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Updating Biodiversity Status and Changes in the Permanent Monitoring Stations of San Roque Metals Incorporated Mining Areas, Tubay, Agusan del Norte, Philippines

Roger T. Sarmiento , Kevin D. Balagon, Fritz Floyd T. Merisco, Mhar Christian V. Medrano, and Kyle Kitche*

Department of Forestry, College of Forestry and Environmental Sciences, Caraga State University, Ampayon, Butuan City, Agusan del Norte, Philippines

*Corresponding Author
*Email: rtsarmiento@carsu.edu.ph
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A B S T R A C T

Since 2015, biodiversity-related surveys have been conducted biennially in the San Roque Metals Incorporated (SRMI) mineral production areas in the Municipality of Tubay, Agusan del Norte, Philippines. The company established five permanent monitoring stations in the selected habitats to monitor biodiversity and species richness effectively. The present study assessed changes in the monitoring stations using a quadrat-transect method and compared the diversity and species richness of the previous sampling periods. The results of the floristic survey recorded 160 morpho-species of seed plants (angiosperms and gymnosperms), ferns, and their allies, with 52% comprising tree species. Over time, a significant increase in the number of species was observed at the monitoring stations; however, Shannon's Diversity Index remained low (H'=2.3610; range 0.68-1.73) for all sites. The most dominant plant habits were trees, followed by ground-dwelling herbs, vines, and climbers. *Paspalum conjugatum* was the most dominant ground cover, occupying 22%, and other common grass species, such as *Scleria scrobiculata, Dicranopteris linearis,* and *Imperata cylindrica*, accounting for 19%, 14%, and 14%, respectively. Approximately 70% of the identified species were native, and 13.5% were endemic to the Philippines. Nine recorded species were listed on the Philippine Red List or the IUCN Red List of Threatened Species. Although it was found that the species richness of mining areas has slightly increased since the last floristic surveys, the study recommends considering the provisions for no-mine zones and genetic conservation areas for future mine restoration and rehabilitation activities.

Keywords: *Floristic assessment, nickel mining, threatened species, ultramafic soil formation*

1 Introduction

Ultramafic ecosystems support a large number of indigenous and endemic flora species (Along et al. 2020; Sarmiento 2018; Sarmiento 2020). The biodiversity of an area is a building block of ecosystems, and mining activities have troublesome impacts, especially those identified as biodiversity hotspots (Nyul 2023). In practice, biodiversity loss is evident as trees are cut, topsoil is removed, habitats are cleared, and biodiversity becomes part of the waste materials preceding mining operations (Pollisco 2013).

Mining has had a significant impact on the biodiversity of the Philippines. The loss of biodiversity affects ecosystem services, including providing food and water, pollination, and carbon sequestration. According to a study by the Philippine Biodiversity Conservation Foundation Inc., (PBCFI 2016), mining activities have resulted in habitat degradation, fragmentation, and destruction, leading to the loss of native flora and fauna. Mining operations often disturb and destroy ecosystems, causing soil erosion and sedimentation, which can harm aquatic life, including coral reef and fish populations.

The destruction of habitats and loss of biodiversity due to mining activities have negative consequences for the long-term sustainability of ecosystems and the overall well-being of communities that rely on them. A decline in biodiversity caused by mining activities can threaten the existence of endangered species, reduce the availability of essential resources, and affect the overall health and resilience of ecosystems.

The Municipality of Tubay is an ultramafic region. It is a third-class municipality located at 9° 10' North, 125° 31' East in the northwestern portion of Agusan del Norte, Philippines (PhilAtlas 2022). With the presence of large amounts of gold, cobalt, copper, the largest iron deposits in the world, and the second largest nickel deposits (Chavez 2008; Mines and Geoscience Bureau XIII [MGB XIII] 2018), the area has been occupied by several mining companies since the mining boom in 2006, including San Roque Metals Incorporated (SRMI), which started operating as a small-scale venture in 2006 (EJOLT 2015). Covering a total consolidated area of 1,079.05 ha, the company primarily produces cobalt, iron, and nickel ore as its main export product (MGB XIII 2022).

With the establishment of permanent monitoring stations in 2015, mining companies have conducted regular assessments in their mineral production sharing agreement (MPSA) areas to ensure compliance with environmental laws (Department of Environment and Natural Resources [DENR] 2022, Government of the Philippines 1995). Assessments of terrestrial flora, especially in active mining sites, will provide an overview of the nature, distribution, and variation of plant communities and allow complete identification, prediction, and evaluation of the potential impacts of the activities on the flora community (Corneau 2019). Through close monitoring, potential impacts can be identified, avoided, or reduced if possible (Williams 2019).

Since establishing permanent monitoring stations in 2015, the company has regularly monitored the flora, fauna, and diverse habitats. The generated data become the basis for managing biological resources while maintaining a balance with the company's mining activities. In some areas, biodiversity assessments are conducted only to comply with government requirements. The present study reassessed established permanent monitoring stations to update the status and conditions of vegetation and its biodiversity, forest structure, and species richness from the last sampling period. Similarly, ecologically important species were reevaluated to recommend sound conservation strategies for protecting threatened and endemic floral species.

2 Materials and Methods

Description of Study Area

The floristic survey was conducted on September 11–14, 2021, in selected habitats within the consolidated MPSA of SRMI, which covers the barangays La Fraternidad, Binuangan, and Tagpangahoy in the municipality of Tubay, Agusan del Norte. In 2015, five permanent monitoring stations were established in different areas to monitor the MPSA biodiversity (Figure 1). The permanent monitoring stations comprised the following areas: nursery site (S1), water lag area (S2), Mountain Beach Resort (MBR) (S3), Mt. Minaasog (S4), and Delta (S5).

