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Returning biodiversity of rehabilitated forest on a coal mined site at Tanjung Enim, South Sumatra

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ABSTRACT

Suhartoyo H, Munawar A, Wiryono. 2012. Returning biodiversity of rehabilitated forest on a coal mined site at Tanjung Enim, South Sumatra. Biodiversitas 13: 13-17. Restoring disturbed mined land is challenging since the outcomes of various rehabilitation procedures on mined sites in terms of vegetation structure, composition and ecological function are not presently understood, especially in the developing countries. This study examined the mechanism of biodiversity recruitment, especially on structural attributes of an undisturbed forest community and rehabilitated forests of different ages on sites disturbed by coal-mining operations at Tanjung Enim, South Sumatra. Un-mined forest was characterised by complex structural features including a dense stand of trees in a range of size classes, an almost closed canopy, and a shrubby understorey. In contrast, young mined sites were characterised by a low density of woody stems, a relatively open canopy and herbaceous ground cover. Soil characteristics of rehabilitated site were progressing towards the reference site. The marked differences in structural complexity between unmined and mined sites suggest that it will will take very long time for the mined sites to recover into their original conditions. So, more restoration intervention will be needed to speed the recovery processes.

Key words: restoration, mining, biodiversity, structural complexity.

INTRODUCTION

Rehabilitation of disturbed areas due to mining activities is intended to assist the environment in returning to a stable and sustainable land use as soon as possible (Bell 1996; Parker 1997). The nature of the post-mining land use will depend on a number of factors including the ecological potential of the mined environment and the wishes of the neighbouring society. Currently, in Australia, many mining operations are using native plant species in rehabilitation programs leading to the establishment of pastures and forests (Bell 1996; Bell 2001; Gardner 2001), however in Indonesia, mining operators are mostly using fast growing exotic species in their rehabilitation (Suhartoyo 2008), as in many other countries al around the world (Martínez-Ruiz et al. 2007; Alday et al. 2010).

As more mine operators need to establish their post mining plan for sustainable development of mine lease, the question on how ecosystem develop and whether the rehabilitated site progresses toward surrounding undisturbed site become important to regulator and miners. Designing rehabilitation with a specific end point has to be put into a general ecological context (Bradshaw 1995). Assessing the development of an ecosystem along a successionally gradient provides information on the trajectory of rehabilitated areas toward the desired end point (Morgan and Short 2002; Prach and Walker 2011; Alday et al. 2011a). Progress along the trajectory can be assessed through ecosystem characteristics such as species richness and the ability to undergo natural development and change in both structure and the functioning of the ecosystem (Bradshaw 1995).

Restoring mined areas to their original ecosystem is not easy because in many cases mining creates a new environment that may not reproduce the same features or function as the pre-mining conditions (Dragovich and Patterson 1995; Court, et al 1996; Alday et al. 2011b). At Myall Lakes National Park, Australia, Buckney and Morrison (1992) found clear differences in species composition along a temporal gradient between recently disturbed areas and pre-mining sand dune locations.

In this paper, we examined the species composition and structural attributes of rehabilitated coal mined sites. The study was part of broader research project quantifying ecosystem development of forested area at Tanjung Enim, South Sumatra. Hypothesis of this research was that ecosystem development, in term of species composition, structural attributes and soil characteristics, would progress toward their original ecosystem as indicated by similarity with neighbouring forest as a reference site. We were interested in structural attributes, partly because the structural complexity of a rehabilitated forest contributes to the availability of resources for wildlife and because the enhancement of ecological processes will follow the establishment of vegetation (Young 2000; Ruiz-Jaen and Aide 2005).

MATERIALS AND METHODS

Study area

The study was conducted within some rehabilitated coal mined sites and undamaged site of PT. Bukit Asam, (3^0 40' -3^0 45' S dan 103^0 40'-103^0 48' E), located 13 km south of Muara Enim, South Sumatra (Figure 1). The region has a humid tropical climate. Mean annual rainfall is 3100 mm with only two months of dry season (rainfall < 100 mm/month).

