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Research Article

IDENTIFICATION AND CHARACTERIZATION OF FLORA IN THE AREA OF FORMER CLAY MINING AT THE TUBAN CEMENT FACTORY

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Abstract

The study of plant species diversity and vegetation structure in clay post-mining areas of Tuban, East Java, reveals significant insights into ecological recovery and community dynamics. Method this research Field surveys, site mapping, and vegetation assessments were carried out from the second week of July to the second week of August 2022. The climate of the region is classified as tropical monsoonal, with distinct dry and wet seasons influencing vegetation dynamics. Result this finding the highest number of pole species is in SUM with 14 species while the lowest number of pole species is in TED with 4 species. The highest number of pile species is located in the SUM location with 22 species and the lowest number of pile species is located in the TED location with 4 species. For the seedling growth category, it tends to have more species, this is because at 22 sampling times tend to have high rainfall, so the nursery category becomes more abundant. The highest number of seedling species is located in SUG with 57 species while the lowest number of seedling species is located in TED with 28 species. Conclusion from the entire area, it can be said that terrestrial flora has "LOW to HIGH DIVERSITY" (H'=0.80-3.83).

Keywords: Identification, Characreization, Flora, Clay mining, Cement factory.

INTRODUCTION

Post-mining landscapes are among the most ecologically degraded ecosystems globally, characterized by significant vegetation loss and soil disturbance that severely diminish biodiversity and ecosystem functionality. Mining activities lead to extensive environmental degradation, including soil contamination and habitat destruction, which disrupts ecological balance and adversely affects local (Prach, 2016). Restoration efforts are critical yet challenging, as they must address harsh physical and chemical soil properties while promoting plant-soil feedbacks that enhance biodiversity recover (Li *et al.,* 2022). Effective rehabilitation strategies, such as soil remediation, reforestation, and the use of native species, are essential for restoring ecosystem services and functionality (Tibbett, 2024) (Muñoz-Rojas *et al.,* 2017). Moreover, successful restoration requires a multidisciplinary approach, integrating ecological, social, and regulatory frameworks to ensure sustainable outcomes and community resilience ("Revitalizing the Land: Ecosystem Restora...", 2024) (Tibbett, 2024). Ultimately, the complexity of post-mining ecosystem reconstruction necessitates innovative and adaptive management practices to achieve long-term ecological recovery (Anawar *et al.,* 2013). Post-mining areas in tropical countries like Indonesia face significant challenges due to their rich biodiversity and the pressures from industrial activities, particularly cement production. Studies indicate that effective reclamation practices can restore ecological functions and enhance biodiversity, as demonstrated by the successful reclamation efforts at PT Indocement, where diverse flora and fauna were observed alongside substantial carbon stock recovery (Patria *et al.,* 2025). Bird species, serving as bioindicators, reflect the health of these ecosystems, with high diversity indices noted in reclaimed areas, suggesting that certain species thrive while others remain less abundant (Syahputra *et al.,* 2025). Furthermore, comprehensive management strategies that integrate institutional frameworks and community engagement are essential for sustainable post-mining landscapes, emphasizing the need for a dual-pathway approach that combines technical rehabilitation with social empowerment (Siahaan *et al.,* 2025). Overall, the restoration of post-mining landscapes not only supports biodiversity but also contributes to climate change mitigation and community resilience (Pratiwi *et al.,* 2021) (Kusumoarto *et al.,* 2020). Problem Statement (Spesifik: Tambang Tanah Liat)Clay mining activities, particularly in cement industrial zones, lead to substantial alterations in vegetation structure, soil properties, and natural regeneration processes, resulting in simplified and unstable plant communities. Understanding floristic composition and vegetation structure in post-mining areas is crucial for evaluating ecological recovery and succession dynamics, as evidenced by various studies. For instance, Garate-Quispe et al. found significant changes in floristic composition and structure over 23 years in abandoned gold-mining lands in Peru, highlighting a rapid recovery in tree species density but slower recovery in species composition (Garate-Quispe *et al.,* 2024). Similarly, Riviera et al. noted that restoration outcomes in Australian shrublands varied significantly, influenced by management practices and environmental factors, with adaptive management improving recovery over time (Riviera *et al.,* 2021). Nurtjahyani et al.

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observed distinct floristic compositions in different-aged tin-mined lands in Indonesia, indicating that older sites had more complex vegetation structures (Nurtjahyani *et al.,* 2009). Furthermore, Yuningsih et al. reported that post-coal mining reclamation in Sumatra resulted in vegetation structures resembling natural forests, albeit with lower biodiversity (Yuningsih *et al.,* 2021). Lastly, Mudrak et al. emphasized the role of edaphic conditions in shaping vegetation dynamics in mining landscapes, suggesting that anthropogenic factors significantly influence succession (Mudrak *et al.,* 2026). Collectively, these studies underscore the importance of understanding floristic and structural dynamics for effective ecosystem restoration in post-mining

