Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 6, No. 6, p. 29-39, 2015
http://www.innspub.net

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RESEARCH PAPER
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Dominance and diversity of forest plant species growth on post coal mining soil in the Samarinda City, East Kalimantan Province, Indonesia

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Article published on June 05, 2015

Key words: Forest plant species, Post coal mining soil, Dominance, Diversity, soil remediation

Abstract

A post coal mining land contains soil physicochemical properties that are not suitable for plant growth as well as contained high heavy metal. Only resistance plants species would be able to survive in those conditions. Utilization of forest plant species to rehabilitate and remedy an ex-coal mining land at the same time supports biodiversity conservation for Indonesian forest. This study aimed to analyze dominance and diversity of forest plant species growth in post coal mining soil for plant selection in metal phytoremediation. Forest plant density, frequency, dominance, Important Value Index (IVI), diversity index, dominance index and Summed Dominance Ratio (SDR) were analyzed. Forest plant species found in post coal mining site were *Acacia mangium* Willd., *Trema* sp, *Macaranga gigantea* (Reichb.f.& Zoll.), *Terminalia cattapa* L., *Pometia pinnata* J.R. & G. Forst., *Mangifera indica* L., *Samanea saman* (Jacq.) Merr., *Arthocarphus Integra* Merr. and *Anthocephalus cadamba* (Roxb.) Miq. Post coal mining land had homogenous forest plant species due to low diversity. However dominance forest plant species found in those sites were *A. mangium*, *A. cadamba* and *S. saman*. Among those species, *A. cadamba* is a new potential endemic species in Indonesia for metal remediation in post coal mining soil. Those species had resistances to low soil pH, low soil fertility and high metal content. On the other hand, they also had a potency to be utilized as plants for metal remediation on post coal mining land as well as their economical potencies.

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Introduction

A post coal mining land has soil physicochemical properties that are not suitable for plant growth. A Study conducted by Forestry Faculty of Mulawarman University (unpublised) reported that a post coal mining site contained low fertility soil, low water absorption, low pH and high metal content. This soil conditions inhibit growth of vegetation root and plant biomass. In addition, several studies showed that post coal mining lands contained high Cd, Co, Cu, Cr, As, Mn, Fe, Pb and Zn (Maiti *et al*., 2004, Dowarah *et al*., 2009; Wan Yaacob *et al*., 2009; Saidi and Badruzsaufari, 2009; Shan *et al*., 2010; Yenilmez *et al*., 2011). These exceeded metals in soil are toxic to plant (Kabata and Pendias, 2001).

Therefore, land rehabilitation including land cover addition and metal remediation in post coal mining soil play an important role in ecosystem recovery after coal mining (FAO, 2002). The most important factor for a successful post coal mining land rehabilitation is plant species selection. Plant species criteria for this purpose are to have wide and deep root system to bind water in order to prevent erosion as well as to absorb metal at the same time (Mwegoha, 2008); to produce high biomass (Wong, 2004) and to have high economic value. Plants with these criteria are belonged to forest plant species. Studies in Malaysia reported that forest plant species, i.e. *Hopea odorata* Roxb., *Acacia mangium* Willd., *Dalbergia sisso* Roxb., and *Samanea saman* (Jacq.) Merr. capable to remove Pb, Cu, Cd, Zn, Ni, Cr and Fe in post mining soil (Ashraf *et al*., 2011, Ghafoori *et al*., 2011, Kabir *et al*., 2011, Majid *et al*., 2011, Widyati, 2011).

In addition to above criteria, those plants should have characteristic i.e. fast growing and resistant to low fertile soil, acid pH, and high metal content (Mukhopadhayay and Maiti, 2010). Selection for plant with this criteria can be performed by conducting a survey of plants species growth surrounding post coal mining. The dominance plants species are assumed resistant to low fertile soil and potential for metal remediation in post coal mining land (Maiti *et al.,* 2005), improvement of soil physic-chemical properties and addition of land cover (Ashraf *et al*., 2010).

