**Original Research Article**

**Distance Gradient Effects of Mining on Tree Composition and Forest Structure in Central Indian Tropical Dry Deciduous Forests**

# Abstract

This study investigates the impact of mining-related disturbances on forest structure and biodiversity in tropical dry deciduous forests within the Katghora Forest Division of Chhattisgarh, India. Vegetation sampling was carried out across four zones situated at increasing distances from a coal mining site to assess variations in species composition, diversity, and structural attributes. Sixty species and 3,007 individual trees were recorded and analyzed using ecological indices, including the Shannon-Wiener Index, Simpson's Dominance and Diversity Indices, Pielou's Evenness, and Margalef's Richness Index. Results revealed a gradient in forest conditions. Zone I (nearest to the mining site) showed the highest species richness but the lowest basal area, suggesting early successional stages with high disturbance. In contrast, Zone IV (farthest from the mine) exhibited higher basal area, evenness, and diversity, indicative of a more mature and stable forest. One-way ANOVA confirmed significant differences in ecological parameters across zones. The findings highlight the adverse effects of mining on forest ecosystems and underscore the need for restoration and conservation efforts to maintain ecological resilience in disturbed landscapes.

**Keywords:** Diversity, Indices, Ecological, Anthropogenic, Mining, Biodiversity

**Introduction**

Mining is an important and essential in the economic development plan of any country enriched with mineral resources (Unanaonwi and Amonum, 2017). The process of mining especially surface mining is removing rocks, soil, and vegetation in order to extract valuable minerals (Nayak, 2010), can significantly increase the global carbon dioxide (CO2) emission of by deforestation and forest degradation. Forests are essential for maintaining biodiversity, controlling hydrological cycles, and storing carbon in the atmosphere (FAO 2020). Tropical forests contain the highest levels of species richness and are home to almost two-thirds of Earth's terrestrial biodiversity (Barlow et al. 2021, Sagar et al., 2003). Tropical dry deciduous forests predominate in most of central India, including Chhattisgarh state, where forests occupy over 44% of the land area (Negi et al., 2015). These forests are especially significant because they provide livelihoods for communities that depend on them, operate as carbon sinks, support a diverse range of plants and animals, and control the hydrological cycle. In regions like Katghora Forest Division in korba district, increasing anthropogenic pressures such as coal mining have significantly altered natural forest structures. The transformation of land for mining and industrial use leads to habitat loss, fragmentation, and a decline in tree species diversity and regeneration potential (Neeraja et al., 2021). Comparative assessments of forest ecosystems along disturbance gradients have consistently shown shifts in species composition, structure, and reduced floristic diversity with increasing disturbance intensity (Sagar et al., 2003). For example, studies conducted in dry tropical forests have demonstrated a marked decline in species richness and uneven distribution of trees in areas exposed to frequent anthropogenic activities such as logging, fire, grazing, and mining (Negi et al., 2015; Neeraja et al., 2021). These pressures not only reduce biodiversity but also affect ecological resilience and the ability of forests to recover from degradation.

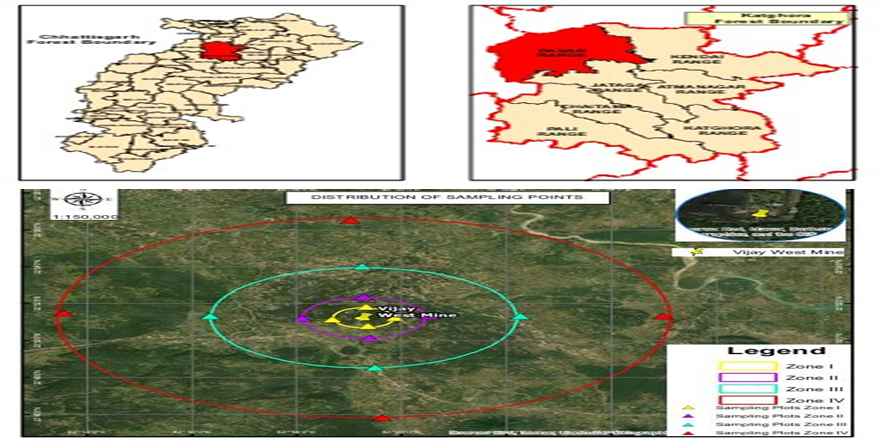
Understanding how mining and other disturbances affect forest dynamics is essential for developing effective conservation strategies and rehabilitation frameworks in tropical regions. Monitoring tree population structure, composition, and diversity can provide critical insights into the ecological health of the forest and guide restoration efforts in degraded landscapes such as Katghora.

