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Plant diversity after sixteen years post coal mining in East Kalimantan, Indonesia

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Abstract. *Komara LL, Choesin DN, Syamsudin TS. 2016. Plant diversity after sixteen years post coal mining in East Kalimantan, Indonesia. Biodiversitas 17: 531-538.* Post coal mining areas need to be rehabilitated through reclamation and revegetation. The objective of this study was to evaluate plant diversity after 16 years of revegetation activities in a coal mining reclamation site in East Kalimantan. In an effort to restore plant diversity, the coal mining company began by planting fast growing species as pioneers, then planting local species after three years. This study compared a 20 hectare reclamation site with conditions in the pre-mining area, which covered 14,988 hectares. Vegetation sampling was conducted in 20 plots measuring 20x20 m^2 along line transects, with 100 m distance between plots. A total of 104 plant species were found in the reclamation site, consisting of 76 tree species and 28 herbaceous species. Tree species consisted of 35 planted local species (e.g., *Dryobalanops aromatica, Eusideroxylon zwageri, Macaranga gigantea*), 25 planted non-local species, and 16 local species that grew spontaneously (e.g., *Leucaena glauca, Lansium domesticum, Shorea laevis*). In comparison, 133 species were found in the pre-mining site, consisting of 132 local tree species, one non-local tree species (*Acacia mangium*) and 52 herbaceous species. Tree species diversity index in the reclamation site after 16 years post mining (i.e., 3.54) was still lower than in the pre-mining area (4.29); while the diversity indices for herbaceous plants were relatively similar (2.97 and 2.67 in the reclamation and pre-mining sites respectively). The slightly higher diversity of herbaceous plants in the reclamation site may be attributed to higher coverage per species in this site, despite lower species richness.

Keywords: Kalimantan, local species, plant diversity, reclamation, revegetation

INTRODUCTION

Plant species composition in an area depends on environmental factors, such as temperature, humidity, nutrition, sunlight, topography, bedrock geology, soil characteristics, canopy structure and land use history (Hutchinson et al. 1999). Tropical rain forests are the most important plant species diversity centers in the world (Turner 2004). Situated in the tropics, the island of Borneo, including within it the Indonesian provinces of Kalimantan, contains a highly diverse flora, due partly to its unique geological and climatic history. The island is known to have 15,000 flowering plant species, and more than 3,000 species of trees, including 267 Dipterocarpaceae species (WWF 2005). However, this high diversity is currently being threatened by human activity and changes in land use.

Coal mining is a major activity that is changing landscapes. Coal mining causes changes in biodiversity (Cooke and Johnson 2002); soil profile (Makineci et al. 2011) and geological structure permanently (Shrestha and Lal 2011) by leaving large overburden areas (Graham and Haynes 2004; Sheoran and Sheoran 2009; Alday et al. 2011). Considering the impact of mining on the environment, post-mining areas need to be rehabilitated by conducting reclamation and revegetation (Hazarika et al. 2006). Reclamation in post coal mining areas involves moving the overburden to its original contour and spreading top soil over it (Shrestha and Lal 2011; Malakar et al. 2015). After the reclamation process is completed, the reclamation site is then ready to be revegetated (Shrestha and Lal 2011; Wardana 2008). At reclamation sites, soil nutrients are generally limited, soil pH is low, and there are often metal contaminants; therefore, revegetation activity must be carried out with plants selected on the basis of their ability to survive and regenerate or reproduce under severe conditions. Normally the revegetation process is started by selecting plants that are resistant to drought, or fast growing crops or fodder which can grow with limited nutrients (Sheoran et al. 2010).

In East Kalimantan province, Indonesia, coal mining covers an area of almost 3.27 million hectares (Nugroho and Adman 2011). Previous reclamation efforts in Kalimantan have shown that directly planting local tree species in reclamation sites is not successful, compared to planting pioneer plants such as *Acacia mangium*, *Paraserianthes falcataria* (Mansur 2010). According to Indonesian regulation, the success of post mining reclamation is indicated by 90% growth of vegetation and vegetation conditions that are close to pre-mining conditions (Regulation of State Minister for The Environment no. 4/2012). According to Claassen et al. (2008) one of the indicators of reclamation success is the presence of vegetation. Specifically, Perrow and Davy (2002) mention plant species composition and richness as criteria for evaluating the success of restoration. These parameters are easy to measure and are quite sensitive (Dale and Beyeler 2001; Ludwig et al. 2003). The objective of this study was to evaluate plant diversity after 16 years of revegetation activities in a coal mining reclamation site in East Kalimantan.