Vegetation analysis including dominance and diversity of forest plant species growth in post coal mining land therefore become very important, because of lacking information concerning resistant forest plant species growth in post coal mining in Indonesia. This study aimed to analyze dominance and diversity of forest plant species growth in post coal mining soil in Indonesia. This study describe several potential new forest plant species for metal phytoremediation especially in Indonesia and become a fundamental of plant selection for post mining land rehabilitation.

Material and methods

Study Area

This study was conducted in a post coal mining land belong to CV. TujuhTujuh that was located in North Samarinda, Samarinda City, East Kalimantan, Indonesia, as seen in Figure 1. The study area consisted of 2 reclamation sites for 5 and 3 ha respectively as well as an over-burden filled soil for 1 ha. Reclamation site was a post coal land, which had been reclaimed and planted for a year. Meanwhile an over-burden site was an ex landfill site for back filling soil from coal mining dump.

Vegetation Analysis

Identification for dominant forest plant species was performed using census method by numerate one by one whole of forest plant species either shrub, pole, or tree size which were grown in each plots. Each plot was made using quadrant method in 20 x 20 m (0.04 ha) for 7 and 12 plots randomize distributed in 3 and 5 ha respectively (Myers and Bazely, 2003). Vegetation analysis included density, frequency, dominance, Important Value Index (IVI), diversity index, dominance index and Summed Dominance Ratio (SDR).

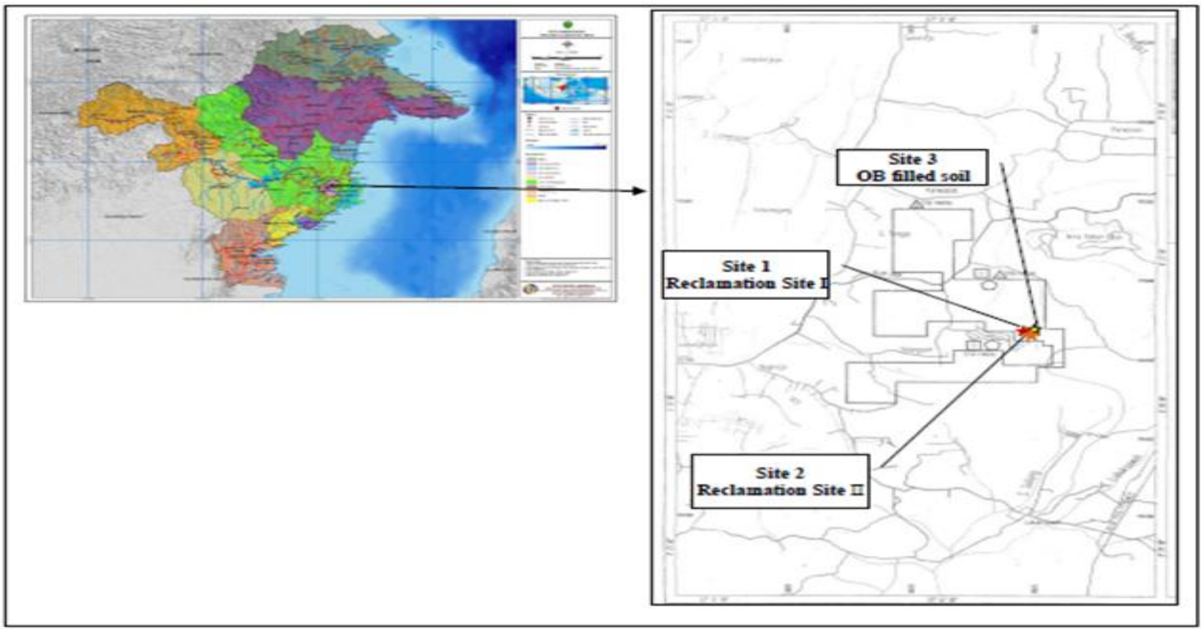

Fig. 1. Map of Province of East Kalimantan, Indonesia showing Study Area for Vegetation Analysis in Post Coal Mining Sites at CV. TujuhTujuh.