Sampling sites Selection

We sampled the possible sequence of ecosystem development with different stand ages of mined areas (chronosequence approach) and adjacent undamaged forest.

Stands selection

We selected 3 mined sites varying in age of vegetation and secondary forest nearby as a reference site. Most restoration efforts need to specify a reference ecosystem toward which restorations are directed. Nearby forest is the most practical reference site because no virgin forest is found nearby (SER 2004). The ages of rehabilitation ranged from 1 to 17 years, however, rehabilitation techniques varied from time to time as rehabilitation knowledge and regulation were developed, so that there was no common initial condition or management regime for all of the sites. However, after establishment of planted vegetation, succession is assumed to occur and all sites will move toward their original conditions. Sites in un-mined secondary forest were used to compare the effects of forest rehabilitation on coal mined areas and to evaluate whether rehabilitated mined sites move toward the natural conditions.

Table 1. Some characteristic of Sites selected for this study at the PT. Bukit Asam

Sites	Stand age and planted species	Plot area (m^2)
Site 1	4 year-old rehabilitated stand, dominated by *Acacia mangium*	0.8 ha
Site 2	6 year-old rehabilitated stand, dominated by *Acacia mangium*	0.8 ha
Site 3	16 year-old rehabilitated stand, dominated by *Acacia auriculiformis*	0.8 ha
Site 4	Secondary forest, dominated by local Laban (*Vitex pinnata*) and Serut species	1 ha

Vegetation and soil sampling

Vegetation sampling was carried out on two 100m x 20 m transects per site (Table 2). We measured a range of vegetation composition and structural attributes at each site including canopy cover, the basal area and abundance of woody stems in a range of height and diameter categories, understorey and ground cover.

Table 2. Vegetation structural attributes recorded per transect.

Species richness	Methodology	Plot area (m^2)
Basal area (m^2/ha)	All trees and sapling above 1 cm DBH by species	20x20
Canopy cover (%)	Visual estimate of foliage projective cover of vegetation >2m above ground	20x20
Shrub cover (index)	Frequency of woody vegetation, including seedlings, with stem <2.5 cm DBH	5x5
Ground cover (%)	Percent cover of herbs, by species	5 of 1x1