Given the ecological importance of tropical dry deciduous forests and the increasing anthropogenic pressures—particularly mining-related disturbances—in the Katghora Forest Division, it becomes crucial to assess how these activities influence forest composition and diversity. The present study is therefore designed To compare tree species distribution patterns between relatively undisturbed and heavily disturbed forest patches to identify signs of ecological degradation and community shift.

**Materials and Method**

**Study Area**

The study was conducted in the Pasan range of the Katghora Forest Division**,** located in the Korba District of Chhattisgarh, central India. This region is characterized by tropical dry deciduous forests dominated by species such as *Tectona grandis*, *Terminalia tomentosa*, *Diospyros melanoxylon*, and *Lagerstroemia parviflora*. An approximate geographical location of Latitude: 22.8367° N, Longitude: 82.3074° E, and Elevation Approximately 325 meters above sea level.



**Fig 1:** Study Area

The terrain mixes undulating hills, plateaus, and plains interspersed with dense, degraded forest patches. The climate of the study area is tropical monsoon with three distinct seasons: Summer (March-June)**:** Temperatures range from 30°C to 46°C with low humidity. Monsoon (July-September)**:** Most of the annual rainfall is received. The average annual rainfall is 1200-1600 mm**,** mostly from the southwest monsoon. Winter (November–February)**:** Cool and dry, with temperatures ranging between 10°C to 25°C**.**The forest has seen increasing fragmentation due to coal mining, road expansion, and other land-use changes. The focus area includes the regions surrounding the Vijay West Coal Mine and nearby forested villages, which experience varying degrees of anthropogenic disturbances due to mining activities. Four sites were selected based on the distance from the mining site: Zone I, II, III and IV located at 1, 2, 5 and 10 km from coal mining zone respectively. Each site type included four replicates in each direction, leading to sixteen sampling locations. Each sampling location has nested quadrat. Vegetation sampling was conducted using 31.62 m × 31.62 m quadrats (0.1 ha) with ≥20 cm GBH. All individuals were identified at the species level, and data on girth at breast height (GBH), height, and abundance were recorded

# Data Analysis

The collected data were analyzed using the following ecological indices and statistical tools:

Species Richness (S) and Shannon-Wiener Diversity Index (H')**:** To assess species diversity across disturbance gradients.

Shannon −  = − ∑ 𝑝𝑖 × ln 𝑝𝑖 Eq. (1)

Simpson's Index of Dominance (D)**:** To determine species dominance in each site.

Simpson′s Diversity Index (D) = ∑𝑆 𝑝𝑖2 Eq. (2)

𝑖=1

Simpson′s Diversity Index (1-D) =Eq. (3)

Pielou's Evenness Index (E) (Pielou, 1975) takes rare species into account.

Pielou′s Evenness Index (E) = Eq. (4)

Margalef's Richness Index (d) to quantify species richness, accounting for the number of species and individuals:

Margalef's Richness Index (d)= Eq. (5)

Basal Area (m²/ha)**:** Calculated from GBH data to assess forest structure.

BA = 0.00007854 × DBH2 Eq. (6)

# Results and Discussion

A comparative analysis of floristic diversity and structural parameters was conducted across four zones at increasing distances from the mining site. Zone I was the nearest and Zone IV the farthest. A gradient in species richness, diversity, and stand structure was observed, suggesting varying degrees of anthropogenic disturbance.



60

50

40

30

20

Zone I Zone II Zone III Zone IV

10

0

20-40 40-60 60-80 80-100 100-150 150<

**GBH**

Fig 2: Percentage of species composition of different girth

**Species Percentage %**

The observed variation in species richness, diversity, and forest structural attributes across the four zones provides strong evidence for a clear ecological gradient driven by proximity to mining activities. This gradient reflects not only the spatial influence of disturbance but also the successional trajectory of the forest ecosystem in response to anthropogenic stressors.