Vegetation frequency was calculated by number of individual in whole of sampling plot, whereas relative density was obtained from frequency of species A in whole of species frequency (Michael, 1984; Myers and Bazely, 2003; Fachrul, 2007). Dominance and Dominance Index (Michael, 1984; Myers and Bazely, 2003; Fachrul, 2007), as well as SDR, IVI, and diversity index (Michael, 1984; Southwood, 1996; Myers and Bazely, 2003; Fachrul, 2007) were determined using the equation below:

$$\text{Dominance} = \frac{\text{Basal Area for Species A}}{\text{Plot Size}}$$

$$\text{Dominance Index} = \sum \left(\frac{\text{IVI for each species}}{\text{total IVI}} \right)^2$$

$$\text{IVI} = \text{Relative Dominance} + \text{Relative Frequency} + \text{Relative Density}$$

$$\text{SDR} = \frac{\text{IVI}}{3}$$

$$\text{Diversity Index of Shanon Weiner} = -\sum \left\{ \left(\frac{\text{IVI for each species}}{\text{total IVI}} \right) \times \log \left(\frac{\text{IVI for each species}}{\text{total IVI}} \right) \right\}$$

Soil physicochemical properties on ex-coal mining land were obtained from laboratory analysis as seen in Table 1.

Result and discussion

Result for vegetation analysis on ex-coal mining site in location I, II and II are seen in Table 2, 3, and 4. Based on analysis to two ex-coal mining sites, which had been reclaimed, were found several forest plant species growth naturally and planted as well. Forest plant species, which had been growth naturally, were *Acacia mangium* Willd., *Trema* sp, *Macaranga gigantea* (Reichb.f.& Zoll.), *Terminalia cattapa* L., and *Pometia pinnata* J.R. & G. Forst. Whereas forest plant species which had been planted in reclamation sites were *Mangifera indica* L., *Samanea saman* (Jacq.) Merr., *Arthocarphus Integra* Merr. and *Anthocephalus cadamba* (Roxb.) Miq. Meanwhile, forest plant species that were found on those three sites were *A. mangium* and *S. saman*.

Several forest plant species, which were found in the first reclamation site (Table 1), were *S. saman*, *A. mangium*, *A. integra* and *Trema* sp with density reached 739 trees/ha, 161 trees/ha, 46 trees/ha and 261 trees/ha respectively in total of 1207 trees/ha. *S. saman*, *A. mangium* and *Trema* sp had 100% frequency in abundance category, whereas *A. integra* only had 43% frequency in normal category (Ahmad *et al.*, 2007). This frequency described distribution level for each plant species that was analyzed in the first reclamation site (Indrayanto, 2006). According to Raunkier Frequency class (1934) in Reddy and Ugle (2008), there were 96.15% plant species in E class and 3.85% plant species in C class. A low C percentage and < E indicated that post coal mining land had a homogenous community.

Forest plant species which were found in the second reclamation site (Site II) (Table 2), were 906.25 trees/ha. It consisted of *S. saman* with density for 684.42 trees/ha*, A. mangium* for 14.58 trees/ha, *A. integra* for 14.58 trees/ha*, Trema* sp for 152.08 trees/ha*, M. gigantea* for 20.83 trees/ha, *A. cadamba* for 2.08 trees/ha*,* and *T. catappa* for 16.67 trees/ha. *S. saman* and *Trema* sp had 100% and 83% frequency respectively with very abundance distribution. *M. gigantea* had 42% frequency that was distributed frequently, whereas *A. mangium* had 33% frequency with occasional distributions. Meanwhile, *A. integra* had frequencies for 17% as well as *A. cadamba* and *T. catappa* had frequencies for 8% with rare distributions (Ahmad *et al.*, 2007).