MATERIALS AND METHODS

Study area

The study was conducted at a post coal mining area in the lowlands (approximately 58-200 m above sea level) of East Kutai District. East Kalimantan Province (Figure 1). The mining area was previously a production forest, i.e., a forest concession area, loaned from the Ministry of Forestry under condition that at the end of mining activities, the area should be returned to its pre-mining condition. This study was conducted in two sites: 1) a pre-mining area, i.e., a production forest dominated by *Acacia mangium* (mainly for pulp and paper production) which has been abandoned for a period of 16 years, and 2) a reclamation site, i.e., a post mining area which has been prepared for reclamation by forming it following its original contour. The latter site was covered with 30 cm of top soil in order to plant vegetation. The distance between the two locations was approximately 3 km. At the reclamation site, about 48 tree species were planted, including fast growing species (*Acacia mangium*, *Cassia siamea*, *Paraserianthes falcataria* etc.). In the reclamation program, plant survival was monitored every three months for a period of one year. Trees showing unsuccessful growth were replaced using the same species. In order to restore plant diversity to its pre-mining condition, in the third year of revegetation, a total of 56 local species, e.g., *Dryobalanops aromatica* and *Shorea leprosula*, were planted.

Procedures

Plant diversity in both the pre-mining and reclamation sites was studied for a period of six months (from March to September 2013). In each location, vegetation sampling was conducted in 20 plots measuring 20x20 m^2 along line transects (Soerianegara and Indrawan 1998). The distance between plots was 100 m (Fig.2). The 20x20 m^2 plots were used to sample tree species within these plots, 5x5 m^2 subplots were used to sample non-tree woody plants and 1x1 m^2 subplots to sample herbaceous plants. Non-tree woody plants were later grouped together with herbaceous plants. Plant samples (both tree and herbaceous species) were collected if needed in order to identify unknown species for identification. Plant species were identified using references in Herbarium Bandungense, School of Life Sciences and Technology, Institut Teknologi Bandung, West Java, Indonesia.

Degree of vegetation cover was measured as percentage of area occupied by a plant's crown, stem (basal area) or patch. Tree basal area was determined after measuring diameter at breast height (Phillips 1959). The data collected from plots were analyzed for frequency, density and abundance (Kent and Coker 1992), their relative values were calculated as follows:

$$Relative\,density = \frac{Number\,of\,individuals\,of\,species}{Total\,number\,of\,inviduals}\,x\,100$$

$$Relative\,dominance = \frac{Dominance\,of\,a\,species}{Dominance\,of\,all\,species}\,x\,100$$

$$Relative\,frequency = \frac{Frequency\,of\,species}{Frequency\,of\,all\,inviduals}\,x\,100$$