Table 1: Diversity indices of different zones of the study area

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Index** | **Zone I** | **Zone II** | **Zone III** | **Zone IV** |
| Total Species (S) | 37 | 32 | 25 | 28 |
| Total Individuals (N) | 677 | 706 | 831 | 793 |
| Basal area (m2 ha-1) | 13.42 | 16.94 | 22.35 | 22.88 |
| Shannon-Wiener Index (H') | 2.6319 | 2.4156 | 2.3115 | 2.5580 |
| Simpson's Dominance Index (D) | 0.1095 | 0.1317 | 0.1335 | 0.0979 |
| Simpson's Diversity Index (1 - D) | 0.8905 | 0.8683 | 0.8665 | 0.9021 |
| Pielou's Evenness (E) | 0.7289 | 0.697 | 0.7181 | 0.8690 |
| Margalef's Richness Index | 5.5234 | 4.7260 | 3.5700 | 4.0444 |

Margalef's Richness Index (5.52) and species richness (S = 37) were highest in Zone I, which was closest to the mining activity. A more thorough ecological analysis reveals a different reality, despite the initial suggestion of a very bio diverse environment. Zone I has the lowest basal area (13.42 m² ha⁻¹) despite this richness, suggesting that the forest is primarily made up of smaller and probably younger individuals. The classification of this area as a regenerating or early successional forest is further supported by the preponderance of trees in the lower DBH classes (20–40 cm). In disturbed ecosystems, where fast-growing, opportunistic, or pioneer species quickly occupy open niches generated by habitat disruption, this paradox of high richness but low structural complexity is common (Chazdon, 2003; Meyer et al 2021). The establishment of climax species and the development of complex forest structures are hampered by mining activities, which frequently result in extensive deforestation, soil compaction, and microclimatic changes (Bian & Lu, 2013; Jafari et al., 2022; Jentsch et al. 2022). Similar trends have been observed in the Amazon region of Peru. Pioneer species predominated at mining-affected areas, according to Kaushal & Baishya (2021); Bury & Dyderski (2025), which resulted in exaggerated species counts but poor biomass and basal area. These results are consistent with the trends seen in Zone I and imply that diminished ecosystem maturity and halted forest development are related to mining proximity.

Zone IV, the location most far from the mining influence, displayed notably distinct biological features at the other end of the gradient. This zone has the highest basal area (22.88 m² ha⁻¹), Simpson's Diversity Index (1 - D = 0.9021), and evenness (E = 0.8690), despite having a lower total species richness (S = 28). These measurements point to a better developed and ecologically balanced forest structure where no species dominates the community. This change in structural and compositional characteristics is in line with trends seen in late-successional or undisturbed forests, where resource partitioning permits greater functional diversity and slower-growing, shade-tolerant species predominate (Laurance et al., 1998; Dislich 2011; Wilfahrt et al., 2016). Greater basal area and bigger trees in Zone IV suggest a longer duration of ecological stability and less human influence. According to Mangen et al. (2020), these intact regions in Brazil's Atlantic Forests have higher ecological resilience and structural integrity despite occasionally having fewer species. To sustain ecosystem services like nutrient cycling, carbon storage, and habitat provision, these systems depend more on functional diversity and balanced species composition than on the sheer number of species..

Between the severely disturbed Zone I and the intact Zone IV, Zones II and III showed intermediate values for the majority of ecological parameters. These zones, which show disturbed and recovering ecosystem traits, are probably in an ecological, structural, and compositional transition. Interestingly, Zone III exhibited the lowest species richness and diversity indices despite recording the greatest number of individuals (N = 831). This points to the phenomena known as density compensation, in which the abundance of a small number of tolerant species increases to compensate for the loss of species diversity. Degraded secondary forests frequently exhibit this pattern, with a small number of generalist or disturbance-adapted species monopolising ecological niches (Pardini et al. 2017). This situation is similar to findings from tropical forests in Southeast Asia, where Dhyni et al. (2019) reported high stem densities in forests that had been somewhat disturbed. They also found that the dominance of a few number of fast-growing, competitive species had reduced species diversity. The consequences are substantial: biodiversity and ecological functionality may continue to be in danger even though forest cover may appear to recover.

A fundamental ecological concept is shown by the general pattern observed in all zones: the severity of mining impacts decreases as one gets farther away from the source of the disturbance. A successional process influenced by human pressure is suggested by the gradient from high richness but low structure (Zone I) to reduced richness but higher structural maturity (Zone IV). Forest resilience is undermined by mining, which has long been identified as a primary cause of habitat fragmentation, soil degradation, hydrological modification, and microclimatic disruption (Timms 2023; Tannor., 2024). Similar spatial gradients were documented by Brandt et al. (2013) in Canadian boreal forests, where zones close to mineral extraction demonstrated sharp declines in biodiversity as a result of extensive canopy and soil disturbances. These impacts on forest systems next to extractive industries are not unique; rather, they are part of a global trend. According to McDowell & Potter (2022), the kind of forest, the severity of the disturbance, and the biological history of the site all affect how quickly a site recovers from such disturbances. Restoration must therefore be customised to the biophysical characteristics and degradation routes of each impacted site.

