

Research Article

Composition and diversity of arbuscular mycorrhizal fungi spore associated with different land-use types in tropical gold mine

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Abstract: Understanding the composition and diversity of arbuscular mycorrhizal fungi (AMF) is imperative for potentially enhancing their ecological role in different terrestrial ecosystems. Land use can have substantial effects on AMF species composition and diversity, but such effects have been explored less in tropical landscapes. In this study, we assessed the effects of disturbances on AMF species richness, observed the potential development of AMF types to produce mycorrhizal biofertilizer bioinoculants. This study was conducted identifying and selecting AMFs was for the purpose of managing post-mining land in Bombana District, Southeast Sulawesi, Indonesia. AMF spores collected from the field and trap culture were directly isolated and morphologically identified. A total of 15 AMF species were identified, including 11 species from field samples and 9 species from trap cultures. We noted that five AMF species were unique to field conditions and 5 AMF species were uniquely isolated from trap culture. It appears that Glomeraceae family contributed the highest number of species in all land-use types. *Glomus* sp. 1 was the most frequent species found in all land-use types. The Simpson's index, Shannon index and evenness ranged from 1.60 ± 0.51 to 2.40 ± 0.40 ; 0.41 ± 0.17 to 0.62 ± 0.17 ; 0.25 ± 0.10 to 0.39 ± 0.11 , respectively. In this study, we found three new records of AMF species including *Entrophospora colombiana*, *Sclerocystis microcarpa* and *Glomus coronatum* for Indonesia, i.e. from this study, it is clear that different land-use types affected AMF spore composition and species diversity. All AMF species found in this study were then applied to the land to improve land quality.

Keywords: arbuscular mycorrhizal fungi, Glomeraceae, gold tailings, land-use, Indonesia

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Introduction

Mycorrhizae have a mutually beneficial relationship between plant roots with certain fungi (Smith and Read, 2008). One of the mycorrhiza-forming fungi is Arbuscular Mycorrhizal Fungi (AMF). AMF is an obligate fungus of the phylum Glomeromycota and forms symbiotic relationships with 90% of higher plants in terrestrial ecosystems (Smith and Read, 2008) and wetlands (Tuheteru

and Wu, 2017). AM fungi can be beneficial for plant life and growth in a variety of biotic and abiotic environmental conditions, such as salinity (He et al., 2019), drought (Zhang et al., 2019), heavy metal toxicity (Husna et al., 2019) and waterlogging (Tuheteru et al., 2015). In addition, AMF is also potential to be developed as a tool for vegetation, reforestation, and restoration program in degraded ecosystems (Wang, 2017) and for phytoremediation process for land contaminated

with organic and inorganic materials (Tuheteru et al., 2016; 2020).

AMF has a global distribution in diverse ecosystems where the environment is still intact or damaged. The distribution of the AMF is strongly influenced by various factors affecting the abundance, wealth, and diversity of AMF. The composition and richness of the AMF species in a habitat or ecosystem are very dependent on various factors including soil types (Lekberg et al., 2007), soil depth (Oehl et al., 2005), pH (Bainard et al., 2015), climate (Kivlin et al., 2011), altitude (Gai et al., 2012), spatial and temporal distribution (Lovelock et al., 2003), host specificity plants (Johnson et al., 2013; Govindan et al., 2019), plant species distribution (Kivlin et al., 2011) and differences in plant growth and location (Uhlmann et al., 2004). Other contributing factors include disturbance (Guadarrama and Alvarez-Sanchez, 1999; Dandan and Zhiwei, 2007; Tchabi et al., 2008;), and land use types intensity (Oehl et al., 2010; Bainard et al., 2012; Soka and Ritchie, 2018).