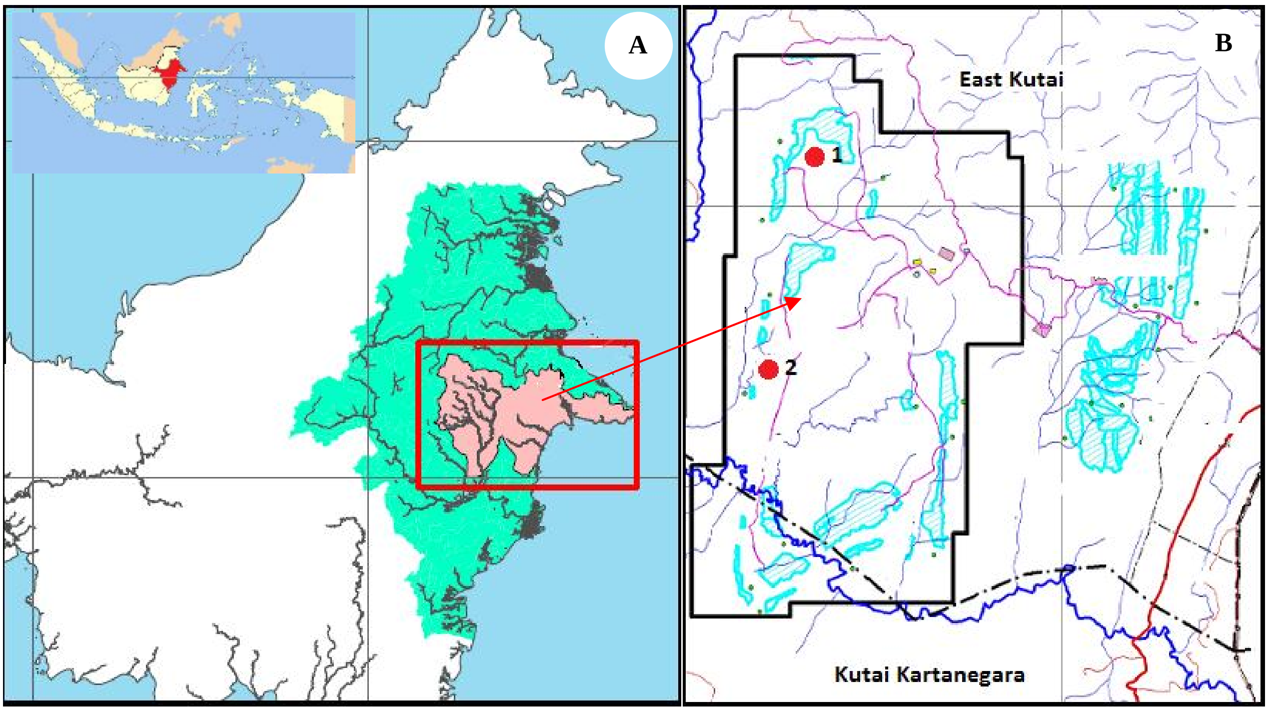
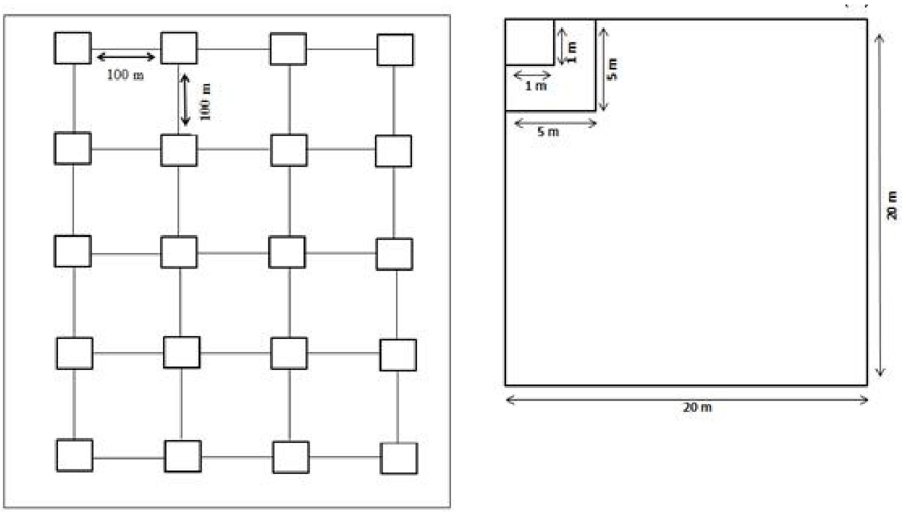


Figure 1. Location of the study area in East Kalimantan at 117º12'50"-117º23'30" EL and 00º02'20"-00º13'00" NL. A. Borneo island, B. Red circle 1 is the pre-mining site and red circle 2 is reclamation site location.



A **B**

Figure 2.A. Plots in line transects in pre-mining and reclamation sites, each plot measuring 20x20 m^2 with 100 m distance between plots; B. Nested plot measuring 20x20 m^2 for trees, 5x5 m^2 for non-tree woody plants and 1x1 m^2 for herbaceous plants.

Importance value for each species = relative density + relative dominance + relative frequency

Where, dominance is defined as the mean basal area per tree times the number of trees of the species.

The species diversity index (H') was determined following Shannon-Wiener (Kent and Coker 1992; Hazarika et al. 2006; Ekka and Behera 2011), i.e., as follows:

$$H' = -\sum_{i=1}^{S}(pi \ln pi)$$

Where, H' = observed species diversity, S = the number of species; pi = the proportion of individuals or the abundance of the i^{th} species expressed as a proportion of total cover; ln = log $base_n$.

Data analysis

All data were calculated using Excel for Windows 7 for the relative density, relative frequency, relative dominance, Importance value index and diversity index (H').

RESULTS AND DISCUSSION

Plant diversity in pre-mining area

The pre-mining area was formerly a production forest dominated by *Acacia mangium* and *Cassia siamea*. After the change of management from production forest to mining company, no activities were conducted in the area. The land was abandoned and vegetation grew naturally for 16 years without any human interference. In this area, we found 185 plant species, consisting of 133 tree species and 52 herbaceous plant species (Table 1 and 2). Among the tree species, there were 132 local species and one non-local species (*Acacia mangium*) which was present since the area was still a production forest. The importance value indices of plant species in this area varied from 0.64% to 46.08%. Fifteen species of tree species had importance value indices higher than 20%, while 15 species of herbaceous plants had indices higher than 5% (Figure 3). Specifically, tree species were dominated by *Macaranga gigantea* (46.08 %), *Eusideroxylon zwageri* (40.96%), *Cananga odorata* (39.04 %), *Euodia speciosa* (36.48 %) and *Dillenia excelsa* (33.92 %); while the herbaceous understorey was dominated by *Blumea balsamifera* (29.04 %), *Pandanus* sp. (23.05%), *Donax cannaeformis* (19.27%), *Phrynium placentarium* (19.10 %) and *Selaginella plana* (17.76 %).

