Rehabilitation of Coal Mined Land Using Economically Valuable Local Tree Species

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ABSTRACT

Coal mining in Bengkulu Province is conducted mostly in forest areas, using open mining method, which causes significant ecosystem degradation . Before mining operation is closed and the land is returned to the government, the significantly degraded ecosystems must be rehabilitated in order to restore their original function. Most coal companies use fast-growing exotic species for reforestation of mined land because these species are capable of growing relatively fast in mined land. However, the establishment of exotic species changes the vegetation. According to the international Society of Ecological Restoration, one of criteria for successful restoration of degraded ecosystem is the presence of native species. It is important, therefore, that coal mined land be restored into its original ecosystem using native species. This paper reports the early growth of *Dysoxillum mollissimum* and *Madhuca aspera*, economically valuable local tree species, we used for reforestation of mined land in Central Bengkulu. Until three months after plantation both species grew relatively well in open mined land. If both species continue growing into mature stage, the rehabilitated mined land will have high economic value and ecological value.

Key words: Bengkulu, coal, mined soil, restoration, local species.

INTRODUCTION

Bengkulu Province produces coal as a source of its local revenue. While mining brings economic benefit to the region, it causes environmental degradation. Coal mining in Bengkulu, conducted using open system, has destroyed vegetation and drastically altered the soil. Material previously burried deep underground is brought to the surface during mining. This material, called mine soil or overburden, is usually deficient of nitrogen, phosphorus and potassium. Some mine soils contain a significant amount of pyritic-S in excess of their carbonates which causes drop of the pH to a range of 2.2-3.5 after exposure to water and oxygen (Sheoran et al 2010). Very acidic soil will increase may cause metal toxicity to plants. Increasing soil pH and fertilization are often required to increase mine soil fertility.

The use of heavy equipments during mining has caused soil compaction which results in decrease of soil porosity, permeability, and water holding capacity (Bussler et al, 1984). Mined land needs to be rehabilitated before the land can be used for end use (Bradshaw, 1997, Lottermosser, 2010). Mechanical treatments, such as ripping, are sometimes used to improve physical properties of mine soil for plant growth.

The ministry of energy and mineral resources of Republic of Indonesia has stipulated that mined lands must be reclaimed so that they can function adequately for the designated land use. If the mined land is in the forest area, the companies must also follow the guidance from the Ministry of Forestry on the reclamation of disturbed forest. Most companies plant exotic, fast growing tree species for revegetation of mined soil, such as *Acacia mangium* (Suhartoyo et al., 2012), *Paraserianthes falcataria* and *Sesbania grandiflora* (Munawar *et al*., 2011). The establishment of vegetation in mined soil prevents soil erosion, improves soil properties and restores some of ecosystem functions.

In the long term, the exotic species in mined will be replaced by native species. Wiryono and Douny (2012) reported that after 14 years of revegetation using *Acacia mangium*, no saplings and seedlings of *A. mangium* were found, indicating that *A. mangium* failed to regenerate. So, native species would dominate the stand after the death of Acacia trees. According to the Society Ecological Restoration (SER) two of nine ecosystem attributes as the criteria of restoration success are: (1) The

restored ecosystem must have similar diversity and community structure in comparison with reference sites; (2) Indigenous species must be present in the area (Clewell and Aronson, 2007).

Although natural succession will replace exotic species with the indigenous ones, most native species growing during early succession are of the lesser commercial species. Economically, the rehabilitated land will have low value. In order to improve the economic value of coal mined land, we planted economically valuable local tree species for rehabilitation, namely *Dysoxillum mollissimum* and *Madhuca aspera*. This paper reports the early growth of those species on coal mined land in Central Bengkulu.

MATERIALS AND METHODS

Sites and Time

This study was conducted in coal mined area of PT Inti Bara Perdana, a coal mining company, in Central Bengkulu, Indonesia. The study site is approximately 300 m above sea level and has wet climate with an average annual rainfall of 3,485 mm. However, during 2015, Indonesia is experiencing El Nino, a climate phenomenon causing long drought. We planted the seedlings in June 2015.

Species planted

We planted two local tree species which have high economic value, namely *Kayu Bawang* and *Bambang Lanang*. There is no agreement on the scientific name of Kayu Bawang. The two names most frequently assigned for Kayu Bawang are *Dysoxillum mollissimum* (Siahaan and Sumadi, 2013) and *Protium javanicum* (Apriyanto, 2003). Also, there are two scientific names for Bambang Lanang, namely *Madhuca aspera* (Nurhayati, 2009) and *Michelia champaca* (Sumadi *et al.*, 2013). In this study we choose *Dysoxillum mollissimum* and *Madhuca aspera*.

