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CARBON STOCK ESTIMATION ON REPONG DAMAR LANDSCAPE IN PESISIR BARAT REGENCY, LAMPUNG PROVINCE

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ABSTRACT

Climate change mitigation activities in the forestry sector are currently widely carried out through the REDD+ scheme, especially in tropical regions. In the REDD+ scheme, information on forest carbon stocks in areas used as REDD+ activity locations will be essential. This study aims to estimate aboveground carbon stocks in the damar repong landscape in Pesisir Barat Regency, Lampung Province, which consists of three main land cover types, namely repong damar, natural forest, and mixed gardens. The approach used is a non-destructive method with a purposive sampling technique on 42 sample plots. Vegetation data were collected by measuring the diameter, height, and density of wood, then biomass was calculated using allometric equations and converted into carbon stocks. The results showed that the highest average carbon stock was found in repong damar at 269.74 tC/ha, followed by natural forest at 167.01 tC/ha, and mixed gardens at 96.61 tC/ha. Variations in carbon stocks in the three land covers were influenced by stand structure, tree size, and vegetation density. Statistical analysis showed the highest level of uncertainty in natural forest and the lowest in mixed gardens. This study confirms that traditional agroforestry systems such as damar repong have significant potential in mitigating climate change through high carbon storage.

Keywords*: Agroforestry; Biomass; Carbon Stocks; Land Cover; Repong Damar.*

INTRODUCTION

The current climate change phenomenon such as prolonged droughts, sea level rise is an implication of global warming which is none other than due to human activities, one of which is through deforestation and forest degradation activities (Noor'An *et al*., 2015). According to *the World Agroforestry Centre* in (Boreel *et al*., 2015), about 20% of CO_2 and greenhouse gas emissions come from land-use change in the tropics. Deforestation and forest degradation release CO2 emissions stored in forests into the atmosphere as well as reduced CO2 absorption by trees through photosynthesis (Putri & Wulandari, 2015).

Faced with increasingly critical environmental challenges, the role of protected areas has been expanded to climate change mitigation, particularly in tropical countries, whose main concept is Reducing Emissions from Deforestation and Forest Degradation (REDD+) (Harada *et al*., 2015). Indonesia is one of the countries that has expressed a positive attitude towards the REDD scheme. Indonesia's commitment to participate in efforts to reduce greenhouse gas emissions was affirmed by issuing Presidential Regulation No. 16/2001 concerning the Action Plan for Reducing Greenhouse Gases (Zunnuraeni & Zuhairi, 2018).

Indonesia's tropical forests are among the largest in the world and hold significant carbon reserves. Therefore, sustainable forest management and efforts to reduce deforestation and forest degradation through the REDD+ (Reducing Emissions from Deforestation and Forest Degradation) scheme have significant potential to reduce GHG emissions, the certificates of which can be traded on carbon markets or other non-market mechanisms (Cadizza *et al*., 2024). Technically, REDD+ is a carbon payment scheme aimed at mitigating climate change through reducing deforestation, reducing forest degradation, conserving forest carbon stocks, sustainable forest management, and enhancing forest carbon stocks (e.g., through regeneration and planting on previously forested land). (Gardner *et al*., 2012).

Repong damar is a land management system that integrates plantation and forestry plants that physically resemble natural forest (Hariyanto *et al*., 2022). The types of plants found on the land consist of fruits, timber and rattan, and are dominated by resin plants that form complex structures. (Wardah, 2005). The diversity of plant types in the repong damar land cover affects the carbon sequestration capacity and reserves. Resin trees as the main species that can live up to 150 years have a major contribution to the potential carbon stocks in the area (Casson, 2005). According to research (Laura & Darmawan, 2020), it shows that the carbon stock in the repong damar reaches 318 tC/ha. However, the study has not included the potential for vegetation in other land covers to store carbon, as a comparison of the potential for carbon storage in repong damar. This study aims to estimate the estimated carbon stocks in repong damar cover, natural forest, and mixed gardens in Pesisir Barat Regency, Lampung Province.

METHOD

Research and Time Location

This research was conducted in Pesisir Barat Regency, Lampung Province in February 2025. The tools and materials used in the form of digital camera, *roll meter*, tape meter, haga meter, *Global Positioning System* (GPS), stationery and *tally sheets*, and other supporting tools used in this study include a set of laptops equipped with software in the form of *Microsoft office* and *ArcGIS 10.8.*