Plant diversity in reclamation site

In the first year of reclamation, 48 non-local species were planted, consisting of pioneer plants and fast growing trees. Three years later, 52 local tree species were planted. After 16 years of reclamation, we found 104 species which consist of 76 tree species and 28 herbaceous species (Table 1). The importance value indices of plant species in this area varied from 0.75% to 66.75%. The top 15 species with highest importance value indices (higher than 4.35% for tree species and more than 7.51% for the herbaceous plants) are presented in Figure 4. tree species were dominated by *Acacia mangium* as shown by the highest importance value index of 37.75%, followed by *Cassia siamea* (35.08%), *Paraserianthes falcataria* (28.28%), *Dryobalanops aromatic* (18.85%) and *Samanea saman* (15.23%). Herbaceous species were dominated by *Diplazium esculentum* with importance value index of 66.75%, followed by *Blumea balsamifera* (30.01%), *Ageratum conyzoides* (18.75%), *Acmella oleracea* (14.25%) and *Merremia peltata* (12.75%).

Table 1. Diversity of tree species at pre-mining and reclamation site (√ for present or × for absent)

Tree species	Pre-mining	Recla-mation
Acacia mangium Willd.	√	√
Actinodaphne diversifolia Merr.	√	×
Actinodaphne glomerata (Bl.) Nees.	√	√
Aglaia grandis Korth.ex Miq.	√	×
Aglaia tomentosa Teijsm.& Binn.	√	×
Aleurites moluccana (L.) Willd.	√	√
Alstonia angustiloba Miq.	√	√
Anthocephalus chinensis (Roxb) Bosser.	√	√
Aquilaria malaccensis Lam.	√	√
Archidendron havilandii (Ridl.) I.C.Nielsen.	√	√
Artocarpus altilis(Parkinson) Fosberg.	√	√
Artocarpus champeden (Lour.) Stokes.	√	√
Artocarpus rigidus Blume, Bijdr.	√	√
Averrhoa carambola L.	√	√
Baccaurea macrocarpa (Miq.) Müll.Arg.	√	×
Baccaurea sp.	√	√
Baccaurea stipulata J.J.Sm.	√	×
Barringtonia sarcostachys (Blume) Miq.	√	×
Bauhinia sp.	√	√
Beilschmiedia rivularis Kosterm.	√	×
Bischofia javanica Blume.	√	√
Callicarpa pentandra Roxb.	√	√
Cananga odorata (Lam.) Hook.f. & Thomson	√	√
Canarium odontophyllum Miq.	√	×
Canthium confertum (Burm.f.) Alston	√	×
Casuarina equisetifolia L.	√	√
Cleistanthus myrianthus (Hassk.) Kurz.	√	√
Clerodendrum confusum Hallier f.	√	×
Cratoxylum arborescens (Vahl) Blume.	√	√
Croton argyratus Blume, Bijdr.	√	×
Cryptocarya sp	√	×
Cyathea contaminans (Wall. ex Hook.) Copel	√	×
Dacryodes rostrata (Blume) H.J.Lam	√	×
Dehaasia incrassata (Jack) Nees.	√	×
Dillenia excelsa (Jack) Martelli ex Gilg.	√	×
Dillenia reticulata King.	√	×
Dillenia sumatrana Miq.	√	×
Dimocarpus longan Lour.	√	×
Diospyros borneesis Hiern.	√	×
Diospyros macrophylla Blume.	√	×
Diospyros sp.	√	×
Dipterocarpus confertus Slooten.	√	×
Dipterocarpus cornutus Dyer.	√	×
Dipterocarpus humeratus Slooten	√	×
Disepalum anomalum Hook.f.	√	×
Dracontomelon dao (Blanco) Merr. & Rolfe.	√	√
Drimycarpus luridus (Hook. f.) Ding Hou.	√	×
Dryobalanops aromatica Gaertn.*f., nom cons.*	√	√
Drypetes longifolia (Blume) Pax & K. Hoffm.	√	×
Drypetes subcubica (J.J.Sm.) Pax & K.Hoffm.	√	×
Duabanga moluccana Blume.	√	√
Durio zibethinus Rumph. ex Murray.	√	√
Dyera costulosa (Miq.) Hook. film.	√	×
Euodia alba Hook. f.	√	×
Euodia speciosa Rchb.f. & Zoll. ex Teijsm. & Binn.	√	×
Elmerrillia tsiampacca (L.) Dandy.	√	×
Eusideroxylon zwageri Teijsm. & Binn.	√	√
Evodia latifolia DC.	√	√
Ficus fistulosa Reinw. ex Blume	√	×
Ficus geocarpa Teijsm. ex Miq.	√	×
Ficus sp.	√	√
Ficus uncinata (King) Becc.,	√	×
Ficus variegata Blume	√	×
Flacourtia rukam Zoll. & Moritzi	√	×
Glochidion sp.	√	√
*Gluta renghas*L.	√	√
Hibiscus similis Bl.	√	√
Homalanthus populneus (Giesel.) Pax.	√	×
Horsfieldia grandis (Hk. f.) Warb.	√	√
Ilex cymosa Blume	√	√
Knema conferta (King) Warb.	√	×
Knema latericia Elm.	√	×
*Koompassia malaccensis*Maingay ex Benth.	√	√
Koordersiodendron pinnatum (Blanco) Merr. Bull.	√	√
Lansium Domisticum Corr.	√	√
Lansium parasiticum (Osbeck) Sahni et. Bennet	√	√
Leea aculeata Blume	√	√
Lepisanthes alata (Blume) Leenh.	√	√
Leucaena glauca (Linn.) Benth.	√	√
Lithocarpus sp.	√	×
Litsea accendens (Blume) Boerl.	√	√
Litsea sp.	√	√
Macaranga gigantea (Reichb.f. & Zoll.) Muell.	√	√
Macaranga hypoleuca (Rchb.f. & Zoll.) Müll.Arg.	√	×
Macaranga pruinosa (Miq.) Mull Arg	√	×
Macaranga sp.	√	×
Macaranga tanarius (L.) Müll.Arg.	√	×
Macaranga triloba Thunb.) Müll.Arg.	√	√
Maranthes corymbosa Blume.	√	×
Merremia peltata (L.) Merr.	√	×
Memecylon garcinioides Blume.	√	×
Mitrephora fragrans Merr.	√	×
Myristica elliptica Wall.ex. Hook. f. Thoms.	√	×
Myristica guatteriifolia A.DC.	√	×
Myristica maxima Warb.	√	√
Nauclea calycina Bartl. ex DC	√	×
Nauclea purpurascens Korth.	√	×
Neouvaria acuminatissima (Miq.) Airy Shaw	√	×
Nephelium cuspidatum Blume.	√	×
Nephelium lappaceum L.	√	×
Nypa fruticans Wurmb	√	×
Ochanostachys amentacea Mast.	√	×
Octomeles sumatrana Miq.	√	×
Homalanthus sp.	√	√
Orophea corymbosa (Blume) Miq	√	×
Palaquium quercifolium (de Vriese) Burck	√	√
Planchonia valida (Blume) Blume	√	×
Pholidocarpus sp.	√	×
Polyalthia obliqua Hook.	√	×

