Cajuput in Ex- Coal Mining Land to Support Sustainable Development

Abdul Kodir
Environmental Science Universitas Indonesia,
Jakarta 10430, Indonesia

Djoko M Hartono
Faculty of Engineering Universitas Indonesia,
Depok 16424, Indonesia

Irdika Mansur
SEAMEO BIOTROP, Bogor 16134, Indonesia

Abstract:- **Coal-mined lands face the problems of acidic soil conditions, a lack of top soil, and an excess of surface rocks, which result in less fertile soil. Under these conditions, plants must adapt to grow well in soil that is acidic and less fertile. To counteract these harsh conditions for plant growth, the use of cajuput (*Melaleuca cajuputi*) in the land formerly mined by PT Bukit Asam is tested. This study aims to determine the growth, leaf production, oil quality and economic potential of cajuput. This study finds that cajuput is suitable to be developed in ex-mining areas with acidic, less fertile soil conditions; is resistant to puddling if it is planted in a garden pattern; and can be profitable.**

Keyword: Mined land; Cajuput; Cajuput oil.

I. INTRODUCTION

The negative impacts that occur as a result of mining activity can be counteracted by conducting reclamation activities throughout the stages of mining to restructure, recover, and improve the quality of the environment and ecosystems to function in accordance with allotment [1]. Reclamation of land damaged by mining activities is intended to help the environment return to stable and sustainable land use as soon as possible [2,3]. One method to stabilize environmental conditions on mined land is through revegetation, which is the process of repairing and restoring degraded vegetation through planting and maintenance activities [4]. Problems on coal-mined lands, which have acidic soil conditions, a lack of top soil, and a large amount of surface rocks, result in less fertile soil. Under these conditions, it is necessary for plants to grow well in soil that is acidic and less fertile. Cajuput (*Melaleuca cajuputi*) is a variety of plant that is suitable for growth under these conditions. Cajuput grows naturally in Moluccas, Timor, and northern and southwestern Australia. This species grows at elevations of 5 to 400 m above sea level in tropical climate zones where the average rainfall is 1300-1750 mm per year [5]. Cajuput grows well in marginal lands, swamps and puddles [6]. In the Maluku Islands, cajuput grows under various site conditions in both high and low plains bordering the coastal forest or grown as a monoculture. Cajuput is able to adapt to soil with poor drainage, is resistant to fire, and tolerates soil with both and low and high salinity [7]. *Melaleuca cajuputi subsp. cajuputi* [8] is used for the production of cajuput oil through the process of distilling the leaves and terminal buds. The main active ingredients in cajuput oil are 1.8-cineol and alpha-terpineol, which are used in medicine as well as in medicinal antiseptic and insect repellent [9]. Cajuput oil is rich in essential oils that are critical to pharmacology. *Melaleuca cajuputi subsp. cajuputi* contains compounds and by-products of essential oils; the main compound consists of 1.8-cineole (15-60%), sesquiterpene alcohols globulol (0.2-8%), viridiflorol (0.2-30%), and spathulenol (0.4-30%), while the follow-up compound consists of limonene (1.3-5%), β-caryophyllene (1-4%), humulene (0.2-2%), viridiflorene (0.5-7%), α-terpineol (1-7%), α- and β-selinene (each 0.3-2%) and caryophyllene oxide (1-8%). The yield of the oil produced by these types of fresh leaves ranges from 0.4 to 1.2% [5]. By using a distillation method that has been prepared, the yield of cajuput oil can be improved to 1.23% [10].