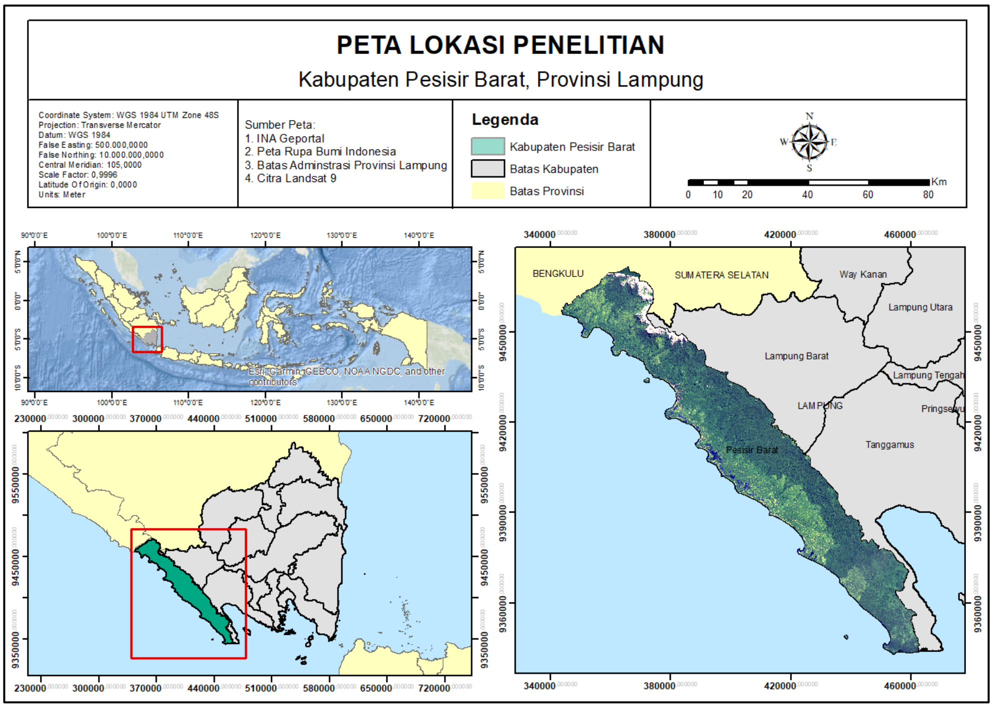

Figure 1. Map of The Research Location

Data Collection

Vegetation data was obtained through stand inventory plots at the research site in predetermined plot samples on three land covers consisting of repong damar, natural forest, and mixed gardens. The data collected included the name of the tree, the scientific name as well as the height measurement, and the diameter on the sample plot.

Sample Determination

Sampling is carried out by *the purposive sampling method*, which is the deliberate selection of samples based on certain criteria that are considered to be in accordance with the needs of the research. This approach was chosen to ensure that the data obtained is relevant and in accordance with the focus of the research. Based on research (Laura *et al.*, 2019), the area of repong damar in Pesisir Barat Regency is 99,693 hectares. Meanwhile, data from *the Wildlife Conservation Society* (WCS) noted that the area of natural forest or Bukit Barisan Selatan National Park (TNBBS) in Pesisir Barat Regency reached 280,300 hectares, and data from the Central Statistics Agency (BPS) showed that the area of mixed gardens in Pesisir Barat Regency was 24,499 hectares. The minimum number of sample plots was calculated using a formula (Cochran, 1977) with a margin of error of 15% in the research area of 404,492 hectares. Cochran's formula is as follows:

$$n = \frac{\frac{t^2 \times p \times q}{d^2}}{1 + \frac{1}{N}\left(\left(\frac{t^2 \times p \times q}{d^2}\right) - 1\right)}$$

Description:
n = Minimum number of samples required
N = Total population (forest area (ha) divided by sample plot area (ha))
t = Confidence level (used 0.95 so t-value = 1.96)
d = Margin of error, used 15%)
p = Proportion of a given characteristic (group) of 50% (0.5)
q = 1 – p
1 = Constant number

The calculation of the Cochran formula in the study to determine the number of sample plots, namely.

$$n = \frac{\frac{t^2 \times p \times q}{d^2}}{1 + \frac{1}{N}\left(\left(\frac{t^2 \times p \times q}{d^2}\right) - 1\right)}$$

$$n = \frac{\frac{1{,}96^2 \times 0{,}5 \times 0{,}5}{0{,}15^2}}{1 + \frac{1}{4044920}\left(\left(\frac{1{,}96^2 \times 0{,}5 \times 0{,}5}{0{,}15^2}\right) - 1\right)}$$

$$n = \frac{42{,}6844}{1{,}0000103}$$

$$n = 42$$

Based on the results of the sample calculation using the Cochran formula, the total sample plot was 42 units. The plots were then evenly distributed over three land covers, with 14 sample plots each. The placement of sample points is done using ArcGIS software as shown in Figure 2.

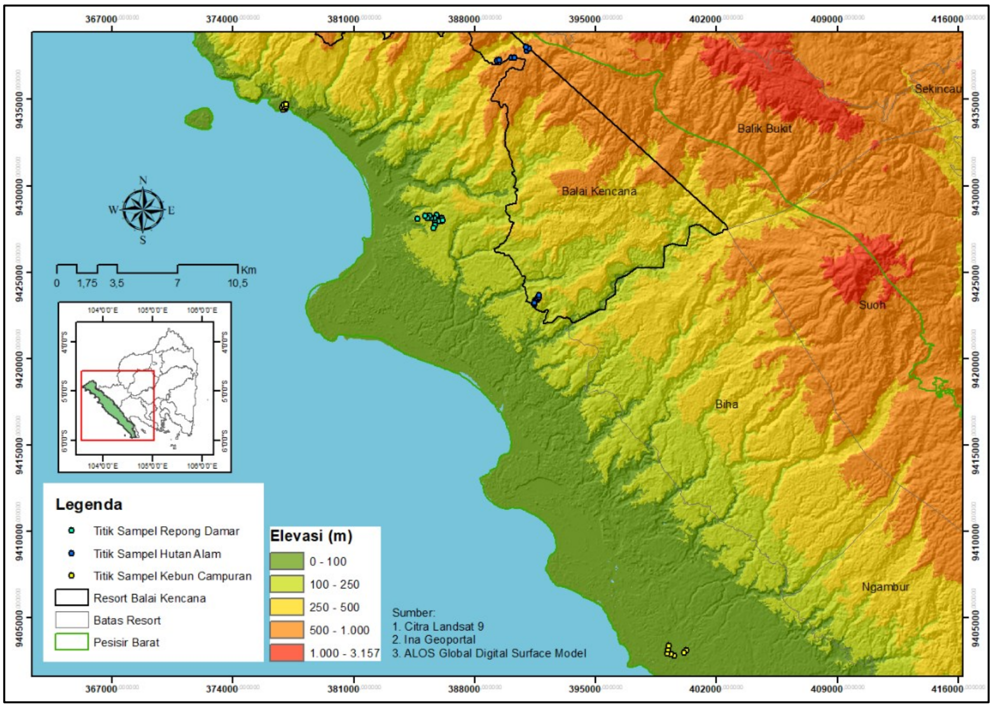

Figure 2. Sample Plot Placement

Vegetation Analysis

Vegetation analysis was carried out to collect data on the type of tree, tree height, tree diameter using Diameter Breast Height (DBH), and wood density in each sample. The DBH measurement in this study was measured according to the growing conditions of the vegetation. The DBH measurement procedure refers to the Indonesian National Standard (SNI) 7724:2011, measurement and calculation of carbon stocks - field measurements for forest carbon stock estimation can be seen in Figure 3.

