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Role of bamboo for revegetation of post coal mining in South Sumatera, Indonesia

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Abstract *:*

Coal mining activities have affected the soil and vegetation conditions on the mined land. Revegetation of ex-mining land is a must to balance environmental functions. The choice of plants must be adapted to the condi-tions of the ex-mining land so that growth continues. The use of local plants for revegetation is fascinating to study. This study aimed to investigate the soil characteristics of ex-coal mining land and bamboo growth as a plant used for revegetation. Bamboo is collected from around the former coal mining area. Bamboo growth is observed through its branching for 12 weeks of measurement. Soil is analyzed based on its physical and chemi-cal properties. The Schmidt-Ferguson method was used to analyze the climate type in the study area. The results of the soil analysis show that the plants can still grow for revegetation. Of the three types of bamboo observed (Schizostachyum brachycladum kurz, Dendrocalamus asper, and Gigantochloa robusta), Schizostachyum brachycladum kurz is the best growing bamboo in ex-coal mining land with a branch length of 42 cm in 12 weeks of measurement. The climate in the ex-coal mining area studied is a wet type (Q = 0.184). Bamboo is a suitable plant for revegetation, especially in coal mining areas in South Sumatra, Indonesia.

Keywords: Branch; climate; growth; soil

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1. Introduction

Coal mining is one of the most vital activities in Indonesia. Coal mining has contributed to meeting energy needs and economic turnover. Meanwhile, coal mining in Indonesia adheres to a continuous open-pit mining system so that changes in the landscape due to open vegetation are inevitable. This has resulted in physical, chemical, and biological soil damage [1]. Mining activities also cause soil pH to drop due to the soil being lifted to the surface, while open areas are inundated by water and minerals [2]. Acidic soil conditions and nutrient deficiency limit plant growth in post-mining land. Chemically, ex-mining land has a low cation exchange capacity (CEC), low content, and availability of N, P, K, Ca, Mg [3].

The productivity of ex-mining land can be increased through revegetation with suitable plant species. The Indonesian government has made decisions regarding the problems posed by mining activities (Minister of EMR Decree No.1211.K/008/M.PE/1995 and Minister of Forestry and Plantation No. 145/Kpts-II/1999) [4]. Based on this decision, there is an obligation for mining activity opera-

tors to carry out post-mining land reclamation and revegetation. Revegetation is an effort to repair and restore damaged vegetation through planting and maintenance activities on land used for forest areas [5]. Revegetation is generally carried out in three stages: planting cover crops, planting fast-growing trees, and finally planting additional plants with climax species [6].

Several plants have been reported to be used for revegetation on ex-mining land, namely Acacia, Eucalyptus, Sengon, and others [7]. Of the various types of plants, bamboo has not been used as a plant for revegetation in former coal mining areas. Bamboo is a type of grass with bamboo shoots, midribs, and leaves [8]. Bamboo has been proven to improve land quality and generate added value economically. Bamboo has been used as a soil cover, fertilizers, protection, water storage, and erosion resistance [9], [10]. Bamboo maintains and improves soil fertility through physical, chemical, and biological processes by preventing water loss, especially on sloping land, excessively porous land, and degraded land [11].

Previous research revealed 17 types of bamboo with 10 different species in the Congong Hill conservation area, South Sumatera, with the largest distribution based on environmental conditions [12]. Bamboo is a local plant often found around the Muara Enim area as a study location for the former coal mining area. The study aims to assess the growth of bamboo on ex-coal mining land for revegetation.

2. Materials and Methods

The study was carried out on post mining reclamation land in South Sumatra (figure 1-2). The sampling location is at PIT 3 Timur Banko Barat, located at 03° 43 'south latitude and 103º 07 east longitude with a mining area of 134.7 ha, the highest elevation area is 75 masl, and the lowest elevation is -16 masl. Soil samples were taken using a soil drill with a depth of 170 cm. Then, the sample is put into a plastic bag for analysis of the soil's physical and chemical properties.