Studies on identifying and diversify of AMF from native and degraded ecosystems in tropical regions of Indonesia are relatively limited. AMF species composition and diversity in Indonesia were carried out in farmlands, orchards, forests, grasslands, peatlands, forest conservation areas, degraded or polluted lands and forest ecosystems (Husna et al., 2018). A total of 72 AMF types from 4 orders, 16 genera, and 8 families were reported in Indonesia (Husna et al., 2018). AMF diversity studies on disturbed were reported from lands such as the gold tailings land in Timika Papua (Suharno et al., 2016; 2017) and Lombok West Nusa Tenggara (Prasetyo et al., 2010) and South Africa (Buck et al., 2019). In addition, research on AMF diversity in tropical grasslands is still limited (Soka and Ritchie, 2018; Stürmer et al., 2018). In tropical regions of Indonesia, studies on AMF diversity in one location that includes forest ecosystem, grassland, gold tailing land and post gold mining land have never been conducted. Mining activities can have an impact on decreasing biodiversity, including soil biota such as arbuscular mycorrhizal fungi (Husna et al., 2015; Wang 2017).

In this study, we hypothesized that AMF spore density and species richness are low in disturbed sites (post gold mining land). In addition, variations in soil properties such as pH as well as N, P and Mn content in soil affect AMF density and diversity. This study is expected 1) to provide information on AMF types in Indonesia; 2) gather information on the effects of disturbances on AMF species richness; 3) observe potential development of AMF types to produce mycorrhizal biofertilizer bio-inoculants. The aim of this study was

conducted identifying and selecting AMFs was for the purpose of managing post mining land in Bombana District, Southeast Sulawesi, Indonesia and the AMF obtained were then applied to the land to improve land quality.

Materials and Methods

Study site description

This study was conducted at four study sites, namely PT. Panca Logam Makmur, a 3-year old Artisanal Small-scale Gold Mining (ASGM) Tailings, community's post gold mining land (PGML), savanna and forest in Rarowatu Utara District, Bombana Regency, Southeast Sulawesi Province, Indonesia. Mean annual rainfall ranged from 1,083 mm to 1,325 mm. The elevation is 110 meters above sea level.

Field soil sampling

Soil samples were collected from all four study sites in March 2019. Sampling square plots 2 x 2 m were made at each study site, i.e. 10 plots at the community's post gold mining land (PGML) and forest and 15 plots for Artisanal Small-scale Gold Mining (ASGM) Tailings and savanna tailings (Figure 1). Soil samples taken were \pm 500 g of soil from each plot at 4 different sampling points at a depth of 0-20 cm. Soil samples were respectively collected and were made into 3 sub-samples. Thus, there were 12 soil samples. The collected soil samples were respectively kept in plastic bags and labelled with code names and plant names at each point or plot. All soil samples were dried in the laboratory for further AMF spores isolation and identification process as well as soil physical-chemical analyses.

Soil laboratory analyses

The analyses of soil physical and chemical properties were conducted at the SEAMEO BIOTROP's Soil and Plant Laboratory in Bogor, Indonesia. Soil analyses for each sample were repeated three times.

Soil trap culture

Trapping technique was used following the method by Brundrett et al. (1996) using open culture pots. The planting medium used was a mixture of 50 g soil samples and 150 g zeolite rocks. Weaning *Sorghum bicolor* sprouts were planted in the pot. Maintenance included watering, nutrient administration and manual pest control.

Isolation of AMF spores

AMF spores and sporocarp were isolated from 100 g of soil using the wet pouring technique from

Pacioni (1992) and continued with centrifugation techniques from Brundrett et al. (1996). Healthy spores were selected and mounted on an object glass that has been given a solution of Polyvinyl alcohol/lactic acid/glycerol (PVLG) and a mixture of PVLG and Melzer solution, then covered with a glass cover. Characteristics observation of AMF spores were carried out using the OLYMPUS CX22LED compound microscope at RCB-LIPI.

Identification of AMF spores was conducted based on shape, size, colour, hyphae of carriers, spores ornamentation and bulbous suspensors. The nomenclature of the AMF spores was carried out following the method by Schüßler and Walker (2010) and Redecker et al., (2013). All specimens of AMF were deposited in the Department of Forestry, Halu Oleo University, Kendari, Indonesia.