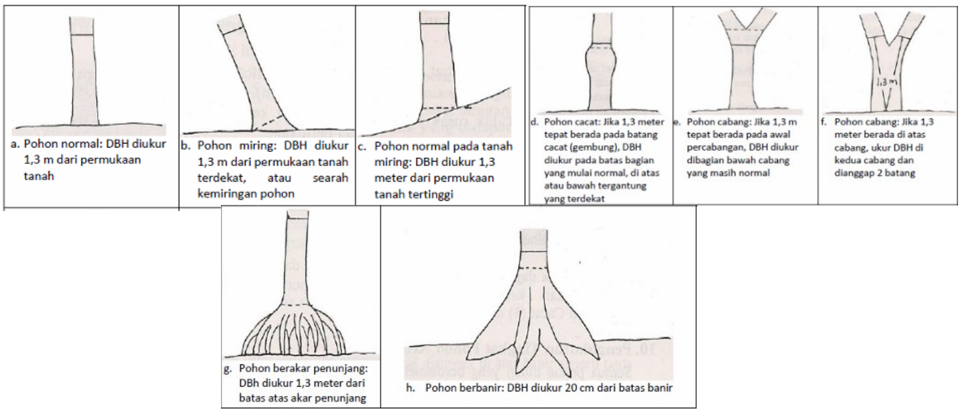

Figure 3. DBH Measurement Procedure on Rods

The selection of a plot size of 20x20 m refers to (Nanjaya *et al*., 2020), which states that the optimal plot size for forest inventory, especially for estimating stand variables (base area and biomass) is 0.40 ha. Measurements were made on the tree phase stand, pole phase, and pile phase. The plot design of the stand measurement can be seen in Figure 4.

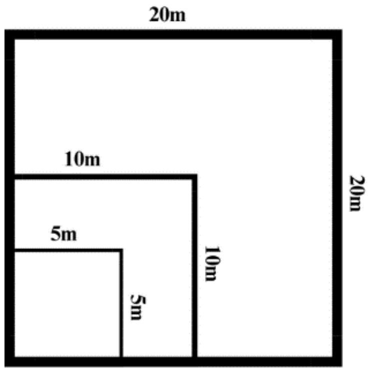

Figure 4. Sampling Plot

Nested sample plots are made in the field, as seen in Figure 4. Stands with a chest height bar diameter (dbh) of 5.0–9.9 cm or pile phase are measured in sub-plots measuring 5 × 5 m or 25 m². Stands with a dbh of 10.0–19.9 cm or pole phase are measured in sub-plots measuring 10 × 10 m or 100 m². Meanwhile, stands with a DBH above 20 cm or tree phase are measured in a main plot measuring 20 × 20 m or 400 m².

Calculation of Biomass on the Surface

Biomass in the study is biomass on the ground surface with a non-destructive method, namely without logging each tree. The measurement results were then analyzed using an allometric equation formula to obtain biomass values. According to (Manuri *et al*., 2017), the formula for tree biomass is as follows.

$$AGB = 0{,}206 \times (DBH^{2{,}56} \times WD^{0{,}889})$$

Description:
AGB = Aboveground Biomass
DBH = Diameter at Breast Height
WD = Wood Density

Carbon Stock Calculation

The value of carbon stocks can be estimated using the biomass content approach developed by (BSN, 2011), where the carbon conversion factor used is 47% of the total biomass. The calculation is carried out by multiplying the value of biomass by the carbon conversion factor. Carbon value conversion is carried out on each vegetation stand throughout the plot. The value of carbon stocks obtained in kilograms is converted into tonC/ha units according to the SNI Carbon Measurement and Calculation Standards.

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

Description:
C = Carbon Stock (tC)
B = Biomass (kg)
0.47 = International standard conversion factor for carbon estimation.

The total value of estimated carbon stores is obtained using the BSN formula (2011):

$$C_{total} = \left(\frac{\sum Cplot}{n\ plot}\right) \times \text{Area}$$

Description:
∑Cplot = the total amount of carbon across the entire plot tile
n plot = total plot tiles

Statistical Analysis of the Uncertainty Value of Carbon Reserves

Statistical analysis of the uncertainty value of carbon stocks was used to measure sampling errors in studies conducted using the sampling method. This analysis focuses on the value of carbon and aims to calculate the size of sampling errors. The calculation uses a statistical formula adapted from (Darmawan *et al*., 2022), which is also used to determine the range of estimated carbon storage intervals. The statistical analysis in this study is presented in Table 1.

Table 1. Statistical Analysis

Jenis tutupan lahan	Statistical Analysis							
	Rerata/*Mj*	Simpangan Baku/*SD*	Sample (n)	t-stat at 95% (t)	Confidence Interval/*CI*	Lower Bound/*LB*	Upper Bound/*UP*	Sampling Error/*SE* (%)
Tutupan lahan ke-j	$1/n\sum_{i=1}^{n} Mi$	$\sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(Mi+Mj)^2}$	3 5 8 10 50 100 ∞	4,30 2,78 2,37 2,26 2,01 1,98 1,96	$\frac{SD\ x\ t}{\sqrt{n}}$	*Mj-CI*	*Mj+CI*	$\frac{Mj}{CI}$ *x 100%*

Description:
Mi = Total carbon stock (in tC/ha) of plot-i in forest cover type-j
n = Total plots in forest cover type-j

RESULTS AND DISCUSSION

Stand Composition and Characteristics

The composition of vegetation species is the arrangement and number of individuals that exist in a plant community. The composition and structure of vegetation are influenced by various factors, one of which is the condition of the growing place which includes climatic factors and soil conditions (Naharuddin, 2018). The composition of forests can be interpreted as the variety of types that make up a community (Seran, 2019). (Fachrul, 2007) states that the composition of vegetation is a floristic list of plant types found in a community. Meanwhile, the structure of vegetation is described as a result of spatial arrangement by the components that make up the stand. The structure is described through parameters such as diameter, height, and header diversity. The composition of vegetation is divided into three phases of growth, namely the tree phase, the pole phase, and the pile phase. The results showed that there were 307 individuals in the tree phase, 202 individuals in the pole phase, and 262 individuals in the pile phase. Overall, there were 771 individual trees with trunk Diameter Breast Height (DBH) ranging from 0.64 cm to 87.90 cm. Details of the distribution of the number of individuals in each growth phase in each land type are presented in Table 2.

