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VEGETATION STRUCTURE AND BIODIVERSITY OF QUARRY SITES: A COMPARATIVE ANALYSIS WITH REFERENCE FOREST SITES

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ABSTRACT

Quarrying activities alter environmental conditions and vegetation dynamics, yet local comparisons between disturbed and undisturbed ecosystems remain limited. This study aimed to assess and compare environmental characteristics, vegetation structure, diversity indices, and species richness between selected sites in Barangay Simborio and Barangay Mangoto, Pamplona, Negros Oriental. A quantitative descriptive-comparative design was used, applying quadrat sampling, transects, and subplot analysis to gather data on soil, microclimate, and vegetation. The Mann–Whitney U test was used to determine significant differences. Results showed that undisturbed sites had higher soil fertility, more stable moisture, and greater species diversity and richness, while disturbed sites were dominated by pioneer and invasive species with simpler vegetation structure. Despite these ecological differences, statistical analysis revealed no significant differences ($p > 0.05$), indicating ongoing secondary succession. The findings suggest that disturbed areas may appear similar to undisturbed sites in terms of diversity indices but differ in ecological function. Active restoration strategies, such as reforestation, soil improvement, and invasive species management, are recommended to support ecosystem recovery.

Keywords: *quarry disturbance, vegetation diversity, soil characteristics, ecological succession, restoration ecology*

INTRODUCTION

Quarrying which helps produce materials for construction plus other industrial minerals, poses a serious threat to ecosystems around the world. The process of extracting resources usually results in habitat destruction, soil erosion, and less wildlife. Quarrying causes a great injury to variety of local plants and leads to soil erosion. Quarrying refers to the removal of stone from the earth's crust by methods like cutting, blasting, or drilling by the United States Geological Survey (USGS) (2021). Such stones are useful for a range of purposes, including construction, road building, landscaping, etc. Thus, quarrying is helpful in socio-economic development (Jenni et al. 2021). Gaining awareness of the various ecological risks involved in quarrying can massively assist in the presence of rehabilitation measures.

Sand and gravel (S&G) quarrying is a widespread form of resource extraction in the Philippines, necessary for infrastructure and development. However, studies published between 2020 and 2025 consistently identify quarrying as a persistent and significant driver of Deforestation and Forest Degradation (DFD) in critical ecological regions, such as the Southern Sierra Madre in Rodriguez, Rizal, and General Nakar, Quezon. The socio-environmental effects of Sand and Gravel operations are well documented at the perceptual level (Gu et al., 2022). Research characterizing the effects of gravel and sand quarrying operations in the Northern Philippines Highlights several strongly agreed-upon impacts, including dust and noise pollution, soil erosion, sedimentation, and the creation of 'unproductive wastelands. Furthermore, quarrying has been linked to the diversion of river streams, impacting water flow and increasing the risk of massive flooding in provinces like Negros Occidental, leading to specific regulatory interventions that strictly prohibit quarrying within designated River Dredging Zones (RDZ) to restore the natural flow and integrity of river systems (Tamayo, 2020).

The persistent of these issues, particularly the creation of unproductive wastelands, suggests a critical failure in the current regulatory cycle to mandate and verify the successful ecological output of rehabilitation efforts. If required revegetation and land restoration efforts were structurally and functionally successful, the long-term ecological footprint would be reversed, leading to documented ecological gains rather than sustained descriptions of degradation.

To help with the ecological rehabilitation of quarry sites, it is necessary to conduct an assessment of biodiversity. It would include compiling an inventory of floristic diversity. The species richness and composition can help to assess the health of the ecosystem. An analysis of the structure of vegetation (tree density, basal area and potential for regeneration) is useful to understand the intensity of habitat degradation and possible recovery (Zhang et al., 2018). Through an environmental impact assessment, this study will gain insight into the impact quarrying has on the microclimate and the subsequent increase in erosion across the landscape. It also aims at rehabilitative priority, which means to control invasive plant species and mitigate bare-ground exposures, which is necessary for directing field efforts and valuating soils and litter. The physical and chemical soil conditions that can maintain the vegetation resilience and self-recovery capacity are captured for the first time in this study. The integrated framework will ensure that the restoration strategies are scientifically fact-based and ecologically relevant.

The study focused on the floristic diversity and vegetation structure of the selected Simborio quarry site and controlled site in Mangoto, Pamplona, Negros Oriental, Philippines. This would help us to evaluate the level of environmental disturbance due to quarrying activities and compare the vegetative structure of controlled site. The Simborio quarry site, like many others, struggles to balance resource extraction with environmental conservation. The quarrying activities in this area have removed native vegetation and disrupted the structure of the soil which can also change the local microclimate (Stephan & Hubbart, 2022). Humans can alter habitats or disrupt ecosystems of which the animals and plants are a part. As a result, species richness is lost. The main issue at present is the absence of an altogether evaluation of the ecological impact of quarrying which will assist in developing remedial actions in Simborio.

Research Questions

This case study examines how quarrying activities have influenced the vegetation structure of selected quarry sites in Negros Oriental. Specifically, it seeks to determine the current biodiversity condition, vegetation structure, regeneration potential, community composition, and rehabilitation needs of these sites, and how these characteristics compare with those of adjacent undisturbed reference areas. Through intensive field sampling using quadrats, transects, and seedling plots, the study analyzes species composition, structural attributes, regeneration status, and ecological resilience indicators across quarry and reference sites.

Specifically, it sought to answer the following specific questions:

1. What are the environmental characteristics of the disturbed and undisturbed sites in terms of the following:
    1.1. Mean environmental parameters
    1.2. Vegetation structure and diversity indices
    1.3. Dominant plant species
    1.4. Understory vegetation diversity and structure
    1.5. Species richness
2. Is there a significant difference in the environmental characteristics between the disturbed and undisturbed sites?

METHODOLOGY

Research Design. This study was employed a quantitative, descriptive correlational research design to assess vegetation structure as indicators of quarry disturbance and compared to undisturbed site. The descriptive aspect was appropriate since the study aimed to measure and document existing ecological conditions without manipulating any variables, while the correlational component allowed the examination of potential relationships among biodiversity indices, vegetation parameters, and environmental indicators. A field-based ecological survey and observational study approach was used, wherein data were gathered directly from the disturbed and undisturbed site through systematic sampling of species richness, species diversity, tree measurements such as Diameter at Breast Height (DBH), basal area, density, as well as microclimate and soil attributes. By quantifying and analyzing these parameters, the study sought to establish patterns of disturbance, regeneration potential, and environmental impacts. This design was chosen because it provides objective, measurable, and comparable data that not only describe the current state of the ecosystem but also reveal linkages useful for informing conservation and rehabilitation strategies.