Because ex-coal mine land is marginal land, its uses are considered to be very limited. The focus of recovery of damaged mined lands is generally directed toward the restoration of vegetation for environmental improvement through conservation activities and improvement of biodiversity. However, the recovery of damaged mined land through reclamation and revegetation is not only intended to improve environmental conditions but is also intended to prepare sources of a new economy that can improve the surrounding communities, as was done by the mining company PT Bukit Asam Mining Unit Tanjung Enim, South Sumatera, which developed the cajuput plant on ex-coal mine land [11]. It was initially a trial planting of cajuput to mitigate acidic soil conditions, a lack of top soil, and puddling in the majority of the land mined by PT Bukit Asam; during its development, cajuput plants were able to grow well and maintain stable growth. The increasing number of cajuput plants on land mined by PT Bukit Asam will certainly increase the potential of cajuput leaves, realize that potential, and then allow for use of the leaves as raw material for cajuput oil refining. Cajuput oil refining is then performed by a processing plant built in proximity to the location of the plants. This study aims to determine the growth, leaf production, cajuput oil quality and economic potential of cajuput.

II. MATERIALS AND METHODS

A. Study Area

The research was conducted on the PT Bukit Asam mining areas in South Sumatera province, Indonesia. The total mining area studied covers 15,421 hectares (ha), which consists of the Tanjung Air Laya (7,621 ha), Banko Barat (4,500 ha) and Muara Tiga Besar (3,300 ha) blocks, fig. 1.

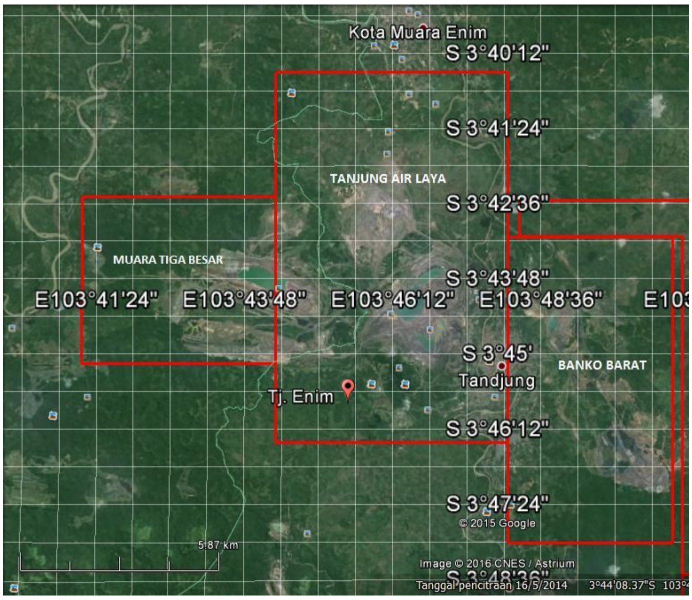

Fig. 1. Cajuput research sites

B. Sample Plots

A total of 7 plots with dimensions of 40 m x 25 m (0.1 hectare) were made based on secondary data from the results of the plant evaluation conducted in 2014, consisting of 2 plots in Banko Barat, 3 plots in Tanjung Air Laya, and 2 plots in Muara Tiga Besar. The number of Cajuput trees was calculated for each plot and then multiplied by 10 to obtain the quantity per hectare. Height and diameter measurements were carried out directly on plants with an age >4 years, and the cajuput leaves were weighed in the field.

C. Method of Study

This study combined secondary and primary data; secondary data were used in the form of plant evaluation results in each block performed by the company periodically and the test results of cajuput oil from the Center Study of Biofarm of Bogor Agricultural University [12]. The primary data consisted of leaves per tree, which were calculated based on weight measurements, and the diameter and height of sample trees; the diameter (d) was calculated by dividing the circumference (c) by pi (d = c/pi), with the value of pi rounded to 3.14; the tree height was measured using a Haga altimeter. Other primary data were used to support the economic value calculation for the development of cajuput. The feasibility study is based on the methods of Net Present Value (NPV) eq.1, Internal Rate Return (IRR) eq.2 and Benefit Cost Ratio or B/C ratio eq.3 [13]; the equations are as follows:

a. $$\text{NPV} = \sum_{i=1}^{n} \frac{CF_i}{(1+k)^i} - I_o \qquad (1)$$

where I_o = initial investment, k = discount rate or expected return, and CF_i = A = cash flow in year *i*.