Previous studies on post-mining ecosystems have indeed emphasized species diversity indices and vegetation composition, often neglecting structural characteristics and site-specific recovery patterns, particularly in tropical clay mining areas. For instance, research in the kwongan vegetation of Australia highlighted significant variability in restoration outcomes, driven by factors such as age, fire, and seedling planting, indicating that structural recovery can differ markedly across sites (Riviera *et al.,* 2021). Similarly, studies in South Sumatra revealed that while pioneer species like Melaleuca cajuputi and Eucalyptus cyclocarpum dominated early stages, the overall community exhibited low diversity, suggesting that structural recovery is often limited by the dominance of a few species (Juniarto *et al.,* 2025). In the Peruvian Amazon, natural regeneration post-gold mining showed rapid recovery of tree density but slow species richness, emphasizing the need for a nuanced understanding of structural dynamics over time (Legoas *et al.,* 2024). Furthermore, a study in Chhattisgarh, India, identified a diverse array of species in limestone mines, underscoring the importance of assessing both composition and structural characteristics for effective ecological restoration (Maitry *et al.,* 2025). Thus, a comprehensive approach that includes structural assessments alongside diversity indices is essential for understanding recovery in these ecosystems.

Quantitative assessments of floristic diversity and vegetation structure in post-mining landscapes, particularly in regions like Tuban, are indeed limited. Research indicates that post-mining areas can support diverse plant communities, with studies revealing the presence of pioneer species that play crucial roles in ecological restoration. For instance, in limestone mining areas, species such as Lamium barbatum and Chromolena odoratum were identified as dominant, showcasing their potential for soil stabilization and habitat recovery (Andriani, 2019). Similarly, studies in coal mining reclamation highlighted the dominance of Acacia auriculiformis, which, while effective in initial recovery, can suppress indigenous flora (Riswan *et al.,* 2015). Furthermore, the importance of management strategies, such as renaturation over recultivation, has been emphasized to enhance biodiversity outcomes in disturbed landscapes (Acosta, 2025). These findings underscore the necessity for comprehensive studies in Tuban to document and manage its unique post-mining ecological dynamics effectively (Desiani, 2025)(Maitry *et al.,* 2025). The analysis of floristic composition and vegetation structure across clay post-mining sites reveals significant insights into ecological recovery patterns, particularly in cement industry landscapes. Studies indicate that vegetation recovery can vary widely, influenced by factors such as age, fire, and management practices, with adaptive management showing promise in enhancing restoration outcomes over time (Riviera *et al.,* 2021). In South Kalimantan, Indonesia, post-mining reclamation efforts demonstrated substantial ecological recovery, with increased biodiversity and carbon stocks, particularly in clay plots, although these exhibited lower carbon storage compared to other soil types (Patria *et al.,* 2025). Additionally, research in Brazil highlighted the natural regeneration of vegetation in abandoned mining sites, suggesting a transition towards more advanced successional stages, albeit with some invasive species hindering diversity (Lima *et al.,* 2020). Overall, effective management strategies, including renaturation, are crucial for maximizing biodiversity and ecological function in post-mining landscapes(Acosta, 2025).

The study of plant species diversity and vegetation structure in clay post-mining areas of Tuban, East Java, reveals significant insights into ecological recovery and community dynamics. Research indicates that pioneer species, such as Lamium barbatum and Chromolena odoratum, play a crucial role in stabilizing soil and promoting biodiversity in post-mining landscapes, as they are adapted to thrive in disturbed environments (Andriani *et al.,* 2019). Monitoring of macrozoobenthos in these areas has shown a diverse aquatic ecosystem, which contributes to the overall health of the habitat, indicating a complex interplay between terrestrial and aquatic systems (Oktafitria *et al.,* 2024). Furthermore, employing varied quadrat sizes for vegetation analysis has demonstrated distinct patterns of species composition and dominance, essential for understanding ecological succession and informing rehabilitation efforts (Mulya & Agatha, 2025). Overall, these findings underscore the importance of assessing both plant and macrozoobenthic diversity to enhance ecological restoration strategies in post-mining environments (Fajri & Garsetiasih, 2019).

MATERIALS AND METHODS

Study Area

This study was conducted in post-mining areas of clay extraction located within the operational region of PT Semen Indonesia (Persero) Tbk, Tuban Plant, East Java, Indonesia. Administratively, the study sites are situated in Kerek and Merakurak Districts, Tuban Regency. The study area represents a tropical post-mining landscape characterized by varying stages of ecological disturbance and vegetation recovery. Field surveys, site mapping, and vegetation assessments were carried out from the second week of July to the second week of August 2022. The climate of the region is classified as tropical monsoonal, with distinct dry and wet seasons influencing vegetation dynamics. The selected sites included former clay mining areas distributed across several villages, representing different environmental conditions and post-disturbance recovery stages. The geographic coordinates of each sampling location are presented in Table 1.

Study Site Mapping and Sampling Locations

The study locations were determined based on previous mining activities and ecological representativeness. The sampling sites specifically focused on clay mining areas, including Sugihan, Tobo, Mliwang, and Kasiman villages. These areas were selected to capture variations in vegetation structure and recovery conditions following mining disturbance.

Table 1. Geographic Coordinates of Study Sites in Clay Post-Mining Areas

No	Location	Code	Latitude (S)	Longitude (E)	Mining Type
1	Sugihan	SUG	06°50.954'	111°56.898'	Clay
2	Tobo	TOB	06°49.790'	111°53.981'	Clay
3	Mliwang	MLI	06°49.447'	111°54.243'	Clay
4	Kasiman	KAS	06°49'21.90”	111°54'38.40"	Clay

These sites were selected to ensure spatial consistency for long-term biodiversity monitoring and to minimize variability due to land-use changes.