Research Environment. The study was conducted in selected quarry sites within Simborio, and chosen undisturbed site within Brgy. Mangoto, Pamplona Negros Oriental, covering both active quarry zones and rehabilitating areas. These sites were selected due to their accessibility, relevance to current quarrying activities, and their potential to represent varying levels of ecological disturbance. The choice of this setting was also based on the pressing need to evaluate the ecological impacts of quarrying on biodiversity health and vegetation recovery within the region.

Research Instrument. The primary research instruments were field sampling tools and standard ecological protocols. A floristic inventory sheet was used to record plant species, their abundance, and growth stage such as seedling, sapling or tree. A diameter tape a or tape measure were used for DBH measurements, while a soil auger and thermometer were used to assess soil properties and microclimate variables. The instruments and protocols were adapted from standard ecological field guides and validated through consultation with forestry and environmental science experts.

Research Data Gathering Procedures. The collected data takes place at selected quarry sites in Simborio, Pamplona as a disturbed site, that focused on the floristic diversity and vegetation structure of disturb area and another site in Brgy. Mangoto for baseline data and considered a controlled area. The study used nested sampling plots representing vegetation and ecological parameters. Sampling units consisted of quadrats and transects lines laid out in disturbed areas of the quarry and undisturbed areas. A purposive sampling method was used to ensure coverage of key ecological zones such as extraction sites, buffer areas, and partially restored areas. Within each plot, all plant species were recorded and measured following standard ecological survey protocols. Only plant species rooted within the designated plots were included, while isolated individuals outside the sampling boundaries were excluded. The following methods were used to collect the data:

Securing Approval and Permission to Conduct the Study. Prior to any field activities, formal permission was sought to ensure ethical compliance and institutional authorization. A letter of request has submitted to the thesis adviser for approval to conduct the study, outlining the research objectives, methodology, study site, and expected outputs. Upon approval, a formal permission letter is address to the appropriate authorities managing the selected Simborio quarry site as a disturbed area and controlled area in Mangoto. This letter requested to access the area for vegetation assessment and data collection. Approval from both academic and site authorities ensured compliance with research ethics, safety protocols, and local regulations.

Site Delineation and Preliminary Reconnaissance. After obtaining permission, a reconnaissance survey is conducted to delineate the boundaries of the Brgy. Simborio quarry site and Brgy. Mangoto for undisturbed sites using GPS and existing site maps. The survey identified major quarry-disturbed zones, vegetation patches, slopes, and areas with visible erosion or rehabilitation. This step provided an overview of site conditions and guide the placement of transects to adequately represent disturbance gradients.

Establishment of Transects. Systematic transect lines were established across the quarry site and undisturbed sites following major environmental and disturbance gradients such as slope direction, proximity to quarry pits, and spoil areas. Transects were laid out using measuring tapes, compass, and GPS to ensure consistency. The starting and ending coordinates of each transect were recorded for spatial reference and repeatability.

Placement of Nested Quadrats Along Transects. At predetermine intervals along each transect, nested square quadrats was established to sample different vegetation layers. A 20 m × 20 m quadrat was used for tree assessment, within which 5 m × 5 m quadrat is laid out for shrubs and saplings, and a 1 m × 1 m quadrat for grasses, herbs, and seedlings. This nested approach allows efficient sampling of floristic diversity and vegetation structure at multiple strata.

Floristic Inventory for Biodiversity Health Assessment. Within all quadrats, plant species were identified and recorded. Species richness was determined by counting the number of species per quadrat and across the site, while species abundance data is collected to support species diversity analysis. This step addressed the assessment of overall biodiversity health of the Simborio quarry site.

Measurement of Vegetation Structural Attributes. Within the 20 m × 20 m tree quadrats, to attain a 100% sampling intensity all trees were counted and measured for Diameter at Breast Height (DBH) at 1.3 m above ground. Basal area is later calculated from DBH values, and vegetation density is computed as the number of individuals per unit area. These parameters provide indicators of vegetation structural condition.

Assessment of Seedling, Sapling Regeneration, Grasses and Herbs. Seedlings and saplings were recorded within the 5 m × 5 m and within 1 m × 1 m quadrats for grasses, herbs, and seedlings. Individuals were identified by species and counted to evaluate regeneration potential and recovery capacity of vegetation in the quarry site.

Observation of Microclimate and Erosion Risk. Microclimatic conditions such as canopy openness, soil moisture, and exposure were recorded through field observations. Evidence of erosion including rills, gullies, expose soil, and unstable slopes is documented to assess ecological effects of quarry disturbance.

Identification of Rehabilitation Priorities. The presence and dominance of invasive species were recorded, and areas of bare ground were visually estimated. These observations are used to identify priority areas for rehabilitation and management intervention.

Assessment of Soil and Litter Support for Vegetation Resilience. Soil surface conditions such as soil ph, soil texture, litter depth, bulk density and organic matter presence is assessed within each quadrat. These parameters serve as indicators of soil quality and litter support, which are essential for vegetation resilience and long-term recovery.

Data Validation, Documentation, and Compilation. All field data were recorded in standardize datasheets and validates daily for accuracy and completeness. Photographs of each quadrat is taken for documentation. After fieldwork, data is encoded and organized into a database for analysis addressing biodiversity health, vegetation structure, regeneration potential, ecological effects, and rehabilitation priorities.

Species identification relies primarily on standard field guides and taxonomic references commonly used in floristic studies. To strengthen the reliability of the floristic inventory, a voucher specimen verification protocol is followed. Plant species that are difficult to identify in the field are collected carefully, pressed, properly labeled, and preserved as voucher specimens. These specimens are submitted to a recognized herbarium or are examined in consultation with a qualified plant taxonomist for proper identification and verification. This process ensures taxonomic accuracy and enhances the scientific credibility of the species records.

Data collection was carried out over a period of one (1) week in March 1-7, 2026 after obtaining permission from school administrators. The researcher scheduling this time was intentional to capture a broader range of ecological conditions and provide a more representative assessment of quarry disturbance and recovery potential.

