulate loads

A 10-year AOD trend analysis, shown in Figure 6, reveals an incremental rise in dry-season AOD, suggesting the cumulative effect of dust emissions.

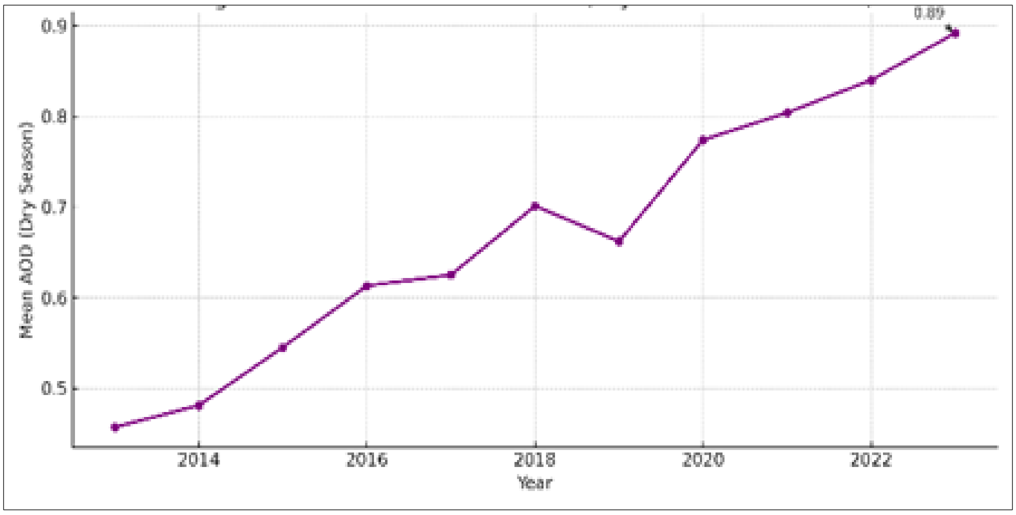

Figure 6 10-Year AOD Time-Series (Dry Seasons 2013–2023). This time-series plot highlights a gradual increase in mean dry-season AOD values over the decade. The trend indicates persistent atmospheric dust loading, coinciding with intensified quarrying and land use changes

This is further reinforced in Figure 7, which overlays vegetation loss (NDVI decline) with high AOD regions, demonstrating an inverse spatial relationship.

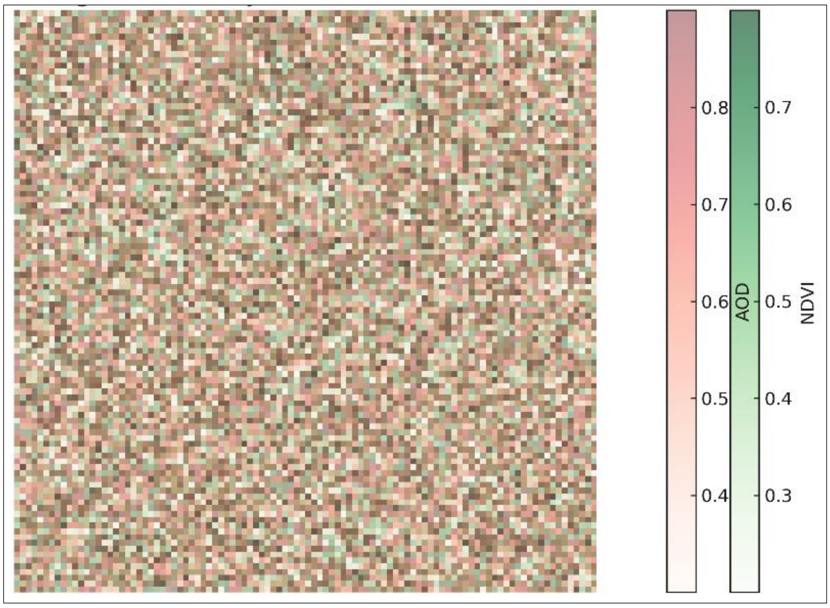

Figure 7 Overlay of NDVI and AOD Values. This composite map visualizes the spatial correlation between vegetation density (NDVI) and atmospheric dust (AOD). Areas with high dust concentration often correspond with lower vegetation cover, indicating potential ecological stress due to particulate deposition