Research Design

This study employed a field-based ecological survey using a quantitative descriptive approach to assess vegetation composition and structure in post-mining clay areas. The research design focused on vegetation analysis to evaluate biodiversity patterns and ecological conditions in disturbed landscapes. The study was conducted as part of a continuous environmental monitoring program, allowing for consistent observation of vegetation dynamics over time.

Vegetation Sampling Design

Vegetation sampling was conducted using a quadrat method to assess species composition and vegetation structure. Sampling plots measuring 20 × 20 m were established systematically across the study sites. Plot locations were selected randomly within each site to ensure representativeness of the overall vegetation condition. Each main plot was further subdivided into smaller subplots to accommodate different vegetation strata, allowing for detailed analysis of plant growth stages and structural composition. Vegetation was classified into four growth categories based on diameter and developmental stage: tree, pole, sapling, and seedling. This classification enabled a comprehensive assessment of vegetation regeneration and succession processes.

Data Collection Procedures

Within each sampling plot, all plant species were identified and recorded. For each individual plant, data were collected on species name, diameter at breast height (DBH), and abundance. Additional observations included plant height and general morphological characteristics to support species identification. Vegetation data collection followed standard ecological survey protocols to ensure consistency and comparability across sampling sites. Environmental observations, such as soil condition and disturbance level, were also noted to support ecological interpretation.

Vegetation Classification and Variable Definition

Vegetation structure was categorized into four strata based on plant size and growth stage. Trees were defined as woody plants with a diameter at breast height (DBH) ≥ 20 cm. Poles were defined as young trees with a DBH ranging from 7 cm to less than 20 cm. Saplings included smaller woody plants with a DBH below 7 cm but with a height exceeding 1.5 m. Seedlings were defined as young plants with a height below 1.5 m. This classification allowed for the evaluation of regeneration dynamics and vertical vegetation structure within the study area.

Data Analysis

Vegetation data were analyzed to determine species composition, dominance, and diversity. The Importance Value Index (IVI) was calculated for each species based on relative density, relative frequency, and relative dominance, providing an integrated measure of species ecological importance. Species diversity was quantified using the Shannon-Wiener diversity index (H'), which reflects both species richness and evenness within the community. Higher index values indicate greater biodiversity and ecological stability. Comparative analysis was conducted across different sites to identify patterns of vegetation recovery and ecological variation in post-mining landscapes. All statistical analyses were performed using standard data processing tools to ensure accuracy and reproducibility of results.

RESULTS

Condition of Terrestrial Flora Community

In general, the ecosystem in the mining area of PT Semen Indonesia (Persero) Tbk Tuban factory is an artificial ecosystem or has been degraded from the process of land clearing and clearing. Related to these conditions, of course, the biodiversity or biodiversity of existing flora and fauna is of lower value when compared to a community or ecosystem that has not undergone development. Observation of flora and fauna was carried out in 8 locations (Figure 2), namely Temandang Village (TED), Pongpongan Village (PON), Sumberarum Village (SUM), Sugihan Village (SUG), Tobo Village (TOB), Mliwang Village (MLI), Temaji Village (TEJ), and Kasiman Village (KAS) which were affected by mining activities. The Kasiman Village (KAS) area is an area affected by clay mining activities to date and Temaji Village (TEJ) is a mining plan area for clay and is currently still used as agricultural land local residents. In this chapter and so on, the writing of the observation location will use the acronym more. The following are the complete coordinates of each plot at the observation location (Table 1).

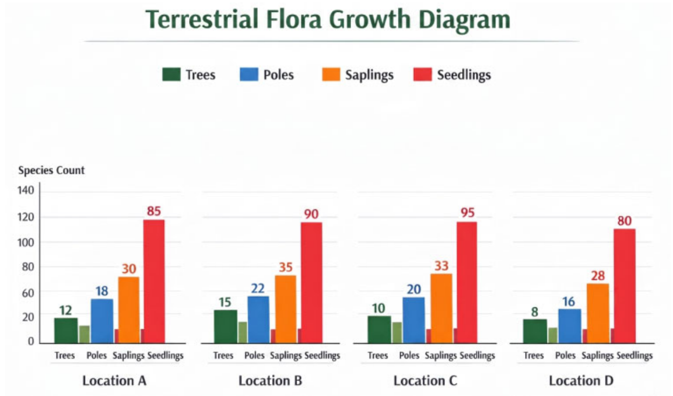
Table 2. Coordinates of the Location of the Biodiversity Study Environmental Monitoring of the Flora and Fauna Community of PT Semen Indonesia (Persero) Tbk Tuban Factory for the Period of July December 2022 Geographical Position