Statistical Treatment of Data. The tools used by the researcher in analyzing the data are the following:

Microsoft Excel and Jamovi. This was used for data organization, basic calculations and statistical testing. Descriptive statistics such as frequency, mean, percentage, and standard deviation are used to summarize species occurrence, abundance, and vegetation structure.

Diversity Indices. Species richness, Shannon–Wiener Index, Simpson's Diversity Index, Pielou's Evenness, Species Richness, Mann-Whitney U test s and vegetation cover are computed to describe floristic diversity. These indices are used to compare plant diversity among the disturbed area and controlled area. Vegetation structural condition is evaluated using Diameter at Breast Height (DBH), basal area, and vegetation density.

To identify the diversity of vegetation between two sites, Undisturbed and Disturbed, the researcher applied the following interpretations (Napaldet, 2023):

Values	INTERPRETATION
Shannon (H')	
>3.5000	Very High
3.0000-3.4999	High
2.5000-2.9999	Moderate
2.0000-2.5999	Low
<1.9999	Very Low
Evenness Pielou Index (E)	
0.96-1.0	Balanced
0.76-0.95	Almost Balanced
0.51-0.75	Semi-balanced
0.26-0.50	Less balanced
0.00-0.25	Unbalanced
Simpson's Index	
0.00	Absence of diversity
0.01-0.40	Low Diversity
0.41-0.60	Moderate Diversity
0.60-0.80	Moderately High Diversity
0.81-0.99	High Diversity
1.00	Absolute (perfect) diversity
Margalef's Index (R)	
>5	High Species Richness
2.5-5	Medium Species Richness
<2.5	Low Species Richness

Mean and Standard Deviation. This was used to describe these structural parameters across sampling plots.

Inferential statistical analysis. This was used to determine whether significant differences existed between disturbed and undisturbed sites. A normality test was first conducted to assess data distribution. Since some variables did not meet the assumption of normality, the Mann-Whitney U Test was applied as a non-parametric alternative for comparing two independent groups. This test was used for environmental parameters, vegetation structure and diversity indices, understory vegetation, and species richness.

Scope of the study. This study focused on assessing the biodiversity, vegetation structure, and regeneration potential of selected quarry sites in Negros Oriental to understand the ecological impacts of quarrying activities. Specifically, the research evaluates vegetation biodiversity in terms of species richness, species diversity, and species evenness. It also examined key vegetation structural attributes, including tree density, basal area, canopy cover, and Diameter at Breast Height (DBH) distribution, to determine the condition and structural development of vegetation within the quarry sites. This study also investigates the regeneration potential of vegetation by assessing seedling and sapling density, species composition of regenerating plants, and the survival potential of these species. It analyzes community composition and functional group representation, particularly the presence and distribution of pioneer species, shade-tolerant species, nitrogen-fixing species, and invasive species, which serve as indicators of ecological recovery and disturbance. To identify areas requiring ecological restoration, the study evaluates selected habitat attributes, including soil cover, slope, and disturbance intensity, which may influence vegetation recovery and rehabilitation needs. The research was also examined the relationship between biodiversity indicators (species richness, diversity, and evenness) and vegetation structural attributes (tree density, basal area, canopy cover, and DBH distribution) to better understand how vegetation structure relates to biodiversity patterns in disturbed quarry landscapes.

The study was geographically focused to selected quarry sites in Negros Oriental, including adjacent undisturbed reference areas for comparison. Data collection focuses on plant species and vegetation structure within designated sampling plots, using quadrats, transects, and seedling plots to document species composition, structural characteristics, and regeneration status. The research was conducted within a specific or single fieldwork/survey period, and therefore the findings represent the current ecological condition of the quarry sites during the time of data collection. Data collection is concentrated on flora species and vegetative structure present within designated plots in disturbed and controlled site. The study was conducted within a defined period, ensuring data reflect current site conditions during the fieldwork.

Limitation of the study. Despite its contributions, the study is subject to several limitations. The geographical coverage is limited to the Simborio quarry site and selected sites for undisturbed, which may not fully represent vegetation conditions and disturbance responses in other quarry areas with different ecological settings and not fully covered all the quarry sites in Simborio, Negros Oriental. As a result, the findings are expected to reflect site-specific conditions rather than broader regional patterns.

The study focuses on vegetation conditions observed during a single survey period, which means that seasonal variations in species occurrence and regeneration are not fully captured. In particular, ephemeral plant species, especially those that emerge only during the wet season, may be underrepresented. Although conducting separate surveys during wet and dry seasons could provide a more complete floristic inventory, the study primarily emphasizes woody perennials, vegetation structure, and regeneration indicators, which are relatively stable across seasons and are appropriate indicators of quarry disturbance and recovery status. The use of transect and quadrat sampling methods also presents limitations. While these methods are widely accepted for vegetation assessment, they may not capture all species within the quarry site, particularly rare, cryptic, or short-lived species occurring outside the sampled plots. In addition, restricted access to certain quarry zones, limited availability of materials, and safety concerns in active quarry areas may limit the extent of field sampling. Potential researcher bias in species identification and interpretation is also acknowledged, despite the use of standard field guides and validation procedures. Uncontrolled environmental factors such as weather conditions during sampling, soil variability, and ongoing human activities within the quarry may influence vegetation patterns and environmental observations. The study provides ecological insights, it does not extensively cover socio-economic aspects of quarrying impacts, focusing primarily on biophysical indicators.

RESULTS

1. What are the environmental characteristics of the disturbed and undisturbed sites

1.1. Mean environmental parameters

Table 1.1

Mean Environmental Characteristics of Disturbed and Undisturbed Sites

Variable	Disturbed Site (C1) Mean ± SD	Undisturbed Site Mean ± SD
Soil Fertility (µS/cm)	292.47 ± 150.45	706.47 ± 158.35
Soil Moisture (%)	92.20 ± 12.20	99.00 ± 0.00
pH	5.45 ± 1.11	4.79 ± 1.12
Temperature (°C)	29.39 ± 2.48	33.07 ± 3.42
Sunlight (lux)	5,427.40 ± 6,641.45	18,263.93 ± 19,903.90
Humidity (%)	74.13 ± 8.50	60.00 ± 14.62
Litter Depth (inch)	3.05 ± 1.23	3.17 ± 0.73
Soil Bulk Density (g/cm³)	1.35 ± 0.57	1.51 ± 0.42

Values are presented as mean ± standard deviation.