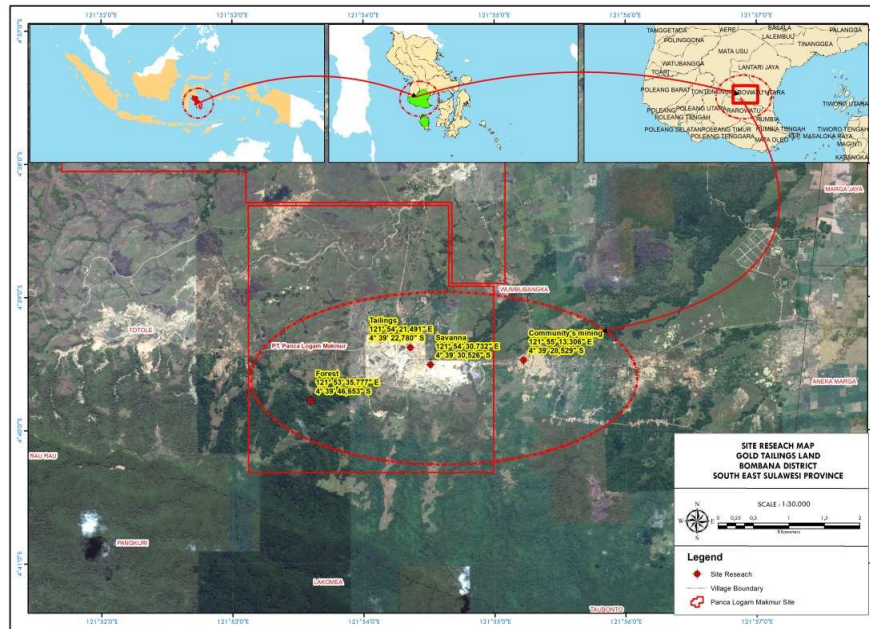


Figure 1. Map of study site showing different land-use types in tropical gold mines in Indonesia.

Tabel 1. AMF diversity parameters and formula.

Parameter	Formula
Isolation frequency (IF)	[the number of soil samples where AMF types or genera were found / total sample] x 100%
Relative abundance (RA)	Percentage of AMF spores based on species or genus
Important value (IV)	(IF + RA) / 2. IV value of ≥ 20 indicates the dominant type or genus
Spore density	Amount of AMF spores per 100 g of soil
Species richness	Number of AMF types in each soil sample
Shannon-Weiner index	$H' = -\sum p_i \ln p_i$
Evenness	$E = H' / H'_{\max}$
Simpson's index	$D = \sum [n_i(n_i - 1) / N(N - 1)]$

Notes: $P_i = n_i / N$, n_i = the number of AMF spores per species; N = the total number of spores that are identified; $H'_{\max} = \ln S$, S = the total number of species identified.

AMF colonization

Ten stained root segments of one cm long were randomly selected and mounted on the slide to determine the presence and absence of AMF structure. Root samples were cleaned and preserved in 70% alcohol solution. AMF colonies

were observed using trypan blue stain (Phillips and Hayman 1970). The mycorrhizal roots were examined to calculate the AMF percentage using the following formula:

$[\sum \text{field view of mycorrhizal root} / \sum \text{total of the observed field view}] \times 100\%$ (Brundrett et al., 1996).

AMF diversity indices

Diversity data observed in this study were isolation frequency, relative abundance, importance value, spore density, species richness, Shannon-Wiener index, evenness and Simpson's index as presented in Table 1.

Statistical analysis

Data were analyzed using analysis of variance (F test), including soil chemical properties, spore density and AMF colonization, species richness, Shannon-Weiner index, Evenness and Simpson Index. The test of treatment differences using LSD at 95% confidence level was conducted when the F-test result showed a significant effect. Correlations between soil chemical properties and spore density were carried out using Pearson's correlation.