If NPV>0, the project is feasible; if NPV<0, the project is not feasible.

b. $$\text{IRR} = \sum_{t=1}^{n} \frac{Ct}{(1+r)t} - Co \qquad (2)$$

where Ct = net cash flow, Co= initial cost, n = time of project, and t = rate.

If IRR> rate, the project is feasible; if IRR< rate, the project is not feasible.

c. $$\text{B/C} = \frac{\text{PV benefits}}{\text{PV cost}} \qquad (3)$$

where PV benefits = present value benefits, and PV cost = present value costs.

If BC>1, the project is feasible; if BC<1, the project is not feasible.

III. RESULTS AND DISCUSSION

A. Revegetation

The area of the mine openings was 4,951.88 ha until 2014; of this area, 2,379.42 ha have been revegetated [14], see Table 1.

TABLE 1. REALIZATION OF REVEGETATION

No	Descriptions	Years (hectares)				
		2010	*2011*	*2012*	*2013*	*2014*
1	area of mine openings	4,515.38	4,604.08	4,740.83	4,858.72	4,951.88
2	area of completed revegetated	2,047.45	2,128.99	2,231.73	2,306.26	2,379.42

Source of Sustainability Report PTBA; 2014

PT Bukit Asam (PTBA) has not opened the entire work area; through the use of selective mining methods, the company has only opened areas that have economic reserves to minimize the damage to the land. The soil in the PTBA ex-coal mine land generally has a low pH (H_2O) based on samples taken at 7 locations; the pH (H_2O) is 4.7 to 5.3 (acidic) in the block of Banko Barat, 3.6 to 6.1 (very acidic to somewhat acidic) in Tanjung Air Laya, and 4.6 to 5.1 (acidic) in Muara Tiga Besar [15]. The soil has a coarse texture and rapid drainage, and the percentage of surface rocks ranges between 15 and 40%. The cajuput plant is able to grow well under such conditions (Fig. 2) and has been used to produce cajuput oil from leaves.

Fig. 2. Cajuput trees in the ex-coal mine site

The diameter measurement at breast height was calculated after measuring the stem circumference. In each block, samples were taken at random of 20 trees that have been aged 4 years (period of harvest). The average diameter of the cajuput trees was 8.82 cm, and the average height was 4.31 m.

B. Cropping Patterns

Planting of cajuput (*Melaleuca cajuputi)* on mined land is part of a land reclamation process that requires the successful planting (revegetation) of at least 625 trees/hectare (spacing of 4 m x 4 m). Revegetation in PTBA mined land involves planting not only a monoculture but also a variety of species whether they are other types of fast-growing species or endemic species. Under the planting pattern, cajuput plants are unevenly distributed. Additionally, because the plants are allowed to grow tall, harvesting the leaves is difficult.

Perum Perhutani (a state-owned enterprise) has been implementing a garden for cajuput plant development with a spacing of 3 m x 3 m (Fig. 3); if this pattern is applied by PTBA, then each hectare will produce many more leaves and cajuput oil production will increase significantly – a yield of 0.7% will produce 1,111 kg of cajuput leaves, which will produce 77.77 kg of cajuput oil. Furthermore, it remains possible to perform agroforestry using this cropping pattern.

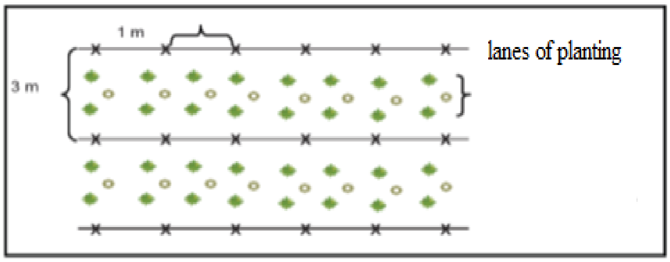

Fig. 3 Cropping pattern with agroforestry

After planting in a garden pattern with dimensions of 3 m x 1 m in Perum Perhutani, Forest Management Unit of Indramayu carried out the stem pruning; trimming aims to regenerate branches to facilitate the harvesting of leaves [16]. The pattern of the mounds (Fig. 4) shows that the area is often flooded. The mounds are also useful for preventing staple crops from being compromised and for preventing leaves from interfering with agroforestry crops at harvest time.