Table 2. Vegetation Composition

Land Type	Growth Phase			Number of Individuals
	Tree (Individual)	Pole (Individual)	Stake (Individual)	
Repong Damar	151	67	88	306
Natural Forest	91	73	91	255
Mixed Garden	65	62	83	210
Total	307	202	262	771

Source : Primary Data (2025)

Table 3. Types of Plants in Repong Damar Land

No.	Species Type	Family	Number of Individuals
1	Ampelas (*Ficus ampelos*)	*Moraceae*	1
2	Angsana (*Pterocarpus indicus*)	*Fabaceae*	1
3	Asam kandis (*Garcinia xanthochymus*)	*Clusiaceae*	3
4	Bayur (*Pterospermum javanicum*)	*Sterculiaceae*	6
5	Binjai (*Mangifera caesia*)	*Anacardiaceae*	2
6	Cempedak (*Artocarpus integer*)	*Moraceae*	1
7	Cengkeh (*Syzygium aromaticum*)	*Myrtaceae*	2
8	Damar (*Shorea javanica*)	*Dipterocarpaceae*	107
9	Duku (*Lansium domesticum*)	*Meliaceae*	35
10	Durian (*Durio zibethinus*)	*Malvaceae*	26
11	Gaharu (*Aquilaria malaccensis*)	*Thymelaeaceae*	3
12	Handam mali (*Leea indica*)	*Leeaceae*	1
13	Handitak (*Myristica sp.*)	*Myristicaceae*	5
14	Haneban (*Vitex pinnata*)	*Verbenaceae*	5
15	Heling (*Cinnamomum sp.*)	*Lauraceae*	9
16	Jambu biji (*Psidium guajava*)	*Myrtaceae*	1
17	Jengkol (*Archidendron pauciflorum*)	*Fabaceae*	2
18	Kakao (*Theobroma cacao*)	*Malvaceae*	2
19	Kanihai (*Bridelia tomentosa*)	*Euphorbiaceae*	1
20	Kayu afrika (*Maesopsis eminii*)	*Rhamnaceae*	1
21	Kayu angsor (*Ficus callosa*)	*Moraceae*	2
22	Kayu lada (*Litsea cubeba*)	*Lauraceae*	13
23	Kayu langit (*Dysoxylum quercifolium*)	*Meliaceae*	2
24	Kayu rah (*Cotylelobium melanoxylon*)	*Fabaceae*	1
25	Kayu semang (*Caesalpinia sappan*)	*Fabaceae*	1
26	Kemiri (*Aleurites moluccanus*)	*Euphorbiaceae*	1
27	Kuwak (*Pangium edule*)	*Achariaceae*	1
28	Kuwau (*Ficus septica*)	*Moraceae*	10
29	Mangga (*Mangifera indica*)	*Anacardiaceae*	1
30	Manggis (*Garcinia mangostana*)	*Clusiaceae*	5
31	Medang telor (*Litsea sp.*)	*Lauraceae*	1
32	Nangka (*Artocarpus heterophyllus*)	*Moraceae*	1
33	Pasak bumi (*Eurycoma longifolia*)	*Simaroubaceae*	1
34	Petai (*Parkia speciosa*)	*Fabaceae*	15
35	Pulai (*Alstonia scholaris*)	*Apocynaceae*	12
36	Rarebu (*Macaranga trichocarpa*)	*Euphorbiaceae*	2
37	Rukam (*Flacourtia rukam*)	*Salicaceae*	2
38	Salam (*Syzygium polyanthum*)	*Myrtaceae*	2
39	Simpur (*Dillenia excelsa*)	*Dilleniaceae*	2
40	Sirsak (*Annona muricata*)	*Annonaceae*	1
41	Sungkai (*Peronema canescens*)	*Verbenaceae*	6
42	Tambah irom (*Eusideroxylon zwager*)	*Thymelaeaceae*	1
43	Tangkil (*Gnetum gnemon*)	*Gnetaceae*	3
44	Trembesi (*Samanea saman*)	*Fabaceae*	1
45	Tupa (*Baccaurea macrocarpa*)	*Euphorbiaceae*	5

Source : Primary Data (2025)

Table 4. Types of Plants in Natural Forest Land

No.	Species Type	Family	Number of Individuals
1	Bawang (*Dysoxylum quercifolium*)	*Meliaceae*	7
2	Bayur (*Pterospermum javanicum*)	*Sterculiaceae*	6
3	Cengkeh (*Syzygium aromaticum*)	*Myrtaceae*	1
4	Dadap serep (*Erythrina subumbrans*)	*Fabaceae*	8
5	Durian (*Durio zibethinus*)	*Malvaceae*	9
6	Gaharu (*Aquilaria malaccensis*)	*Thymelaeaceae*	3
7	Gelam (*Melaleuca cajuputi*)	*Myrtaceae*	11
8	Haneban (*Vitex pinnata*)	*Lamiaceae*	5
9	Jambu air (*Syzygium picnanthum*)	*Myrtaceae*	2
10	Jati putih (*Gmelina arborea*)	*Lamiaceae*	2
11	Jengkol (*Archidendron pauciflorum*)	*Fabaceae*	1
12	Kalingi (*Lithocarpus sp.*)	*Fagaceae*	4
13	Kayu langit (*Dysoxylum quercifolium*)	*Meliaceae*	5
14	Kecrutan (*Spathodea campanulata*)	*Bignoniaceae*	1
15	Kelumpang (*Sterculia foetida*)	*Malvaceae*	6
16	Kerbang (*Baccaurea lanceolata*)	*Phyllanthaceae*	3
17	Loteh (*Bischofia javanica*)	*Euphorbiaceae*	15
18	Medang batu (*Dipterocarpus sublamellatus*)	*Dipterocarpaceae*	4
19	Medang telor (*Litsea sp.*)	*Lauraceae*	20
20	Merantang (*Shorea sp.*)	*Dipterocarpaceae*	8
21	Meranti merah (*Shorea johorensis*)	*Dipterocarpaceae*	23
22	Mersawa tenam (*Anisoptera marginata*)	*Dipterocarpaceae*	27
23	Mindi (*Melia azedarach*)	*Meliaceae*	42
24	Molow (*Elaeocarpus serratus*)	*Elaeocarpaceae*	4
25	Pasang (*Quercus sumatrana*)	*Fagaceae*	2
26	Petai (*Parkia speciosa*)	*Fabaceae*	11
27	Pulai (*Alstonia scholaris*)	*Apocynaceae*	4
28	Rumpangan (*Palaquium sp.*)	*Sapotaceae*	1
29	Simpur (*Dillenia excelsa*)	*Dilleniaceae*	18
30	Tapak badak (*Aglaia llanosiana*)	*Meliaceae*	2