The Nursery site (S1) is a slightly elevated area that raises forest trees for rehabilitation activities. This station is a strategic location for rapidly transporting seedlings to planting sites within active mining sites (Figure 1). Other ornamental plants are also present in this area. The water lag area (S2) is sparsely vegetated and serves as a temporary water catchment, particularly during massive rainfall events. Low-lying areas from mining excavations and road construction are regularly flooded; thus, water-tolerant species such as *Pandanus*, grasses, and sedges dominate. MBR (S3), located in the western portion of the mine, was a former tourist resort. It has been reported that the water quality at the beach began to deteriorate immediately after the opening of the mining operation. The dominant vegetation was mostly beach type and characterized by rocky substrates, boulders, and rocks, including high-density short-pole trees. Mt. Minaasog (S4) is a natural forest patch composed of high-canopy forest trees. The site is also classified as an agroforestry area consisting of cultivated land and residual secondary forests. Finally, Delta (S5) is located near the boundaries of SRMI and the adjacent mining company. It is an elevated area with stunted trees, medium-sized shrubs, and tree plantation species. An access road towards Barangay Binuangan has already been developed, where roadside areas are planted with Falcata.

Data Gathering

Permanent monitoring stations were selected because of the mining areas' dynamics and frequent vegetation cover (Along and Seronay 2018). The floristic evaluation focused purposively on the remaining forest patches and other vegetated areas. For each station, a 20×20 m quadrat was set up on the densest part of the site, with the lower left corner marked and geotagged for reference. A nested quadrat sampling technique (Figure 2) was used to assess and characterize the structure and species composition of the different plant communities (Umali et al. 2018). This method is most applicable in areas with almost all major plant groups. All trees with a DBH not less than 10 cm were identified, measured, and recorded in a 20×20 m quadrat. The frequency of shrubs, poles, and saplings inside the 5×5 m quadrat was counted, and the percentage cover of grasses and other ground covers inside the 1m x 1m quadrat was determined.

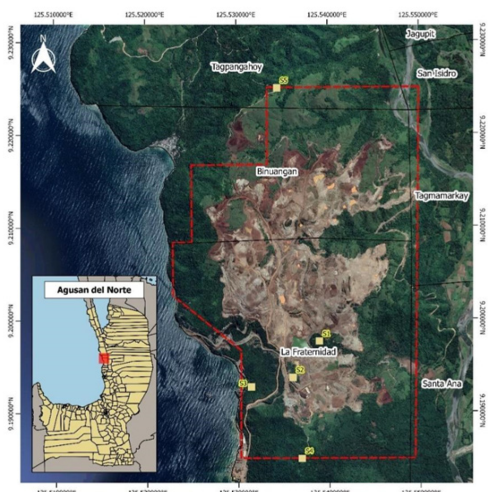

Figure 1. Location map of different sampling sites in the mining areas of SRMI. (Source: MGB XIII 2023)

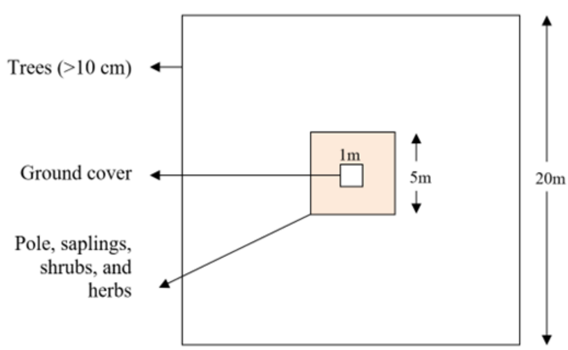

Figure 2. Schematic diagram of the sampling quadrats per site.

A 1000 m transect (with the quadrat in the center) was laid out for an opportunistic flora survey that involved listing and photo documentation of only the different species found outside the sampling plots. This coverage accounted for the maximum number of species at the mining sites.

Plants were identified in the field with the help of local guides, photographs, field taxonomy keys, and the online website PhytoImages (Nickrent et al. 2006). Alpha taxonomy was used to identify the plants to the lowest possible taxon. The plants were documented using photographs of their diagnostic features, including flowers, fruits, leaves, and plant habits. Plants were classified into taxonomic groups, plant growth habits, and other relevant information for further analysis. Family and species names were counterchecked in the World Flora Online (2022), while the common names were adapted from Rojo (1999).

Data Analysis

The information collected in the field was tabulated and analyzed to characterize the habitats of the study area. The different measures of plant diversity were determined using Paleontological Statistical Software 4.0 (Hammer et al. 2001), and the species abundance, dominance, density, and their relative values were computed in a spreadsheet. The relative values were then used to obtain the Importance Value (IV) (Kindt and Newton 2022), a standard measurement in forest ecology for determining the rank relationships of species.

Relative frequencies, relative density, relative dominance, and importance values were calculated using the following formulae:

$$\textbf{Density} = \frac{\text{Number of individuals}}{\text{Area sampled}}$$

$$\textbf{Frequency} = \frac{\text{Number of plots where the species occur}}{\text{Total number of plots sampled}}$$

$$\textbf{Dominance} = \frac{\text{Basal area of a species}}{\text{Area sampled}}$$

$$\textbf{Relative Density} = \frac{\text{Density for a species}}{\text{Total density for all species}} \times 100$$

$$\textbf{Relative Frequency} = \frac{\text{Frequency value of species}}{\text{Total frequency for all species}} \times 100$$

$$\textbf{Relative Dominance} = \frac{\text{Dominance for a species}}{\text{Total dominance for all species}} \times 100$$

$$\textbf{Importance Value} = \text{Rel Density} + \text{Rel Frequency} + \text{Rel Dominance}$$

A cluster analysis using PAST 4.03 was performed to determine the hierarchical clustering of quadrats based on the species composition and abundance of each sampling transect. Additionally, the ecological importance of vegetation in the area, endemism, and ecological status of the different species was determined based on the most recent taxonomic publications and global and national assessments (DENR 2017, IUCN 2022).