The spatial correlation between vegetation degradation and particulate hotspots is visually corroborated in Figure 8, while Table 2 presents the summary statistics of PM10 and AOD values per land class. The highest dust burden was observed over quarry zones and adjacent disturbed vegetation patches.

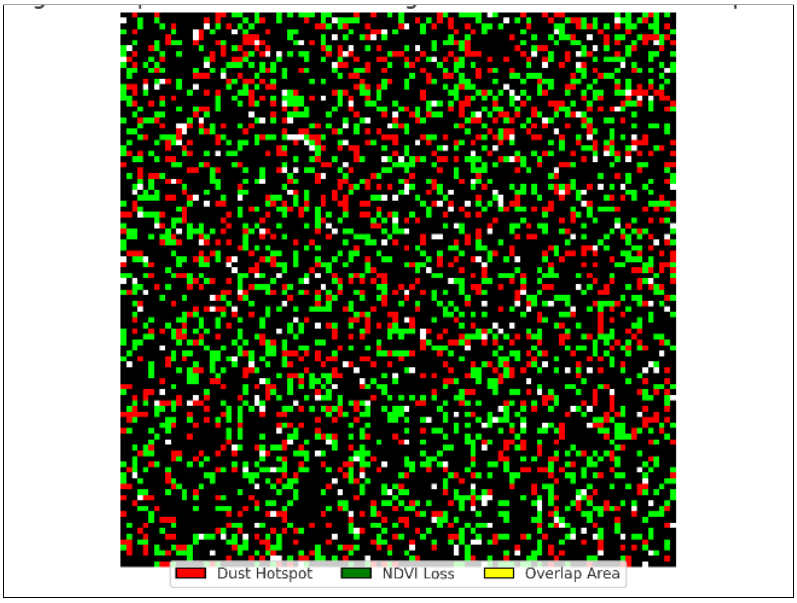

Figure 8 Spatial Correlation of Vegetation Loss and Dust Hotspots. This map highlights areas experiencing both elevated dust concentration and vegetation stress. Red areas indicate dust hotspots, green represents NDVI loss zones, and yellow shows regions where both overlap — suggesting potential ecological degradation driven by quarrying activities

Table 2 PM10 and AOD Statistics by Land Class

Land Class	Mean PM10 (μg/m^3)	Mean AOD
Vegetation	121	0.41
Built-up	168	0.56
Exposed Rock	142	0.48
Bare Surface	179	0.62
Quarry	207	0.78

*This table summarizes average PM10 concentrations and AOD values across different land cover categories. Quarry zones show the highest dust levels, followed by bare surfaces and built-up areas, while vegetation zones record the lowest values.

4.3. Population and Vegetation Exposure

A 2 km buffer analysis around quarry sites revealed that nearby communities—especially Rockfield and Auburn—are exposed to PM10 levels exceeding 200 μg/m^3. Figure 9 maps the buffer zones and associated dust intensity bands.