No	Lokasi	Variabel	Latitude (S)	Longitude (E)
1	Temandang (TED)	Fl, Fa	06º52.434'	111º55.616'
2	Pongpongan (PON)	Fl, Fa	06º52.741'	111º56.457'
3	Sumberarum (SUM)	Fl, Fa	06º52.704'	111º54.654'
4	Temaji (TEJ)	Fl, Fa	6°48'10.60”	111°54'6.30"
5	Sugihan (SUG)	Fl, Fa, P, B, N	06º50.954'	111º56.898'
6	Tobo (TOB)	Fl, Fa, P, B, N	06º49.790'	111º53.981'
7	Mliwang (MLI)	Fl, Fa, P, B, N	06º49.447'	111º54.243'
8	Kasiman (KAS)	Fl, Fa	6°49'21.90”	111°54'38.40"

Description: Fl = Flora;Fa = Fauna;P = Plankton;B = Bentos;N = Nekton

Composition and Abundance of Species

Data on the composition and abundance of terrestrial flora species at the mining study site of Temandang (TED); Pongpongan (PON); Sumberarum (SUM); Sugihan 21 (SUG); Tobo (TOB); Mliwang (MLI); Kasiman (KAS); and Temaji (TEJ) can be seen in the following salts:



The graph above shows that the highest number of tree species is in the PON of 10 species while the lowest number of tree species is in TED of 4 species. The highest number of pole species is in SUM with 14 species while the lowest number of pole species is in TED with 4 species. The highest number of pile species is located in the SUM location with 22 species and the lowest number of pile species is located in the TED location with 4 species. For the seedling growth category, it tends to have more species, this is because at 22 sampling times tend to have high rainfall, so the nursery category becomes more abundant. The highest number of seedling species is located in SUG with 57 species while the lowest number of seedling species is located in TED with 28 species. There are 10 dominant plant types in each growth category in all locations, which are as follows:

1. Tree growth categories consist of Samanea saman (Trembesi), Paraserianthes falcataria (Sea sengon), Swietenia mahagoni (Mahogany), Lannea coromandelica (Bejaran), Senna siamea (Johar), Artocarpus camansi (Kluwih), Azadirachta indica (Bamb), Musa paradisiaca (Banana), Enterolobium cyclocarpum (Sengon buto), and Tectona grandis (Teak).
2. Pole growth categories consist of Swietenia mahagoni (Mahogany), Lannea coromandelica (Jaran), Senna siamea (Johar), Paraserianthes falcataria (Sea sengon), Samanea saman (Trembesi), Tectona grandis (Teak), Musa paradisiaca (Banana), Artocarpus camansi (Kluwih), Manilkara kauki (Sawo kecik), and Azadirachta indica (Mimba).
3. The stake growth category consists of Musa paradisiaca (Banana), Tectona grandis (Teak), Leucaena glauca (Lamtoro), Manilkara kauki (Sawo kecik), Paraserianthes falcataria (Sea sengon), Mangifera indica (Mango), Swietenia mahagoni (Mahogan), Samanea saman (Trembesi), Senna siamea (Johar), and Artocarpus camansi (Kluwih).
4. Seedling growth category consists of Cynodon dactylon (Grinting grass), Chromolaena odorata (Grass), Tridax procumbens (Gletang), Cyperus rotundus (Grass Grass), Pennisetum purpureum (Elephant grass), Chrysopogon aciculatus (Needle grass), Digitaria sanguinalis (Grass), Eleusine indica (Grass), Imperata cylindrica (Reed), and Chloris barbata (Rocking flower grass),

DISCUSSION

The results of this study demonstrate that vegetation in clay post-mining areas is characterized by relatively low tree diversity but high abundance of intermediate growth stages, particularly pole-level vegetation.

The studied ecosystems are indeed in a secondary succession phase, characterized by ongoing vegetation recovery that has not yet achieved a stable or mature ecological state. Research indicates that during secondary succession, species richness and diversity often fluctuate, typically peaking at intermediate stages before declining, as observed in various ecosystems, including grasslands and tropical forests (Stadler *et al.,* 2025) (Sun *et al.,* 2017). For instance, in Mizoram, India, the recovery of tree and shrub species showed significant increases over 25 years, although herbaceous species declined, highlighting the complexity of recovery dynamics (Sahoo, n.d.). Similarly, in Venezuelan montane rainforests, species diversity and structural complexity increased with age, yet secondary forests remained distinct from mature forests, suggesting a prolonged recovery process (Howorth & Pendry, 2006). These findings collectively underscore that while ecosystems are progressing through secondary succession, they often exhibit transient states rather than reaching a stable climax community (Pignatti & Pignatti, 2014**).**

The dominance of pole-stage vegetation over trees and seedlings in post-disturbance ecosystems indicates a transitional phase characterized by specific ecological dynamics. Following disturbances such as fire or wind throw, early-successional species, including herbs and shrubs, often proliferate due to their rapid growth and colonization abilities, leading to a temporary imbalance in vegetation structure where these species outnumber trees and seedlings (Bonan, n.d.) (Swanson *et al.,* 2011). This phenomenon reflects the ecological memory and legacies left by previous vegetation, which influence recovery trajectories and species composition (Johnstone *et al.,* 2016). For instance, in a study of a pine-oak forest, areas affected by fire exhibited lower diversity and a predominance of early-successional species, highlighting the impact of disturbance severity on vegetation dynamics (Angeles *et al.,* 2022). Over time, as these early dominants decline, slower-growing, longer-lived tree species gradually establish, restoring a more balanced ecosystem structure (Schulze *et al.,* 2005). Thus, the observed dominance of pole-stage vegetation underscores the complex interplay of disturbance, succession, and ecological resilience in shaping forest ecosystems. The presence of seedlings and saplings across the study sites indicates active natural regeneration processes, although their relatively lower abundance may limit long-term ecosystem recovery.