Source : Primary Data (2025)

Table 5. Types of Plants in Mixed Garden Land

No.	Species Type	Family	Number of Individuals
1	Alpukat (*Persea americana*)	*Lauraceae*	1
2	Angsor (*Ficus callosa*)	*Moraceae*	4
3	Bayur (*Pterospermum javanicum*)	*Sterculiaceae*	6
4	Cempaka (*Magnolia champaca*)	*Magnoliaceae*	10
5	Cengkeh (*Syzygium aromaticum*)	*Myrtaceae*	18
6	Duku (*Lansium domesticum*)	*Meliaceae*	8
7	Durian (*Durio zibethinus*)	*Malvaceae*	3
8	Halingau (*Alpinia galanga*)	*Zingiberaceae*	1
9	Haneban (*Vitex pinnata*)	*Lamiaceae*	6
10	Harebing (*Mitrephora polypirena*)	*Annonaceae*	1
11	Heling (*Cinnamomum sp.*)	*Lauraceae*	1
12	Jabon (*Neolamarckia cadamba*)	*Rubiaceae*	17
13	Jambu biji (*Psidium guajava*)	*Myrtaceae*	1
14	Jambu bol (*Syzygium malaccense*)	*Myrtaceae*	4
15	Jati putih (*Gmelina arborea*)	*Lamiaceae*	2
16	Jengkol (*Archidendron pauciflorum*)	*Fabaceae*	24

17	Jeruk (*Citrus sinensis*)	*Rutaceae*	2
18	Kanihai (*Bridelia tomentosa*)	*Euphorbiaceae*	6
19	Kayu afrika (*Maesopsis eminii*)	*Rhamnaceae*	1
20	Kayu lada (*Litsea cubeba*)	*Lauraceae*	1
21	Kayu putih (*Melaleuca leucadendra*)	*Myrtaceae*	1
22	Kayu sepat (*Macaranga triloba*)	*Euphorbiaceae*	2
23	Kelor (*Moringa oleifera*)	*Moringaceae*	2
24	Kungki (*Baccaurea lanceolata*)	*Phyllanthaceae*	6
25	Kuwau (*Ficus septica*)	*Moraceae*	1
26	Lahu (*Beilschmiedia madang*)	*Lauraceae*	1
27	Larebu (*Cotylelobium melanoxylon*)	*Fabaceae*	5
28	Mahoni (*Swietenia mahagoni*)	*Meliaceae*	3
29	Mangga (*Mangifera indica*)	*Anacardiaceae*	3
30	Manggis (*Garcinia mangostana*)	*Clusiaceae*	3
31	Mungkol (*Vatica pauciflora*)	*Dipterocarpaceae*	6
32	Nangka (*Artocarpus heterophyllus*)	*Moraceae*	10
33	Pancung (*Macropanax dispermus*)	*Araliaceae*	2
34	Petai (*Parkia speciosa*)	*Fabaceae*	10
35	Pulai (*Alstonia scholaris*)	*Apocynaceae*	6
36	Salam (*Syzygium polyanthum*)	*Myrtaceae*	1
37	Sawo (*Manilkara zapota*)	*Sapotaceae*	1
38	Sengon (*Albizia chinensis*)	*Fabaceae*	1
39	Simpur (*Dillenia excelsa*)	*Dilleniaceae*	5
40	Sirsak (*Annona muricata*)	*Annonaceae*	3
41	Sukun (Artocarpus altilis)	*Moraceae*	1
42	Tangkil (Gnetum gnemon)	*Gnetaceae*	1
43	Trembesi (Samanea saman)	*Fabaceae*	11
44	Tuba kepayang (Pangium edule)	*Achariaceae*	1
45	Tupa (Baccaurea macrocarpa)	*Phyllanthaceae*	1
46	Waru laut (*Thespesia populnea*)	*Malvaceae*	6

Source : Primary Data (2025)

Based on the table, the species density found in each type of land shows that there are 306 individuals in the repong damar, consisting of 45 species and 23 families. The dominant species in the repong damar is cat's eye resin (*Shorea javanica*) with a total of 107 individuals, followed by duku (*Lansium domesticum*) with 35 individuals, and durian (*Durio zibethinus*) with 26 individuals. In the natural forest, 255 individuals with 30 species and 17 families were found. The dominant species in the natural forest is the mindi (*Melia azedarach*) with a total of 42 individuals, followed by the tenam mersawa (*Anisoptera marginata*) with 27 individuals, and the red meranti (*Shorea johorensis*) with 23 individuals. In the mixed garden there are 210 individuals with 46 species and 26 families. The dominant species in mixed gardens are jengkol (*Archidendron pauciflorum*) with a total of 24 individuals, followed by cloves (*Syzygium aromaticum*) with 18 individuals, and jabon (*Neolamarckia cadamba*) with 17 individuals. The *Fabaceae* family is the dominant family of the three land covers with 9 species and 92 individuals. The number of individuals in repong damar is related to public belief in planting resin trees, so that until now there are still many farmers who plant resin trees on the grounds that resin is a heritage and a plant with real results (Wibowo *et al*., 2024).