Table 1. Physicochemical Properties of an Overburden-filled Soil and Reclamation Soil from Post Coal Mining Land.

No	Variable	Overburden-Filled Soil			Soil from Reclamation Site		
Soil Physic Properties							
1.	Texture	Clay sandy			Clay sandy		
2.	Bulk Density (g/cm^3)	1.17	±	0.91	1.29	±	0.14
3.	Porosity (%)	54.81	±	2.36	49.86	±	5.56
4.	Permeability (cm/hour)	15.29	±	3.58	7.75	±	7.30
Soil Chemical Properties							
1.	Organic Matter (%)	0.02	±	0.02	0.02	±	0.01
2.	pH ($CaCl_2$)	3.18	±	0.64	3.73	±	0.05
3.	Base Cation						
a.	Na^+ (meq/100 g)	0.96	±	0.04	0.99	±	0.03
b.	K^+ (meq/100 g)	0.20	±	0.15	0.14	±	0.09
c.	Ca^{2+} (meq/100 g)	0.41	±	0.26	0.79	±	0.26
d.	Mg^{2+} (meq/100 g)	0.73	±	0.34	0.77	±	0.26
4.	CEC (meq/100 g)	6.19	±	0.82	3.52	±	0.73
5.	Base Saturation (%)	36.77	±	5.08	18.15	±	7.10
6.	K (ppm)	0.50	±	0.19	0.52	±	0.04
7.	P (ppm)	0.04	±	0.00	0.04	±	0.01
8.	N (%)	0.03	±	0.02	0.03	±	0.02
9.	C (%)	0.01	±	0.01	0.01	±	0.00
10.	C/N Ration	0.56	±	0.77	0.09	±	0.04

*These data are reported detailed in another manuscript in title of "Physicochemical Properties and Metal Contents of Soil from Ex-Coal Mining in Samarinda City, East Kalimantan Provinsi, Indonesia" (Ayub *et al.*, unpublished). (It has been submitted and under reviewed in the Journal of Biotropia).

Forest plant species which were found in an overburden-filled soil (Site III) (Table 3), were 19 trees/ha. It consisted of *A. cadamba* with density for 10 trees/ha*, P. pinnata* for 2 trees/ha, *M. indica* for 2 trees/ha*, S. saman* for 1 trees/ha*, A. mangium* for 3 trees/ha, and *T. catappa* for 1 trees/ha. Those species had 100% frequencies that were distributed in very abundance (Ahmad *et al.*, 2007). An overburden-filled soil was only 1 ha, therefore plant sampling were plant population at the same time.

According to Raunkier (1934) vegetation class distribution in Reddy and Ugle (2008), an overburden filled-soil had 100% plant species in E class, which were classified as a homogenous community for forest species.

Dominant plant species in those sites were determined by parameter of IVI, and SDR (Myers and Bazely, 2003). IVI is determined by a total of relative density, relative frequency and relative dominance (Odum, 1993). Whereas SDR is identical to IVI due to IVI divide to its component parameter (Myers and Bazely, 2003). IVI from the first reclamation site (site I) from the highest to the lowest was *S. saman* > *Trema* sp > *A. mangium* > *A. Integra* with SDR respectively for 55.72%, 21.73%, 16.43% and 6.08%. Meanwhile, IVI from site II was *S. saman* > *Trema* sp > *M. gigantea* > *A. mangium* > *A. integra* > *T. cattapa* > *A. cadamba* with SDR respectively for 64.61%, 18.54%, 6.07%, 4.41%, 3.03%, 2.04% and 1.33%. Whereas IVI for an overburden-filled soil was *A. mangium* > *S. saman* > *A. integra* > *P. pinnata* > *T. cattapa* with SDR respectively for 34.88%, 28.8%, 9.68%, 9.48%, 9.38% and 7.70%.