3 Results and Discussion

Plant Diversity

Rapid plant survey results revealed that the MPSA areas of SRMI have a distinctive yet narrow range of flora diversity, despite ample survey time and effort. Based on the species accumulation curve used to estimate the sampling effort of PAST 4.03 (Figure 3), the curve began to saturate as it approached the fifth sampling station, which shows that the sampling effort was highly adequate based on the species richness estimator using Michaelis-Menten at 95% confidence (Raaijmakers 1987). These results further implied that the observed species were sufficiently sampled. The following model was developed using the MM estimator function to determine the probable number of species as sampling effort increased.

A total of 160 morphospecies belonging to 63 families and 125 genera of seed plants (angiosperms and gymnosperms), ferns, and their allies were recorded in the consolidated MPSA (Table 1). Species richness was found to have significantly increased to 306 species compared to the previous two assessment periods, which recorded only approximately 198 and 303 species in 2017 and 2019, respectively. The permanent sampling stations showed increasing trends for nursery sites (S1) and MBR (S3) and decreasing trends in water lag (S2) and delta (S5) during the assessment period due to conversion into agriculture and mining operations, respectively. In contrast, Mt. Minaasog (S4) remained unchanged (Figure 4).

Although some specimens were not identified at the species level, they were cautiously assigned to the most probable taxon (family or genus). Most of these are in the juvenile stage (seedlings or saplings) or are sterile specimens (without flowers or spores), as the identification of plant species is highly dependent on reproductive structures. The identified plants were grouped according to their growth habits according to the FAO

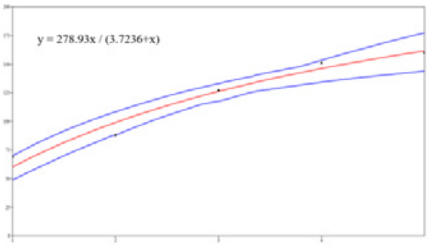

Figure 3. Species accumulation curves of terrestrial species found at five sampling locations in SRMI.

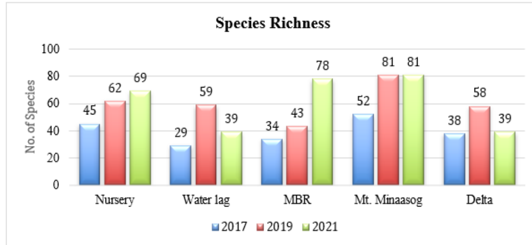

Figure 4. The species richness of the MPSA in the past assessment periods (2017-2021)

Table 1. List of species encountered in SRMI mining area study stations.

Family Name	Scientific Name	Local Name	Uses	Plant Group	Ecological Distribution	S1 N	S2 W	S3 Mb	S4 Mt	S5 D
Acanthaceae	*Asystasia gangetica*	Asistasia	M,W	G	Exotic				/	
Acanthaceae	*Pachystachys lutea*	Golden Shrimp	O,	O	Exotic	/				
Anacardiaceae	*Buchanania arborescens*	Balinghasai	T	T	Native					/
Anacardiaceae	*Mangifera indica*	Mangga	E	T	Native			/	/	
Anonaceae	*Cananga odorata*	Ilang-ilang	M,T	T	Native			/		/
Apocynaceae	*Alstonia macrophylla*	Batino	M,T	T	Native					/
Apocynaceae	*Alstonia scholaris*	Dita	T	T	Native		/			
Apocynaceae	*Cerbera manghas*	Manghas	I	T	Native			/		
Araceae	*Colocasia esculenta*	Gabi	E,O	O	Native	/			/	
Araceae	*Epipremnum pinnatum*	Tibatib	O,W	O	Native			/	/	
Araceae	*Homalomena philippinensis*	Alipayo	E, M	O	Native				/	
Araceae	*Monstera deliciosa*	Mostera plant	O	O	Exotic	/		/		
Araceae	*Syngonium podophyllum*	Arrowhead vine	O	V	Exotic	/				
Araliaceae	*Polyscias nodosa*	Malapapaya	T	T	Native	/	/	/	/	/
Araucariaceae	*Araucaria heterophylla*	Araucaria	T,O	T	Exotic			/		
Arecaceae	*Adonidia merrillii*	Manila Palm	O	P	Native	/		/		
Arecaceae	*Alocasia macrorrhizos*	Badjang	O,M	O	Native				/	
Arecaceae	*Areca catechu*	Bunga de china	O,M	P	Native		/	/		
Arecaceae	*Arenga pinnata*	Kaong	E,M	P	Native			/		
Arecaceae	*Calamus merrillii*	Palasan	I	V	Endemic	/	/	/		
Arecaceae	*Calamus* sp 1	Uway	I	V	Native		/			
Arecaceae	*Calamus* sp 2	Uway	I	V	Native		/			
Arecaceae	*Calamus* sp 3	Uway	I	V	Native		/			
Arecaceae	*Caryota mitis*	Pugahan	M,T	P	Native		/			
Arecaceae	*Caryota rumphiana*	Takipan	M,T	P	Native			/	/	
Arecaceae	*Cocos nucifera*	Niyog	E,T	P	Native	/		/	/	/
Arecaceae	*Orania palindan*	Palindan	M,O	P	Native	/		/		
Asparagaceae	*Agave* sp	Agave	O	O	Exotic			/		
Asparagaceae	*Dracaena fragrans*	Fortune plant	O,P	O	Exotic	/			/	
Asparagaceae	*Dracaena marginata*	Dragon tree	O,P	O	Exotic			/	/	
Asparagaceae	*Dracaena trifasciata*	Snake plant	O,P	O	Exotic	/		/		
Asteraceae	*Acmella uliginosa*	Borikat	E	O	Native			/	/	