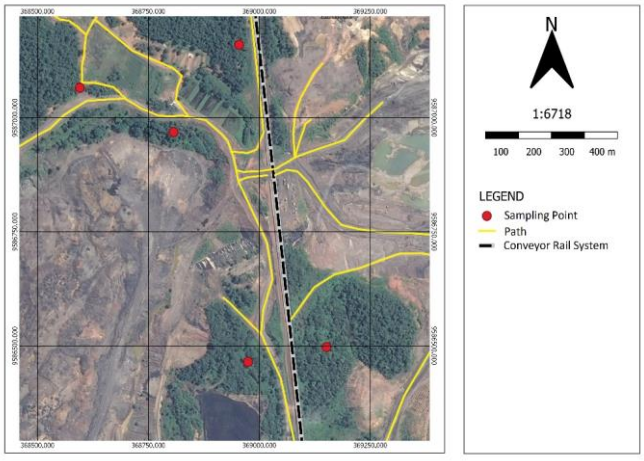

Figure 1. Location of study

Figure 2. The appearance of the post-mining land as the study area

In general, the land's topography is hilly and undulating, with an altitude of about 70-80 meters above sea level. The vegetation in PIT 3 Timur Banko Barat is the secondary natural forest, which is ecologically unstable because it is smallholder plantations, shrubs, and oil palm plantations. The initial color of vegetation is a lot found are the types of perennial cultivated plants and shrub forest vegetation.

Bamboo Characteristics

The bamboos used in this study consist of bamboo Kuning (*Schizostachyum brachycladum kurz*), Betung bamboo (*Dendrocalamus asper*), and Mayan Labu bamboo (*Gigantochloa robusta*) (figure 3). The bamboo is obtained from the land around the post-coal mining area, which has never been mined. Bamboo Kuning (*Schizostachyum brachycladum kurz*) has bright green strait yellow stems, with trichomes on the stem surface brown and uneven (Figure 3a). This type of bamboo can grow to a height of 7-10 m, internodes 33-48 cm long, 5.5 -7 cm in diameter, and 2-4 mm thick.

Furthermore, different from bamboo Kuning, the Betung bamboo stems are dirty green with white spots (figure 3b). The bamboo's underside appears to have grown roots, and the trichomes on the stem surface are dark black and uneven. This bamboo lives with an average height of between 17 and 20 m, internodes 40-60 cm, diameter 18-25 cm, and thickness 8-30 mm. The last bamboo, Mayan bamboo, has a bright green stem, while the trichomes on the stem surface are brown and evenly distributed (Figure 3c). Bamboo height, space length, diameter, and bamboo width range from 9-15 m, 35-47 cm, 6 -10 cm, and 14-19 mm, respectively.

(a (b (c

Figure 3. Bamboo types for revegetation in ex-coal mining: (a) (*Schizostachyum brachycladum kurz*, (b) *Dendrocalamus asper*, and (c) *Gigantochloa robusta*

Analysis of Climate Types Classification

The climatic classification determination at the location of this study uses a method that refers to the Schmidt-Ferguson climate type and Q value. Monthly rainfall is analyzed over a period of 10 years to determine the dry month (DM), humid month (HM), and wet month (WM) every year. Value of Q was calculated by the following equation (Eq. 1) [13].

$$Q = \frac{mean\ DM}{mean\ DW} \times 100\%$$

3. Results and Discussion

Soil Properties

Soil pH has a value of 2-3, categorized as very acidic (Table 1). The acidity of ex-mining may have melted from coal, which tends to contain sulfates. High rainfall can lead to leaching of alkaline cations (K^+, Na^+, Ca^{2+}, and Mg^{2+}), contributing to soil acidity. When rain falls on the mining soil, rainwater and coal reaction occurs and will form Al, Fe, and other oxidized metals, which cause high acidity [14]. Soil C-organic content was 6.57 (very high). Soil C-organic content was 6.57 (very high). High levels of soil C-organic indicate a high level of soil fertility. Li et al. [15] stated that this occurs because the ex-coal mine soil studied has not been developed so that it contains high C-organic with a C/N ratio of 66 (very high category).