Results and Discussion

AMF root colonization and spore density

The results of microscopic observations on plant root samples showed that AMF structures were found including internal hyphae> vesicles> external hyphae> hyphae coil. The AMF colonization ranged from 67.2 to 83.3% (Table 2). The total number of AMF spores varied by locations ranging from 10 to 18 per 100 g of soil. The highest number of spores was found in soil

samples from the forest location. Conversion of natural forests into mining land contributed negative impact on AMF abundance and species richness. Mining activity may cause extensive environmental stresses and damages to soil, plants and ecosystems (Wang 2017). Soil disturbance from mining activity may cause a reduction or loss of AMF propagule and infectivity. On the other hand, conversion land can change soil properties and changing plant community structure and diversity (Johnson et al. 2013; Wang 2017). AMF species richness and types decreased with increasing land-use type intensity (Oehl et al., 2010; Bainard et al., 2012). Different types and varieties of plants also affected the presence of AMF (Govindan et al., 2019).

The total of AMF types identified from soil samples and trap culture

A total of 15 AMF types were identified from soil samples from the four study sites, including seven genera, i.e. *Acaulospora*, *Entrophospora*, *Glomus*, *Sclerocystis*, *Gigaspora*, *Racocetra* and *Scutellospora*. Of the total species identified, 40% belong to Glomeraceae, 33.3% belong to Gigasporaceae, 20% belong to Acaulosporaceae, and 6.7% belong to Entrophosporaceae (Table 3). *Glomus* sp. was present in all study sites. AMF species richness varied by sites. AMF species were highest in forest > gold > tailing > savannah (Table 3).

Table 2. AMF colonization and spores density.

Site	Plant richness	Colonization (%)	Spore density	
			Field (per 100 g soil)	Trap culture (50 g soil)
Forest	8	67.2	18	43
ASGM tailings	37	82.5	14	103
Savanna	14	71.9	12	17
Community's PGML	16	83.3	10	74
Means		76.2		

Overall, nine AMF species were detected sporulating in trap cultures, of which; five species were previously recorded from field samples, while four species including *Entrophospora colombiana*, *Gigaspora gregaria*, *Gigaspora* sp. 1 and *Gigaspora* sp. 2 were recovered exclusively from trap culture (Table 3). Glomeraceae belongs to the dominant family of Glomeraceae six types of AMF. Various studies also showed that Glomeraceae has been dominant in various sites and ecosystems such as post-mining land (Singh and Jamaluddin, 2011; Husna et al., 2015),

savannah (Soka and Ritchie, 2018), saline (Zu et al., 2018), tropical forest (Kramadibrata, 2012; 2016) and land use types (Guadarrama and Alvarez-Sanchez, 1999). In tropical Indonesia, Glomeraceae was reportedly dominant with 36 species or 53% of 72 AMF types in Indonesia (Husna et al. 2018). In this study, there were three new AMF types that have never been revealed in Indonesia, namely *E. colombiana*, *S. microcarpa*, and *G. coronatum*. Thus, the discovery of three types of AMFs can add to the wealth of AMF types in tropical Indonesia.

Tabel 3. Glomeromycota species recovered from field soils and trap cultures.

Family	AMF species	Forest		ASGM Tailings		Savannah		Community's PGML	
		Fs	Tc	Fs	Tc	Fs	Tc	Fs	Tc
Acauloporaceae	<i>Acaulospora scrobiculata</i>	*	*	*	*				*
	<i>Acaulospora tuberculata</i>	*	*					*	
	<i>Acaulospora foveata</i>	*							
Entrophosporaceae	<i>Entrophospora colombiana</i>				*				*
Glomeraceae	<i>Glomus coronatum</i>				*	*			
	<i>Glomus</i> sp.1	*		*	*	*		*	*
	<i>Glomus</i> sp.2			*					
	<i>Sclerocystis microcarpa</i>	*							
	<i>Sclerocystis rubiformis</i>	*							
	<i>Sclerocystis sinuosa</i>					*	*	*	
Gigasporaceae	<i>Racocetra gregaria</i>								*
	<i>Gigaspora</i> sp.1				*				
	<i>Gigaspora</i> sp.2								*
	<i>Scutellospora pellucida</i>			*				*	
	<i>Scutellospora</i> sp.1	*		*	*			*	

Fs (Field soils), Tc (Trap cultures)