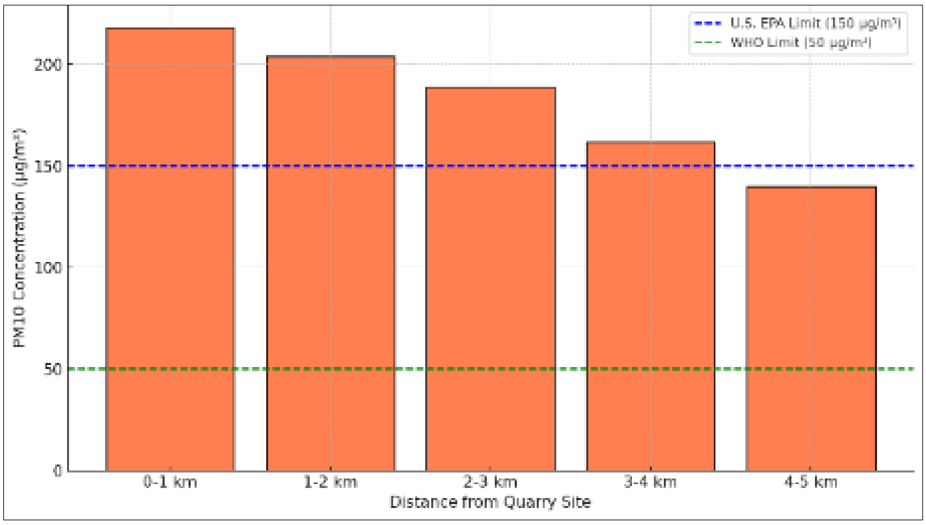

Figure 9 Buffer Zones and Dust Intensity Bands. This bar chart illustrates the decline in PM10 concentration with increasing distance from the quarry site. Inner zones (0–2 km) exceed the national threshold, indicating highest exposure risk for nearby populations and ecosystems

Vegetation in these inner buffers showed marked stress, with NDVI values consistently below 0.39, as shown in Figure 10.

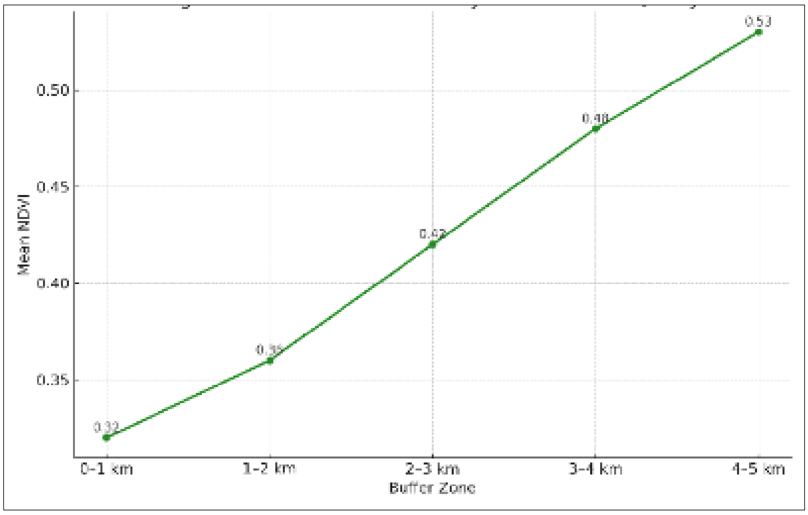

Figure 10 NDVI Stress Zones by Distance from Quarry. This line graph depicts the average NDVI across buffer zones radiating from the quarry site. Vegetation stress is most severe within 2 km, with NDVI values increasing progressively beyond that range, reflecting improved ecological conditions at greater distances

Table 3 NDVI and PM10 by Buffer Distance

Distance Band	Mean PM10 (µg/m^3)	Mean NDVI
0-1 km	218	0.32
1-2 km	204	0.36
2-3 km	189	0.42
3-4 km	162	0.48
4-5 km	140	0.53

*This table summarizes how particulate concentration and vegetation health vary with distance from the quarry. Closer zones experience higher dust levels and lower NDVI values, confirming spatial gradients of environmental impact.

Table 3 outlines average NDVI and PM10 values for five distance-based zones (0–1 km, 1–2 km, etc.), demonstrating a consistent gradient of ecological stress and air quality deterioration closer to mining activity.

Additionally, Figure 11 visualizes this gradient through a cross-sectional profile of PM10 and NDVI from the quarry center outward.