Table 1. List of species encountered in SRMI mining area study stations. (continuation)

Family Name	Scientific Name	Local Name	Uses	Plant Group	Ecological Distribution	S1 N	S2 W	S3 Mb	S4 Mt	S5 D
Asteraceae	*Wollastonia biflora*	Hagonoi	M,W	G	Native	/	/	/		/
Astiraceae	*Eclipta zippeliana*	Tinta-tinta	W	G	Exotic			/	/	
Bombacaceae	*Ceiba pentandra*	Dol-dol	T,O	T	Exotic					/
Bromeliaceae	*Ananas comosus*	Pinya	E	O	Exotic	/			/	
Byttneriaceae	*Commersonia bartramia*	Banitlong	I	T	Native	/	/		/	
Byttneriaceae	*Kleinhovia hospita*	Tan-ag	I	T	Native			/		
Byttneriaceae	*Theobroma cacao*	Cacao	E	T	Exotic				/	/
Cactaceae	*Opuntia monacantha*	Cactus	O	O	Exotic	/		/		
Calophyllaceae	*Calophyllum inophyllum*	Bitaog	T	T	Native			/		
Cannabaceae	*Trema orientalis*	Anabiong	I	T	Native	/			/	
Caricaceae	*Carica papaya*	Papaya	E	O	Exotic			/		
Casuarinaceae	*Casuarina equisetifolia*	Agoho	T	T	Native	/	/	/		
Casuarinaceae	*Gymnostoma rumphianum*	Agoho del Monte	T	T	Native	/				
Clusiaceae	*Garcinia mangostana*	Mangoosteen	E	T	Native			/		
Clusiaceae	*Garcinia* sp	Kandiis	E	T	Native		/			
Combretaceae	*Terminalia catappa*	Talisay	T,O	T	Native			/		
Convolulaceae	*Ipomoea batatas*	Kamote	E	O	Native			/		
Convolulaceae	*Ipomoea binectarifera*	Ipomea sp	W	V	Native			/		
Convolvulaceae	*Decalobanthus peltatus*	Bulakan	W	V	Native			/	/	
Convolvulaceae	*Ipomoea triloba*	Kakamote	W	V	Exotic			/	/	
Costaceae	*Hellenia speciosa*	Tambabasi	M,O	O	Native			/	/	/
Cucurbitaceae	*Echinocystis lobata*	Wild cocumber	W	V	Exotic			/		
Cyatheaceae	*Cyathea contaminans*	Anutong	O	F	Native				/	
Cycadaceae	*Cycas rumphii*	Pitogo	O	P	Endemic			/		
Cyperaceae	*Scleria scrobiculata*	Daat	M,W	G	Native	/	/	/	/	/
Dennstaedtiaceae	*Pteridium aquilinum*	Bracken fern	W	F	Native		/		/	
Dilleniaceae	*Tetracera scandens*	Katmon baging	W	V	Native	/	/	/	/	
Durionaceae	*Durio zibethinus*	Durian	E	T	Exotic					/
Elaeocarpaceae	*Elaeocarpus* sp	Elaeocarpus	O	T	Native	/				
Euphorbiaceae	*Codiaeum variegatum*	Sagilala	O	O	Native	/				
Euphorbiaceae	*Euphorbia hirta*	Tawa-tawa	M	O	Exotic	/		/	/	/
Euphorbiaceae	*Excoecaria cochinchinensis*	Harusawa	O	T	Exotic	/				
Euphorbiaceae	*Homalanthus populneus*	Balante	I	T	Native	/				
Euphorbiaceae	*Macaranga bicolor*	Hamindang	M,I	T	Endemic		/			
Euphorbiaceae	*Macaranga hispida*	Patuwang	I	T	Native				/	
Euphorbiaceae	*Macaranga tanarius*	Binunga	I	T	Native	/	/	/	/	
Euphorbiaceae	*Manihot esculenta*	Kamoteng kahoy	E	T	Exotic	/		/	/	
Euphorbiaceae	*Phyllanthus debilis*	Sampa-sampalukan	M,	G	Exotic	/		/	/	
Fabaceae	*Acacia auriculiformis*	Auri	O,T	T	Exotic	/				/
Fabaceae	*Acacia mangium*	Mangium	O,T	T	Exotic	/	/			/
Fabaceae	*Adenanthera pavonina*	Tanglin	M	T	Exotic				/	
Fabaceae	*Arachis pintoi*	Mani-manian	O,W	V	Native	/			/	
Fabaceae	*Caesalpinia pulcherrima*	Caballero	O	T	Exotic	/		/		
Fabaceae	*Calopogonium mucunoides*	Calopo	W	V	Exotic			/		

Table 1. List of species encountered in SRMI mining area study stations. (continuation)

