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A Study of Above-Surface Carbon Storage in the Post-Coal Mining AREA of PT Bukit Asam

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Abstract: Both biotic and abiotic natural resources are the capital of the biosphere that may be exploited to meet human needs and promote human welfare. Global warming is a consequence of increasing environmental degradation. During photosynthesis, trees may collect carbon from the atmosphere, separate carbon from oxygen, and release oxygen back into the atmosphere. This investigation was conducted on post-coal mining reclamation land that PT. Bukit Asam (BA) restored in 2009, 2012, and 2015. This study employs a quantitative approach with a purposive sampling methodology. The utilized sampling intensities were 1%, 2.5%, and 5%. The plot chosen is a 20-by-20-meter rectangle. Carbon storage for the 2009 planting time averaged 40.57 tons per hectare over a total area of 32.89 ha. Carbon storage for the planting year of 2012 with a total area of 5.73 hectares and an average carbon storage of 26.37 tons per hectare. Carbon sequestration in 2015 with a total area of 3.90 hectares and an average carbon storage of 20.86 tons per hectare.
Keywords: land destruction, reclamation, restoration, revegetation, post-mining

1. Introduction

The natural resources that are present on our planet, including both biotic and abiotic resources, are valuable assets that can be utilized to satisfy human needs and improve the well-being of people [1]. These resources provide us with the necessary elements to build and maintain societies, economies, and industries that contribute to our standard of living and overall quality of life [2]. We use these resources wisely and sustainably to ensure their continued availability for future generations.

Natural resources are divided into two categories: renewable natural resources, where the flow of resources depends on their management, with the possibility that their supply may decrease, be sustainable, or increase; and nonrenewable natural resources, such as coal, oil, and natural gas, whose supply will eventually be exhausted [3].

According to [4], the most serious environmental harm caused by coal mining is the result of open pit mining operations, specifically the removal of flora covering the ground and the stripping of the topsoil layer (topsoil) to recover coal ore. Increasing concentrations of greenhouse gases as a result of human activities and increasing environmental damage have led to the process of global warming, which has caused the earth's temperature to rise. Global warming is one of the most significant environmental concerns the world faces today.

Based on [5] state that the positive effects of post-mining land reclamation and revegetation include an increase in biodiversity, soil fertility, the acceleration of the reintroduction of wildlife, and the improvement of environmental conditions, land cover, and canopy stratification, which can absorb and store carbon to create a microclimate. This topsoil layer is reapplied to the reclaimed ground that has been sculpted in preparation for replanting during the revegetation phase.

Aboveground biomass consists of all biological material above the ground, including stems, stumps, branches, bark, seeds, and leaves from tree stratum and understory formations. Forest ecosystems dominated by trees are a natural system for preventing a rise in atmospheric carbon concentrations. During photosynthesis, trees may collect carbon from the atmosphere, separate carbon from oxygen, and release oxygen back into the atmosphere [6]. Carbon storage in PT Bukit Asam's revegetated post-coal mining land has not been extensively examined; therefore, it is necessary to estimate land surface carbon stocks for the planting years 2009, 2012, and 2015.

2. Material and Methods

This study was conducted on post-coal mining reclamation land held by PT. Bukit Asam (Persero) at the Air Laya Mine (TAL), planting years in 2009, 2012, and 2015, respectively (in detail, see Figure 1). City of Tanjung Enim, Province of South Sumatra. The research spanned two months, from October to November 2020.