Polyalthia sumatrana (Miq.) Kurz.	√	×
Pternandra rostrata (Cogn.) M.P.Nayar.	√	×
Pterospermum diversifolium Blume.	√	×
Pterospermum javanicum Jungh.	√	×
Sageraea lanceolata Miq.	√	×
Sageraea glabra Merr.	√	×
Saraca hullettii Prain.	√	×
Saurauia nudiflora DC.	√	×
Schima wallichii (DC.) Korth.	√	×
Semecarpus glaucus Engl.	√	×
Shorea dispar Ashton.	√	√
Shorea laevis Ridl.	√	√
Shorea leprosula Miq.	√	×
Shorea pinanga Scheff.	√	√
Shorea seminis (de Viese) v.Slooten	√	×
Syzygium acuminatissima (Blume) Merr. & Perry.	√	√
Syzygium sp. 1	√	×
Tetramerista glabra Miq.	√	√
Trema orientalis (L.) Blume	√	×
Vatica sp.	√	×
Vernonia arborea Buch.-Ham.	√	×
Vitex pubescens Vahl.	√	√
Walsura pinnata Hassk.	√	×
Xanthophyllum vitellinum (Blume) D.Dietr.	√	×

Comparison between pre-mining and reclamation sites

After 16 years of reclamation, plant diversity in the reclamation site was still lower than in the pre-mining site which was used as reference. Comparison of species diversity indices (H’) between the two sites indicate a significant different in tree species, however, diversity indices for herbaceous plants were similar between the two sites. The diversity index for tree species in pre-mining area was 4.29 and in reclamation site was 3.54. Table 3 presents species richness and diversity indices in the two sites.