1.2. Vegetation structure and diversity indices

Table 1.2

Vegetation Structure and Diversity Indices Across Sampling Sites

Variable	Undisturbed Site (C1)	Disturbed Site
Mean Shannon-Wiener Index	2.14	1.5
Mean Simpson's Index	0.85	0.88
Mean Margalef's Index	3.35	1.69
Mean Pielou's Evenness	0.86	0.95
Estimated Species Richness	Higher	Lower
Vegetation Cover (%)	Highly variable (23–250%)	Generally lower but more uniform
Mean DBH (cm)	Larger trees present	Smaller diameter dominance

Values are averaged from R1–R3 plots and SP1 subplots.

1.3. Dominant plant species

Table 1.3.1
Dominant Plant Species Observed in Undisturbed Site (C1)

Common Name	Scientific Name	Frequency (approx.)
Coconut	*Cocos nucifera*	High
Gmelina	*Gmelina arborea*	Moderate
Marang	*Artocarpus odoratissimus*	Moderate
Mahogany	*Swietenia macrophylla*	Moderate
Madre de cacao	*Gliricidia sepium*	Low
Rambutan	*Nephelium lappaceum*	Moderate
Suha	*Citrus maxima*	Low
Narra	*Pterocarpus indicus*	Moderate

Table 1.3.2
Dominant Plant Species Observed in Disturbed Sites (S1 & S2)

Common Name	Scientific Name	Frequency (approx.)
Ipil-ipil	*Leucaena leucocephala*	High
Acacia	*Samanea saman*	Moderate
Lagnob	*Ficus septica*	Moderate
Hagonoy	*Chromolaena odorata*	High
Mimosa (Shame plant)	*Mimosa pudica*	Moderate
Ruellia	*Ruellia blechum*	Moderate
Sida	*Sida rhombifolia*	Moderate

1.4. Understory vegetation diversity and structure

Table 1.4.1
Understory Vegetation Diversity (SP1 Subplots)

Site	Shannon Index	Simpson Index	Margalef Index	Evenness
Disturbed (C1 SP1 avg)	1.77	0.79	1.25	0.85
Undisturbed (S1/S2 SP1 avg)	2.02	0.85	1.34	0.92

Table 1.4.2
Understory Vegetation Diversity Indices (1 m × 1 m Subplots)

Site	Mean Shannon Index	Mean Simpson Index	Mean Margalef Index	Mean Pielou’s Evenness
Undisturbed (C1)	3.27	0.95	10.25	2.24

Disturbed (S1)	3.97	0.98	8.88	0.93
Disturbed (S2)	2.02	0.85	1.34	0.92

Values were averaged across all 1 m × 1 m subplots per site.

Table 1.4.3
Dominant Understory Species and Vegetation Cover (Undisturbed Site – C1)

Species	Scientific Name	Dominance Pattern
Guinea Millet Grass (Lusa-lusa)	*Urochloa deflexa*	Very high (often 80–90%)
Hagonoy	*Chromolaena odorata*	High (invasive dominance)
Cogon	*Imperata cylindrica*	Moderate–high
Climbing hempvine	*Mikania scandens*	Moderate
Giant Sword Fern	*Nephrolepis biserrata*	Moderate
Carabao grass	*Paspalum conjugatum*	Moderate

Strong dominance by grasses + invasive species

Table 1.4.4
Dominant Understory Species and Vegetation Cover (Disturbed Sites – S1 & S2)

Species	Scientific Name	Dominance Pattern
Napier Grass	*Pennisetum purpureum*	Very high (up to 90%)
Cogon	*Imperata cylindrica*	High
Nut Grass	*Cyperus rotundus*	High
Climbing Dayflower	*Commelina diffusa*	Moderate
Asthma Plant	*Euphorbia hirta*	Moderate
Singapore Daisy	*Sphagneticola trilobata*	Moderate

Still grass-dominated, but more species mixing than C1

Table 1.4.5
Understory Vegetation Structure (Coverage Patterns Across Sites)

Site	Dominant Growth Form	Cover Pattern	Species Distribution
Undisturbed (C1)	Grasses + Invasive shrubs	Highly concentrated (monodominant patches)	Uneven
Disturbed (S1)	Mixed grasses and herbs	More distributed	More even
Disturbed (S2)	Grass-dominated	Moderately uniform	Moderately even

1.5. Species richness

Table 1.5
Species Richness per Subplot (Estimated Range)

Site	Minimum Species	Maximum Species	Average Diversity Trend
Undisturbed (C1)	3	9	High richness but uneven
Disturbed (S1)	2	5	Moderate richness, high evenness
Diisturbed (S2)	2	4	Lower richness, moderate evenness

2. Is there a significant difference in the environmental characteristics between the disturbed and undisturbed sites?

Table 2.0
significant difference in the environmental characteristics between the disturbed and undisturbed sites

Characteristics	Normality	Test	P
Mean Environmental Characteristics	<0.001	Mann-Whitney U	0.902
Vegetation Structure and Diversity	0.468	Mann-Whitney U	1
Understory vegetation diversity and structure	<0.001	Mann-Whitney U	0.787
Species Richness	0.826	Mann-Whitney U	0.481

DISCUSSION

The mean environmental parameters provide a quantitative basis for comparing disturbed and controlled sites. These parameters typically included Soil Fertility (µS/cm), Soil Moisture (%), pH, Temperature (°C), Sunlight (lux), Humidity (%), Litter Depth (inch), and Soil Bulk Density (g/cm³). Variations in these indicators reflected the degree of environmental degradation or stability within the study areas. The vegetation degradation significantly alters soil properties, ultimately reducing ecosystem services such as erosion control, water regulation, and carbon storage (Mashagiro et al., 2024).