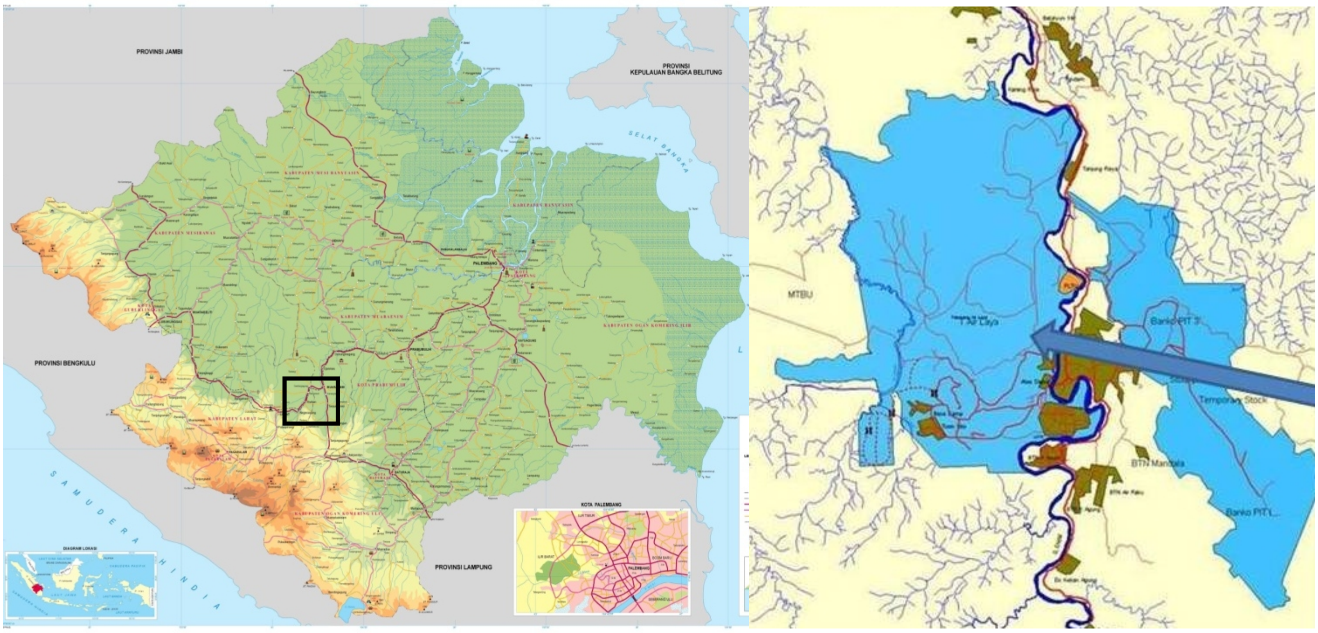

Figure 1. Study site at Tanjung Enim, Muara Enim, South Sumatra

Within each of the five 20x20m plots in each transect, five soil samples were taken to 5 cm depth, and bulked for further analysis. Soil samples were analysed at Soil Laboratory, University of Bengkulu for pH (1: 5 water), total and extractable phosphorus, potassium, total organic carbon, total nitrogen, and cation exchange capacity (CEC)

Data analysis

The data collected are presented in two ways: first, a descriptive approach, and second, a quantitative approach on important value and species diversity.

$$H = -\Sigma \{(n.i/N) \log(n.i/N)\}$$

H = Shannon-Wiener index of general diversity
n.i = importance value of each species
N = total importance value

RESULTS AND DISCUSSION

Species composition

Species composition of ground cover changed over time. The youngest site had the highest species richness, while the secondary forest had the lowest richness (Table 3). Most groundcover species are pioneer species requiring open space. As the forest canopy closes in secondary forest, the species richness of ground cover decreases. *Schleria purpurascens* was present in all sites. *Axonophus* was present in all mined sites, but absent in secondary forest. Axonophus is a mat forming grass.

Species richness of trees in mined sites was very low. Most of the trees found in mined sites were artificially planted. Only two species of trees grew naturally in mined sites, namely *Mallotus paniculatus* and *Hibiscus tiliaceous.* The species composition of mined sites was quite different from that of secondary forest. It was clear that natural succession progressed slowly in these sites. Poor soil condition is presumably responsible for this slow progress.

Table 3. Change in groundcover composition over years.

Species	Important values			
	4 year old	6 year old	16 year old	Secondary forest
Axonopus compressus	85.62	19.96	31.66	
Paspalum scorbiculatum	30.76	57.56		
Mimosa pudica	21.99			
Eupatorium odoratum	10.87			
Purpurea javanica	9.03		8.72	
Scleria purpurascens	8.77	47.09	22.95	22.92
Ruellia tuberose	8.24			
Mikania cordata	8.24		13.44	19.79
Cyperus sp.	8.24			
Imperata cylindrica	8.24	29.26	16.65	
Ottocloa nodosa		21.32	16.59	
Tetracera indica			81.27	
Eleuthera ruderalis			8.72	
Ardisia humilis				137.50
Digitaria sp.				19.79

Table 4. Species composition of trees.