Family Name	Scientific Name	Local Name	Uses	Plant Group	Ecological Distribution	S1 N	S2 W	S3 Mb	S4 Mt	S5 D
Fabaceae	*Centrosema pubescens*	Centrosema	W	V	Exotic				/	
Fabaceae	*Falcataria moluccana*	Falcata	F,T	T	Exotic				/	/
Fabaceae	*Leucaena leucocephala*	Ipil-ipil	F	T	Exotic	/		/	/	
Fabaceae	*Mimosa pudica*	Makahiya	M,W	G	Native	/	/	/	/	
Fabaceae	*Pterocarpus indicus*	Narra	T	T	Native		/			/
Fabaceae	*Pueraria montana var. lobata*	Baai	W	V	Native			/	/	
Gleicheniaceae	*Dicranopteris linearis*	Agsam	O,W	F	Native	/	/		/	
Goodeniaceae	*Scaevola taccada*	Bokabok	O	O	Native	/		/		
Hypericaceae	*Cratoxylum sumatranum*	Ulingon	F	T	Native					/
Lamiaceae	*Gmelina arborea*	Gmelina	T	T	Exotic	/	/		/	/
Lamiaceae	*Premna odorata*	Alagau	M	T	Native	/		/	/	
Lamiaceae	*Vitex negundo*	Lagundi	M	T	Native			/		
Lamiaceae	*Vitex parviflora*	Tugas	T	T	Native				/	
Lauraceae	*Cinnamomum mercadoi*	Kaningag	M	T	Endemic			/		
Lauraceae	*Persea americana*	Avocado	E	T	Exotic			/	/	
Lecythidaceae	*Barringtonia asiatica*	Botong	P	T	Native				/	
Loganiaceae	*Norrisia malaccensis*	Sua-sua	I	T	Native		/			
Malvaceae	*Hibiscus rosa-sinensis*	Gumamela	O	T	Exotic	/		/		
Malvaceae	*Hibiscus tiliaceus*	Malubago	O,M	T	Native				/	/
Malvaceae	*Urena lobata*	Dalupang	W	G	Exotic				/	
Marantaceae	*Donax canniformis*	Banban	I	O	Native		/		/	
Melastomataceae	*Melastoma malabathricum*	Malatungao	I	T	Native	/			/	
Meliaceae	*Azadirachta indica*	Neem	M	T	Native	/		/	/	
Meliaceae	*Melia azedarach*	Bagalunga	F,T	T	Native			/	/	/
Meliaceae	*Sandoricum koetjape*	Santol	E	T	Native	/		/	/	/
Menispermaceae	*Tinospora rumphii*	Panyawan	M	V	Native					/
Moraceae	*Artocarpus blancoi*	Antipolo	E,T	T	Endemic	/	/	/	/	/
Moraceae	*Artocarpus camansi*	Kamansi	E,T	T	Native	/				
Moraceae	*Artocarpus heterophyllus*	Nangka	E	T	Native	/		/		/
Moraceae	*Artocarpus odoratissimus*	Marang banguhan	E	T	Native	/			/	/
Moraceae	*Ficus balete*	Balete	W	T	Endemic				/	/
Moraceae	*Ficus benjamina*	Salisi	O	T	Native	/				
Moraceae	*Ficus congesta*	Malatibig	I	T	Native				/	
Moraceae	*Ficus nota*	Tibig	I	T	Native				/	
Moraceae	*Ficus pseudopalma*	Niyog-niyogan	I	T	Endemic				/	/
Moraceae	*Ficus punctata*	Ficus sp	W	V	Native				/	
Moraceae	*Ficus septica*	Hauili	W	T	Native	/		/	/	
Musaceae	*Musa × paradisiaca*	Saging (Sarabia)	E	O	Native				/	/
Musaceae	*Musa × paradisiaca*	Saging (Tundan)	E	O	Native					/
Musaceae	*Musa acuminata*	Saging (Agutay)	E	O	Endemic				/	/
Myrtaceae	*Leptospermum amboinense*	Payospos	I	T	Native	/			/	
Myrtaceae	*Psidium guajava*	Bayabas	E	T	Exotic	/			/	/
Myrtaceae	*Syzigium huchinsonii*	Malatambis	I	T	Native		/	/		
Myrtaceae	*Syzygium brevistylum*	Saguimsim	I	T	Native		/			

Table 1. List of species encountered in SRMI mining area study stations. (continuation)