Table 1.1 showed the differences of ecological conditions between the disturbed and undisturbed sites, indicating the influence of disturbance on soil and microclimatic characteristics (Leul et al., 2023). The undisturbed sites showed higher soil fertility

(706.47 ± 158.35μS/cm) compared to the disturbed site (292.47 ± 150.45μS/cm), suggesting that lower fertility in the disturbed site caused by quarry activities have degraded soil nutrient content which can negatively affect plant growth and species diversity (Job Isaboke et al., 2025). Soil moisture was slightly higher and more stable in undisturbed site (99.00 ± 0.00%) than in the disturbed site (92.20 ± 12.20%) indicating that slightly lower soil moisture in the disturbed site could stress moisture-sensitive species, reducing biodiversity (Liu et al., 2021). In terms of soil pH, both sites are acidic but the disturbed site is slightly less acidic (5.45 ± 1.11) than the undisturbed site (4.79 ± 1.12) which may reflects that slightly higher pH in disturbed site may favor some generalist species over specialist or endemic species (Mir et al., 2025). Microclimate in the undisturbed site is recorded higher temperature (33.07 ± 3.42 °C) and substantially greater sunlight exposure (18,263.93 ± 19,903.90lux) suggesting more open or naturally structured canopy conditions while the disturbed site (29.39 ± 2.48°C) had lower temperature and sunlight (: 5,427.40 ± 6,641.45lux) possibly due to dust accumulation or altered surface condition (Podong et al., 2025). Humidity was higher in disturbed site (74.13 ± 8.50%) that might be a result of less airflow or changes in water drainage, potentially favoring certain fungi or moss species than in undisturbed site (60.00 ± 14.62%) (Xu et al., 2024). Litter depth in undisturbed (3.17 ± 0.73 inch) and disturbed site (3.05 ± 1.23 inch) is fairly similar suggests that organic matter accumulation is not drastically affected yet, though species composition may differ (Manpoong et al., 2025). Soil bulk density in undisturbed site (1.51 ± 0.42g/cm³) has slightly denser soil than disturbed site (1.35 ± 0.57g/cm³) which indicates lower soil bulk density in disturbed sites may indicate soil compaction from machinery, reducing water infiltration and root penetration, which could impact plant and soil fauna diversity (Roșian et al., 2025). These findings imply that disturbance such as quarrying activities, has led to reduced soil fertility, slight moisture variability, and altered microclimatic conditions which can negatively impact vegetation growth, species composition and long-term ecosystem stability.

Table 1.2 shown the vegetation structure and diversity indices across sampling sites reveals notable differences between disturbed and disturbed sites that possess ecological effects of disturbance on plant communities. The higher Shannon-Weiner Index observed in the undisturbed area (2.14) compared to the disturbed area (1.5) suggests greater species diversity under stable environmental conditions which is consistent with studies showing that intact ecosystems support more complex and diverse plant communities due to long-term ecological balance (Wu et al., 2023). The Simpson's Index value for undisturbed (0.85) and disturbed site (0.88) indicates high diversity in both sites, although they slightly higher value is disturbed site may reflect the dominance of few opportunistic species that thrive under altered conditions (Sharashy, 2022). Margalef's Index showed higher species richness in the undisturbed site (3.35) compared to the disturbed site (1.69), suggesting that undisturbed environments provide more favorable conditions for sustaining greater number of species (Jiang et al., 2022). In Pielou's Evenness, species distribution is more even in disturbed site (0.95) rather than undisturbed site (0.86) that may have patchy distribution that could leads to microhabitat variability, potentially favoring certain fauna species while disadvantaging others (Kennerley et al., 2022). Species richness the undisturbed site is higher than disturbed site (lower), indicates that undisturbed site supports more species likely due to opportunistic colonizer or early successional species. In terms of vegetation cover, the undisturbed site shown highly variable vegetation cover (23-250%) while disturbed areas often reveals generally lower but uniform cover, suggested that natural ecosystems tend to have heterogenous vegetation layer while disturbed site often shows simplified and more heterogeneous structure (Lin et al., 2023). The presence larger trees in the undisturbed site compared to the dominance of smaller diameter classes in disturbed site, showed that undisturbed forest maintain mature vegetation and complex structure while disturbed site characterized by younger, regenerating stands (Cheng et al., 2024). These finding suggest that undisturbed site supports higher species diversity and richness due stable environmental conditions while disturbed sites reveal more even but simplifies plant communities where disturbance can reduce ecological complexity and long-term ecosystem resilience despite occasional increase in species uniformity.

In Table 1.3.1, dominant plant species observed in undisturbed site shows a community shaped by both anthropogenic influence and ecological succession. The high frequency species is Coconut *(Cocos nucifera)* indicates its strong adaptability to open areas, commonly planted or naturally regenerating and its commonly associated with human-modified landscapes and lowland ecosystems (Rezzouk et al., 2023). The moderate frequency and fast-growing species are Gmelina *(Gmelina arborea),* Marang *(Artocarpus odoratissimus),* Rambutan *(Nephelium lappaceum)* a fruit-bearing trees are often intentionally planted or retained in agroforestry systems, Narra *(Pterocarpus indicus)*, Mahogany *(Swietenia macrophylla)* indicates a widely planted timber species, a remnants of past reforestation or planted activities. The low frequency is Madre-de-cacao (Gliricidia sepium), indicates a nitrogen-fixing species, suggests although soil-improving species are present, they are not yet dominant enough to significantly enhance soil fertility and ecosystem recovery. Suha (Citrus maxima) showed low frequency that reflects selective planting or low natural regeneration in the area. The species composition of disturbed and undisturbed site reveals a mixture of pioneer species, cultivated fruit trees, and residual timber species shows both ecological disturbance and human intervention. The presence of economically valuable and fast-growing species suggests some degree of resilience, the dominance of opportunistic and invasive plants indicates reduced ecological stability and shift away from native forest composition (Stromberg & Ranjula Bali Swain, 2024).

Table 1.3.2 showed dominant plant species observed I disturbed site (S1 & S2) showed that high frequency species is Ipil-ipil *(Leucaena leucocephala)* implies that nitrogen-fixing tree improves fertility and facilitates vegetation recovery in degraded environments a function widely recognized in restoration ecology (Wang et al., 2023). The moderate occurrence of acacia *(Samanea saman)* contributes to canopy development and microhabitat formation as large leguminous trees improves soil nutrients and provide shade that supports understory growth. The presence of Lagnob *(Ficus septica)* reveals moderate frequency where native fig species, supports frugivores and promotes biodiversity through seed dispersal (Dawson, 2023). Hagonoy *(Chromolaena odorata)* shows high frequency that indicates strong disturbance effects, as invasive species is known for aggressive colonization and has the ability to outcompete native vegetation, potentially slowing natural forest regeneration (Lengyel et al., 2023). The moderate presence of herbaceous species such as mimosa (Mimosa pudica), ruellia (Ruelia blechum) and sida (Sida rhombifolia) reveals that low-growing herbaceous plant adds to understory diversity but sensitive to disturbance (Liu et al., 2023). Overall, species composition reflects a transitional ecosystem where nitrogen-fixing trees and pioneer species promote initial recovery but invasive species and herbaceous plants still dominate the vegetation structure (Stromberg & Ranjula Bali Swain, 2024).