Table 2. Vegetation Analysis in the First Reclamation Site at Post Coal Mining Land (Site I).

No	Parameter	*S. saman*	*A. mangium*	*A. integra*	*Trema* sp	Total
1.	Density(tree/ha)	739.00	161.00	46.00	261.00	1.21
2.	Relative Density (%)	61.24	13.31	3.85	21.60	
3.	Frequency	1.00	1.00	0.43	1.00	3.43
4.	Relative Frequency (%)	29.00	29.00	13.00	29.00	
5.	Dominance (m²/ha)	0.57	0.05	0.01	0.11	0.74
6.	Relative Dominance (%)	76.75	6.82	1.88	14.55	
7.	IVI (%)	167.16	49.30	18.23	65.31	300
8.	SDR (%)	55.72	16.43	6.08	21.77	
9.	Dominance Index	0.39				
10.	Diversity Index	0.49				

The highest to the lowest dominance forest plant species found in Site I were *S. saman* > *Trema* sp > *A. mangium* > *A. integra*, whereas in Site II were *S. saman* > *Trema* sp. > *A. integra* > *M. gigantea* > *T. cattapa* > *A. cadamba* > *A. mangium*. Meanwhile, an overburden-filled soil had dominance respectively for *A. mangium* > *A. cadamba* > *S. saman* > *M. indica* > *T. cattapa* > *P. pinnata*. *S. saman* had the highest dominance species in both reclamation sites (Site I and II) among other species, whereas *A. mangium* was found as the highest dominance species in the ex-overburden filled site (Site III).

Table 3. Vegetation Analysis in the Second Reclamation Site at Post Coal Mining Land (Site II)

No	Parameter	*S. saman*	*A. mangium*	*A. integra*	*Trema* sp	*M. gigantea*	*A. cadamba*	*T. catappa*	Total
1.	Density (tree/ha)	685.42	14.58	14.58	152.08	20.83	2.08	16.67	906.25
2.	Relative Density (%)	75.63	1.61	1.61	16.78	2.30	0.23	1.84	
3.	Frequency	1.00	0.33	0.17	0.83	0.42	0.08	0.08	2.92
4.	Relative Frequency (%)	34.29	11.43	5.71	28.57	14.29	2.86	2.86	
5.	Dominance (m²/ha)	0.72	0.00	0.02	0.09	0.01	0.01	0.01	0.86
6.	Relative Dominance (%)	83.91	0.20	1.78	10.27	1.63	0.91	1.30	
7.	IVI (%)	193.83	13.24	9.10	55.63	18.22	4.00	5.99	300
8.	SDR (%)	64.61	4.41	3.03	18.54	6.07	1.33	2.00	100
9.	Dominance Index	0.46							
10.	Diversity Index	0.50							

Dominance Index indicates dominant forest plant species that belong to either mono- species or several species (Indrayanto, 2006). The first reclamation site (Site I) in ex-coal mining land had dominance index for 0.39, which indicated that forest plant species dominance belong to several plant species i.e. *S.*

saman, Trema sp, and *A. mangium*. Similar to the first reclamation site (Site I), the second reclamation site (Site II) also had dominance index for 0.49 that showed dominancy belong to more than one species, i.e. *S. saman* and *Trema* sp. Meanwhile, dominance index for 0.24 belonged to several forest plant species that growth in an overburden-filled soil i.e. *A. cadamba*, *A. mangium*, *S. saman* and *M. indica*.

Dominance Index that was belonged to Site II > Site I > Site III, indicated dominant forest plant species growth in site II were the fewest among others. Determinant factor for dominant vegetation species is not only obtained from individual number for each vegetation species but also from the individual diameter and height. Although vegetation density was the least but because its basal area was bigger, so its dominancy became higher as well. This condition was occurred on *T. cattapa* growth in Site II and on *S. saman* growth in an overburden-filled soil.