Similar patterns of vegetation recovery in post-mining ecosystems have been observed across various studies, highlighting the dominance of early and intermediate successional stages due to environmental constraints and soil degradation. For instance, in the Peruvian Amazon, abandoned gold mining sites showed a slow natural regeneration process, with pioneer species like Ochroma pyramidale and Cecropia engleriana dominating early stages, comprising 63% of species in the first few years (Legoas *et al.,* 2024). In Eastern Germany, extensive research on post-mining landscapes revealed that primary succession is significantly influenced by abiotic factors, with vegetation recovery being documented over two decades (Jünger *et al.,* 2012). Similarly, in Western Australia, bauxite mining rehabilitation demonstrated that while native species richness increased with seeding, the overall composition remained distinct from unmined forests, indicating a unique successional trajectory (Norman *et al.,* 2006). Furthermore, a global review emphasized that post-mining sites generally recover faster than other primary succession areas, with various factors such as soil conditions. However, the lower tree diversity observed in this study compared to natural forest ecosystems highlights the incomplete recovery of vegetation structure in clay mining landscapes.

The establishment of late-successional species in ecosystems is often hindered by altered soil properties, nutrient limitations, and ongoing anthropogenic disturbances. For instance, studies indicate that agricultural practices significantly degrade soil quality, leading to reduced nutrient availability and altered soil structure, which restricts the recovery of native vegetation in post-agricultural landscapes (Tikhonova *et al.,* 2025). Similarly, in the campo rupestre grasslands, gravel extraction resulted in soils with lower nutrient concentrations and a predominance of non-target species in the seed bank, severely limiting the recovery of native plant communities (Stradic *et al.,* 2018). In subtropical forests, persistent anthropogenic disturbances have been shown to complicate the interplay between vegetation and soil, further exacerbating nutrient limitations and affecting species diversity during recovery (Huang *et al.,* 2018). Additionally, in the Central Himalayas, factors such as fire and grazing have been identified as significant barriers to the natural progression towards late-successional oak communities, illustrating how human activities can disrupt ecological

Ecological succession theory posits that ecosystems recover from disturbances through a series of predictable stages influenced by environmental conditions and species interactions. This process begins with pioneer species that are resilient to harsh conditions, gradually transitioning to a more diverse and competitive community as conditions stabilize (Shugart, 2024) (Lohnes, 2022). For instance, in seagrass ecosystems, recovery involves distinct seral stages where colonizing species facilitate the establishment of later successional species through mechanisms like sediment stabilization ("Seagrass resilience: Exploring recovery...", 2024). Additionally, disturbances can lead to shifts in community dynamics, where species interactions and functional trade-offs play critical roles in recovery(Kang *et al.,* 2024). The biodiversity of landscapes often peaks at intermediate disturbance levels, highlighting the complex interplay between disturbance, species composition, and ecosystem resilience (Shugart, 2024) (Kang *et al.,* 2024). Thus, understanding these dynamics is essential for effective ecosystem management and restoration efforts. Therefore, this study provides important insights into vegetation recovery patterns in clay post-mining areas and highlights the need for targeted restoration strategies to accelerate biodiversity recovery in industrial landscapes.

The absence of soil and microclimatic analyses in studies of vegetation succession in post-mining ecosystems limits the understanding of the complex interactions that drive these processes. Research indicates that abiotic factors, such as soil properties and microclimatic conditions, significantly influence plant community dynamics and succession. For instance, studies have shown that soil quality, including organic matter content and pH, affects species composition and richness in restored mining sites (Alday, 2011) ((Freitas, 2013) Additionally, microclimatic variations, such as moisture and temperature gradients, can lead to distinct vegetation communities, as observed in abandoned quarries(Stephan & Hubbart, 2022). The integration of these factors is crucial, as they not only shape the immediate vegetation response but also influence long-term ecological recovery and sustainability in disturbed landscapes (Wlodarczyk *et al.,* 2025) (Radosz *et al.,* 2024). Future research should prioritize these analyses to enhance restoration strategies and ecological understanding in post-mining environments.

Conclusion

The diversity index (H') of flora for the highest tree growth category is located in TOB (H'=1.68); pile growth is located in TEJ (H'=2.49); pile growth is located in SUM (H'=2.66); and seedling growth is located in TEJ (H'=3.83). From the entire area, it can be said that terrestrial flora has "LOW to HIGH DIVERSITY" (H'=0.80-3.83).