Species	Important values			
	4 year old	6 year old	16 year old	Secondary forest
Acacia mangium	139	178	72	
Acacia auriculiformis	119	88	195	5.23
Melaleuca cajuputi	10	33		
Casia siamea	21			
Hibiscus tiliaceus	11			6.95
Paraserientes falcataria			16	84.41
Mallotus paniculatus			14	8.88
Vitex pinnata				42.77
Schima wallichii				35.49
Dillenia pentagyna				25.91
Peronema canescen				19.80
Blechnum orientale				9.17
Arthocarpus elasticus				8.75
Arthophyllum sp.				8.14
Aporosa octandra				7.85
Syzyghyum sp.				7.40
Alstonia scolaris				6.82
Pithecellobium jiringa				6.33
Cratoxylum glaucum				5.82
Macaranga trichocarpa				5.48
Neonauclea calycina				4.81

Structural attributes of unmined and rehabilitation stands

The structure of the woody vegetation varied markedly between the different sites (Figures 3). Young rehabilitation sites invariably had smaller trees than the older site and unmined forest.

In general, the basal area of woody stems increased with the density of planted stems and the age of rehabilitation. Medium and large diameter trees were well presented in mature rehabilitation and reference site. The basal areas of mature rehabilitated stand approached above that of the unmined forest (Figure 4).

The diameter distribution and basal area among sites showed that as the age of rehabilitated sites increased, their structural attribute moved closer toward that secondary forest. Mature, intact un-mined forest was characterised by complex structural features including a closed canopy, a high density of woody stems spanning a range of height and diameter classes, a shrubby understorey, and a well-developed layer of leaf litter and woody debris. Although the majority of woody stems were small diameter trees, the obvious feature of intact un-mined forest is the presence of relatively big diameter.

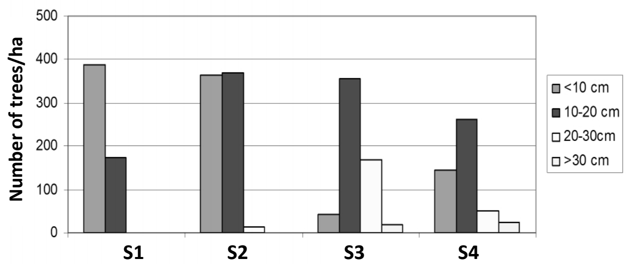

Figure 3. Diameter distribution of rehabilitated stands. (S1 = 4 yrs, S2 = 6 yrs, S3 = 16 yrs and S4 = reference)

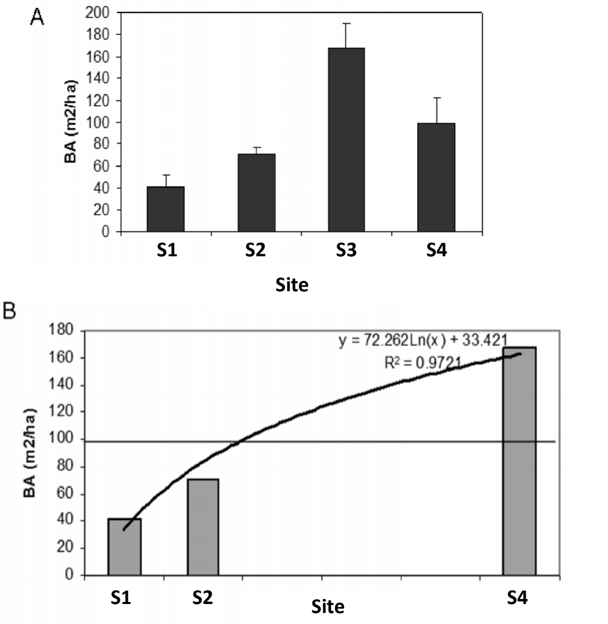

Figure 4. Basal area (m^2/ha) of acacia stands. (S1 = 4 yrs, S2 = 6 yrs, S3 = 16 yrs and S4 = reference)

Functional attributes of rehabilitated mined sites

Ecosystem functional attribute can be approached by its diversity and its nutrient cycling which can be assessed by its soil chemical properties. The Shannon-Wiener diversity index (Table 5) showed an increasing trend in tree diversity and in the contrary within ground species diversity.

Table 5. Shannon Diversity Index of tree and ground species.