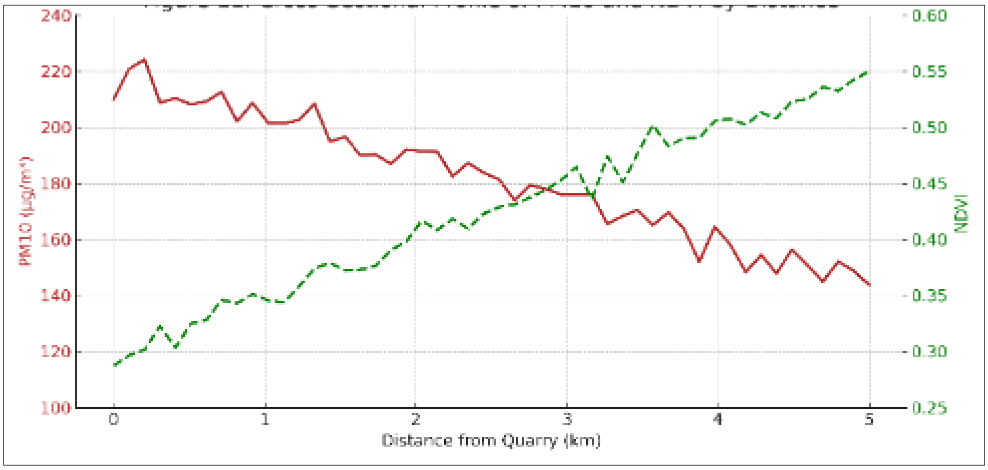

Figure 11 Cross-Sectional Profile of PM10 and NDVI by Distance. This dual-axis profile demonstrates the inverse relationship between dust concentration and vegetation health. PM10 values decline steadily with distance from the quarry, while NDVI scores increase, indicating recovering vegetation in less polluted zones

A pseudo-3D model in Figure 12 integrates elevation, dust concentration, and land use overlays to depict the topographical influence on dust dispersion.

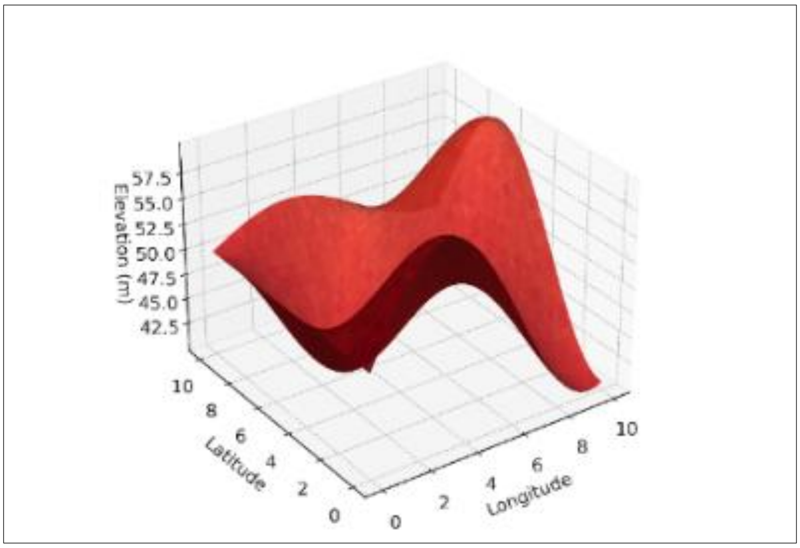

Figure 12 3D Surface Model of Dust and Land Cover Interaction. This 3D model integrates elevation with simulated dust intensity to visualize how topography influences particulate dispersion. Higher terrain appears to buffer some dust spread, while lower-lying and exposed areas show higher dust accumulation

5. Interpretation and Literature Alignment

The spatial patterns uncovered in this study reveal significant land use and air quality transformations in Logan County, Kentucky, over the past two decades, strongly influenced by cement manufacturing and limestone quarrying. A notable tripling in quarry land cover from 4.2% in 2003 to 17.9% in 2023—alongside a 45.7% reduction in vegetation cover—highlights the extent of industrial land conversion. These findings are consistent with patterns observed in quarryimpacted environments globally, where vegetation attrition and urban encroachment follow rapid industrial development (Akintunde & Adewusi, 2020).