It is interesting to note that 16 species of tree species plants in the reclamation site grew spontaneously without being planted by the reclamation program. These were *Leucaena glauca*, *Lansium domesticum*, *Shorea laevis*, *Homalanthus populneus*, *Durio zibethinus*, *Casuarina equisetifolia*, *Averrhoa carambola*, *Artocarpus champeden*, *Bauhinia* sp, *Palaquium quercifolium*, *Horsfieldia grandis*, *Evodia latifolia*, *Cleistanthus myrianthus*, *Bischofia javanica*, *Koompassia malaccensis* and *Actinodaphne glomerata* (Figure 5). Considering the seed form and dispersal process, it is assumed that the presence of these species in the reclamation site is related to the activity of animals which are found near the reclamation site and act as dispersal agents. Both the pre-mining and reclamation sites are in fact not too far from a forest system outside the area. This forest system could be considered as a source of plant diversity, so plant colonization at the reclamation site was presumably assisted by animals from its surroundings. This phenomenon may have benefited the reclamation program, although actual plant dispersal processes need to be confirmed.

Table 3. Diversity of herbaceous species at pre-mining and reclamation site (√ for present or × for absent)

Herbaceous	Pre-mining	Reclamation
Acmella oleracea (L.) R.K.Jansen,	√	√
Ageratum conyzoides L.	√	√
Amomum maximum Roxb	√	√
Asplenium sp.	√	×
Begonia sp.	√	×
Blumea balsamifera L.	√	√
Boehmeria nivea (L.) Gaudich.	√	√
Borreria sp.	√	×
Calathea bachemiana E.Morren.	√	×
Callicarpa longifolia Lamarck.	√	√
Colocasia esculenta (L.) Schott;	√	√
Colocasia sp.	√	×
Commelina sp.	√	×
Curculigo latifolia Dryand.	√	√
Cyperus sp.	√	√
Diplazium esculentum (Retz.) Sw.	√	√
Donax cannaeformis (G.Forst.) K.Sch.	√	√
Dryopteris sp.	√	×
Fimbristylis sp.	√	×
Gleichenia linearis (Burm. f.) S.W. Clarke.	√	×
Globba leucantha Miq.	√	×
Helminthostachys zeylanica (L.) Hook.	√	√
Hornstedtia affinis Riedl.	√	×
Hornstedtia irya (Gaertn.) Warb.	√	×
Labisia pumila Benth. & Hook	√	√
Lantana camara L	√	√
Mapania sp	√	×
Melastoma malabathricum L.	√	√
Merremia peltata (L.) Merr.	√	√
Mimosa pudica L.	√	√
Pandanus sp.	√	×
Pandanus tectorius Parkinson.	√	√
Peperomia pellucida (L.) Kunth.	√	√
Phacelophrynium maximum (Blume) K. Schum	√	√
Phyllanthus urinaria L.	√	×
Phrynium hirtum Riedl.	√	√
Phrynium placentarium (Lour.) Merr.	√	√
Phrynium sp.	√	×
Piper betle L.	√	√
Piper nigrum L.	√	√
Plagiostachys albiflora Riedl.	√	×
Pleomele angustifolia (Roxb.) N.E.Br.	√	×
Pteris sp.	√	×
Rhaphidophora minor Hook.f. Climber.	√	×
Saccharum spontaneum L.	√	√
Scoparia dulcis L.	√	√
Selaginella plana Hieron.	√	√
Stenochlaena palustris (Burm.f.) Bedd.	√	√
Tectaria sp.	√	×
Tetrastigma sp.	√	×
Zingiber longipedunculatum Riedl.	√	√
Zingiber sp.	√	×

Table 3. Plant species diversity indices in pre-mining and reclamation site

Site	Pre-mining		Reclamation	
	Number	H’	Number	H’
Tree species	133	4.29	76	3.54
Herbaceous plants	52	2.67	28	2.97
Total species	185		104	

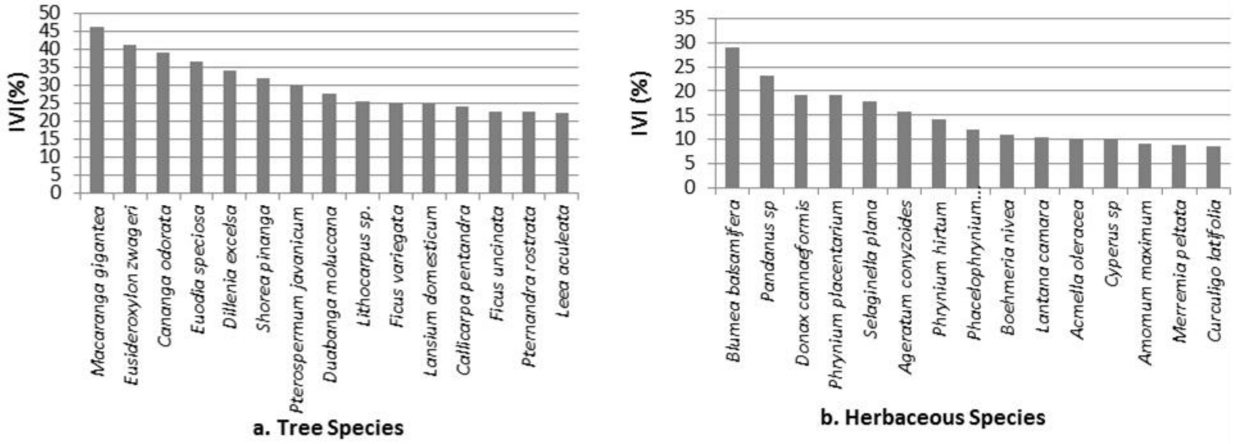


Figure 3. The importance value indices (IVI) of 15 species of tree species (a) and 15 species of herbaceous plants (b) in pre-mining area