The total N content of coal mine soil is 0.10%, which is categorized as low. Coal mine soil contains recalcitrant organic substances characterized by a low N content during a high C/N ratio. Therefore, the carbon content in the soil is very stable. Soils with too high a C/N ratio remove microbial N, which is necessary for protein synthesis. So, the lack of N will slow down the microbial decomposition. The availability of nitrogen in the soil is strongly influenced by decaying organic matter (litter) and mixing with the soil. The same applies to the P-available content. The higher the organic matter will increase the P-available availability [16]. In this study, the P-available content of ex-mining soils is shallow. The activity of acid phosphatase in the soil is also low, and the soil's soluble phosphorus is not available for plants. The Al concentration in the ex-mining soil is categorized as very low (1.09%), which indicates that the plant can grow normally and does not experience stunting in its growth.

Table 1. Physical and chemical properties of soil from coal mining

Parameter	Unit	Value	Criteria
C-organic	%	6.57	Very high
N-total	%	0.10	Low
C/N ratio		66	Very high
P-available	ppm	9.42	Very low
K_2O HCl Olsen	ppm	1.09	Very low
K_2O HCl 25%	(mg/100g)	42.26	High
CEC	(me/100g)	17.02	Medium
K	(me/100g)	0.22	Very low
Na	(me/100g)	0.16	Very low
Mg	(me/100g)	6.02	High
Ca	(me/100g)	4.96	Very low
Base Saturation	%	78.46	Very high
Al (%)	%	1.09	Very low
pH		2-3	Very acid

Bamboo Growth for Revegetation

Plant branches' growth is one of the morphological indicators of the quality of growth of a plant species [17]. The growth of bamboo branches is influenced by plants' ability to interact with environmental factors and the ability to obtain food and space to grow on the former coal mining soil. The interaction of these factors can affect the growth of different bamboo branches in each type. The measurement results for the growth of bamboo branches are presented in

Table 2. The three types of bamboo each have two branches. Bamboo growth is observed through both branches.

Week	Bamboo Type					
	Schizostachyum brachycladum kurz		*Dendrocalamus asper*		*Gigantochloa robusta*	
	Branch 1 (cm)	Branch 2 (cm)	Branch 1 (cm)	Branch 2 (cm)	Branch 1 (cm)	Branch 2 (cm)
1	3	0	2	0	1.8	0
2	8	5	4	2	2.9	2
3	13.3	8	6.2	4	4	3.5
4	17.2	11	7.6	7	5.2	3.8
5	20	14	8.2	7.8	6.9	4.5
6	25.4	15.6	9.7	8.9	8	5.7
7	28.6	18	10.2	10.4	8.9	7
8	30	20.2	12.5	11	10.2	7.8
9	34.5	24.6	15	11.9	11.8	8.4
10	38.8	26.1	18.2	12.2	12	10
11	40.1	27.8	20.4	13.6	15.1	11.9
12	42	29.2	24	15	18	13

The three types of bamboo used (*Schizostachyum brachycladum kurz, Dendrocalamus asper, and Gigantochloa robusta*), the *Schizostachyum brachycladum kurz* bamboo showed good growth on the former coal mining land (Figure 4). The first branch of *Schizostachyum brachycladum kurz* up to the twelfth week has grown to 42 cm from 3 cm, while the second branch has grown to 29.2 cm in length. Branches begin to grow rapidly, starting from the third week with significant growth and growing steadily, increasing the length of 2 cm since the ninth week. The same thing happened to the second branch of the *Schizostachyum brachycladum kurz*.

(a) (b) (c)

Figure 4. Changes in bamboo branches: (a) (*Schizostachyum brachycladum kurz*, (b) *Dendrocalamus asper*, and (c) *Gigantochloa robusta*

The lowest increase in bamboo height occurred in *Gigantochloa robusta*. Until the end of the twelfth week, the first and second bamboo branches were only able to grow up to 18 and 13 cm, respectively. The growth of the two branches on the bamboo tends to increase constantly every week

The influence of local climate on bamboo growth in ex-coal mining land

The physical environment, such as temperature and rainfall, can affect bamboo growth in former coal mining areas. Monthly rainfall at the time bamboo was planted on ex-mining land in March, April, and May were 165.2, 83.2, and 76 mm, respectively. Analysis of the local climate of the ex-mining area used data from four rainfall stations of PT. Bukit Asam, Tbk. (TAL BPK, TAL Mahayung, West Banko, and MTB). Climate is determined by analyzing air temperature in 2020 (Table 3) and monthly rainfall from 2009-2020 (Table 4). The analysis results showed that the study area is categorized as a wet climate (Type B) with a Q value of 0.184 because tropical rain forests dominate it.