Table 1.4.1 understory vegetation diversity (SP1 Subplots) reveals significant differences in community composition and ecological health reflecting the impact of disturbance on lower vegetation layers. The higher Shannon Index in the undisturbed site (2.02) showed a higher understory diversity rather than disturbed site (1.77), indicating a richer mix of species, evenly distributed reflecting a stable and mature system (Li et al., 2020). Simpson Index was higher in undisturbed site (0.85) compared to the disturbed site (0.79) reveals that greater species dominance evenness and less skewed abundance, a characteristics of climax communities where resources are efficiently partitioned among stable species rather than being monopolized by a few dominant taxa (Torresani et al., 2021). The Margalef Index also shows slightly higher species richness in the undisturbed site (1.34) compared to the disturbed site (1.25), indicates that undisturbed environments support more species relative to the number of individuals present (Jiang et al., 2022). The higher evenness value is the undisturbed site (0.92) compared to the disturbed site (0.85) where species distribution is more even in undisturbed site rather than disturbed site shows some dominance by a few species (Kennerley et al., 2022). Disturbed site shows lower diversity and evenness, suggesting that disturbance favors opportunistic or pioneer species in the understory. Management strategies in disturbed sites could encourage native understory species regeneration to enhance biodiversity and restore ecosystem functions (Stromberg & Ranjula Bali Swain, 2024).

Table 1.4.2 understory vegetation diversity indices (1m x 1m Subplots) reveals variations in species composition, richness and distribution across disturbed and undisturbed sites, reflecting differences in ecological conditions and successional stage. The mean Shannon Index reveals that disturbed site1 (3.97) has the highest diversity, followed by the undisturbed site (3.27), while disturbed site2 (2.02) has the lowest diversity. This elevated diversity in certain disturbed patches is often attributed to the Intermediate Disturbance Hypothesis, where the opening of the canopy allows a temporary coexistence of both shade-tolerant survivors and light-demanding colonizers (Bongers et al., 2021). The mean Simpson Index values in disturbed site1 (0.98) indicates species is more dominance or even distribution, it also supports high number of species colonizing gaps caused by disturbance. Undisturbed site (10.25) showed a highest species richness relative to the number of individuals sampled in Mean Margalefs Index compared to disturbed site1 (8.88) and site2 (1.34) showed less species richness mainly due to colonization by pioneer or opportunistic species. The Mean Pielou's Evenness reveals that undisturbed site (2.24) unusually high evenness (likely reflects early successional homogenization (Madrigal-González et al., 2020), whereas undisturbed site1 (0.93) and site2 (0.92) have moderate evenness with some dominance patterns (Lei Lv et al., 2019). These results suggest for long term conservation are profound, although disturbed site currently supports a high number of species and maybe misleading if those species lack the functional traits necessary for ecosystem resilience. Sax & Gaines (2003) emphasizes that disturbance can temporarily inflate diversity metrics while simultaneously phasing out specialized native flora.

Table 1.4.3 Dominant understory species and vegetation cover undisturbed site reveals a community structure strongly influenced by disturbance adapted and invasive species, which significantly alters the successional trajectory of the ecosystems. The very high dominance of Guinea millet grass *(Urochloa deflexa)*, covering up to 80-90% of the area, indicates that grass species strongly dominates the understory typical of open or disturbed habitats (Fernandes et al., 2025). The high invasive dominance is Hagonoy *(Chromolaena odorata)* indicates an invasive pioneer species aggressively colonizes and its role in suppressing native vegetation through rapid growth and allelopathic potential (Hejda et al., 2023). Moderate-high species is cogon *(Imperata cylindrica)* indicates species forms dense mats that inhibit seedling establishment and reduce forest regeneration. It also acts as a physical and biological barrier that inhibits the establishment of native seedlings (Anderson, 2024). The moderate dominance is Climbing vine (*Mikania scadens*) a fast-growing climber that contributes to understory structural complexity, Giant Sword fern (*Nephrolepis biserrata*) a shade tolerant fern that persist under partial canopy and adds to understory diversity and Carabao grass *(Paspalum conjugatum)* contribute to some level of structural complexity and ground cover and it is often secondary to the competitive exclusion exerted by the dominant grass. Ferns are well-adapted to shade, their persistence in disturbed understories is often limited to specific microhabitats that escape the dense shading of invasive mats (Anderson, 2024). The implications for this site suggest that high dominance by pioneer and invasive species limits the recruitment of native plants, thereby reducing long-term ecological stability (Guo et al., 2022).

Table 1.4.4 Dominant Understory Species and Vegetation Cover (Disturb Sites - S1&S2) indicates a vegetation community will largely influenced by disturbance but showing signs of increasing species mixing and structural complexity. The very high dominance of Napier grass (Pennisetum purpureum), reaching up to 90% cover that shows strong grass presence in the understory, it maybe naturally occurring or maintained in open areas. It has the ability to compete in disturb environments where it can rapidly occupy space and suppress the establishment of the other species (Liu et al., 2023). Cogon (Imperata cylindrica) and Nut grass (*Cyperus rotundus*) is high dominance among the sampled. These reveals that this species adapts to disturbed soils and their role in stabilizing the ground while also competing with native vegetation for resources (Bongers et al., 2021). The moderate presence of species is Climbing Dayflower (*Commelina diffusa*), Asthma plant (Euphorbia hirta) and Singapore daisy (*Sphagneticola trilobata*) suggest a more heterogenous understory compared to heavily grass dominated systems. These contributes to the stability of groundcover by protecting topsoil from erosion in open canopy gap (Zhao et al., 2022). These findings revelas that grass still dominated but more species mixing and diversity than Undisturbed site and management focus for disturbed areas may prioritize monitoring gras expansion to maintain balance with other native understory species (Stromberg & Ranjula Bali Swain, 2024).