Fig. 4 Stemps pruning of Cajuput

C. Plots

A total of 7 plots were made with dimensions of 40 m x 25 m based on the secondary data from the plant evaluation conducted in 2014 (Table 2).

TABLE 2. CAJUPUT PLANTS PER HECTARE

No	Block	Year of crops	Spacing of plants (m)	The number of cajuput plants	Cajuput plants/hectare	Total number of plants
1	Air Laya:					
a	Timbunan MTBS	2010	3 X 3	39	390	1,111
b	Klawas Tengah	2013	4 X 4	30	300	625
c	Mahayung 2	2013	4 X 4	0	0	625
2	Banko Barat:					
a	Timbunan Pit 1 Barat-Utara	2012	4 X 4	26	260	625
b	Timbunan Pit 1 Timur	2013	4 X 4	0	0	625
3	Muara Tiga Besar:					
a	Timbunan MTBU	2010	4 X 4	35	350	625
b	Timbunan BFMTBS	2011	4 X 4	0	0	625
Total				130	1300	4.861
Average per hectare					185	

Leaf production was measured, and an average of 1 kg/tree harvested every 9 months was obtained. Then, distillation was performed with 2 large cattle weighing 0.8 tons and 1 ton. The results were analysed in a laboratory distillation at Biofarm Bogor Agricultural University (Table 3).

TABLE 3. THE RESULTS OF THE ANALYSIS OF LEVELS OF VOLATILE COMPOUNDS IN CAJUPUT OIL

Compounds	Levels of volatile compounds in oil (%)			
	Before DPI*)	After DPI*)	Before DPI*)	After DPI*)
	Morning		Daylight	
α-Pinene	1.56	2.00	2.39	2.13
β-Pinene	1.26	1.65	1.76	1.56
b-geraniol	-	-	1.19	-
Cineol	38.83	62.05	58.47	61.26
γ-Terpinene	1.32	1.65	1.60	1.55
Tributylamine	29.10	5.54	-	-
Terpineol	-	14.14	10.79	11.88
Tris[N-butylamine]	5.61	1.53	-	-
α-Terpinenyl acetate	1.00	-	-	-
Kariofilen	5.47	3.69	7.05	7.40
α-Humulene	2.95	2.01	3.88	4.12
Kariofilena oksida	1.04	-	1.21	-
α-Elemenena	-	-	-	1.47
Azulena	1.30	-	6.66	-
Valensena	5.97	4.04	1.5	6.55
α-Selinena	2.38	-	-	-
δ-Selinen	-	-	2.28	2.09
Selinenol	1.17	-	1.24	-
α-Eudesmol	1.05	-	-	-
Ylanglena	-	1.69	-	-
Heavy Metals:				
Pb	No			
Cd	No			
As	No			
Hg	No			
Cr	No			

*) DPI: Distilation Process Improvement

The test results showed: cineol levels are in accordance with Indonesian National Standards [17], that after improvement by the refining process the levels of cineol increased and the cajuput oil from mined land was free of heavy metals.

D. Economic Analysis

1) Business Calculations

The garden pattern spacing of cajuput is 3 m x 1 m. Therefore, in one hectare of a cajuput planting, there are 3,333 trees that produce 3,333 kg of cajuput leaves, with a yield of 0.7%, producing 23.33 kg of cajuput oil; this requires a selling price of Rp240,000.00/kg to obtain a revenue of Rp5,599,200.00/hectare.

Assumptions made for the development of cajuput are shown in Table 4.