Table 4. Intensity of Monthly Rainfall

Year / Month	2010 (mm)	2011 (mm)	2012 (mm)	2013 (mm)	2014 (mm)	2015 (mm)	2016 (mm)	2017 (mm)	2018 (mm)	2019 (mm)	2020 (mm)
January	459.00	214.28	204.12	47.95	350.83	126.85	50.,32	131.27	174.83	484.72	451.43
February	574.83	196.92	389.13	320.82	472.10	347.75	333.22	494.17	286.10	455.21	576.96
March	357.23	204.24	177.65	400.78	370.48	383.15	687.18	193.73	419.70	275.13	273.44
April	343.67	320.42	156.38	324.33	162.58	334.30	542.68	305.33	379.13	401.93	367.12
May	363.33	263.15	167.02	662.27	220.27	37.80	289.70	330.85	191.23	72.46	369.03
June	110.87	145.98	105.47	82.58	179.25	45.30	125.15	87.10	93.17	77.38	126.61
July	96.23	50.43	53.58	447.72	139.03	31.10	88.08	171.30	3.72	76.27	94.94
August	209.43	29.78	44.92	134.37	155.90	145.65	50.38	137.03	183.03	128.57	111.08
September	221.03	55.72	77.00	240.60	16.22	17.40	174.64	211.03	90.68	16.58	172.06
October	274.37	179.08	236.40	201.17	52.70	21.90	295.42	288.03	268.23	44.90	429.44
November	338.30	354.65	322.20	290.15	312.12	308.70	478.02	254.13	426.87	195.80	0
December	94.97	327.08	536.88	448.06	436.30	290.65	25.93	298.53	266.47	349.22	0
Total	3,443.26	2,341.73	2,470.75	4,026.80	2,867.78	2,090.55	3,593.73	2,902.52	2,783.15	2,578.15	2,972.11
DM		3	2		2	5	2		1	2	
HM	2		1	1			1	1	2	3	1
WM	10	9	9	11	10	7	9	11	9	7	9
Average monthly rainfall	286.93	195.144	205.89	335.56	238.98	174.21	299.47	241.87	231.92	214.84	

Table 3. Average temperatures in ex-coal mining areas

Week	Average Temperature (°C)
1	33
2	33
3	34
4	33
5	33
6	31
7	33
8	33
9	34
10	34
11	33
12	34

Bamboo can grow in various types of climates [18]. The wetter the climate type, the more varied the bamboo can grow, but on the other hand, the drier (F), the fewer types of bamboo can grow. The minimum rainfall intensity is 2,867.78 mm per year, and the average temperature ranges from 19 °C - 33 °C. Analysis of monthly rainfall intensity in 2020 (Table 4) when the researchers conducted the feasibility of bamboo plants on reclaimed land, which was quite high, the average monthly rainfall ranged from 100 mm to 500 mm, and the air temperature ranged from 29 °C to 33 °C. Bamboo can grow well with a minimum rainfall [19] of 1,020 mm per year and an air temperature suitable for bamboo growth ranges from 8.8 °C to 36 °C.

4. Conclusion

In this study, the soil analysis results in the study area indicated that the land was still suitable for planting vegetation for revegetation (bamboo). Of the three types of bamboo studied (*Schizostachyum brachycladum* kurz, *Dendrocalamus asper*, and *Gigantochloa robusta*), *Schizostachyum brachycladum* kurz is the most suitable bamboo to be planted in the land of former coal mining areas. This bamboo branch can grow up to 42 cm after 12 weeks of observation. The area of ex-coal mining land studied was categorized as a wet climate (Q = 0.184).

5. Conflict of Interest

Authors stated that there is no conflict of interest with any institution and/or any person related with the research and publication.

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