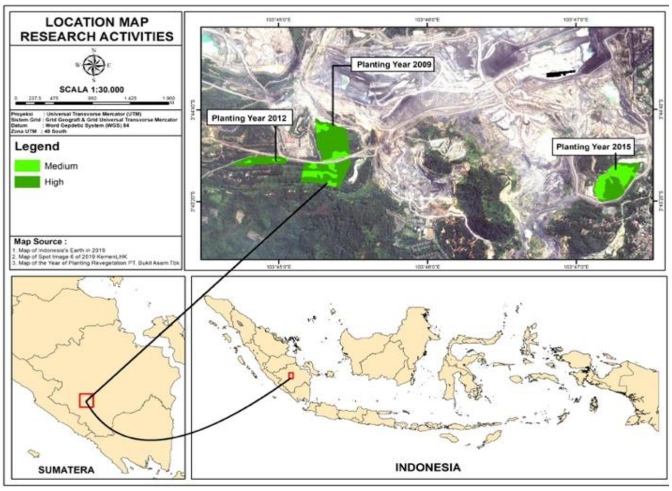

Figure 1. Research location map

2.1. *Materials*

Stationery and paper, binoculars, measuring tape, compass, GPS, digital camera, tape recorder, tidy rope, phi band, and measuring tape were utilized for the research. Count sheets, baseboards, land cover maps, revegetation maps for planting years, and vegetation analysis guidebooks were utilized.

2.2. *Population and Sample*

The sampling intensity (IS) is calculated as a percentage, ranging from 0.5% to 2.5%, and is adjusted based on factors such as the size of the land, number of workers, costs, and time required. To calculate the sampling intensity, the number of plots is multiplied by the plot size of 400 square meters, then divided by the annual planting area in square meters, and finally multiplied by 100. Table 1 provides the calculation of the sampling intensity.

Table 1. Determination of Sampling Intensity

Year	Categorize	Number of Plots	IS
2009	Sparse	5	5,65
	Thick	8	1,09
2012	Sparse	2	4,17
	Thick	4	4,20
2015	Sparse	2	40
	Thick	6	6,49

The distribution map of the plot points is expected to represent the field conditions; therefore, the distribution map of the plot points is also displayed so that the differences from each classification of canopy cover in the planting years of 2009, 2012, and 2015 can be seen in the image display. The distribution map of the plot points can be seen in Figures 2 and 3. In detail, see Table 2.

Figure 2. Distribution map of plot points for the planting years 2009 and 2012

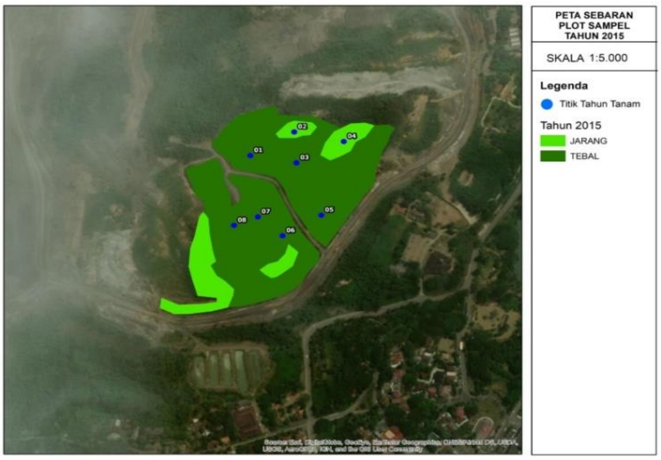

Figure 3. Distribution map of plot points for the planting year 2015

Table 2. The Coordinates of the Survey Location

No	2009		2012		2015	
	X	Y	X	Y	X	Y
1.	361937	9585262	360845	9585353	365361	9585168
2.	361791	9585279	360822	9585301	365453	9585223
3.	361756	9585230	360903	9585356	365458	9585151
4.	361704	9585172	360940	9585308	365557	9585201
5.	361616	9585193	361039	9585371	365510	9585029
6.	361777	9585351	360968	9585370	365429	9584981
7.	361871	9585363			365377	9585025
8.	361936	9585423			365327	9585005
9.	362016	9585451				
10.	361988	9585398				
11.	361619	9585270				
12.	361840	9585450				
13.	361758	9585485				