TABLE 4. ASSUMPTIONS REGARDING THE CULTIVATION AND DEVELOPMENT OF CAJUPUT

No	Description	Amount	Units
1	Cost of nursery	2,000.00	Rp/seed plant
2	Cost of making holes and planting stakes	3,000.00	Rp/seed plant
3	Spacing of plants	3 x 1	meter
4	Number of plants	3,333	trees/ha
5	Total of crops	5,666,100	trees/ha
6	Crop replanting (5%)	283,305	trees/ha
7	Fertilizer: Bokashi	1,300.00	Rp/kg
8	Fertilizer: NPK 125 gr	750.00	Rp/kg
9	Insecticide (Furadan)	5,000,000	Rp/year
10	Cost of harvesting leaves	200.00	Rp/kg
11	Cost of forest protection	50,000.00	Rp/ha/year
12	Production of leaves	1	kg/trees
13	Oil yield of Cajuput	0.7	%
14	Selling price	240,000	Rp/kg
15	Time period	26	years
16	Discount factor	7	%

Explanation of Table 4:

a. Total area for the planting and crop development of cajuput: 1,700 ha. Time of project: 26 years (2017-2043); preparation of the planting area performed in 2017, and planting activities undertaken in 2018, 2019, 2020, and 2021, each covering an area of 425 ha.

b. Fertilization to prepare land using Bokashi fertilizer for 5 kg: Rp6,500.00. Subsequent fertilization with urea or NPK for up to 125 g of crops until the age of 3 years (T + 3): Rp750.00.

c. Cost of making seeds: Rp2,000.00/seed plant. Cost of 5,517,300 stems of seedlings: Rp11,332,200,000.00. Cost of replanting seedlings with up to 283.305 stems valued at: Rp566,610,000.00.

d. If all of the land is planted with cajuput trees with up to 5,666,100 stems, 5,666,100 kg of leaves can be produced, which after further refining can produce 39,662.70 kg of cajuput oil, worth Rp 9,519,048,000,00 (39,662.70 kg x Rp240,000.00). This rate of production is achieved beginning in the fourth year, when there is leaf production in the entire block. It is assumed that there is a decrease in the production of leaves of up to 10% between the 21st and 26th year.

e. Revenue for the duration of the project: Rp199,698,0555,200.00. Reduced costs for expenditures: Rp87,428,210,000.00. Net income before tax: Rp112,269,845,200.00 or Rp103,318,070,969.00 per year.

2) Feasibility

The assessment of the feasibility of cultivating cajuput was performed using NPV, B/C, and IRR criteria [18]. The results of the calculations of the eligibility criteria for cajuput crop cultivation in mined land is shown in Table 5.

TABLE 5. ASSESSMENT OF FEASIBILITY

Criteria	Value	Description
NPV	Rp7,838,207,365.00	Feasible: NPV<0
B/C	1.11	Feasible: B/C>1
IRR	8%	Feasible: IRR> rate

Based on Table 5, the cultivation and development of cajuput is feasible because NPV>0, IRR>, and B/C>1.

3) Sensitivity Analysis

Sensitivity analysis predicts the impact of errors or changes on the variables in a calculation [19]. Some of the parameters that cajuput plant development is sensitive to are a decline in cajuput oil production and higher seed prices. If these factors change, they will affect the NPV, IRR, and B/C. The sensitivity analysis by simulation cost is shown in Table 6.

TABLE 6. SENSITIVITY ANALYSIS

Criteria	5% cajuput oil production decline	5% seed price increase
NPV	Rp 2,335,253,130.00	Rp1,831,437,262.00
B/C	1.03	103
IRR	7%	7%

Under the conditions of a decline in cajuput oil production of 5% and a rise in seed prices of 5%, the criteria NPV>0, B/C>1, and IRR = 7%. According to the results of the sensitivity analysis, the cajuput plant effort is still feasible for development.

IV. CONCLUSION

The cajuput plant (*Melaleuca cajuputi sub sp. Cajuputi*) has proved to be adaptive in mined land where the soil is acidic, and the cajuput oil produced on PTBA ex-coal mine land is free of heavy metals. Because cineol levels are in accordance with Indonesian National Standards, this cajuput oil is fit for sale on the public market. Even cajuput plants that are not intended for environmental restoration on less fertile mined land also provide economic benefits in the long term.

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