Table 1.4.5 understory vegetation structure (coverage pattern across sites) shown that there is a significant divergence in how species occupy physical space that involves dominant growth form, cover patterns and species distribution. The undisturbed site (C1) is characterized by the dominance of grasses and invasive shrubs, forming highly concentrated and monodominant patches with uneven species distribution. This pattern suggests competitive exclusion, where a few aggressive species dominate large areas, limiting the establishment and recruitment of other plants, a condition often associated with invasive species proliferation and reduced biodiversity (Lengyel et al., 2023). In Disturbed site 1 involves mixed grasses and herbs and more evenly distributed across the site with multiple species coexist with less dominance. These types of vegetation structure is commonly observed in intermediate stage of succession where disturbance creates opportunities for species establishment and coexistence (Liu et al., 2023). Disturbed site 2 involves grasses are dominated with a moderately uniform cover pattern and evenness. These findings reveals that the inherent natural variability found in regenerating landscapes and shows some species dominance, it maintains a level of structural complexity that prevents the total exclusion of secondary species. This moderate uniformity is often a sign of a site transitioning from a pioneer-heavy stage toward a more integrated understory community (Currey et al., 2020). Overall, these findings vegetation structure varies significantly across sites, with the undisturbed site exhibiting patchy, uneven distribution due to invasive dominance, while disturbed sites particularly S1 show greater species mixing and more balanced distribution. This suggests that disturbance can, in some cases, increase spatial heterogeneity and promote species coexistence, although excessive dominance by invasive species may still limit ecological recovery (Stromberg & Ranjula Bali Swain, 2024).

Table 1.5 Species richness per subplots (Estimated Range) shows a clear variation among sites. The undisturbed site recorded the highest range of species (3-9 species per sub plots) indicating high species richness but uneven distribution. These may reveal that a few dominant species occupy large portions of the area limiting uniform presence of other species. This pattern suggests that while the site supports a wide range of species, competitive dominance and patch formation may reduce overall ecological balance, a condition often observed in areas influenced by invasive or aggressive plant species (Lengyel et al., 2023). In disturbed site 1 showed a moderate range of species (2–5), but with higher evenness, indicating a more balanced distribution of species across subplots. This suggests that species in S1 are more uniformly represented, which is a characteristic of communities where competition is less intense and resources are more evenly utilized, contributing to greater ecological stability (Liu et al., 2023). Lower richness and moderate evenness (2-4) represent disturbed site 2. These findings reveal that fewer species overall but a relatively consistent distribution among them. This may reflect localized environmental conditions or microhabitat limitations that restrict species establishment while still allowing some degree of coexistence (Currey et al., 2020). These findings suggest that success should not be measured by the number of species alone. Management in disturbed sites should prioritize native species establishment that promotes higher evenness. This structural balance is more critical for long-term ecosystem resilience than a high-species count dominated by a few aggressive pioneers (Krishna, 2013).

Table 2.0 the significant difference in the environmental characteristics between the disturbed and undisturbed sites, mean environmental characteristics the data were not normally distributed ($p < 0.001$) for Mann-Whitney U test was applied, showed a p-value of 0.902 which indicates no significant differences between sites. A vegetation structure and diversity although normally distributed ($p=0.468$) also have showed no significance difference ($p=1.000$), suggesting that overall vegetation metrics are statistically comparable between disturbed and undisturbed areas. In understory vegetation diversity and structure ($p=0.787$) and species richness ($p=0.481$), both indicating no statistically significant differences ($p > 0.05$). These findings reveal no significant differences but despite of this, the variability within each site is relatively high between disturbed and undisturbed conditions. This is consistent with ecological studies showing that high spatial variability and small sample sizes can reduce the ability to detect significant differences, even when ecological changes are present (Perret et al.). The lack of significant difference may indicate that disturbed sites are undergoing recovery or secondary succession, allowing them to exhibit similar diversity indices and structural characteristics to undisturbed sites over time (Dada et al.). These is also implying that disturbance effects in the study area may be subtle, site-specific or operating at a scale not fully captured by the sampling design. It also suggests that early successional stages in disturbed areas can temporarily resemble undisturbed systems in terms of overall diversity metrics, even if the species composition and functional role differ (Viljur et al.). It is possible that early-stage succession in disturbed areas mimics some characteristics of undisturbed systems, particularly in terms of overall diversity indices. Future studies may consider larger sample sizes, longer monitoring periods, or additional indicators (e.g., species composition, functional traits) to better detect differences. These statistical results are limited only to continuous numerical variables included in the analysis. Variables such as vegetation cover patterns, plant species composition, dominant understory species, and qualitative vegetation structure were not included in this test.

Conclusions

This study examined the environmental characteristics, vegetation structure, floristic diversity, and regeneration potential of disturbed and undisturbed quarry sites in Barangay Simborio, and Barangay Mangoto, Pamplona, Negros Oriental. These findings revealed that quarrying activities have influenced key ecological parameters, particularly soil fertility, moisture, and microclimatic conditions. The undisturbed site exhibited higher soil fertility and more stable soil moisture, indicating better nutrient availability and water retention, in contrast, the disturbed site showed reduced fertility and greater variability, suggesting soil degradation (Streitberger et al., 2025) (Viswambharan Sarasan et al., 2025). Although both sites were acidic, the disturbed site had a slightly higher pH, which may favor generalist species over specialized native flora (Duan et al., 2019). Microclimatic conditions also differed, with the undisturbed site showing higher temperature and sunlight exposure, whereas the disturbed site exhibited higher humidity due to altered surface conditions. Disturbance-related changes in habitat structure, such as exposure of bare ground and modification of surface conditions, have been shown to significantly influence environmental parameters and species composition in quarry ecosystems (Streitberger et al., 2025). Litter depth was relatively similar in both sites, indicating that organic matter accumulation has not been completely disrupted, while differences in soil bulk density suggest structural changes in soil composition caused by quarry operations. A previous studies have reported that quarrying and mining activities significantly increase soil bulk density due to compaction, overburden deposition, and loss of soil organic matter, ultimately affecting soil structure and vegetation recovery (Belay et al., 2020). Anthropogenic disturbances are widely recognized to alter soil physical properties, including bulk density, which in turn influences soil porosity, water retention, and plant growth dynamics (Mir et al., 2025).

In terms of vegetation structure and diversity, the undisturbed site demonstrated higher species diversity and richness, as well as greater structural complexity characterized by larger trees and heterogeneous vegetation cover. This pattern is consistent with ecological theory, which suggests that undisturbed habitats typically support more complex vegetation structures and higher biodiversity due to long-term stability and niche differentiation (Tamburini et al., 2018). In contrast, the disturbed site showed lower diversity and was dominated by smaller diameter classes, indicating early stages of ecological succession when pioneer species colonize recently distributed environments. However, species evenness was higher in the disturbed site, suggesting a more uniform distribution of opportunistic species, a common feature in disturbed ecosystems where competitive exclusion is reduced (Yé et al., 2015). Species composition further highlighted these differences, with the undisturbed site containing a mixture of native, planted, and economically important species, while the disturbed site was dominated by pioneer and invasive species such as Hagonoy (*Chromolaena odorata),* indicating ecological imbalance (Owagboriaye et al., 2020).

