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Shrubs assemblage within and outside the hydraulic mining area in Tumpagon, Cagayan de Oro City, Philippines

Cordulo P. Ascaño II [1,*], Queenilyn B. Albutra [1], Vicenta V. Ansigbat [1], Dennis A. Mugot [2], Sherryl L. Paz [3] Cesar G. Demayo [4]

[1]*Department of Environmental Science and Technology, College of Arts and Sciences, Mindanao University of Science and Technology, Cagayan de Oro, Philippines*
[2]*Institute of Arts and Sciences, Misamis Oriental State College of Agriculture and Technology, Claveria, Philippines*
[3]*Department of Natural Sciences, Division of Environmental Science, College of Arts and Sciences, Caraga State University, Butuan City*
[4]*Department of Biological Sciences, College of Science and Mathematics, Mindanao State University - Iligan Institute of Technology, Iligan City, Philippines*

Abstract: Gold mining brings several benefits to developing countries like the Philippines. Although the industry produces economic gains and provides employment, it destroys the environment through deforestation, vegetation removal and loss of biodiversity. In this study, assessment on the distribution, abundance and status of Pteridophytes in and around the gold-mined areas in a village in Cagayan de Oro City, Philippines were considered. Collection and identification of Pteridophytes were done in the established sampling points outside and inside the mining area. Results of the study revealed that the diversity of Pteridophytes outside the mining area is higher than inside the mining area. *Cyathea contaminans,* an endangered species was observed outside and inside the mined site. Decrease in Pteridophytes diversity within the mining area can be attributed to habitat loss and fragmentation.

Key words: Pteridophytes, Surface mining; Ferns; Fern allies

1. Introduction

The Philippine archipelago, being the world's second largest archipelago after Indonesia, is one of the countries in the world considered as both a hotspot and a mega diversity country placing it as one of the top priority hotspots for global conservation (International, 2013). The country was reported home to the 5% of the world's flora with a high number of plant species ranging from 10,000-14,000 species (RP, 2009). This uniqueness is largely correlated with pristine vegetation.

Plants play a major role in the environment not only absorbing heat and release water vapour to maintain temperature (Kurniawan, 2004; Shaojun, 2012) by increasing humidity in the environment (Valsson and Bharat, 2011) but also prevent soil erosion (Zuazo and Pleguezuelo, 2008) and increases soil fertility (Russell, 1997). Man-made activities including mining and logging have been among the forces behind the country's loss of forest cover: from 17 million hectares in 1934 to just three million in 2003 or an 82 per cent decline (Docena, 2010). As a result, the country is considered hotspot of threatened forest tree species, due to anthropogenic habitat alteration (Myers et al., 2000).

Small-scale gold mining (SSGM) activities which play a crucial role in poverty alleviation and rural development in the Philippines, contributed to destruction of many forest areas in the country (ILO, 2003). One example is a village in Cagayan de Oro City, Philippines where the uses of hydraulic equipment which flushes the soil or waiting for the rain to wash tilled soil to leave gold particles behind have caused a lot of erosions. These gold extraction activities showed remarkable changes in the physical appearance of the land cover (Almaden, 2014).

Although studies on the effect of mining on plants have been made, these are mostly focused on trees, often using the traditional lower diameter limit of 10 cm dbh. Smaller trees and other life forms are usually neglected although they account for the bulk of species richness (Langenberger, 2004; Gentry and Dodson, 1987).

As significant as being one of the mega diverse countries, the Philippines is also considered as the 5th most mineral-rich country in the world, with the third largest reserves of gold, the fourth largest copper and the fifth largest nickel reserve (Philippines: Mining Laws and Regulations Handbook, 2013). Mining and mineral processing have the potential to be important sources of income and driving forces behind broader economic development (Eggert, 2001). With this, the country is faced with a great challenge in utilizing the rich available mineral resources for economic growth and development without compromising its ecological integrity and species diversity. In this

* Corresponding Author.

study, the species richness and abundance of shrubs as well as their endemism and conservation status were assessed within and outside the small scale gold mining area of Barangay Tumpagon, Cagayan de Oro City and Philippines to determine the likely impacts of surface mining in the diversity of shrubs. Moreover, the association of shrub species to different environmental variables was determined to provide information about the habitat preference and survival range of each species across different habitat.

2. Materials and methods

Tumpagon, is among the hinterland barangays of Cagayan de Oro City located at 8°19'19"N and 124°28'49"E and has a total area of 11,926.596 hectares. It is bounded by Iponan river on the north and west side; the Province of Lanao del Norte on the south, and barangay Pigsag-an on the east. Tumpagon has abundant supply of sand and gravel as well as gold. The gold mining activity in Tumpagon, Cagayan de Oro started during the 1950's up to the present. The method is surface mining through hydraulic technique (Fig. 1) which utilizes highly pressurized water to dislodge the surface soils and extract the gold nuggets from the area.