AMF Fungal Diversity

The highest relative frequency in *Glomus* sp.1 was 100% followed by *Scutellospora* sp. 1 (75%), *A. scrobiculata*, *A. tuberculata*, *Sclerocystis sinuosa* and *Scutellospora pellucida* were 50% each and the lowest types were 25% (Table 4). AMF spore relative density per location was presented in Table 4. Based on the Important Value, *Scutellospora* sp. 1 was dominant in forest, tailings and community's gold post-mining ecosystems. *A. tuberculata* was dominant in forest and community's gold post-mining ecosystems, *Glomus* sp. 1 and *A. Scrobiculata* were each dominant in forest sites and gold tailings. *Glomus* is a tolerant and adaptive genus in a variety of soil and environmental conditions (Husna et al., 2015). It can survive from acid to alkaline soils, produces small spores in a short time compared to *Gigaspora* and *Scutellospora*.

Glomeraceae has been reported to have the highest number of species in the Glomeromycota phylum (Dandan and Zhiwei, 2007; Schüßler and Walker, 2010; Singh and Jamaluddin, 2011). This study clearly demonstrated that *Glomus* sp.1 was the most dominant AMF species in all four study sites. *Glomus* sp. 1 is suspected to be dominant due to its small size, which can be associated with high sporulation capacity, adaptability to soil, climate and different plants (Shi et al., 2006; Kivlin et al., 2011; Shukla et al., 2013; Morales et al., 2019). Data on AMF diversity indices are presented in Table 5. The results showed that there were no statistically significant differences between AMF diversity in different and use types. The Shannon-Weiner index (H), evenness (E), and Simpson's

index (D) varied from 0.41 to 0.62; 0.25-0.39 and 0.26-0.60, respectively.

Different locations (land use types) affect AMF species richness and diversity. Forests environment supported more spores compared to other study sites. The results of this study were relevant to the soil nature at each study site, the disturbance intensity, and plant differences. The amount of spores, species richness, and AMF species diversity varied in different land use types (Dandan and Zhiwei, 2007). Human activities on each land use type contributed negative influence on AMF species richness/types and population dynamics (Guadarrama and Alvarez-Sanchez, 1999). Johnson et al. (2013) stated that land-use types with high intensity could change the nature of soil and may decrease AMF species richness and diversity. A study conducted by Gonzales-Cortes et al. (2012) also indicated the impact of land-use types changes (forest to avocado plantation and maize fields) was greater on AMF composition and richness. In this study, three types of AMF belonging to Glomeraceae family were found (*Glomus* sp. 1, *Glomus* sp. 2 and *S. sinuosa*) in the savannah ecosystem. The number of AMF types in this study was lower than those in previous research on savanna ecosystems in the tropics. The results of the study by Stürmer et al., (2018) found 21 types of AMF dominated by Gigasporaceae in Tropical Savannas of Roraima, Brazil, and Soka and Ritchie (2018) reported nine types of AMF in tropical savanna landscape of Tanzania. Muchane et al. (2012) found 14 types of AMF in tropical savanna of Maasai Mara in Kenya. A study conducted by Tchabi et al. (2008) found 49 AMF types in the sub-Saharan savannas of Benin.

Table 4. AMF fungal diversity.

AMF Species	Relative Frequency (%)	Forest			ASGM tailings			Savanna			Community's PGML		
		IF	RA	IV	IF	RA	IV	IF	RA	IV	IF	RA	IV
<i>A. scrobiculata</i>	50	20	12	16	40	36.59	38.29	-	-	-	-	-	-
<i>A. tuberculata</i>	50	30	16	23	-	-	-	-	-	-	30	25	27.5
<i>A. foveata</i>	25	20	8	14	-	-	-	-	-	-	-	-	-
<i>S. microcarpa</i>	25	10	4	7	-	-	-	-	-	-	-	-	-
<i>S. rubiformis</i>	25	10	4	7	-	-	-	-	-	-	-	-	-
<i>S. sinuosa</i>	50	-	-	-	-	-	-	40	48.65	30.98	10	10	10
<i>G. coronatum</i>	25	-	-	-	-	-	-	6.67	10.81	5.77	-	-	-
<i>Glomus</i> sp.1	100	10	44	27	20	14.63	17.32	20	40.54	19.15	10	5	7.5
<i>Glomus</i> sp.2	25	-	-	-	6.67	2.44	4.55	-	-	-	-	-	-
<i>S. pellucida</i>	50	-	-	-	6.67	1.22	3.94	-	-	-	10	10	10
<i>Scutellospora</i> sp.1	75	30	12	21	53.33	45.12	49.23	-	-	-	30	50	40

Table 5. AMF fungal diversity indices.