REFERENCES

1. Anawar, H. M., Canha, N., Santa-Regina, I., & Freitas, M. C. (2013). Adaptation, tolerance, and evolution of plant species in a pyrite mine in response to contamination level and properties of mine tailings: sustainable rehabilitation. *Journal of Soils and Sediments*, *13*(4), 730–741. https://doi.org/10.1007/S11368-012-0641-7
2. Andriani, R., Kurniahu, H., & Sriwulan, S. (2019). *Inventarisasi Tumbuhan Pionir Lahan Bekas Tambang Kapur Di Kecamatan Rengel Kabupaten Tuban Jawa Timur*. *3*(1), 56–61. https://doi.org/10.29080/BIOTROPIC.2019.3.1.56-61
3. Bonan, G. (n.d.). *Vegetation Dynamics*. https://doi.org/10.1017/cbo9781107339200.023
4. Campos Angeles, G. V., Ruiz González, M. Á., Reyes Hernández, V. J., Rodríguez Ortiz, G., & Enríquez del Valle, J. R. (2022). Estructura y diversidad vegetal en un bosque de pino encino con disturbios en diferentes cronosecuencias. *Madera Y Bosques*, *28*(1), e2812245. https://doi.org/10.21829/myb.2022.2812245
5. Desiani, A. (2025). Analisis Potensi Keanekaragaman Flora Pasca Proses Pertambangan Pasir Bukit Sepuluh Ribu di Kelurahan Cipari Kecamatan Mangkubumi Kota Tasikmalaya. *Jurnal Pangea Wahana Informasi Pengembangan Profesi Dan Ilmu Geografi*, *7*(1), 78–92. https://doi.org/10.33387/pangea.v7i1.10362
6. Fajri, M., & Garsetiasih, R. (2019). Komposisi jenis vegetasi lahan pasca tambang galian c di khdtk labanan, kabupaten berau. *Jurnal Penelitian Hutan Dan Konservasi Alam*, *16*(2), 101–118. https://doi.org/10.59465/jphka.16.2.101-118
7. Garate-Quispe, J., Canahuire-Robles, R., Alarcon-Aguirre, G., Dueñas-Linares, H., & Roman-Dañobeytia, F. (2024). Changes in floristic and vegetation structure in a chronosequence of abandoned gold-mining lands in a tropical Amazon forest. *Heliyon*. https://doi.org/10.1016/j.heliyon.2024.e29908
8. González Alday, J. (2011). Influencia de factores abióticos en la revegetación temprana tras hidrosiembra de estériles de carbón = Influence of abiotic factors in early revegetation after hydroseeding of coal mines. https://doi.org/10.35376/10324/778
9. Huang, F., Zhang, W., Gan, X., Huang, Y., Guo, Y., & Xiaoying, W. (2018). Changes in vegetation and soil properties during recovery of a subtropical forest in South China. *Journal of Mountain Science*, *15*(1), 46–58. https://doi.org/10.1007/S11629-017-4541-6