Fig. 1: Hydraulick mining technique in Tumpagon, Cagayan de Oro City.

As per record, the City Local Environment and Natural Resources Office through the City Mining Regulatory Board confirmed no existing mining concessions for gold, copper, or any other minerals. As such, any mining activities in the area are all considered illegal (Source: Interview; Engr. Rodante B. Felima, OIC-Mining Environment and Safety Division, DENR-MGB 10; CLENRO, CDO City).

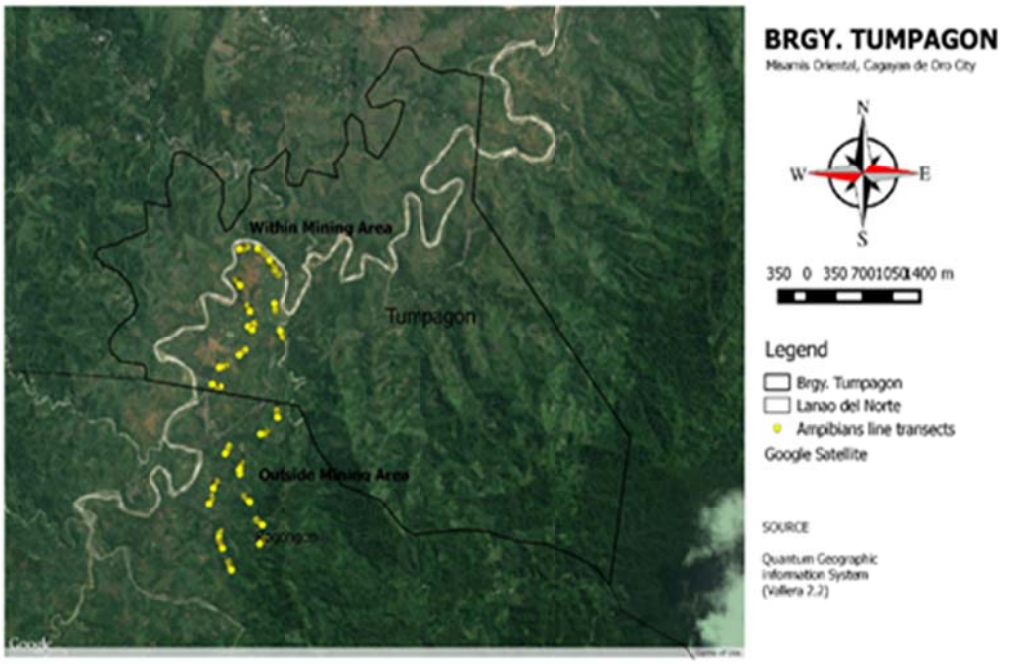

Fig. 2: Map showing the 4 transect lines established within and outside the mining area of Brgy. Tumpagon, Cagayan de Oro City

Four 2-km transect lines were established in the area (two 2-km transects within mine areas and another two 2-km transects outside mine areas with at least 5 km distance). Each line was divided into 9 sampling points placed every 250 m. ensuring that the two 2-km sampling stations were parallel with each other and had a distance of at least 2 km. (Fig. 2). For each sampling point, a 20x20 meter quadrat was established to sample shrubs.

Habitat measurements were taken at every sampling point using a modified habitat assessment procedure of Heaney (1986). Habitat variables were measured including the number of trees with diameter at breast height dbh 40-80 and 10-20 cm, elevation, slope, distance to creek and distance to

mining activity. The percent canopy cover, palms, and Bryophytes were assessed by estimating their percentage cover within a 10-m radius of each sampling point. Relative Humidity (RH), Leaf litter thickness (LLT) was also determined.

The trees selected were measured (tree height in meters, diameter at breast height, height of first branch) using 50-m diameter tape for tree size and clinometers for tree heights. The leaf litter thickness within 5-m radius of each point was measured using a ruler. All the habitat variables except the tree counts were measured in each of the four quadrants per sampling point. The data from all quadrants per point were pooled and mean values for each habitat variable were used for analysis. The elevation of each sampling point was determined using an altimeter. The geographic coordinates of each sampling point were recorded using an e-trex Vista HCx Garmin GPS. The degree of slope at the sampling points was determined using a clinometer.