Site	S	H'	E	D
Forest	2.20 ± 0.37	0.59 ± 0.17	0.37 ± 0.10	0.26 ± 0.13
ASGM tailings	2.40 ± 0.40	0.62 ± 0.17	0.39 ± 0.11	0.60 ± 0.11
Savanna	1.80 ± 0.20	0.53 ± 0.13	0.33 ± 0.08	0.55 ± 0.12
Community's PGML	1.60 ± 0.51	0.41 ± 0.17	0.25 ± 0.10	0.46 ± 0.16
Pr>F	0.468	0.798	0.799	0.304

Table 6. Physical and chemical characteristics of soils across land use types.

Code/methods		Forest	ASGM tailings	Savanna	Community's PGML	CV (%)	P-value	
pH (SNI 03-6787-2002)		H ₂ O	5.73±0.07b	6.17±0.27b	8.07±0.15a	6.30±0.26b	5.44	0.0002
		CaCl ₂	5.13±0.12b	5.10±0.25b	7.43±0.07a	5.27±0.37b	7.03	0.0002
* Organic C %			1.71±0.20a	0.30±0.04b	0.76±0.16b	0.65±0.22b	34.62	0.0023
* Total N (Kjeldahl)		%	0.20±0.02a	0.06±0.01c	0.11±0b	0.12±0.02b	21.18	0.0011
C/N Ratio			8.67±1.20	5±0	7±1.73	5±1	31.49	0.1534
*P ₂ O ₅ (SL-MU-TT-05 (Bray I/II)		ppm	14.77±0.52ab	14.13±0.54b	18.70±1.06a	14.37±2.04b	13.58	0.0865
CEC		cmol/kg	12.53±1.09b	5.60±0.28c	23.77±2.04a	9.93±1.71bc	19.16	0.0001
Texture	Sand	%	41.67±0.81bc	70.93±2.20a	35.07±3.50c	48.03±3.45b	9.63	<.0001
SL-MU-TT-10	Silt	%	33.23±1.61a	18.90±0.90c	30.13±0.23ab	28.23±1.37b	7.25	0.0001
(Hydrometer)	Clay	%	25.10±0.85b	10.17±2.07c	34.80±3.41a	23.73±3.08b	18.86	0.0010
Total Mn (HNO ₃ – HClO ₄ (AAS)		Ppm	574.0±59.10b	553.0±62.65bc	853.0±89.11a	311.0±98.53c	23.94	0.0091
Total Fe (HNO ₃ – HClO ₄ (AAS)		%	1.14±0.03a	0.800.02b	1.30±0.09a	0.89±0.06b	9.44	0.0009

Table 7. Pearson-correlation matrix for edaphic variables associated with AMF abundance.

	*pH		*C Org	*N Total	C/N	*P ₂ O ₅	CEC	Texture			Mn Total	Fe Total
	(H ₂ O)	CaCl ₂						Sand	Silt	Clay		
Colonization	-0.137	-0.340	-0.849	-0.748	-0.988	-0.464	-0.593	0.690	-0.758	-0.600	-0.607	-0.845
Richness	-0.926	-0.827	0.644	0.641	0.384	-0.745	-0.602	0.173	0.205	-0.391	-0.514	-0.281
Spores AMF	-0.499	-0.341	0.697	0.549	0.728	-0.223	-0.153	0.038	0.210	-0.186	0.221	0.193
H'	-0.188	-0.117	0.153	-0.056	0.360	-0.051	-0.138	0.380	-0.303	-0.400	0.481	0.053
E	-0.188	-0.117	0.153	-0.056	0.360	-0.051	-0.138	0.380	-0.303	-0.400	0.481	0.053
D	0.531	0.361	-0.949	-0.976	-0.747	0.251	0.024	0.468	-0.763	-0.256	0.223	-0.291