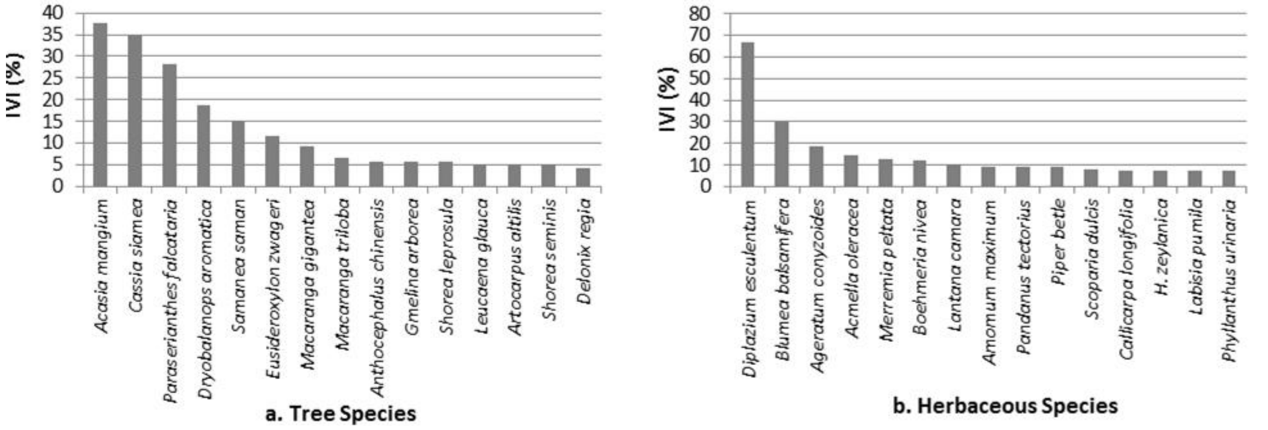


Figure 4. The importance value indices (IVI) of 15 species of tree species plants (a) and 15 species of herbaceous plants (b) in reclamation area

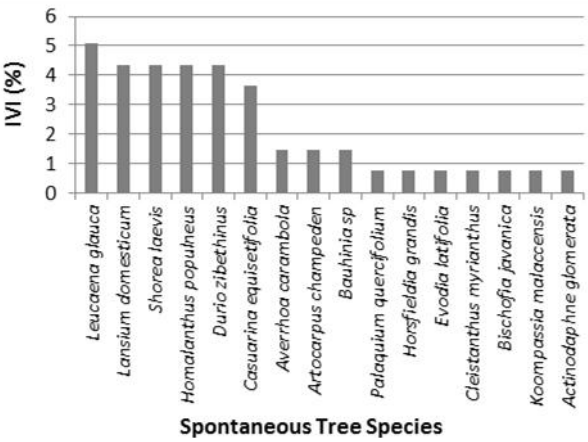


Figure 5. Importance value indices (IVI) of 16 tree species that grew spontaneously at reclamation site

Discussion

The mahang tree (*Macaranga gigantea*) is a local species which dominated in the pre-mining area, as shown by its highest importance value index. *Macaranga* is known as a pioneer and fast growing plant, with soft wood, which sprouts all year round and is able to reach a height of up to 20 meters (Zakaria et al. 2008). In addition, many species of *Macaranga* sp. favor high light intensity, indicating its relative tolerance to open areas. Several species of *Macaranga*, such as *Macaranga tanarius* and *Macaranga javanica* have been used as indicator species for disturbed forest areas (Zakaria et al. 2008). In the reclamation site, the dominant species was *Acacia mangium*. However, *Macaranga* sp. was also quite abundant although not many seedlings were planted (Komara et al., unpublished data). The high number of seedlings of local species planted in the reclamation site was one of the factors contributing to the importance value indices of these plant species. In the case of *Macaranga* sp., however, abundance may also have been supported by the natural availability of seedlings in the site. This phenomenon is in accordance with the generalization of major factors affecting succession, as stated by Noble and Slatyer (1980), i.e. that the composition of species immediately after a disturbance depends on propagules which have either dispersed from elsewhere or have persisted through the disturbance or on vegetative resprouting of organs surviving the disturbance. Three groups of vital attributes are important to vegetation replacement, i.e., the method of arrival or persistence of a species during and after disturbance; the ability to establish and grow to maturity; and the time taken fo them to reach critical stages in their life history (Noble and Slatyer 1980).