Table 4. Forest Plant Species Analysis on an Overburden-Filled Soil from Post Coal Mining Land (Site III).

No.	Parameter	*A. cadamba*	*P. pinnata*	*M. indica*	*S. saman*	*A. mangium*	*T. catappa*	Total
1.	Density (tree/ha)	10.00	2.00	2.00	1.00	3.00	1.00	19.0
2.	Relative Density (%)	52.63	10.53	10.53	5.26	15.79	5.26	100
3.	Frequency	1.000	1.000	1.00	1.00	1.00	1.00	6.00
4.	Relative Frequency (%)	17.00	17.00	17.00	17.00	17.00	17.00	100
5.	Dominance (m^2/ha)	0.03	0.001	0.001	0.01	0.04	0.001	0.08
6.	Relative Dominance (%)	35.33	0.96	1.25	7.12	54.16	1.18	100
7.	IVI (%)	104.63	28.15	28.44	29.05	86.62	23.11	300
8.	SDR (%)	34.88	9.38	9.48	9.68	28.87	7.70	100
9.	Dominance Index	0.24						
10.	Diversity Index	0.69						

Diversity index was < 2, which belonged to forest plant species growth in those three sites. It indicated that biodiversity of forest plant species was low (Magurran, 1988). It means that woody species found in an ex-coal mining land was homogenous (Magurran, 1988; Fachrul, 2007). This study was supported by Sarma (2005). It was reported that diversity index for trees and shrub growth in an ex-coal mining area was lower than in non ex-coal mining area.

Diversity index for forest plant species growth in ex-coal mining land from the highest to the lowest was Site III > Site II > Site I. It indicated that an overburden-filled soil had bigger diversity of forest plant species than Site II and Site I. Forest plant species diversity is influenced by physicochemical properties of soil. An overburden-filled soil had higher supply of organic matter, CEC, C/N ratio, base saturation as well as N, P and K content than soil from reclamation sites. These properties made an overburden-filled soil became an optimum condition for several species growth such as *Trema* sp and *M. gigantea*, which were not found in the reclamation sites. Both species are potential plants but they are still not utilized economically in Indonesia. Meanwhile, both reclamation sites had similar diversity indexes due to similar physicochemical properties of soil from both sites.

Based on analysis of SDR, IVI, density and dominancy, it is known that dominance species growth in both reclamation sites were *S. saman*, whereas in an overburden-filled soil was *A. cadamba* and *A. mangium*. *S. saman* was a primary species in plantation of reclamation sites. It has an ability to adapt to below of soil fertility threshold; therefore, *S. saman* was the highest dominant species among other species.

A. mangium, which was able to grow naturally on those three sites, indicated that it was tolerance and adapted to low soil fertility. Meanwhile, *A. cadamba* found on reclamation site (Site II) and an overburden-filled soil had the second highest dominance after *A. mangium* due to higher basal area. Sarma (2005) explained that post coal mining soil had major influence to plant species growth on those sites. Another research by Zulkarnain (2014) reported that a plantation on reclamation area after post coal mining in Kutai Kartanegara District, East Kalimantan Province using *A. mangium* had a decrease on plant diameter and height in 2 years after plantation. Furthermore, Dias *et al.* (1999) mentioned that several species in Family of Leguminosae including *A. mangium* and *S. saman* were used as cover for post-gold mining land and they had a high survival on clay soil. In addition, *S. saman* has can be utilized as a shade for ground covers.