The collected shrubs were identified onsite by an expert and verified using taxonomic keys from floras, books and monographs of Co's Digital Flora of the Philippines, Pelser et al. (eds.) (2011); The conservation status of floral species was assessed based from The National List of Threatened Philippine Plants (DENR AO No. 2015) and the IUCN Red List. Photographs were taken and herbarium specimens were made for further verification by the experts.

Photographs were taken and herbarium specimens were made for further verification by the experts.

Diversity indices and Canonical Correspondence Analysis (CCA) were performed using the PAST software version 2.14. CCA was performed to determine the association of shrub species to the environmental variables present in its habitat. The CCA scores obtained from the analysis were then used to construct a boxplot which contains information pertaining to the habitat preference and survival envelope or range of tolerance of each shrub species.

3. Results and discussion

A total of 10 shrubs species under seven families were identified within and outside the mining area of Tumpagon village, Cagayan de Oro, Philippines. The shrubs were classified according to its family and conservation status and their distribution inside and outside the mining areas were determined. The relationships of the different locations based on the presence and absence of the shrub species are shown in Table 1 and Figs. 3 and 4.

Species under family Fabaceae are the most prevalent in the area. This may be due to its fast germination ability associated with symbiotic properties which have enabled species to easily establish within habitat types. This plant family is able to fix nitrogen from the atmosphere which makes them potential pioneer species in heavily damaged area.

All of the species are non-endemic with pantropical distribution and are not yet assessed by the IUCN. Although these plant species do not have significant conservation value, they can be aggressively invasive that further weaken destabilized ecosystems (Langenberger, 2004).

Table 1: Species profile of shrubs found outside and inside the small-scale gold mining area of Tumpagon, Cagayan de Oro, Philippines

FAMILY NAME	SCIENTIFIC NAME	IUCN CONSERVATION STATUS/ DISTRIBUTION STATUS	INSIDE MINING		OUTSIDE MINING	
			1	2	1	2
LAMIACEAE	*Clerodendrum speciosissimum* Drapiez	Not yet assessed/ Pantropic	-	-	+	+
LEGUMINOSAE/ FABACEAE	*Senna alata* (L.) Roxb	Not yet assessed/ Pantropic	+	-	-	+
LEGUMINOSAE/ FABACEAE	*Senna tora* (L.)Roxb	Not yet assessed/ Pantropic	+	+	-	-
LEGUMINOSAE/ FABACEAE	*Indigofera tinctoria* L.	Not yet assessed/ Pantropic	+	-	-	-
LEGUMINOSAE/ FABACEAE	*Mimosa pudica* L.	Not yet assessed/ Pantropic	+	+	+	+
MALVACEAE	*Theobroma cacao* L.	Not yet assessed/ Pantropic	-	-	-	+
MELASTOMACEAE	*Melastoma malabathricum* L.	Not yet assessed/ Pantropic	+	+	+	+
MORACEAE	*Ficus septica* Burm. fil.	Not yet assessed/ Pantropic	-	-	+	-
MYRTACEAE	*Psidium guajava L.*	Not yet assessed/ Pantropic	-	+	-	-
RUBIACEAE	*Mycetia javanica* (Blume) Reinw. Ex Korth.	Not yet assessed/ Pantropic	-	-	+	-

Legend: (+) = Present; (-) = Absent

Fig. 3: Flowering and fruiting branches of **A**-*C. speciosissimum,* **B**- *I .tinctoria,* **C**- *S.alata*, **D**-*S.tora*, **E**-*T.cacao*, **F**-*M. malabathricum*, **G**-M.pudica, **H**- *F.septica*, **I**-*P.guajava*, and **J**- *M.javanica*.

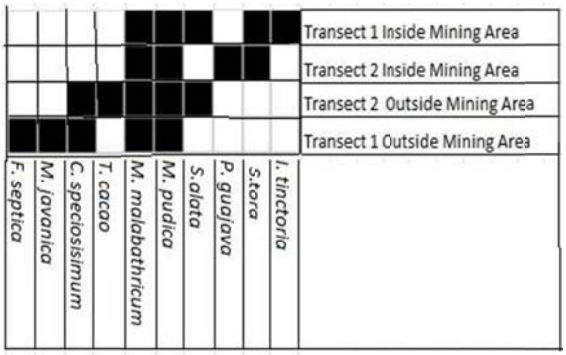

Fig. 4: Seriation of shrub species in different transects within and outside the mining areas of Baranggay Tumpagon, Cagayan de Oro City.