Planting and Caring of Seedlings

The planted *Madhuca* seedlings were one year old with varrying height from 80 cm to 130 cm. However, during the first two weeks, some seedlings died and were replaced with younger and shorther ones. The *Dysoxillum* seedlings were approximately six month old, with varrying height between 25 cm to 65 cm.

The site for planting was an open area with sparse grasses and shrubs. The site had not been leveled or covered with topsoil, but consisted of piles of mine spoils. We chose to plant the seedlings on piles of mine spoils, because the piles were not compacted so the root development would not be impeded. Because the piles were not distributed systematically, the seedlings were not planted at regular distance from one another. Manure was given for each whole before planting the seedlings. When there was not enough rain, every week the seedlings were watered and once a month they were fertilized with N,P,K fertilizer.

Measurement of growth was started one and half month after planting. Stem diameter, plant height and number of leaves were recorded for each plant every other week.

Soil Analyses

Composite soil sample was analyzed in Soil Laboratory of the Agriculture Faculty, University of Bengkulu to know the chemical and physical properties.

RESULTS AND DISCUSSION

All *Dysoxllum* seedlings survived until the end date of recording, approximately 2.5 months old (Table 1).

Within 19 days of recording, *Dysoxillum* seedlings grew 13% in diameter, 7,1% in height and 4,5% in number of leaves. Some plants lose their leaves so the growth signs were minus. *Dysoxillum mollisimum* is known as a fast growing species (Apriyanto, 2003; Siahaan and Sumadi, 2013). It grows naturally in Bengkulu and South Sumatra provinces and also has been cutivated in agroforestry system in these provinces. In monoculture, *Dysoxillum* may grow at a rate of 2.17 cm/year in diameter and 1.60 m/year in height, and in combination with oil palm, it may grow at a rate of 2.56 cm/year in diameter and 1.97 m in height (Siahaan and Sumadi, 2013).

Table 1. The diameter, height and number of leaves of *Dysoxillum mollissimum* three months after planting

No	Diameter (mm)	Increase of diameter in 3 weeks of recording		Height (cm)	Increase of height in 3 weeks of recording		No of leaves	Increase of leaves in 3 weeks of recording	
		mm	%		cm	%		number	%
1	6,9	0,49	7,1	49	5	11,4	10	1	11,1
2	4,75	2,05	43,2	82	10	13,9	10	0	0,0
3	6,17	0,4	6,5	48	5	11,6	5	1	33,3
4	5,44	0,08	1,5	58	4	7,4	4	0	0,0
5	4,3	0,71	16,5	46	5	12,2	6	-1	-14,3
6	5,52	0,75	13,6	70	4	6,1	6	2	50,0
7	5,18	1,31	25,3	45	5	12,5	6	2	25,0
8	4,5	1,04	23,1	46	2	4,5	10	0	0,0
9	4,09	1,17	28,6	43	3	7,5	7	1	14,3
10	4,82	0,08	1,7	37	3	8,8	8	1	12,5
11	4,65	0,55	11,8	39	3	8,3	9	0	0,0
12	4,17	0,5	12,0	68	6	9,7	6	-1	-33,3
13	7,5	0,08	1,1	64	2	3,2	2	0	0,0
14	5,65	1,74	30,8	57	1	1,8	5	0	0,0
15	7,21	0,01	0,1	72	3	4,3	4	0	0,0
16	4,93	0,05	1,0	60	1	1,7	3	0	0,0
17	7,81	0,27	3,5	36	2	5,9	2	2	50,0
18	7,81	0,2	2,6	63	1	1,6	6	0	0,0
19	4,38	0,39	8,9	42	4	10,5	5	2	50,0
20	4,61	4,01	87,0	43	1	2,4	6	0	0,0
21	8,14	0,06	0,7	73	3	4,3	6	1	20,0
22	5,89	0,02	0,3	47	7	17,5	6	-1	-16,7
23	4,88	1,03	21,1	30	1	3,4	5	1	33,3
24	5,95	0,11	1,8	45	3	7,1	4	0	0,0
25	4,98	0,23	4,6	40	1	2,6	3	-1	-12,5
26	4,86	0,53	10,9	42	3	7,7	7	-1	-33,3
27	4,48	0,38	8,5	39	2	5,4	2	-2	-100,0
28	5,78	0,01	0,2	29	3	11,5		0	0,0
29	6,82	0,71	10,4	49	1	2,1	7	1	20
30	4,83	0,26	5,4	39	2	5,4	6	1	11,1
Mean	6,2	0,6	13,0	50,0	3,2	7,1	5,5	0,3	4,5

Note: minus sign means the number of leaves decreased.