Family Name	Scientific Name	Local Name	Uses	Plant Group	Ecological Distribution	S1 N	S2 W	S3 Mb	S4 Mt	S5 D
Myrtaceae	*Syzygium equeum*	Tambis	E	T	Native	/				
Myrtaceae	*Syzygium myrtifolium*	Maglati	O	T	Native	/		/		
Myrtaceae	*Tristaniopsis micratha*	Tiga	T	T	Native			/		
Myrtaceae	*Xanthostemon verdugonianus*	Mangkono	T,O	T	Endemic	/	/	/	/	
Nephrolepidaceae	*Nephrolepis biserrata*	Alolokdo	W	F	Native	/	/	/		
Nephrolepidaceae	*Nephrolepis exaltata*	Bayabang	W	F	Native	/		/	/	
Nyctaginaceae	*Bougainvillea glabra*	Bougainvilla white	O	V	Exotic			/		
Nyctaginaceae	*Bougainvillea spectabilis*	Bougainvilla	O	V	Exotic	/		/		
Pandanaceae	*Pandanus copelandii*	Bariu	O	P	Endemic		/		/	
Pandanaceae	*Pandanus odoratissimus*	Pandan	O	P	Native		/			
Phyllanthaceae	*Flueggea flexuosa*	Anislag	F	T	Native	/		/	/	/
Piperaceae	*Piper aduncum*	Buyo-buyo	W	T	Exotic	/	/		/	
Piperaceae	*Piper betle*	Buyo	M	V	Native		/			
Poaceae	*Bambusa blumeana*	Kawayan	T	G	Exotic		/		/	
Poaceae	*Bambusa vulgaris var striata*	Kawayan dilaw	T	G	Exotic	/	/	/		
Poaceae	*Dinochloa dielsiana*	Bikal	I	G	Endemic		/			
Poaceae	*Imperata cylindrica*	Kogon	M,W	G	Native			/	/	/
Poaceae	*Paspalum conjugatum*	Carabao grass	O,W	G	Exotic			/	/	
Poaceae	*Rottboellia cochinchinensis*	Aguingay	W	G	Native				/	
Poaceae	*Saccharum spontaneum*	Bugang	W	G	Native			/	/	
Poaceae	*Schizostachyum lumampao*	Kawayan Buho	T	G	Endemic				/	
Polypodiaceae	*Drynaria quercifolia*	Kab-kab	O	E	Native			/	/	
Rubiaceae	*Adina* sp	Kiti-kiti	O	T	Native	/	/			
Rubiaceae	*Fagraea racemosa*	Balat buwaya	O	T	Native			/	/	
Rubiaceae	*Ixora coccinea*	Santan	O	T	Native	/		/		
Rubiaceae	*Ixora salicifolia*	Ixora	O	T	Native	/				
Rubiaceae	*Morinda citrifolia*	Noni	E,M	T	Native	/		/	/	
Rubiaceae	*Mussaenda philippica*	Kahoi dalaga	O	T	Endemic			/	/	/
Rubiaceae	*Neonauclea bartlingii*	Lisak	F	T	Endemic	/	/			
Rubiaceae	*Neonuclea media*	Wisak	F	T	Endemic	/				
Rutaceae	*Citrus maxima*	Pomelo	E	T	Exotic	/				/
Sapindaceae	*Nephelium lappaceum*	Rambutan	E	T	Native					/
Sapotaceae	*Chrysophyllum cainito*	Caimito	E	T	Exotic					/
Solanaceae	*Capsicum annuum*	Sili	E	T	Exotic	/				
Sterculiaceae	*Sterculia* sp	Sterculia	I	T	Native		/			
Theaceae	*Camellia sinensis*	Tea plant	I	T	Exotic	/			/	
Urticaceae	*Leucosyke capitellata*	Alagasi	F	T	Native	/	/	/	/	/
Verbenaceae	*Lantana camara*	Kantutay	O, W	G	Exotic				/	/
Verbenaceae	*Stachytarpheta jamaicensis*	Kandi-kandilaan	O, W	G	Exotic				/	
Zingeberaceae	*Hedychium coronarium*	White ginger lily	O, M	O	Exotic			/		
Species Richness						69	39	78	81	39
Percentage Richness						42.8%	24.5%	4.1%	50.9%	24.5%

Plant Group: F:Ferns & Fern allies, G:Grasses & Grass-like plants, O:Other ground dwelling herbs, E:Epiphytes, V:Vines & Climbers, P:Palms, Cycads & Pandans and T:Trees & Shrubs
Importance: F:Fuelwood, E:Edible, M:Medicinal, O:Ornamental, T:Timber/Construction, I:Indicator, W:Weeds, and P:Poisonous

and Wetlands International guidelines (Giesen et al. 2006). Most identified plant species fell under the tree and shrub category (52%; Figure 5). Other ground-dwelling herbs comprised 15% of the species, while a few were classified as vines and climbers (12%), grass, and grass-like plants (11%), among others.

Shannon's index classified all sites as "very low" (Table 2), as most were already disturbed and converted for agroforestry and forest plantation purposes. S4 (Mt. Minaasog) had the highest diversity value, given that the area was still intact and densely vegetated with only a few dominant species. It is a mixture of mangoes, marang, and other fruit-bearing trees. S5 (Delta), on the other hand, had the lowest diversity value because the site was converted into a falcata plantation-monocrop plantation, resulting in a low diversity value. S1 (nursery site) may have had the highest number of individuals but still had a low diversity value because a single species, Acacia mangium, dominated it.

Using PAST 4.03 software, the hierarchical clustering of quadrats, based on the species composition and species abundance of each sampling transect, was generated (Figure 6). The clustering of quadrats showed low to very low similarities in species composition and abundance. Quadrat S5 was the most unique of all quadrats, which is dominantly composed only of tree plantation species *F. moluccana.*

Tree flora

Only 18 species with 10 cm and above diameters were recorded in the sampling quadrats. Most (4/5) surveyed quadrats had fewer than 20 individuals per quadrat. The average number of trees per plot was meager, with only five per 400 m² or one per 100 m² of land.

The relative density, relative dominance, and relative frequency values for each tree species in all quadrats were determined to obtain their importance values (IV), which is a standard measure in ecology that determines the rank relationships of species. High-importance species values indicate a composite score for high relative species dominance, density, and frequency. Based on the IV (Table 3), the five most important species (with the highest IV) are Mangium (*A. mangium*) (72.94), Mangga (*Mangifera indica*) (39.36), Falcata (*Falcataria moluccana*) (30.31), Marang (*Artocarpus odoratissimus*) (22.96) and Coconut (*Cocos nucifera*) (19.57). The enumerated species are common in agroforestry and plantation areas, which are the prevailing and current land use types of sites in mining areas.

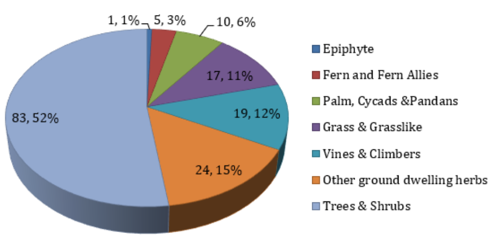

Figure 5. Classification of plant species into groups based on their growth habits.

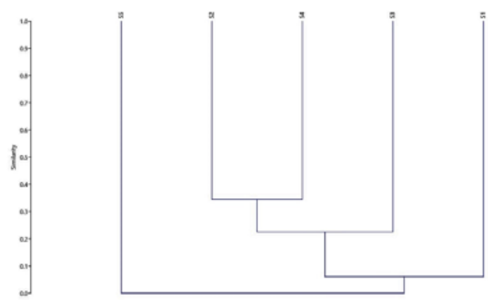

Figure 6. Generated Bray-Curtis analysis of sampled quadrats in the MPSA of SRMI. Higher values suggest higher similarities in species composition and structure.