The seriation of species in Fig. 4, shows that *M. pudica* and *M. malabathricum* are the only species present in all of the transects, while *S. alata* is present only in at least 1 transect both inside and outside the mining area. Exclusively, *T. cacao, C. Speciosissimum, M. javanica* and *F. septica* are present outside the mining area while *I. tinctoria, S. tora* and *P. guajava* are present inside the mining area only. Exclusiveness of species may be due to habitat adaptation and favourable environmental conditions which encourage pollination, dispersal and eventual establishment of plants.

Table 2: Diversity indices of shrubs in Brgy. Tumpagon, Cagayan de Oro City

Diversity Indices	Inside Mining	Outside mining
Species Richness	6	7
Individuals	295	153
Dominance_D	0.6195	0.6314
Simpson_1-D	0.3804	0.2574
Shannon_H'	0.6324	0.4511
Evenness_e^H/S	0.8322	0.93

The comparison of diversity indices within and outside the mining area is shown in Table 2. Results showed that the number of individuals, Shannon_H' and Simpson's 1-D are higher inside the mining area. The higher value of indices inside mining area may be attributed to the lesser number of other plant groups such as trees (Mugot et al., 2015). This provides advantage to the growth and abundance of shrubs since it has greater chance of harvesting light and nutrients from the environment. There is also more space available due to lesser tree vegetation (Egbe et al., 2012). This is consistent with the statement of Campbell and Reece (2005) that after mining clears the forest, weedy and shrubby vegetation colonizes the area and dominates it for years. Species Richness, Evenness and dominance does not have much of a difference between the two areas.

The CCA of the tree species and 12 habitat variables in Fig. 5 revealed information of the habitat type of the shrub species. The arrows for environmental covariates projecting to the left of the main axis include increasing temperature (Temp) which indicates that it is an open area, associated slopes and Distance to Creek (DC). The shrubs *M. malabathricum, F. septica, P. guajava*, *M. pudica* and *S. alata* are associated with this kind of environment. The rest of the shrubs are with the right axis of the CCA biplot which is associated with plants having DBH of 10-20 cm, as well as trees with 40-80cm DBH and Palms (PAL). The values of the following environmental covariates are also increasing: Bryophyte Cover (BC), Relative Humidity (RH), Leaf litter thickness (LLT) distance to mining (DM), and altitude (Alt). This indicates that the area is both cultivated and early secondary growth forest.

Figure 6 shows the survival envelope of shrubs species. Consistent with the results of CCA biplots, *F. septica, P. guajava, M. malabathricum, M. pudica and S. tora* survive in the open area. Further, the habitat of *M. pudica* and *S. tora* extends to cultivated area which is in agreement with the habitat description of Pelser (2013) that both species thrive in open waste places at low and medium altitudes and are common weeds in settled areas. Similar description was given to *S. alata* which is present in low and medium altitudes, in the settled areas, secondary forests and clearings and is sometimes planted. *I. tinctoria* can be found in roadsides, grassy fields, cultivated grounds, riverbanks and secondary forest.

Boxplot revealed that *S. alata* and *I. tinctoria* survives in open area and cultivated habitats while *C. speciosissimum* survives both in cultivated and early secondary growth habitats. This is also consistent to the description by PIER (2014) which mentioned that *C. speciosissimum* occurs in dry to moist disturbed areas at low elevations, and is weedy in plantations and disturbed areas is also naturalized along the edges of cultivated areas, in clearings, and in coconut plantations. Three species show narrow survival range: *T. cacao*, in cultivated area *while M. javanica and C. speciosissimum* in early secondary growth forest. This finding is attributed to the fact that *T. cacao* is a cultivated crop while *M. javanica*'s natural habitat is very damp forest along the streams

at low and medium altitudes (Pelser and LaFrankie, 2015).