10. Husain, H. J., Wang, X., Pirasteh, S., Mafi-Gholami, D., Chouhan, B., Khan, M. L., & Gheisari, M. (2024). Review and assessment of the potential restoration of ecosystem services through the implementation of the biodiversity management plans for SDG-15 localization. *Heliyon*. https://doi.org/10.1016/j.heliyon.2024.e29877
11. Howorth, R. T., & Pendry, C. A. (2006). Post-cultivation Secondary Succession in a Venezuelan Lower Montane Rain Forest. *Biodiversity and Conservation*, *15*(2), 693–715. https://doi.org/10.1007/S10531-004-1061-9
12. Johnstone, J. F., Allen, C. D., Franklin, J. F., Frelich, L. E., Harvey, B. J., Higuera, P. E., Mack, M. C., Meentemeyer, R. K., Metz, M. R., Perry, G. L. W., Schoennagel, T., & Turner, M. G. (2016). Changing disturbance regimes, ecological memory, and forest resilience. *Frontiers in Ecology and the Environment*, *14*(7), 369–378. https://doi.org/10.1002/FEE.1311
13. Jünger, G., Baasch, A., Kirmer, A., Lorenz, A., & Tischew, S. (2012). Post-Mining Vegetation Database Eastern Germany. *Biodiversity and Ecology*, *4*, 363. https://doi.org/10.7809/B-E.00154
14. Juniarto, A., Hardiwinoto, S., Faridah, E., & Mansur, I. (2025). Regeneration status and floristic composition at pioneer stands on reclaimed ex-coal mine sites in South Sumatra, Indonesia. *Biodiversitas*, *26*(7). https://doi.org/10.13057/biodiv/d260735
15. Kang, D., Deng, L., Andersen, L. H., & Sándor, A. D. (2024). Editorial: Regeneration mechanisms and tradeoffs of ecosystem function after drastic environmental changes. *Frontiers in Ecology and Evolution*, *12*. https://doi.org/10.3389/fevo.2024.1531956
16. Knispel de Acosta, S. (2025). *Post-gypsum mining landscapes in Germany - Unveiling Biodiversity*. https://doi.org/10.5194/egusphere-egu25-20330
17. Kusumoarto, A., Kusumoarto, A., Gunawan, A., Machfud, & Hikmat, A. (2020). *The Biodiversity of Flora and Fauna in the Re-vegetation Area in The Post-Mining Area of Pongkor*. *501*(1), 012035. https://doi.org/10.1088/1755-1315/501/1/012035
18. Le Stradic, S., Le Stradic, S., Le Stradic, S., Fernandes, G. W., & Buisson, E. (2018). No recovery of campo rupestre grasslands after gravel extraction: implications for conservation and restoration. *Restoration Ecology*, *26*. https://doi.org/10.1111/REC.12713
19. Legoas, R. C., Rodriguez, D. R. O., Figueiredo, F. de M. de, Valdeiglesias, J. P., Pollito, P. A. Z., Peña, J. L. M., & Rother, D. C. (2024). Natural Regeneration After Gold Mining in the Peruvian Amazon: Implications for Restoration of Tropical Forests. https://doi.org/10.60692/8eskk-nr312
20. Lima, M. T., Tonello, K. C., Leite, E. C., Franco, F. S., & Corrêa, C. J. P. (2020). Dinâmica da recuperação ambiental de pilhas de estéril em mineração de calcário por regeneração natural. *Engenharia Sanitaria E Ambiental*, *25*(1), 11–19. https://doi.org/10.1590/S1413-41522020180571
21. Lohnes, D. (2022). *Community dynamics* (pp. 463–514). Elsevier eBooks. https://doi.org/10.1016/b978-0-323-85673-7.00018-6
22. Maitry, A., Patil, G., & Dubey, P. (2025). Quantitative Assessment of Vegetation Dynamics through Species Composition and Diversity Indices in Restoring Nandini Limestone Mines, Chhattisgarh. *International Journal of Bio-Resource and Stress Management*, *16*(Apr, 4), 01–11. https://doi.org/10.23910/1.2025.6035
23. Mudrak, O. V., Mahdiichuk, A., Mudrak, H., & Yermishev, O. V. (2026). Distinctive features of phytocenotic successions in mining-industrial landscapes. *Agrology*. https://doi.org/10.32819/202523
24. Mulya, B., & Agatha, G. (2025). Keanekaragaman dan Analisis Vegetasi Menggunakan Pola Kuadran dalam Ekologi Tumbuhan. *Tsaqofah*. https://doi.org/10.58578/tsaqofah.v6i2.8565
25. Muñoz-Rojas, M., Bateman, A., Erickson, T. E., Turner, S. R., & Merritt, D. J. (2017). The Soil Program of the Restoration Seedbank Initiative: addressing knowledge gaps in degraded soils for use in dryland restoration. 13688.http://ui.adsabs.harvard.edu/abs/2017EGUGA..1913688M/abstrac
26. Norman, M. A., Koch, J. M., Grant, C. D., Morald, T. K., & Ward, S. C. (2006). Vegetation succession after bauxite mining in Western Australia. *Restoration Ecology*, *14*(2), 278–288. https://doi.org/10.1111/J.1526-100X.2006.00130.X
27. Nurtjahya, E., Setiadi, D., Guhardja, E., Muhadiono, & Setiadi, Y. (2009). Succession on tin-mined land in Bangka Island. *Blumea*, *54*(1), 131–138. https://doi.org/10.3767/000651909X475491
28. Oktafitria, D., Purnomo, E., Nurtjahyani, S. D., & Sriwulan, S. (2024). Fungsi dan peran makrozoobentos di area embung lahan bekas tambang tanah liat di pt semen indonesia (persero) tbk pabrik tuban. https://doi.org/10.55719/binar.v3i1.100
29. Patria, W. A., Ariani, E., Sudiarta, I. W. K., Cangara, M. I. Z., Anshari, R., Hafizianor, Masrun, Susilawati, Shiba, Y. N., & Karim, H. (2025). Biodiversity and Carbon Stock as Indicators of Mine Reclamation Success at PT Indocement Tunggal Prakarsa, Tarjun, South Kalimantan, Indonesia. *International Journal of Research and Review*. https://doi.org/10.52403/ijrr.20251291
30. Pignatti, E., & Pignatti, S. (2014). *Vegetation in a Diachronic View* (pp. 597–629). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-31043-0_17
31. Prach, K., Prach, K., & Tolvanen, A. (2016). How can we restore biodiversity and ecosystem services in mining and industrial sites. *Environmental Science and Pollution Research*, *23*(14), 13587–13590. https://doi.org/10.1007/S11356-016-7113-3
32. Pratiwi, B. H. N., Siregar, C. A., Turjaman, M., Hidayat, A., Rachmat, H. H., Mulyanto, B., Suwardi, Iskandar, Maharani, R., Rayadin, Y., Prayudyaningsih, R., Yuwati, T. W., Prematuri, R., & Susilowati, A. (2021). Managing and Reforesting Degraded Post-Mining Landscape in Indonesia: A Review. *Land*, *10*(6), 658. https://doi.org/10.3390/LAND10060658
33. Revitalizing the Land: Ecosystem Restoration in Post-Mining Areas. (2024). https://doi.org/10.5281/zenodo.14261457
34. Riswan, R., Harun, U., & Irsan, C. (2015). Keragaman flora di lahan reklamasi pasca tambang batubara pt ba sumatera selatan (Flora Diversity at Post-Coal Mining Reclamation in the PT BA South Sumatera). 22(2), 160–168. https://doi.org/10.22146/JML.18738
35. Radosz, Ł., Chmura, D., Dyczko, A., & Woźniak, G. (2024). Factors driving plant diversity in the spontaneous vegetation of the novel ecosystem of post-coal mining spoil heaps and their relationship with soil respiration. *Journal of Water and Land Development*, 190–201. https://doi.org/10.24425/jwld.2024.150270