The study's conclusions directly affect conservation planning and forest management in areas affected by mining. Zones nearer the mining front in the early successional stages need to be treated right away to stop biodiversity loss and long-term degradation. Planting trees and restoring native species composition, functional diversity, and structural complexity should be the top priorities of restoration projects. Reforested transition zones and conserved remnant patches are examples of ecological buffers that can be essential for soil regeneration, microclimate stabilisation, and species dispersal. These tactics have worked well in post-mining settings in South America; Griscom and Ashton (2011) showed that restoration projects that used pre-existing forest pieces and soil amendment techniques boosted regeneration. In addition, Bernard et al. (2017) make the case for comprehensive ecological restoration frameworks that guarantee the complete reassembly of ecosystem processes, going beyond biomass recovery. To address continuous ecological changes, this entails combining long-term monitoring, adaptive management, and local ecological expertise.

# The geographical distribution of species diversity, richness, and structural characteristics throughout the zones under study provides a convincing illustration of ecological gradients brought about by mining. The fragility of such biodiversity is highlighted by the damaged zones' low ecological stability and structural immaturity, even if species richness may first seem high there. On the other hand, ecologically balanced and structurally complex communities that are indicative of greater forest health and resilience are supported by more remote and less disturbed zones. A workable solution to lessen the long-term ecological effects of mining and encourage sustainable forest recovery is targeted restoration, which is informed by ecological principles and actual data. To track developments and improve restoration tactics suited to the particular circumstances of post-mining landscapes, further investigation and observation will be necessary.

# Conclusion

This study reveals the notable biological differences in biodiversity and forest structure along a disturbance gradient brought on by mining operations. The findings show that Zone I, the areas nearest to the mining site, has lower structural maturity but higher species richness, indicating an environment dominated by early successional species and impacted by frequent disruptions. On the other hand, Zone IV, which is the area furthest away from the mining site, has larger basal area, more balanced species distribution, and more structural complexity—all of which are signs of more established and stable forest ecosystems. With modest species richness and diversity values, the intermediate zones (Zones II and III) had transitional features and highlighted a gradient of ecological recovery or degradation affected by the level of anthropogenic impact. The impact of the mining ecological footprint is spatially extensive, as evidenced by its decreasing influence with distance from the mining site. These results highlight the critical need for ecological restoration and conservation measures close to mining areas. Reforestation initiatives employing native species, habitat establishment, and efficient land-use planning may all aid in reducing the negative effects of mining and promoting forest regeneration. To fully evaluate ecosystem health and recovery paths, future studies should concentrate on long-term monitoring and incorporate soil quality, faunal diversity, and regeneration dynamics.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

DECLARATION OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that they have no known competing financial interests OR non-financial interests OR personal relationships that could have appeared to influence the work reported in this paper.

# References

Barlow, J., Lennox, G.D., Ferreira, J., et al. (2021). The future of tropical forests in the Anthropocene. Nature Communications, 12(1), 2616.

Bernard-Jannin, L., Sun, X., Teissier, S., Sauvage, S., & Sánchez-Pérez, J. M. (2017). Spatio-temporal analysis of factors controlling nitrate dynamics and potential denitrification hot spots and hot moments in groundwater of an alluvial floodplain. *Ecological Engineering*, *103*, 372-384.

Bian, Z., & Lu, Q. (2013). Ecological effects analysis of land use change in coal mining area based on ecosystem service valuing: a case study in Jiawang. *Environmental Earth Sciences*, *68*, 1619-1630.

Brandt, J. P., Flannigan, M. D., Maynard, D. G., Thompson, I. D., & Volney, W. J. A. (2013). An introduction to Canada’s boreal zone: ecosystem processes, health, sustainability, and environmental issues. *Environmental Reviews*, *21*(4), 207-226.

Bury, S., & Dyderski, M. K. (2025). Invasive tree species affect terricolous bryophytes biomass and biodiversity in nutrient-poor but not nutrient-rich temperate forests. *Scientific Reports*, *15*(1), 5272.

Chazdon, R. L., Careaga, S., Webb, C., & Vargas, O. (2003). Community and phylogenetic structure of reproductive traits of woody species in wet tropical forests. *Ecological monographs*, *73*(3), 331-348.

Dislich, C. (2011). *The role of life history traits for coexistence and forest recovery after disturbance–a modelling perspective. Towards a better understanding of species-rich forests* (Doctoral dissertation).

Forest Survey of India (FSI). (2021). *India State of Forest Report 2021*. Available at: <https://fsi.nic.in/forest-report-2021-details>

Griscom, H. P., & Ashton, M. S. (2011). Restoration of dry tropical forests in Central America: A review of pattern and process. *Forest Ecology and Management*, *261*(10), 1564-1579.