The problem we faced in the field was depredation of *Dysoxyllum* leaves by goat. We dealt with this problem by protecting each seedling with net. So far this method had been effective.

`It is good that all *Dysoxyllum* seedlings survived within two and half months in mined land without top soil. However, because the age of seedlings was very short, we have to wait for several years before we can conclude that this species is suitable for mine soil reclamation.

Unlike *Dysoxyllum*, three out of 30 *Madhuca* seedlings died. Within 21 days of recording, *Madhuca* seedlings grew, on average, 15% in diameter, 11.8% and height and 19.6% of leaf numbers. Some plants lose their leaves, so the growth of leaf number had a minus sign. Like *Dysoxyllum*, *Madhuca* is also a fast growing species. It has straight and tall trunk and narrow crown, making it suitable for agroforestry (Sumadi *et al.*, 2013). At 9 month in agroforestry system this species can reach 150 cm in height, and 3 cm in diameter.

Table 2. The diameter, height and number of *Madhuca aspera* in mined soil 3 months after planting

No	Diameter (mm)	Increase of diameter in a month of recording		Height (cm)	Increase of height in a month of recording		No of leaves	Increase of leaves in a month of recording	
		mm	%		cm	%		number	%
1	8,2	1,2	17,1	92	6	7,0	5	-1	-16,7
2	10,88	0,83	8,3	28	1	3,7	16	1	6,7
3	5,51	0,51	10,2	32	4	14,3	13	-6	-31,6
4	10,76	0,91	9,2	123	5	4,2	31	4	14,8
5	9,19	0,93	11,3	101	6	6,3	12	0	0,0
6	11,87	2,4	25,3	114	7	6,5	35	5	16,7
7	5,07	0,59	13,2	26	4	18,2	6	-1	-14,3
8	8,9	0,74	9,1	83	0	0,0	27	10	58,8
9	8,28	0,28	3,5	56	15	36,6	28	5	21,7
10	9,87	0,38	4,0	112	4	3,7	24	7	41,2
11	6,86	1,2	21,2	70	1	1,4	4	-2	-33,3
12	10,68	1,33	14,2	74	7	10,4	19	-1	-5,0
13	11,41	1,52	15,4	146	6	4,3	63	31	96,9
14	6,96	0,44	6,7	26	6	30,0	7	1	16,7
15	5,53	0,69	14,3	42	18	75,0	13	0	0,0
16	8,85	0,71	8,7	94	3	3,3	20	2	11,1
17	10,67	1	10,3	142	2	1,4	20	-2	-9,1
18	dead								
19	10,25	0,28	2,8	86	6	7,5	20	0	0,0
20	7,62	1,07	16,3	75	5	7,1	13	1	8,3
21	9,84	0,76	8,4	73	4	5,8	10	7	233,3
22	9,17	1,19	14,9	43	4	10,3	14	1	7,7
23	dead								
24	9,84	0,35	3,7	99	2	2,1	45	4	9,8
25	8,9	3,03	51,6	74	4	5,7	18	-2	-10,0
26	9,95	1,01	11,3	156	9	6,1	13	3	30,0
27	8,09	0,54	7,2	111	3	2,8	13	2	18,2
28	dead				0				
29	8,78	3,43	64,1	66	4	6,5	15	3	25,0
30	5,78	1,03	21,7	51	14	37,8	8	2	33,3
Mean	8,8	1,05	15,0	81,3	5,6	11,8	19,0	2,7	19,6

Note: minus sign means the number of leaves decreased.

The result of soil analyses showed this mined soil was very acidic and had low fertility (Table 3). This was not surprising because the area consited of minespoil and had not been vovered with topsoil.

Table 3. Soil chemical and physical properties

Chemical properties	Category	Physical properties	Category
pH 3.7	Very acidic	Bulk density 1.32	High
Ca 3.32 me/100g	low	sand 44.16%,	Clay loam
Ka 0.18 me/100g	low	silt 21.86 %	
Mg 4.55 me/100g	high	clay 33.98 %	
CEC 12.32 me/100g	Low		
N 0.13%	low		
P_2O_5 0.23 ppm	Very low		
C 1.32 %	low		

CONCLUSION

Economically valuable species, *Dysoxillum mollissimum* and *Madhuca aspera*, could grow relatively well in mined soil which had low fertility because the area had not been rehabilitated. If the species survive to mature stage, the mined land would have high economic value.

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