Each type of land cover observed in this study shows striking differences in vegetation characteristics, both in terms of stand structure, growth phase, and ecological conditions. Repong damar has a high vegetation density with the dominance of large trees that are mostly in the adult phase, especially damar (*Shorea javanica*) as the main type that reflects a stable ecosystem and minimal anthropogenic disturbances. In addition to its ecological function, repong damar also has high socio-cultural value because it is managed from generation to generation based on local wisdom, which helps maintain the sustainability of its vegetation.

Natural forest shows a dense stand structure with fairly active regeneration through the presence of vegetation in the pole and stake phase, but it is under pressure due to human activities such as encroachment, as well as landslides at several points, so it requires rehabilitation to maintain its ecological function. Meanwhile, mixed gardens have sparse to moderate stand structures, dominated by young vegetation with few large trees and unstructured planting patterns, so their carbon storage capacity is the lowest; However, it still has potential as an agroforestry system if managed optimally.

Above-Ground Carbon Stocks

Measuring the amount of carbon stored in biomass in a field can describe how much plants absorb CO_2 from the atmosphere, while in dead plant parts (necromase) it describes CO_2 that is not released into the air through combustion. The potential for carbon storage and carbon dioxide absorption at the research site is presented in Table 6.

Table 6. Calculation of Biomass and Above-Surface Carbon Stocks

Land Cover	Aboveground Biomass (kg)	Carbon Stocks (tC)	Sample Area (ha)
Repong Damar	290.184,40	136,39	0,56
Natural Forest	157.536,56	74,04	0,56
Mixed Gardens	67.325,51	31,64	0,56

Source: Primary Data (2025)

The results of the calculation of biomass and carbon stock on the repong damar surface have the highest biomass value of 290,184.40 kg with a carbon stock of 136.39 tC. This is because the repong damar is dominated by cat's eye resin (*Shorea javanica*) which has a large diameter. A diameter with a high value will affect the tree biomass because the tree biomass is measured using allometric equations based on the diameter of the trunk. Furthermore, the Natural Forest recorded a biomass of 157,536.56 kg and a carbon stock of 74.04 tC in the same sample area. Natural forest have a high carbon storage capacity because natural forest have a high diversity of trees, undergrowth and dead plant residues (litter) on the forest soil surface. Carbon deposits at each study site have different amounts, this is due to differences in type density. (Istomo & Farida, 2017) states that stand biomass and carbon potential are increasing with the increase in stand density. (Mutuo *et al*., 2005) stated that this difference may be due to differences in structure, constituent components, tree population density and tree age differences. The type of vegetation also affects carbon storage in a land use system.

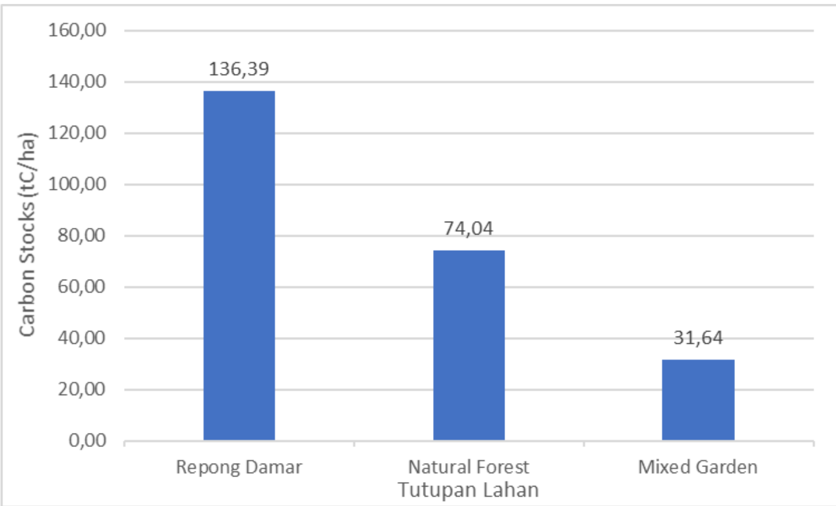

Figure 5. Comparison of Carbon Stocks Between Land Cover

In Figure 5, there is a graph that illustrates the comparison of aboveground carbon stocks between the three types of land cover. It is clear that repong damar has the highest carbon stock compared to natural forest and mixed gardens. This shows that management practices based on local wisdom such as repong damar not only support biodiversity conservation, but also make a major contribution to carbon storage. In addition, the size of the diameter and the condition of the tree footprint have a significant influence on the accumulation of carbon stocks (Insusanty *et al*., 2018). Natural forest are in the middle position in this graph with relatively high carbon stock values. This condition reflects the existence of trees with medium to large diameters and vegetation structures that are still quite complex and diverse. Although the accumulation of biomass in natural forest is not as large as in repong damar, this area still has an important role in storing carbon. This indicates that forests still retain their natural properties, despite being disturbed. In contrast, mixed gardens tend to be intensively managed with short-lived crop types, storing much lower amounts of carbon (Danial *et al*., 2019). The characteristics of mixed gardens that are generally not dominated by large trees cause relatively lower carbon storage potential compared to land cover that has a tighter stand structure (Rozalina, 2020).

Carbon Stocks on Repong Damar Land

Repong damar is a traditional agroforestry system that developed in Lampung Province, by integrating the cultivation of resin trees (*Shorea javanica*) with forestry and agricultural elements in an integrated manner (Hariyanto *et al*., 2022). In addition to providing economic benefits, this system also contributes to climate change mitigation through the ability to store carbon. The results of measurements on 14 observation plots are presented in Table 7.