Jafari, M., Tahmoures, M., Ehteram, M., Ghorbani, M., & Panahi, F. (2022). The role of vegetation in confronting erosion and degradation of soil and land. In *Soil erosion control in drylands* (pp. 33-141). Cham: Springer International Publishing.

Jentsch, A., von Heßberg, A., Schuchardt, M., & Gutt, J. (2022). Disturbance Regimes and Climate Extremes of the Earth’s Vegetation Zones. In *Disturbance ecology* (pp. 41- 75). Cham: Springer International Publishing.

Kaushal, S., & Baishya, R. (2021). Stand structure and species diversity regulate biomass carbon stock under major Central Himalayan forest types of India. *Ecological Processes*, *10*, 1-18.

Laurance, W. F., Delamonica, P., Laurance, S. G., Vasconcelos, H. L., & Lovejoy, T. E. (1998). Rainforest fragmentation and the structure of Amazonian liana communities. *Ecology, 79*(4), 1484–1495.

McDowell, W. H., & Potter, J. D. (2022). Context dependence in a tropical forest: Repeated disturbance reduces soil nitrate response but increases phosphate. *Ecosphere*, *13*(6), e4068.

Meyer, S. E., Callaham, M. A., Stewart, J. E., & Warren, S. D. (2021). Invasive species response to natural and anthropogenic disturbance. *Invasive species in forests and rangelands of the United States: A comprehensive science synthesis for the United States forest sector*, 85-110.

Neeraja, U. V., Rajendrakumar, S., Saneesh, C. S., Dyda, V., & Knight, T. M. (2021). Fire alters diversity, composition, and structure of dry tropical forests in the Eastern Ghats. *Ecology and Evolution*, 11(12), 7481–7491. <https://doi.org/10.1002/ece3.7552>

Negi, C., Singh, L., Attri, V., & Sarvade, S. (2015). Tree species diversity, distribution and population structure in a tropical dry deciduous forests of Chhattisgarh, India. *Journal of Applied and Natural Science*, 7(2), 857–861. https://doi.org/10.31018/jans.v7i2.666

Pardini, R., Nichols, E., & Püttker, T. (2017). Biodiversity response to habitat loss and fragmentation. *Encyclopedia of the Anthropocene*, *3*, 229-239.

Rao, P., Barik, S. K., Pandey, H. N., & Tripathi, R. S. (1990). Community composition and tree population structure in a sub-tropical broad-leaved forest along a disturbance gradient. *Vegetatio*, 88(2), 151–162. https://doi.org/10.1007/BF00044832

Raven, P., & Wackernagel, M. (2020). Maintaining biodiversity will define our long-term success. *Plant Diversity, 42*(4), 211–220.

Sagar, R., Raghubanshi, A. S., & Singh, J. S. (2003). Tree species composition, dispersion and diversity along a disturbance gradient in a dry tropical forest region of India. *Forest Ecology and Management*, 186(1–3), 61–71. https://doi.org/10.1016/S0378- 1127(03)00235-4

Sarma K. Impact of coal mining on vegetation: a case study in Jaintia hills district of Meghalaya, India. M.Sc. Thesis. International Geoinformation, 2005.

Stork, N. E., & Habel, J. C. (2014). Can biodiversity hotspots protect more than tropical forest plants and vertebrates? *Journal of Biogeography, 41*(3), 421–428.

Tannor, S. J. (2024). *Climate-Mining interactions and the effects on rural resilience* (Doctoral dissertation, Universitäts-und Landesbibliothek Bonn).

Thompson, D. K., & Waddington, J. M. (2008). Sphagnum under pressure: towards an ecohydrological approach to examining Sphagnum productivity. *Ecohydrology: Ecosystems, Land and Water Process Interactions, Ecohydrogeomorphology*, *1*(4), 299- 308.

Timms, M. (2023). *Tropical forest fragmentation: a global review and African insights* (Doctoral dissertation, Stellenbosch University).

Unanaonwi OE, Amonum JI. Effect of Mining Activities on Vegetation Composition and nutrient status of Forest Soil in Benue Cement Company, Benue State, Nigeria. International Journal of Environment, Agriculture and Biotechnology (IJEAB). 2017; 2(1).

Wilfahrt, P. A. (2016). *From old fields to forests: Understanding plant successional dynamics through the lens of functional traits* (Doctoral dissertation, The University of North Carolina at Chapel Hill).