The same phenomenon was found in *Eusideroxylon zwageri*, known as the ulin tree. This local species was the second dominant species in the pre-mining site. This plant is well known for its high quality wood but slow growth rate. The high importance value index of ulin in this area indicates that this area could conserve the ulin tree in its natural habitat. In the reclamation site, *Eusideroxylon zwageri* was the sixth rank. The slow growth rate of this species seems to have contributed to its relatively low importance value in the reclamation site.

In the pre-mining site, the dominant herbaceous species was *Blumea balsamifera* with the highest importance value index (29.04%), while in the reclamation site this plant was the second dominant species with an importance value index of 30.01%. The dominant species in the reclamation site was the fern *Diplazium esculentum* with an importance value index of 66.75%. *Blumea balsamifera* has abundant leaves, grows relatively fast, and is extremely tolerant to minimum light intensity (shade plant). In contrast, *Diplazium esculentum* is tolerant to high light intensity. The presence of *Diplazium esculentum* could be related to its dispersal ability, i.e., dispersed by wind from the forest system. However, this needs to be reconfirmed.

The presence of herbaceous plants benefits the reclamation program through their role as ground cover. Plants such as *Diplazium esculentum*, *Blumea balsamifera*, *Ageratum conyzoides*, *Acmella oleracea* and *Merremia peltata* easily grow in relatively poor soil conditions under sufficient sunlight. Besides its rapid growth, *Diplazium esculentum* seems to be an adaptable species for post-mining areas. Several herbaceous species from the pre-mining area were found in the reclamation site, e.g., *Piper betel*, *Selaginella plana*, *Selaginella deoderleinii* and *Piper nigrum*.

The ability of plants to grow in the reclamation site can be attributed to seeds already present in the top soil during reclamation process, or by seed dispersal. For example, *Leucaena glauca* (5.08 %) is propagated by seeds, and is easy to grow after being cut, felled or burned. *Lansium domesticum* (4.35%), *Durio zibethinus* (4.35%), *Averrhoa carambola* (1.45%) and others are several fruits species with seeds that could be dispersed by animals. *Shorea laevis* (4.35%) seeds contain a lot of fat that is commonly eaten by animals. Dispersion of plant species depends on animal species and the distance between the reclamation site and the nearby vegetation source, e.g., the nearest forest that will affect the distribution of the species (Novianti 2013; Traveset et al. 2014).

Based on the number of plant species that successfully grew at the reclamation site, the following findings could be used to suggest further management of this study site: in terms of species richness, there were 132 local species in the pre-mining area as reference site, while at the reclamation site there were 35 planted local species and 16 local species which grew spontaneously. In other words, a total of 51 local species successfully grew at the reclamation site after a period of 16 years. To restore plant diversity in the reclamation site to its assumed pre-mining conditions, it should be planted with 81 local species of tree species. The next step is to select the local tree species from the pre-mining area by considering the species importance value indices. In the pre-mining area, only eight local species had importance value indices higher than 20%, e.g., *Euodia speciosa* (36.48%), *Shorea pinanga* (31.80%), *Lithocarpus* sp. (25.44%), *Ficus variegata* (25.01%), *Ficus uncinata* (22.72%), *Pternandra rostrata* (22.40%), *Shorea dispar* (21.76%) and *Canarium odontophyllum* (21.76%); however the reclamation program must consider the availability of seedlings and the ability of the plant to grow successfully in reclamation conditions.

To conclude, after 16 years of reclamation, 104 plant species were found in the reclamation site, consisting of 76 tree species and 28 herbaceous species. tree species that successfully grew in this site consisted of 35 planted local species (e.g., *Dryobalanops aromatica*, *Eusideroxylon zwageri*, *Macaranga gigantea*), 25 planted non local species, and 16 local species that grew spontaneously (e.g., *Leucaena glauca*, *Lansium domesticum*, *Shorea laevis*). In comparison, data from the pre-mining area indicate the presence of 133 plant species, consisting of 132 local tree species, one non local tree species (*Acacia mangium*) and 52 herbaceous species. Tree species diversity index in the reclamation site after 16 years post mining (i.e., 3.54) was still lower than in the pre-mining area (4.29); while the diversity indices for herbaceous plants were relatively similar (2.97 and 2.67 in the reclamation and pre-mining sites respectively). The slightly higher diversity index in the reclamation site can be attributed to higher coverage per species in this site, despite lower species richness.

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