Table 7. Carbon Stock Calculation of Repong Damar

Plot ID	Carbon Stocks (tC/ha)			Total
	Tree	Pole	Stake	
1	213,36	16,69	7,87	237,92
2	160,89	26,28	6,11	193,27
3	177,86	23,92	7,00	208,78
4	251,27	27,52	16,45	295,24
5	173,02	31,29	14,05	218,36
6	156,85	4,61	1,75	163,22
7	262,61	22,31	11,29	296,20
8	131,53	19,98	18,02	169,52
9	202,04	17,02	5,27	224,33
10	283,20	7,81	13,42	304,44
11	315,71	36,11	2,56	354,39
12	370,63	24,45	8,13	403,21
13	362,83	23,62	3,37	389,83
14	259,29	38,91	19,42	317,63
Average	237,22	22,89	9,62	269,74
StanDev	76,51	9,54	5,85	78,89

Source : Primary Data (2025)

Based on Table 7, the average carbon stock stored in all repong damar plots reached 269.74 tC/ha which came from three growth phases, namely trees, poles, and sapling. The largest contribution came from the tree phase with an average carbon stock of 237.22 tC/ha, followed by the pole phase of 22.89 tC/ha, and the sapling phase of 9.62 tC/ha. The plot with the highest total carbon stock is located in 12 plots with a value of 403.21 tC/ha. The number of plants in plot 12 is 23 individuals consisting of 10 types of plants, namely ampelas, bayur, damar, duku, durian, haneban, heling, jengkol, mangga, and pulai. The plot with the lowest total carbon stock is found in plot 6 with a value of 163.22 tC/ha. The number of plants in plot 6 is 16 individuals consisting of 7 types of plants, namely bayur, resin, durian, heling, kuwau, salam, and tupa. The differences between these plots reflect the variation in stand structure, density, and age differences in each observation plot.

The existence of old trees with high biomass also strengthens carbon storage capabilities. On the contrary, the low value of carbon stocks is due to the dominance of small vegetation and low tree density levels. This shows that variations in structure and stand life between plots affect carbon storage capacity. This is in line with research (Casson, 2005), which states that resin trees as the main species in the repong damar are able to live up to 150 years and contribute quite high to the potential for carbon storage in the region. (Manuri *et al*., 2011) also stated that the difference in the conditions of the research location also affects the results where the older the age of the erection, the larger the tree biomass.

Carbon Stocks in Natural Forest Lands

Tropical natural forest such as the TNBBS area have a high diversity of vegetation and layered structures, making them one of the most effective natural carbon sinks (Suryandari *et al*., 2019). Forests not only serve as biodiversity habitats, but also have an important function in regulating the carbon cycle. Through the process of photosynthesis, forest vegetation absorbs carbon dioxide (CO_2) from the atmosphere and converts it into biomass. The carbon stored in biomass contributes to the accumulation of carbon stocks, so forests play an effective role as carbon absorbers and stores in climate change mitigation. (Chanan, 2012). The results of measurements on 14 observation plots are presented in Table 8.

Table 8. Natural Forest Carbon Stock Calculation

Plot ID	Carbon Stocks (tC/ha)			Total
	Tree	Pole	Stake	
1	81,14	21,29	29,51	131,95
2	171,79	35,60	6,81	214,20
3	110,87	27,25	4,14	142,26
4	142,58	25,68	3,73	171,98
5	110,71	33,03	5,80	149,54
6	87,13	24,87	6,00	118,00
7	47,37	24,25	9,34	80,96
8	186,52	39,62	13,85	239,99
9	64,43	27,47	30,77	122,66
10	259,76	34,33	4,84	298,93
11	64,44	77,64	25,82	167,90
12	124,07	8,62	4,81	137,51
13	119,74	24,41	12,03	156,18
14	160,77	32,32	13,03	206,12
Average	123,66	31,17	12,18	167,01
StanDev	57,41	15,35	9,59	56,44

Source : Primary Data (2025)

Based on Table 8, the average carbon stock stored on all natural forest plots reached 167.01 tC/ha which came from three growth phases, namely trees, poles, and stakes. The largest contribution came from the tree phase with an average carbon stock of 123.66 tC/ha, followed by the pole phase of 31.17 tC/ha, and the sapling phase of 12.18 tC/ha. The plot with the highest total carbon stock is located in 10 plots with a value of 298.93 tC/ha. The number of plants in plot 10 is 16 individuals consisting of 6 types of plants, namely bayur, kalingi, loteh, medang telor, red meranti, and mersawa tenam. The plot with the lowest total carbon stock is found in plot 7 with a value of 80.96 tC/ha. The number of plants in plot 7 is 16 individuals consisting of 9 types of plants, namely dadap serep, durian, gelam, loteh, meranti merah, mersawa tenam, mindi, petai, and simpur. The differences between the plots reflect the variation in diameter size in each observation plot, where the plots with the highest carbon stocks and the plots with the lowest stocks have the same number of individuals, but the total carbon stocks in the two plots are very different.

The high value of carbon stocks is influenced by the presence of large trees and high vegetation density. This statement is in line with the opinion (Hambali *et al*., 2023) which states that the higher the level of vegetation density, the greater the potential for energy accumulation on a land. In addition, the size of the diameter and height of the tree also affect the amount of biomass and the amount of carbon that can be stored. When compared to repong damar, natural forest have lower carbon storage capacity and average values. These findings are in line with the results of a study (Noor'An *et al*., 2015) in Bromo Tengger Semeru National Park (TNBTS), which recorded an average carbon store of 193.49 tC/ha in primary forests, and 267.42 tC/ha in secondary forests.

Carbon Stocks in Mixed Plantation Land

Mixed gardens are a form of agroforestry system that resembles the structure of tropical forests (Foroughbakhch *et al*., 2011). Ecologically, mixed garden systems are able to support the increase in biodiversity by providing a habitat for a wide variety of species of flora and fauna. This encourages the formation of a more stable ecosystem and is better able to cope with environmental pressures (Norgrove & Beck, 2016). In addition, according to (Steinfeld *et al*., 2023), mixed gardens also contribute to improving soil fertility through interaction between different types of plants so that this system has the potential to store carbon. The results of measurements on 14 observation plots are presented in Table 9.