Table 3. Allometric Models

Tree Type	Allometric Model	Reference
Acacia mangium	$Y = 0.070\ D^{2.580}$	Rusolono *et al.*, 2015.
Swietenia macrophylla	$Y = 0.048\ D^{2.68}$	Adinugroho and Sidiyasa 2006.
Dryland plantation forest	$Y=0.1728D^{2.2234}$	Siregar, CA 2009. *in* Hendrawan *et al* . 2014.

note: Y = total of biomass (kg), DBH = diameter at breast height (cm)

2.3. Methods

The study methodology employed a quantitative approach and incorporated the purposive sampling technique. This technique involved selecting and analyzing a predetermined sample for specific research purposes [7]. The data consists of a map of forest stands arising from revegetation in former coal mine reclamation zones for the planting years 2009, 2012, and 2015.

The calculation of carbon storage starts from the calculation of the sourced biomass tree stands, undergrowth, and litter. Data stands in the form of stakes, poles, and trees in each header type along with data information diameter at breast height (dbh) and laboratory, oven litter, and understorey samples were carried out to determine the dry weight of the sample used in the calculation of carbon storage.

Furthermore, drying was carried out using an oven in the laboratory with a temperature range of 70ºC to 85ºC until it reached a constant weight for 2x24 hours to obtain the value of the biomass used by calculating the carbon storage of understoreys and litter. Calculation of the above-ground biomass of saplings, poles, and trees in each plot is calculated based on the allometric equation as shown in Table 3.

Roughly 50% of tropical wood biomass is consisted of carbon, the carbon storage of each tree is approximated by multiplying its biomass value by a conversion factor of 50%. After obtaining the biomass value, the carbon storage is calculated. Using the following formula, the carbon content is calculated by multiplying the estimated biomass value by the conversion factor.

$$C = Y \times 0{,}5$$

where C = carbon (tons/Ha), Y = tree biomass (tons/ha), 0.5= conversion factor for estimation.

The wet weight of the understorey samples (BBCtb, Grams), the total wet weight of the understoreys (TBBtb, Grams), and the dry weight of the understorey samples were acquired from the three plots in each sample plot (BKCtb, Grams). Primary understory data was determined for its wet- dry weight, and samples were oven-dried to measure their dry weight (Rusolono, et al. 2015). The following formula is used to calculate understory biomass:

$$B = \frac{BKC}{BBC} \times TBB$$

where B = Biomass of undergrowth/litter, BKCtb = Dry weight of understorey samples/litter, BBCtb = Wet weight of the understorey/litter sample, TBBtb = Total wet weight of undergrowth/Litter.

After frying, the dry weight of theunderstory and litter was determined. After drying, the dry weight is expressed in grams, which is then converted to Kg/m2 and Tons/Ha. After determining the value of understory biomass using a constant value of 0.47, carbon storage was calculated for the understory [8]. The following formula is employed:

$$C = B \times 0{,}47$$

where C = carbon (tons/Ha), B = biomass of undergrowth/litter, 0.47 = constant value

Calculation of total carbon, the total carbon value is obtained from the sum of the total carbon value of the understorey, the total carbon of the stands (saplings, poles, and trees) and the total carbon of the litter [8]. The formula used to obtain the total carbon value is as follows:

Sample carbon = C. Understorey + C. Trees + C. Litter
Total carbon = K. Sample × Total Area of Revegetation Area

3. Results and Discussion

3.1. Short Description of PT. Bukit Asam

The Tanjung Enim Mining Unit is located in the northwest direction approximately 3 kilometers from the city of Tanjung Enim, approximately 200 kilometers from the city of Palembang, approximately 4 kilometers from the Muara Enim Regency, 165 kilometers from the coal jetty in Kertapati, and 420 kilometers from Tarahan Harbor Bandar Lampung. The Tanjung Enim Mining Unit is comprised of two mining areas: the Air Laya Mine (TAL) and the Non-Air Laya Mine (NAL), which is comprised of the IUP Bangko Barat (BB) and the IUP Muara Tiga Besar (MTB). Muara Enim Regency is located in the centre of South Sumatra Province, and its boundaries are as follows:

- North side with Musi Banyu Asin Regency
- South side with Ogan Komering Ulu Regency
- West side with Lahat Regency
- East side with Ogan Komering Ilir Regency

Geographically, it lies between 3'42'30" and 4'47'30" south latitude and 103'43'00" and 103'50'10' east longitude [9]. Location Mine Air Laya is situated in three districts, namely Muara Enim Kota District, Merapi District, and Lawang Kidul District, on Iup TAL ownership and the allotment of the Air Laya mining area, extensive Permission Business Mining Operations Production (KW.01.SS.2010) based on decision Governor Sumatra South Number: 751/ KPTS/DISTAMBEN-2010, date October 29th, 2010 about agreement extension first permission operational mining business production, period applies 10 years (1 January 2011 is broad 7,621 Ha of the entire area, there are 3,453.5 Ha of the forest, which has authority to utilize forest area based on Decision Minister Forestry Number: SK 396/Menhut-II:2008 (Air Laya Post Mining Plan, 2010-2020).

3.2. Value of Carbon Storage Through Field Measurements

In the field, calculation data is retrieved by measuring the diameter of the stand, which consists of saplings and trees. In the laboratory, the understory and litter are collected and dried, and the carbon values of the stand, understory, and litter are added to determine the overall carbon storage. Table 4 depicts the 2009 planting year with a planting area of 32.89 ha, the 2012 planting year with a planting area of 5.73 ha, and the 2015 planting year with a planting area of 3.90 ha.

Figure 4 illustrates the association between planting year and carbon storage as determined by the research. According to this graph, plants that are 11 years old store the most carbon with an average of 40.75 tons/ha, followed by plants that are 8 years old with 26,73 tons/ha and plants that are 5 years old with 32.99 tons/ha. 2009 had the highest average carbon storage between 2012 and 2015, as shown in the graph above.

Table 4. Total of the carbon storage in every year of planting

Planting year	Carbon Storage (Tons/Ha)			Amount	Total Carbon Storage (Tons/Ha)	Average (Tons/Ha)
	Tree	Understorey	Litter			
2009	47.99	1.90	4.60	54.50	1340,20	40,57
2012	34,77	4.66	5,42	44.90	153,17	26,73
2015	48,34	1.20	1.80	51,53	128,67	32.99

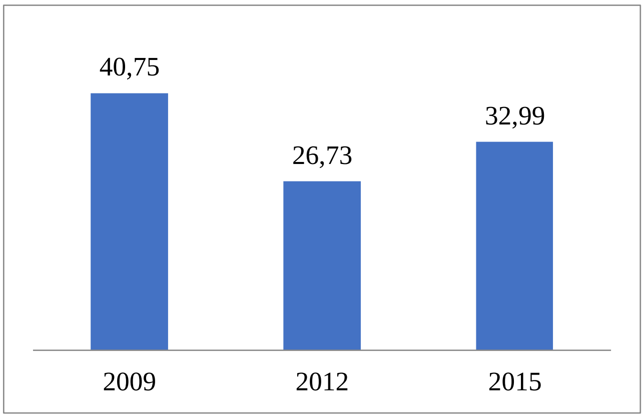

Figure 4. Value of carbon storage based on canopy cover density

The difference in carbon stocks is quite large, which is influenced by the small number of stands, few trees with a large diameter, and the density of tree species. In 2009, there were many trees with a diameter >20 cm, such as the Trembesi (*Samanea saman*), which has a diameter of 45.5 cm and a high capacity to absorb and store carbon, and a large number of trees, such as broadleaf acacia (*Acacia mangium*). In addition, there were tree species that were not planted so that it could be determined that natural success had occurred, plants for long-cycle tree species such as Tamarind (*Tamarindus indica*) and windfall (*Malotus paniculatus*), which have the same capacity to store carbon as living stands in a natural forest. According to [10], the largest carbon stores on land are large trees and natural or secondary forests contain the most carbon (C).