A. mangium, S. saman, and *A. cadamba* are categorized as fast growing species that grow well on tropical humid soil in low land area (Jøker, 2000; ICRAFT, 2004; Krisnawati et.al., 2011 and Orwa, et.al., 2009a,b,c). *A. mangium* and *A. cadamba* are pioneers for woody species due to naturally growth on disturbance soil with pH of 4.5 to 6.5 (Pinyopusarerk *et al.*, 1993; Jøker, 2000). They are native species in Indonesia, in which *A. cadamba* is suitable to rehabilitate along the watershed, eroded soil, and critical land as well as have a function as a shade for Dipterocarpaceae species ((Jøker, 2000; Orwa *et al.*, 2009a,b). *S. saman* is an endemic species in northern South America, Central America and Caribbean island distributed and planted in most tropical country which grows on rather acid soil with low pH up to 4.6 and low fertility (Schmidt., 2008; Orwa *et al.*, 2009c). *A. cadamba* and *S. saman* had an ability to improve soil fertility. A decomposition of *A. cadamba* leaves under its canopy causes increases on soil C-organic, CEC, nutrition supply and base exchange (ICRAFT, 2004; Orwa *et al.*, 2009b). Whereas root nodule of *S. saman* has infection of rhizobium bacteria with michoriza fungal for Nitrogen fixation (Qadri *et al.*, 2007).

Wood from those three species had high economical potency. Wood from *A. mangium* can be used for light construction materials such as furniture and moulding (Hadjib *et al.*, 2007), material for pulp and paper (Syafii and Siregar, 2006; Orwa *et al.*, 2009a; Krisnawati *et al.*, 2011), fuel wood and charcoal, material for particle board, sawing wood and veneer (Abdul-Kader and Sahri, 1993; Orwa *et al*, 2009a; Krisnawati *et al.*, 2011; Hedge *et al.*, 2013), as well as for tannin production (Abdul-Kadir and Sahri, 1993; Hedge *et al.*, 2013). Wood of *A. cadamba* can be utilized as material for light construction, floor, toy, pencil, boat, and mixture material for pulp (ICRAFT, 2004; Krisnawati *et.al.*, 2011). Root bark of *A. cadamba* can be utilized for dye material, whereas its flower is an admixture with sandalwood for perfume production, as well as the tree barks as medicine for anti-inflammatory and as a tonic (Orwa *et al.*, 2009b). Meanwhile, wood of *S. saman* is used as materials for furniture, panel wood, handcraft, boat wall, boxes, veneer, plywood and light construction, as well as its barks is used for resin source and adhesive (Orwa *et al.*, 2009c). Almost whole parts of *S. saman* are very useful in medical field, such as medicine for diarrhea and TBC (Orwa *et al.*, 2009c), as an anti-microbe and anti-fungal (Ukoha *et al.*, 2011), antioxidant and sitotoxic, potential chloroform and soluble fraction of hexane as well anti-microbe activity on carbon tetrachloride fraction (Ferdous *et al.*, 2010) and analgesic (Muzammil *et al.*, 2013). Therefore, *S. saman* has benefits as sources for herbal medicine, food for energy, as well as raw material for pharmacy, food and bio-diesel industry (Nnamdi *et al.*, 2010).

Conclusion

Post coal mining land had homogenous forest plant species due to low diversity with dominance forest plant species consisted of *A. mangium*, *A. cadamba* and *S. saman*. Among those species, *A. cadamba* is a new potential endemic species in Indonesia for metal remediation in post coal mining soil. Generally, those species had resistances to low soil pH, low soil fertility and high metal content. On the other hand, those species also had a potency to be utilized as plants for metal remediation on post coal mining land as well as their economic potencies.

Recommendation

Vegetation analysis to select dominant forest plant species surrounding post coal mining site should be performed. It becomes a fundamental of selection of plant species especially endemic species for rehabilitation plant and metal phytoremediator in post coal mining sites. This would support biodiversity conservation for forest plant species.

Acknowledgement

This research was funded by the Ministry of Environment and Forestry of Indonesia. Authors would like to thanks to Rakhmat Noveri, S.Hut, M.Agr as a Manager of CV. TujuhTujuh whom gave permission and accessed to post coal mining site as well as M. Haekal Firmanda Ayub for helping authors in conducting the investigation in the field.

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