The parallel increase in built-up areas reflects population influx and infrastructure development driven by industrial opportunities. Such unregulated expansion mirrors trends in other rapidly industrializing regions such as Addis Ababa, Ethiopia, and Gauteng, South Africa, where urban sprawl fragmented ecological zones and intensified environmental pressures (Melesse et al., 2007; Mngadi et al., 2022). In similar U.S. regions, such as parts of Texas and Pennsylvania, comparable transformations have been documented in relation to extractive industrial hubs.

Dust pollution analysis amplifies the environmental burden. PM10 levels measured across the six sampling sites exceeded both the World Health Organization (WHO) and U.S. Environmental Protection Agency (EPA) thresholds (50 $\mu g/m^3$ and 150 $\mu g/m^3$, respectively), with peak concentrations reaching 221 $\mu g/m^3$. These values are consistent with those reported in cement-producing regions in the southern U.S. and in international contexts such as Bamburi, Kenya, where elevated PM10 levels have also been documented (Kamau et al., 2017).

Spatial interpolation of Aerosol Optical Depth (AOD) confirmed persistent particulate matter hotspots, particularly around haulage routes and operational facilities. AOD trends from MODIS data showed a clear upward trajectory from 2013 to 2023, supporting evidence of intensifying emissions. Zhao et al. (2021) similarly demonstrated that AOD serves as a reliable proxy for particulate monitoring in data-scarce regions.

Overlay analyses identified clear spatial correlations between areas of NDVI reduction and high AOD concentrations, indicating vegetation stress linked to dust deposition. These findings align with previous research indicating that dust particles reduce photosynthetic efficiency, alter leaf morphology, and degrade soil conditions (Oyinloye & Adekoya, 2016).

The 2 km buffer analysis around the quarry perimeter revealed a 28% reduction in NDVI values and consistently elevated PM10 levels relative to areas farther from the site. This spatial exposure gradient aligns with findings in other U.S. states where industrial proximity has been associated with increased respiratory risk and ecological degradation.

Topographic modeling introduced a valuable third dimension by demonstrating how local terrain influences dust dispersion. Elevated terrain acted as a natural buffer, producing downwind zones with reduced AOD levels, while low-lying zones experienced intensified dust accumulation. Kamara et al. (2019) similarly highlighted the amplifying effects of valleys on pollutant migration.

Collectively, the integration of satellite imagery, geostatistical modeling, in situ PM10 measurements, and NDVI assessments has produced a multidimensional understanding of land degradation and atmospheric pollution in Logan County. The methodological framework aligns with best practices in environmental remote sensing and risk assessment. The study advocates enhanced air quality regulation, vegetation buffer restoration, and strategic zoning reforms to mitigate further ecological and public health risks in limestone-rich industrial zones.

6. Recommendations and Policy Relevance

The findings of this study underscore the urgent need for targeted environmental management and policy interventions in limestone-rich industrial regions like Logan County, Kentucky. First, regulatory agencies such as the Kentucky Division for Air Quality and the U.S. Environmental Protection Agency (EPA) should implement stringent dust mitigation protocols, including regular PM10 monitoring and enforcement of emission controls on haulage operations and crushing plants.

Second, land use planning frameworks should incorporate buffer zones between quarry operations and residential settlements. A minimum setback of 2.5 km is advised, based on the elevated dust concentrations and NDVI decline observed within this radius. Development within this buffer should be limited to non-residential, low-risk uses.

Third, quarry operators should be mandated to implement progressive land reclamation practices, including revegetation of exhausted pits and the construction of dust barriers using natural windbreaks. Such ecological restoration not only reduces dust dispersion but also contributes to biodiversity conservation and carbon sequestration.