Relationship between spore density and soil properties

Soil chemical properties varied among sites/land-use types. pH, P₂O₅, CEC, clay, Mn and Fe total were significantly higher in savanna. Organic-C and N-total were significantly lower in gold tailing and higher in forest. Sand was higher in gold mine tailings than other land-use types. There were no differences in P₂O₅ in savanna and forest (Table 6).

It was found that C-organic, N total, C/N ratio, total Mn, total Fe, silt and clay fractions were negatively correlated with AMF colonization in plant roots (Table 7). The sand texture was positively correlated with AMF colonization. pH, P₂O₅, CEC and Mn were negatively correlated with the number of AMF types, while total C-org and N were positively correlated. C-organic, N total, and C/N ratio were positively correlated with the number of AMF spores. On the other hand, they were negatively correlated with Simpson's Index (D).

The results of Pearson correlation (Table 7) indicated that AMF species richness and diversity was strongly influenced by the nature of the soil. Organic C and N were positively correlated with the total number of AMF spores and types, while total pH, P and Mn content in soil were negatively correlated with the number of AMF types. The AMF colonization was negatively correlated with all soil properties, except sand texture. Previous studies reported that soil pH (Bainard et al., 2015), organic matter content (Husna et al. 2015) and soil P (Soka and Ritchie, 2018) generally influenced AMF spore density and distribution. Bainard et al. (2015) reported that high pH and P decreased AMF species abundance, whereas low P could increase AMF species diversity (Soka and Ritchie, 2018). Some research also reported that there were no correlations between P and AMF species richness and diversity (Govindan et al., 2019).

In this study, Family Gigasporaceae dominant in degraded land such as ASGM tailings and Community's PGML. Gold post mining land has sandy soil and low organic carbon (Table 6). Lekberg et al. (2007) and Stürmer et al. (2018) reported that Gigasporaceae dominant was found in sandy soil and organic matter. Gigasporaceae also found in post-mining land (Singh and Jamaluddin, 2011; Husna et al. 2015). Table 7 showed that Mn and Fe contents in soil were negatively correlated with AMF colonization and richness. AMF colonization and diversity were low in heavy metal because heavy metals may potential inhibit AM fungi life cycle (Meharg and Carney, 1999) and AM developmental processes (Wang 2017). Finally, the collected AMF types can be reproduced and tested for effectiveness in a local

nursery and field-scale plants. Potential AMF types have been developed for biofertilizers to support the restoration efforts of forest ecosystems and degraded land, including tailings and post-gold mining lands in the tropics. AMF is an integral of ecosystem restoration projects and a key player in the recovery of degraded ecosystems (). Several publications about the role played by AMF in eco-restoration involves improved soil structures, improved growth and reproduction plant, water and nutrient uptake, plant tolerance to biotic and abiotic stresses and ecological succession (Wang, 2017). Further, AMF can also reduce the need for fertilizer so as to reduce the cost of ecological restoration.

Conclusion

The current study confirms that AMF community composition was clearly different between the four land use types, and that AMF spore density and diversity were significantly lowest in disturbed lands (tailings and post-gold mining land). A total of seven genera of AMF were identified: *Gigaspora*, *Acaulospora*, *Entrophospora*, *Sclerocystis*, *Glomus*, *Racocetra* and *Scutellospora*. *Glomus* was the most dominant genus in all four study sites. *Glomus* can be a candidate for screening high ecological restoration strains for the tailings and post-gold mining lands. This study has shown that variability in soil factors within and across land use types can have a significant effect on the AM fungal community structure and should not be ignored. The soil properties including soil pH, C-organic, P and Mn affected the AMF species density and richness. All AMF species found in this study could be potentially be developed into biological fertilizer to restore degraded forest ecosystems.

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