Table 2. Summary of diversity indices for all quadrats at permanent SRMI monitoring stations.

Location	No. of Species	Individuals	Simpson's Index	Shannon's Index	Evenness
S1	6	21	0.5261	1.1280	0.5150
S2	4	8	0.6563	1.2130	0.8409
S3	4	11	0.7273	1.3420	0.9568
S4	7	13	0.7811	1.7330	0.8080
S5	3	9	0.3704	0.6837	0.6604
Area Composite	18	62	0.8595	2.3610	0.5891

Intermediate and understory

Only a few saplings and understory species were found in the study sites. Approximately 71 individuals belonging to 17 species were identified as intermediate species. Five of the 17 species were either non-trees or non-palms. Similarly, the average density was significantly higher than that of trees, 0.57 individuals/m² or equivalent to 56 individuals for every 100 m². barui (*Pandanus copelandii*) emerged as the most abundant understory species (Table 4), primarily because of the numerous saplings (n = 13) growing in S2 (water-lag area). Other species with the highest number of individuals were tambabasi (*Hellenia speciosa*), rattan (*Calamus* sp), mangium (*A. mangium*), and alagasi (*Leucosyke capitellata*). Most species had a low frequency of occurrence. The highest frequency was recorded in only three of the five quadrats. The low frequency of occurrence for each species suggests high variation among quadrats, which also reflects a good sampling representation (i.e., different vegetation types are covered).

Ground cover

Only 11 ground-cover species were recorded from five 1m × 1m quadrats. The plants that grow on the forest floor are mainly forest vines and grasses with exotic invasive grass species, which is understandable because all quadrats were established in disturbed areas. Grass species were the first organisms (pioneers) to occupy after disturbance (Give reference). According to the survey, *Paspalum conjugatum* occupied approximately 22% of the forest floor (Table 5), leaving fewer growing spaces for other ground species and resulting in low species diversity. Other dominant species with the highest relative cover were daat (*Scleria scrobiculata*), agsam (*Dicranopteris linearis*), and cogon grass (*Imperata cylindrica*).

Ecologically Important Species

Endemic Species

The geographical distribution of plant species helps assess the biodiversity values of regions,

Table 3. Top 10 tree species based on importance value in SRMI, Tubay, Agusan del Norte, Philippines

Species	Rfreq	Rden	Rdom	IV
Acacia mangium	8.33	29.03	35.57	72.94
Mangifera indica	12.50	14.52	12.34	39.36
Falcataria moluccana	8.33	12.90	9.07	30.31
Artocarpus odoratissimus	8.33	8.06	6.56	22.96
Cocos nucifera	8.33	4.84	6.39	19.57
Vitex parviflora	4.17	3.23	8.32	15.71
Tristaniopsis micrantha	4.17	3.23	5.83	13.22
Orania palindan	4.17	6.45	1.78	12.40
Chrysophyllum cainito	4.17	1.61	5.43	11.21
Persea americana	4.17	1.61	2.71	8.49
Totals	100.00	100.00	100.00	300.00

Table 4. List of the ten most abundant understory species encountered in the MPSA of SRMI.

Species	Abundance	Frequency
Pandanus copelandii	13	3
Hellenia speciosa	13	1
Calamus sp	8	1
Acacia mangium	7	2
Leucosyke capitellata	4	1
Cocos nucifera	4	2
Morinda citrifolia	4	2
Syzygium myrtifolium	3	1
Falcataria moluccana	3	1
Ficus septica	2	1

countries, and islands. Malabrigo (2013, cited by Umali et al. 2018) believed species confined to a particular site should be given conservation management strategies, as they are more vulnerable to disturbance due to their narrow range. Figure 7 shows the ecological distribution of plant species based on endemism (Pelser et al. 2011 onwards).

Based on the inventory, at least 15 (10%) were considered Philippine endemics in SRMI (Figure 3), which means that these plants have a minimal distribution and are found only in the archipelago. Some of the notable endemics are classified as threatened tree species, such as antipolo (*Artocarpus blancoi*), kalingag (*Cinnamomum mercadoi*), mancono (*Xanthostemon verdugonianus*), and cycad pitogo (*Cycas rumphii*; Table 6).

Table 5. List of dominant ground cover species and their corresponding relative cover (RC) in the mining areas of SRMI.

Species	Relative Cover
Paspalum conjugatum	22.00
Scleria scrobiculata	19.00
Dicranopteris linearis	14.00
Imperata cylindrica	14.00
Eclipta zippeliana	12.00
Stachytarpheta jamaicensis	7.00
Donax canniformis	6.00
Acmella uliginosa	2.00
Ipomoea triloba	2.00
Wollastonia biflora	1.00
Ananas comosus	1.00

Threatened species

Mining affects biodiversity at multiple spatial scales through direct and indirect processes (Sonter et al. 2018) and most likely causes a decline in rare and threatened species and ecosystems (Jacobi et al. 2007). Species conservation status is based on the most recent recommendations of the Philippine Plant Conservation Committee (PPCC) officially issued as DENR Administrative Order (DAO) No. 2017-11, better known as "Updated National List of Threatened Philippine Plants and Their Categories (DENR 2017). The list of threatened species on the IUCN Red

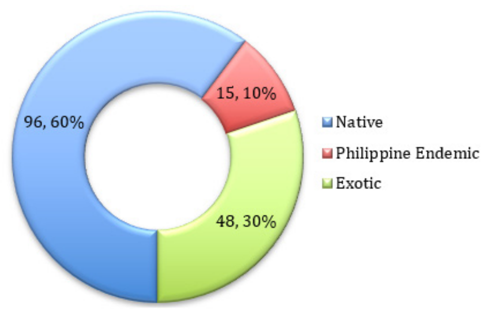

Figure 7. Donut chart showing the classification of plant species relative to global ecological distribution.