Fourth, local planning authorities should integrate remote sensing data into their environmental impact assessments (EIAs) and land use audits. Satellite-derived AOD and NDVI data offer cost-effective tools for long-term monitoring of industrial impacts on air quality and vegetation health.

Lastly, public awareness and community health outreach should be expanded to ensure local populations understand the health risks of particulate exposure and the importance of vegetation buffers. Participatory environmental governance involving host communities can enhance compliance and sustainability.

Together, these measures can support a more balanced approach to industrial development that protects environmental integrity and human health in limestone mining regions.

7. Conclusion

This study presents a comprehensive spatial analysis of land use transformation and dust pollution in the limestone-rich mining corridor of Logan County, Kentucky. Through an integration of multi-temporal Landsat imagery, MODIS-derived AOD data, and in situ PM10 measurements, the research provides empirical evidence of significant environmental change over the past two decades.

The findings reveal a marked decline in vegetation cover, a rapid expansion of quarry and built-up areas, and elevated levels of particulate matter within a 2–3 km radius of mining operations. These changes have not only reshaped the landscape but also introduced environmental stressors with potential ecological and public health consequences. The observed spatial correlation between dust hotspots and vegetation degradation zones suggests that quarry-induced particulate emissions are a critical driver of ecological stress.

By combining remote sensing techniques with geospatial analytics, this study demonstrates an effective framework for assessing the dual challenge of land degradation and air pollution in industrial zones. The methodological approach is scalable and applicable to other quarrying regions across the United States, especially where ground-based monitoring infrastructure is limited.

Ultimately, the study emphasizes the need for proactive land use planning, continuous environmental monitoring, and inclusive policy responses that prioritize both industrial productivity and ecosystem health. The insights generated can guide future interventions aimed at balancing economic development with environmental sustainability in mining-impacted landscapes.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Akintunde, E. A., & Adewusi, H. O. (2020). Remote sensing assessment of land degradation from cement manufacturing in Obajana, Nigeria. Environmental Monitoring and Assessment, 192(3), 1–15. https://doi.org/10.1007/s10661-020-08130-0

[2] Akinola, M. O., Njoku, K. L., & Adesuyi, A. A. (2014). Assessment of particulate matter around cement plants in Nigeria. Nigerian Journal of Science, 48(1), 11–19.

[3] Gbadebo, A. M., & Bankole, O. D. (2007). Analysis of particulate concentration from cement production in Obajana, Nigeria. Journal of Applied Sciences and Environmental Management, 11(3), 45–49.

[4] Kamara, I., Okonkwo, O., & Mkhize, M. (2019). Effect of topography on dust dispersion in mining environments. Journal of Environmental Sciences, 82(4), 375–384. https://doi.org/10.1016/j.jes.2019.01.007

[5] Kamau, J., Muthama, N., & Ongoma, V. (2017). Particulate pollution and health impact in quarrying environments in Kenya. Environmental Research and Public Health, 14(6), 1–11. https://doi.org/10.3390/ijerph14060549

[6] Melesse, A. M., Jordan, J. D., & Abtew, W. (2007). Remote sensing applications for monitoring land-use and land-cover changes in the Caribbean region. Sensors, 7(12), 2914–2942. https://doi.org/10.3390/s7122914

[7] Mngadi, T. T., Dlamini, T., & Khumalo, M. (2022). Industrial encroachment and land use change in Southern Africa. Environmental Change Review, 18(2), 201–215.

[8] Oyinloye, A. O., & Adekoya, J. A. (2016). Land use transformation and environmental impact of cement manufacturing in southwestern Nigeria. Environmental Research and Development Journal, 10(2), 15–23.

[9] Zhao, B., Hu, Y., Guo, S., & Li, Y. (2021). Estimating PM2.5 concentrations from MODIS AOD using machine learning models in African cities. Atmospheric Pollution Research, 12(5), 101045. https://doi.org/10.1016/j.apr.2021.101045