Under [6] research found that trees are capable of storing enormous quantities of carbon in each of their structures, such as their stems, roots, branches, and leaves, and that this capacity increases as the tree matures. According to [11] research, the value of carbon stored represents the quantity of carbon that plants may absorb in the form of biomass. The biomass and carbon stocks of forests are also highly dependent on the physiological processes of plants, specifically photosynthesis.

The rate of photosynthesis inside a stand is proportional to its chlorophyll content, stomatal density per unit leaf area, and age. The greater the leaf area of the land union stand, the greater the amount of CO_2 the stand will absorb [12]. The age of the plantation will result in a rise in leaf area [13]. The more leaves a tree has, the more sunlight it can absorb for the photosynthetic process. Although photosynthesis tries to collect carbon dioxide, the products of photosynthesis are transferred to other portions (stems, branches, and twigs) so that the biomass content of the non-photosynthetic leaf component is greater than that of the photosynthesis-performing portion of the leaf [14].

Environmental factors such as light, humidity, canopy cover from adjacent trees, and intensity of competition between species determine the diversity of undergrowth species. In addition to environmental factors, litter from tree species such as broadleaf acacia (*Acacia mangium*) and eucalyptus (*Melaleuca cajuputi*) in the research location is suspected of causing the undergrowth to not grow properly and even be difficult to live. This is because broadleaf Acacia (*Acacia mangium*) has allelopathy and eucalyptus (*Melaleuca cajuputi*) has metabolite compounds.

This is consistent with the findings of [15], who found that Acacia litter contains allelopathy or substances that limit the growth of other species and includes litter that decomposes slowly, hence inhibiting the formation of undergrowth near the planting site. Moreover, eucalyptus has secondary metabolites that are harmful to other plants and decomposer microorganisms, therefore they may contribute to the poor growth of undergrowth.

A litter is a layer of decomposing plant material, including leaves, twigs, branches, and fruit. Even the bark and other parts that are scattered on the forest floor before decomposition. Before undergoing decomposition, trash is capable of storing carbon dioxide [16]. In the study of [17] the litter produced by the forest has a varying amount and composition based on the structure and diversity of the constituent plant species. The difference in litter production is a result of the tree's distinct litter structure. In addition, according to Rani (2014) in the study by [6], the factors that affect the amount of litter are the number of trees or stand density, the quality of the place to grow, the diameter of the trees, and the number of trees or the density of dense stands will cause crop competition, causing plants to drop their leaves to reduce competition.

Through research on calculating surface carbon stocks, it is clear that total carbon stocks on revegetated reclamation land play a significant role in reducing the concentration of carbon released into the atmosphere and mitigating global warming, notwithstanding their inability to compete with natural forests. Mine reclamation forest has its characteristics, which are distinct from those of other forest types, but has activities similar to plantation forests, namely being constructed through the process of nursery and planting and maintenance, and it has the same tree types as early-stage secondary forests, which are dominated by fast-growing species [18].

According to [19], fast-growing plant species can encourage or support natural succession with natural rejuvenation indicators. Natural rejuvenation is a natural process for trees that comprise dead stands.

4. Conclusions

Offered the research, data analysis, and discussion conducted regarding the calculation of above-surface carbon storage in post-coal mining areas, the following can be concluded:

1. Carbon storage for the 2009 planting year with an average carbon storage of 40.57 tons per hectare across a total area of 32.89 ha.
2. Carbon storage for the planting year of 2012 on a total area of 5.73 hectares with an average carbon storage of 26.37 tons per hectare.
3. Carbon storage in 2015 with a total area of 3.90 ha and an average carbon storage of 20.86 tons per hectare.

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