Table 6. List of Philippine endemic plant species found in SRMI mining areas.

Family	Species	Common Name	Endemism
Arecaceae	*Calamus merrillii*	Palasan	Philippine Endemic
Cycadaceae	*Cycas rumphii*	Pitogo	Philippine Endemic
Euphorbiaceae	*Macaranga bicolor*	Hamindang	Philippine Endemic
Lauraceae	*Cinnamomum mercadoi*	Kaningag	Philippine Endemic
Moraceae	*Artocarpus blancoi*	Antipolo	Philippine Endemic
Moraceae	*Ficus balete*	Balete	Philippine Endemic
Moraceae	*Ficus pseudopalma*	Niyog-niyogan	Philippine Endemic
Musaceae	*Musa acuminate*	Saging (Agutay)	Philippine Endemic
Myrtaceae	*Xanthostemon verdugonianus*	Mangkono	Philippine Endemic
Pandanaceae	*Pandanus copelandii*	Bariu	Philippine Endemic
Poaceae	*Dinochloa dielsiana*	Bikal	Philippine Endemic
Poaceae	*Schizostachyum lumampao*	Kawayan Buho	Philippine Endemic
Rubiaceae	*Mussaenda philippica*	Kahoi dalaga	Philippine Endemic
Rubiaceae	*Neonauclea bartlingii*	Lisak	Philippine Endemic
Rubiaceae	*Neonuclea media*	Wisak	Philippine Endemic

Table 7. List of threatened species encountered in the mining area.

Family Name	Species Name	Common Name	Conservation Status	
			IUCN 2021	DAO 2017-11
Araucariaceae	*Araucaria heterophylla*	Araucaria	VU	-
Arecaceae	*Adonidia merrillii*	Manila Palm	VU	EN
Arecaceae	*Caryota mitis*	Pugahan	-	NT
Cyatheaceae	*Sphaeropteris glauca*	Tree Fern	-	VU
Cycadaceae	*Cycas rumphii*	Pitogo	CR	EN
Fabaceae	*Pterocarpus indicus*	Narra	EN	CR
Lamiaceae	*Vitex parviflora*	Tugas	-	EN
Lauraceae	*Cinnamomum mercadoi*	Kaningag	-	VU
Myrtaceae	*Xanthostemon verdugonianus*	Mancono	VU	EN

Note: CR: Critically Endangered, EN: Endangered, VU: Vulnerable, NT: Nearly Threatened

List was also used as a reference (IUCN 2022).

Nine species encountered in the field survey were listed under the Philippine Red List or IUCN Red List of Threatened Species (Table 4). Of note are the three endangered species: pakong-buwaya, molave, and mancono.

The Philippines is a biodiversity hotspot with abundant unique flora and fauna. However, the country is also home to a thriving mining industry, which has been identified as one of the major drivers of biodiversity loss. The adverse effects of mining on biodiversity have been extensively documented in recent years.

Mining projects in the Philippines have contributed to biodiversity loss through habitat destruction, often involving large-scale excavations and land clearance. Gomez et al. (2016) noted that mining projects in the Philippines were responsible for destroying approximately 25% of the country's remaining forests. Mining has apparent implications for biodiversity, as forests are home to many plant and animal species that cannot survive in other ecosystems.

Mining projects can also exacerbate the existing threats to biodiversity in the Philippines, such as climate change and overexploitation. A study by Wae et al. (2018) noted that many species in the Philippines are already threatened by habitat loss, hunting, and other human activities. Mining projects can compound these threats by destroying additional habitats and altering the climate in the region. For example, mining activities can contribute to deforestation, which, in turn, can impact water cycles and soil health, leading to further environmental degradation.

These findings suggest that the overall diversity of the MPSAs of SRMI was slightly lower than that of the adjacent mining areas in Agusan del Norte (Along et al. 2020, Sarmiento 2020) but higher than other mining areas in the Philippines, such as Surigao del Sur (Sarmiento & Demetillo 2017), Surigao del Norte (Sarmiento 2018), and Zambales (Ata 2016). Therefore, policymakers in the Philippines and worldwide must take steps to mitigate the negative impacts of mining on biodiversity through initiatives such as sustainable mining practices and conservation efforts to protect vulnerable ecosystems and species. This information shows the need for immediate intervention to prevent further decline in diversity in mining areas.

4 Conclusion and Recommendations

The rapid plant survey revealed that the mineral production areas in Tubay, Agusan del Norte, Philippines, had remarkable species richness but critically declining biodiversity values. Despite ample time and effort, the survey encountered only a few Philippine endemics and threatened species. However, considering the number of threatened and ecologically important species in the area, this study suggests that conservation areas should be provided with genetic resources for future rehabilitation and restoration.

It is important to emphasize that the area covered by the survey is a very small fraction of the total consolidated mineral production area. However, a significant number of ecologically important species have been recorded. A more comprehensive plant diversity assessment is strongly recommended to better account for floral diversity in SRMI mining areas.

In conclusion, measures must be taken to mitigate the negative impacts of mining on biodiversity in the Philippines. Implementing strict regulations, proper oversight, and effective management are necessary to ensure that mining activities do not cause irreversible harm to ecosystems and provide numerous benefits.

Lastly, considering the scarcity of biological information on the flora of the mining areas of SRMI, the information that was initially gathered should be supplemented by additional survey information to develop a good reference document. A simplified pictorial guide on flora can be developed to increase stakeholder knowledge and appreciation for the beauty and importance of native trees in mining areas.

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Statement of Conflict of Interest

RT Sarmiento, an Associate Editor of JESEG, abstained from the review process of the article in the journal.

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