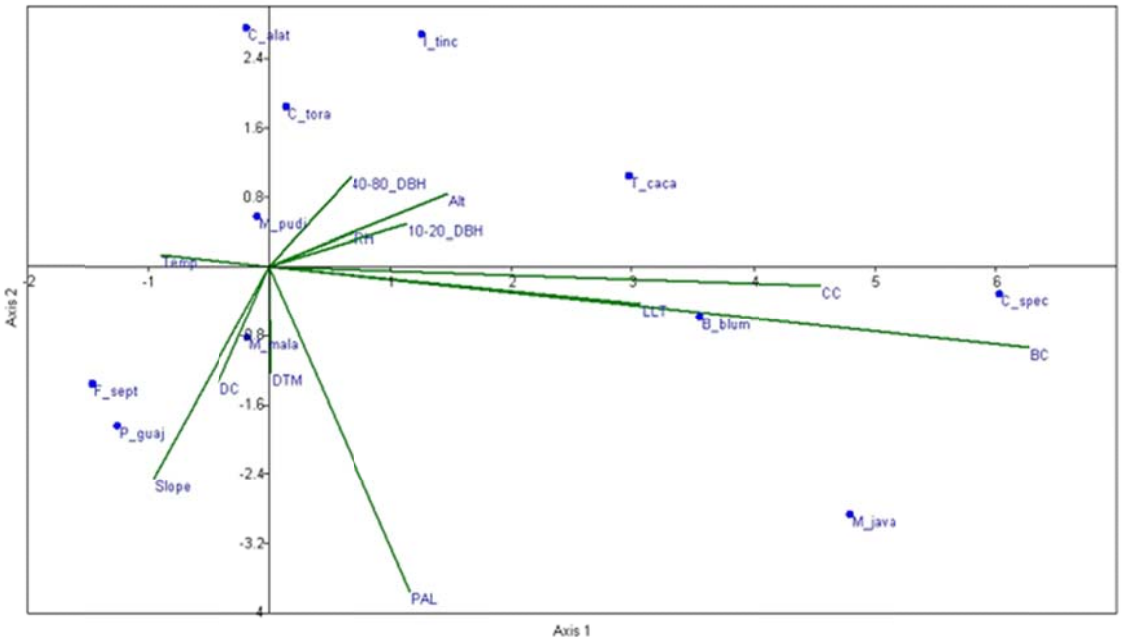

Fig. 5: Canonical Correspondence Analysis (CCA) Biplot showing the Species - Habitat Association of Shrub Species Found Outside and Inside the Mining Area of Barangay Tumpagon, Cagayan de Oro, Philippines. Legend: Alt-Altitude;DBH-Diameter at Breast Height;DC-Distance to Creek; LLT- leaf litter; DTM-distance to mining; PAL-palm; BC-bryophyte Cover;Temp-Temperature; CC-Canopy Cover; C_spec- *C. speciosissimum*, T.caca- *T.cacao* ,F.sep- *F.septica*,P_guaj-*P.guajava*,M_pudi-*M.pudica*,M_mala- *M.malabathricum*,M_java-*M.javanica*,C_tora-*S.tora*,C_alat-*S.alata*,I_tic- *I. tinctoria.*

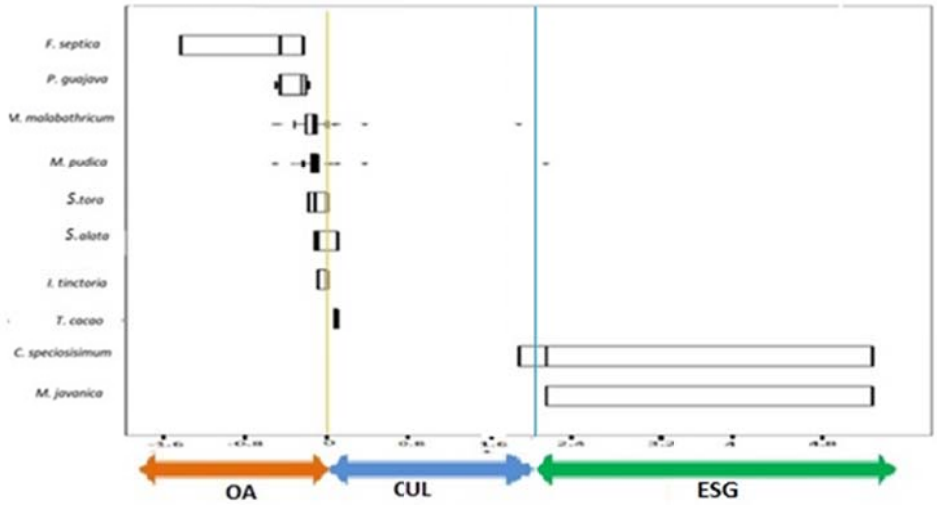

Fig. 6: Box plot showing the habitat preference and survival envelop of shrub species found outside and inside the gold mining area of Brgy. Tumpagon, Cagayan de Oro City, Philippines. (Legend: OA-open Area, CUL-cultivated area, ESG-early secondary growth)

4. Conclusion

The results of this study revealed that there is variation of species composition of shrubs inside and outside the mining area in Barangay Tumpagon, Cagayan de Oro City. Comparison between two areas showed that the mining activity has positively affected the diversity of shrubs in the area. The survival niche of the shrub species is relatively shallow; most of these species have preferred to thrive in the edges of open area and cultivated habitat. Colonization of suitable species brought about by the disturbance of mining activities is the main identified reason for the increased diversity of shrubs. Actions must be taken to rehabilitate the flora of the mined area to ensure the survival of forest dependent species.

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