Site	Shannon Diversity Index	
	Tree species	Ground species
4 year-old	0.496	0.81
6 year-old	0.397	0.74
16 year-old	0.404	0.77
Secondary forest	1.050	0.42

Table 5 showed that, in term of tree species diversity, all rehabilitated sites represented in low diversity. Stand maturity (i.e. increasing age) showed no correlation with species diversity. Whereas, within ground species a decreasing trend appeared as the rehabilitation ages increased. It can be inferred that returning tree species from natural sources is still somewhat difficult in post mining areas. However, vegetation indicator is still valuable and a common measure to evaluate the restoration of an ecosystem after mining (Ruiz-Jaen and Aide 2005; Zedler and Callaway 1999).

The soil properties as an indicator of sustainable ecosystem can be summarized as follow (see Figure 5). The soil pH was relatively low; however the reference site in the Tanjung Enim area showed pH of four to five, meaning that the area is somewhat covered by acidic soil. Total Carbon of mature rehabilitated soil was progressing and approaching that of reference site, whereas total Nitrogen was well above the reference site.

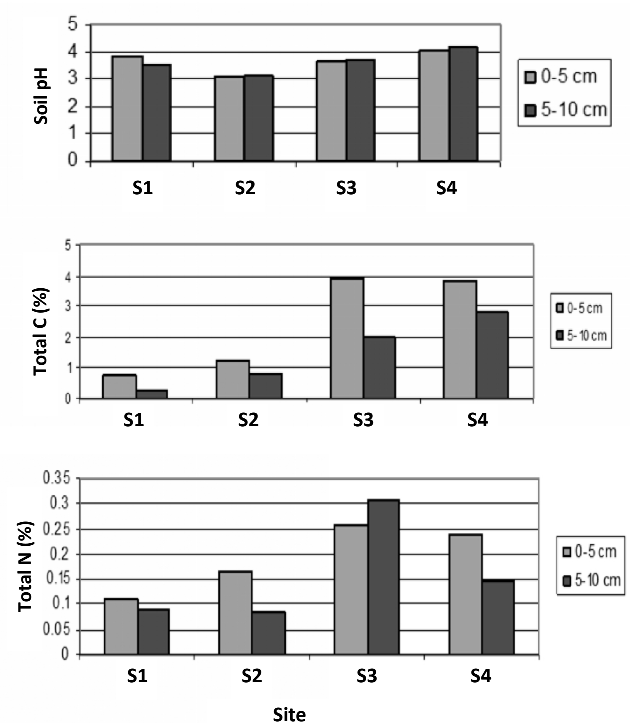

Figure 5. Soil pH, total carbon and total nitrogen of different acacia stands. (S1 = 4 yrs, S2 = 6 yrs, S3 = 16 yrs and S4 = reference)

Ecosystem development of rehabilitated mined sites, in terms of soil properties, is difficult to demonstrate from this study even though a trend can be inferred from graphs (Figure 5). Differences in initial conditions among sites before rehabilitation may contribute to this unclear trend. The unmined forest is associated with higher values of Nitrogen, Potassium and pH. The present results suggest that different soil nutrients increase with different successional pathways in the rehabilitated mined sites, although this conclusion needs to be demonstrated experimentally. Most ecological processes, including nutrient pools are not evaluated as frequently as measure of diversity or vegetation structure because of slow processes (Ruiz-Jaen and Aide 2005: Morgan and Short 2002).

CONCLUSION

The development of structural and functional attributes of rehabilitated forest on mined site at Tanjung Enim was more advanced in the older/mature rehabilitated sites. However, the diversity of older rehabilitated site was still low and it is evident that structurally complex forest cannot be restored in a short time-frame (one or two decades). The vertical distribution of vegetation became more extensive and complex as the rehabilitation aged, although the rehabilitated sites had not equalled the complexity of the unmined native forest. In short, returning biodiversity in mined site is very difficult without any assistance from management. The present results suggest the need for further research on the resilience of rehabilitated mined sites.

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