Table 9. Calculation of Mixed Garden Carbon Stock

Plot ID	Carbon Stocks (tC/ha)			Total
	Tree	Pole	Stake	
1	27,07	31,26	21,98	80,31
2	40,81	34,08	26,98	101,86
3	67,09	24,77	8,35	100,21
4	28,27	40,86	33,42	102,54
5	51,96	21,80	13,99	87,76
6	30,02	34,24	19,00	83,25
7	35,40	14,27	29,45	79,12
8	49,73	7,65	30,28	87,66
9	31,35	25,38	20,04	76,77
10	35,48	54,32	23,29	113,10
11	87,37	23,35	4,19	114,91
12	53,14	26,08	19,19	98,41
13	87,39	13,07	21,77	122,22
14	53,14	26,08	25,16	104,38
Average	48,44	26,94	21,22	96,61
StanDev	20,25	11,89	8,18	14,42

Source : Primary Data (2025)

Based on Table 9, the average total carbon stock stored in all mixed garden plots reached 96.61 tC/ha which came from three growth phases, namely trees, poles, and sapling. The largest contribution came from the tree phase with an average carbon stock of 48.44 tC/ha, followed by the pole phase of 26.94 tC/ha, and the sapling phase of 21.22 tC/ha. The plot with the highest total carbon stock is located in 13 plots with a value of 122.22 tC/ha. The number of plants in plot 13 is 14 individuals consisting of 6 types of plants, namely bayur, duku, guava bol, mangosteen, jackfruit, and tuba kepayang. The plot with the lowest total carbon stock is found in plot 9 with a value of 76.77 tC/ha. The number of plants in plot 7 is 15 individuals consisting of 11 types of plants, namely avocados, cempaka, cloves, guava, kanihai, larebu, mango, petai, simpur, soursop, and waru laut. The total difference in carbon stocks between plots reflects variations in vegetation characteristics, where the plots with the lowest carbon stocks have a fairly large number of individuals and plant types. However, the dominance of small plants and plant types that produce low biomass cause the total carbon stock on the plot to remain lower than other plots.

The low total carbon stock in these mixed gardens is suspected to be due to the dominance of small plants and low vegetation density. The differences between plots show that variations in stand structure, plant type, tree age, and land management intensity have an influence on the amount of carbon that can be stored. According to (Suryanto *et al*., 2020), mixed plantations are included in the category of early-stage agroforestry, where planting and maintenance patterns are still managed intensively. Therefore, the management actions carried out by landowners greatly determine the vegetation composition and carbon storage capacity in this system.

Statistical Analysis of the Uncertainty Value of Carbon Reserves

Statistical analysis is needed to assess the level of uncertainty of carbon stock data obtained from each type of land cover. In this context, uncertainty can be seen from the values of standard deviation (SD), confidence interval (CI), and sampling error (SE) which describe the variation in data and the reliability level of carbon stock estimation. Table 10 presents the results of statistical analysis of three types of land cover, namely repong damar, natural forest, and mixed gardens.

Table 10. Statistical Analysis of Carbon Stocks Values

Forest Cover Type	Statistical Analysis							
	Mj	SD	N	t	CI	LB	UB	SE (%)
RD	269,74	78,89	14	2,145	45,23	224,51	314,97	16,77
HA	167,01	56,44	14	2,145	32,36	134,65	199,37	19,37
KC	96,61	14,42	14	2,145	8,27	88,34	104,88	8,56

Source : Primary Data (2025)

Description: Repong Damar (RD), Natural Forest (HA), Mixed Gardens (KC), Mean (Mj), Standard Deviation (SD), Sample Count (n), t-statistic at 95% (t), Confidence Interval (CI), Lower Bound (LB), Upper Bound (UB), dan Sampling Error (SE).

Based on the results of statistical analysis in Table 10, each land cover has a sample number of 14 plots with a t-stat of 2,145. Repong damar has an average carbon stocks value of 269.74 tC/ha, with a standard deviation of 78.89 tC/ha, which illustrates considerable variation between plots. The 95% confidence interval range for repong damar ranges from 224.51 to 314.97 tC/ha, which indicates the width of the range due to uneven vegetation and biomass distribution. Natural forest have an average carbon stocks value of 167.01 tC/ha with a standard deviation of 56.44 tC/ha, as well as a confidence interval between 134.65–199.37 tC/ha, which reflects a more stable data distribution compared to repong damar. Meanwhile, mixed plantations have the lowest average carbon stocks of 96.61 tC/ha, with the smallest standard deviation of 14.42 tC/ha and a narrower confidence interval of between 88.34–104.88 tC/ha, suggesting that the distribution of data between plots in mixed plantations is relatively more uniform.

Sampling error is an error caused by the sampling technique used and in the context of carbon stock estimation, this value provides an overview of the accuracy of the estimated results obtained (Asrulla *et al*., 2023). Natural forest and repong damar has relatively high sampling errors, at 19.37% and 16.77%, respectively. Both of these land covers show considerable uncertainty in carbon stock estimates, which can be caused by high variations between plots and uneven biomass distribution. Meanwhile, mixed gardens had the lowest sampling error, at 8.56%, which shows a more accurate and consistent distribution of data. The lower the sampling error value, the higher the level of confidence in the accuracy of the carbon stock estimate obtained from the analyzed sample.

CONCLUSION AND RECOMMENDATION

There are significant differences in carbon stocks between the three types of land cover studied. Repong Damar recorded the highest average value of carbon stocks at 269.74 tC/ha, followed by natural forest at 167.01 tC/ha, and mixed gardens at 96.61 tC/ha. This difference is due to variations in vegetation structure, the age of the stand, and the dominant tree type. Repong damar, as a traditional agroforestry system managed sustainably by the community, shows great capacity to store carbon, making it important in climate change mitigation strategies. These results show the importance of preserving and strengthening local wisdom-based management such as repong damar, as well as the need for policy support such as REDD+ to increase the contribution of different types of land cover to reducing carbon emissions.

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