Understory vegetation analysis revealed that the undisturbed site generally had higher diversity, richness, and evenness, reflecting a more stable ecosystem and mature ecosystems as undisturbed habitats tend to support more complex plant communities due to reduced anthropogenic stress and longer successional development (Granger & Buckley, 2021). However, some disturbed areas exhibited relatively high diversity, supporting the Intermediate Disturbance Hypothesis, where moderate disturbance allows coexistence of different species by preventing competitive exclusion and allowing both pioneer and late successional species to persist. Despite this, disturbed sites were largely dominated by grasses such as Napier grass *(Pennisetum purpureum)* and cogon *(Imperata cylindrica)*, which suppress native regeneration by outcompeting seedlings, altering soil conditions and modifying fire regimes (Smith & Finch, 2016). Species richness was highest in the undisturbed site but unevenly distributed, while disturbed areas showed moderate to low richness with higher evenness, a pattern that is commonly observed in early successional ecosystems where species are more evenly distributed due to reduced dominance hierarchies (Wu et al., 2022). Statistical analysis revealed no significant differences between disturbed and undisturbed sites across environmental and vegetation variables. Nevertheless, observable ecological differences indicate that disturbed sites are undergoing secondary succession, and that statistical similarity does not necessarily reflect ecological equivalence, particularly in ecosystems influenced by anthropogenic disturbance (Liu et al., 2022).

The findings of this study clearly shows that quarrying activities have brought noticeable changes to both the physical environment and the biological components of the sites examined. Soil properties, vegetation structure, and overall species composition in disturbed areas have been altered in ways that reflect ecological stress and degradation (Yan et al., 2025). These disturbed sites are still in the early to intermediate stages of ecological succession, which explains why they are largely dominated by pioneer and invasive species. Most of the vegetation observed in these areas consists of small-sized individuals with limited structural complexity, indicating that the ecosystem has not yet fully recovered. The regeneration capacity appears to be weak, suggesting that natural recovery is progressing slowly.

The undisturbed sites present a more stable and balanced ecosystem. These areas support higher biodiversity, with a wider variety of plant species and more complex vegetation layers. The presence of mature trees and diverse understory vegetation reflects a system that has developed over time without major disturbances. As a result, these sites demonstrate stronger ecological resilience and a greater ability to maintain their structure and function.

One important observation in the disturbed areas is the dominance of invasive species and aggressive grasses. These species tend to outcompete native plants for resources such as light, nutrients, and space, making it more difficult for native species to re-establish. This condition slows down natural succession and poses a challenge for long-term ecosystem recovery. If left unmanaged, this dominance could lead to a less diverse and less functional ecosystem in the future.

Although the statistical analysis did not show significant differences between disturbed and undisturbed sites, this result should be interpreted with caution. The lack of significant difference may be influenced by factors such as variability in field data, limited sampling size, and the ongoing recovery processes in disturbed areas. What is evident from field observations is that the two sites are ecologically different. Similar values in diversity indices do not necessarily mean that the ecosystems are alike, especially when species composition and ecological functions differ.

In conclusion, the study suggests that relying on natural or passive recovery alone may not be enough to restore disturbed quarry sites. Active and well-planned restoration efforts are needed to improve vegetation structure, enhance biodiversity, and support ecosystem recovery. Approaches such as reforestation using native species, control of invasive plants, and soil rehabilitation could help accelerate the recovery process and improve the long-term sustainability of these areas.

Recommendations

Based on the findings of this study, it is clear that restoring quarry-affected areas requires more than simply allowing nature to take its course. A more intentional and well-coordinated approach is needed to support ecological recovery and ensure long-term sustainability. One of the most important steps is to prioritize active ecological restoration. This can be done through reforestation efforts that focus on native and endemic species, which are better adapted to local conditions and more capable of supporting biodiversity. At the same time, assisted natural regeneration should be encouraged, as it allows existing vegetation to recover while being supported through minimal but strategic interventions.

For Policy-makers and Quarry Operators. It is recommended to strengthen the implementation of environmental regulations by requiring quarry operators to adopt science-based rehabilitation plans. Active ecological restoration should be prioritized, including reforestation using native and endemic species and the application of assisted natural regeneration. Policies should also ensure that soil rehabilitation, erosion control, and long-term monitoring are integral parts of quarry management and closure plans.

For Local Government Units and Communities. Local authorities and communities are encouraged to actively participate in restoration efforts through tree planting, maintenance, and monitoring activities. Community-based programs can help control invasive species such as Chromolaena odorata (Hagonoy) and promote environmental awareness, fostering shared responsibility in protecting and restoring degraded areas.

For Schools and Teachers. Educational institutions should integrate environmental conservation and ecological restoration topics into their curriculum. Schools can also organize extension activities such as tree-growing initiatives and field-based learning in disturbed areas to help students better understand ecosystem recovery and sustainability.

For Students and the General Public. Students and local residents are encouraged to support restoration efforts by participating in environmental programs and practicing responsible land stewardship. Awareness of the impacts of quarrying and the importance of biodiversity conservation can help promote more sustainable behaviors.

For Future Researchers. Future studies may expand on this research by exploring long-term ecological recovery patterns, including detailed soil analysis, species succession, and biodiversity changes over time. Incorporating additional sites and using both quantitative and qualitative approaches can provide a more comprehensive understanding of restoration success.

For Improving the Study. It is recommended that future research includes longer monitoring periods and a wider range of ecological indicators, such as faunal diversity and microclimatic factors. Increasing sample size and comparing different restoration techniques can also help address current limitations and improve the reliability of findings.

Compliance with Ethical Standards

In adherence to ethical and environmental research standards. Permissions were secured from the quarry management and local government or barangay captain before conducting fieldwork. Data collection did not involve human participants, but care was taken to minimize disturbance to the ecosystem during sampling. Confidentiality of site-specific information provided by quarry operators was maintained. The research was conducted with transparency, honesty, and integrity, ensuring that findings would benefit both scientific knowledge and local rehabilitation efforts.

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