36. Revegetating a mine tailings pond. *Science of The Total Environment*, *1004*, 180705. https://doi.org/10.1016/j.scitotenv.2025.180705
37. Riviera, F., Renton, M., Dobrowolski, M. P., Dobrowolski, M. P., Veneklaas, E. J., Mucina, L., Mucina, L., & Mucina, L. (2021). Patterns and drivers of structure, diversity, and composition in species-rich shrublands restored after mining. *Restoration Ecology*, *29*(6). https://doi.org/10.1111/REC.13360
38. Sahoo, U. K. (n.d.). Recovery Pattern of Vegetation During Succession Following Slash and Burn Agriculture in Mizoram, North-East India. https://doi.org/10.13188/2331-8996.1000012
39. Schulze, E. D., Wirth, C., Mollicone, D., & Ziegler, W. (2005). Succession after stand replacing disturbances by fire, wind throw, and insects in the dark Taiga of Central Siberia. *Oecologia*, *146*(1), 77–88. https://doi.org/10.1007/S00442-005-0173-6
40. Siahaan, J. R., Pagalung, G., Demmallino, E. B., Saleng, A., Sulaiman, A. A., & Nagu, N. (2025). The Dual-Pathway Framework for Post-Mining Sustainability: Institutional and Behavioral Integration in Indonesia. https://doi.org/10.20944/preprints202505.0136.v
41. Syahputra, R., Abdullah, & Abubakar. (2025). Bird Species Richness and Diversity as Bioindicator of Land Reclamation Success in Post-Mining Area, Aceh, Indonesia. https://doi.org/10.1088/1755-1315/1510/1/012032
42. Stadler, J., Brandl, R., & Klotz, S. (2025). Plant communities converge to resource-dependent transient states during succession on old fields. *Dental Science Reports*, *15*(1). https://doi.org/10.1038/s41598-025-16501-8
43. Sun, C., Chai, Z., Liu, G., Liu, G., Xue, S., & Xue, S. (2017). Changes in Species Diversity Patterns and Spatial Heterogeneity during the Secondary Succession of Grassland Vegetation on the Loess Plateau, China. *Frontiers in Plant Science*, *8*, 1465. https://doi.org/10.3389/FPLS.2017.01465
44. Swanson, M. E., Franklin, J. F., Beschta, R. L., Crisafulli, C. M., DellaSala, D. A., Hutto, R. L., Lindenmayer, D. B., & Swanson, F. J. (2011). The forgotten stage of forest succession: early-successional ecosystems on forest sites. *Frontiers in Ecology and the Environment*, *9*(2), 117–125. https://doi.org/10.1890/090157
45. Shugart, H. H. (2024). Succession, Phenomenon of (pp. 272–281). Elsevier BV. https://doi.org/10.1016/b978-0-12-822562-2.00385-6
46. Seagrass resilience: Exploring recovery trajectories, succession and facilitation. (2024). https://doi.org/10.25958/gqhv-w426
47. Stephan, K., & Hubbart, J. A. (2022). Plant Community, Soil and Microclimate Attributes after 70 Years of Natural Recovery of an Abandoned Limestone Quarry. *Land*, *12*(1), 117. https://doi.org/10.3390/land12010117
48. Tibbett, M. (2024). Post-mining ecosystem reconstruction. *Current Biology*, *34*, R387–R393. https://doi.org/10.1016/j.cub.2024.03.065
49. Tikhonova, E. V., Titovets, A. V., Tikhonov, D. N., Shopina, O. V., & Semenkov, I. N. (2025). Functional organization and species diversity of postagrogenic phytocenoses throughout natural reforestation depending on soil properties. *Растительность России*, *52*, 38. https://doi.org/10.31111/vegrus/2025.52.38
50. Yuningsih, L., Hermansyah, H., Ibrahim, E., & Marsi, M. (2021). Diversity, structure and composition of vegetation in post-coal mining reclamation area in Sumatra, Indonesia. *Biodiversitas*, *22*(8). https://doi.org/10.13057/BIODIV/D220836
51. Wlodarczyk, T., Babst, F., Murawska-Wlodarczyk, K., Stokes, O., Salywon, A., van Leeuwen, W. J. D., Norton, C. L., Rader, S., Maier, R. M., & Babst-Kostecka, A. (2025). Dryland ecosystem regeneration and plant metal(loid) accumulation strategies 60 years after
52. Zhu, S.-C., Zheng, H., Liu, W.-S., Liu, C., Guo, M.-N., Huot, H., Morel, J.-L., Qiu, R., Chao, Y., & Tang, Y.-T. (2022). Plant-Soil Feedbacks for the Restoration of Degraded Mine Lands: A Review. *Frontiers in Microbiology*, *12*. https://doi.org/10.3389/fmicb.2021.751794
53. Zine, H., Hakkou, R., Elgadi, S., Ouhammou, A., & Benzaazoua, M. (2023). Native plant diversity for ecological reclamation in Moroccan open-pit phosphate mines. *Biodiversity Data Journal*, *11*. https://doi.org/10.3897/BDJ.11.e104592

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