Ecobios Journal of Environmental Science
Volume 2 Issue 1 (June 2025): 32-39
ISSN (Online): 3064-1470 | DOI: 10.71024/ecobios.2025.v2i1.161

Estimation of Carbon Stocks in Agroforestry Systems under the East Rinjani Forest Management Unit Partnership Scheme

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Received: 12 December 2024, Revised: 19 May 2025, Accepted: 1 June 2025

Abstract. Forests play a critical role in absorbing atmospheric carbon dioxide (CO_2) and serve as major carbon sinks. This study aims to analyze vegetation species biodiversity, estimate carbon stocks, and determine the relationship between carbon stocks, plant density, and biodiversity. A quantitative and descriptive research approach was employed, utilizing observation and survey techniques. Respondents were selected using Slovin's formula with a 15% margin of error, resulting in a total sample of 30 farmers. The number of sample plots was determined using a census approach, based on the number of respondents. The average carbon stock in the Mekarsari Village area, under the East Rinjani Forest Management Unit (KPH) Partnership Scheme, was found to be 39.29 tonnes/ha, measured across three vegetation strata: trees, poles, and saplings. Specifically, carbon stocks were 30.93 tonnes/ha at the tree level, 6.08 tonnes/ha at the pole level, and 2.28 tonnes/ha at the sapling level. Regression analysis showed that plant density accounted for only 0.57% of the variation in carbon stocks, whereas the biodiversity index explained 54.57% of the variation. A total of 23 plant species were identified in the agroforestry plots. These results indicate that carbon stock levels in land use systems are significantly influenced by biodiversity and, to a lesser extent, by plant density. Higher biodiversity and plant density contribute to increased carbon sequestration, thereby enhancing overall carbon stocks.

Keywords: Carbon stocks, agroforestry, biodiversity, forestry partnerships

INTRODUCTION

Climate change is driven by a range of human development activities, including deforestation, agriculture, livestock farming, mining, and industrial processes, all of which contribute to the emission of greenhouse gases (GHGs) (Arif, 2024; Filonchyk et al., 2024). Greenhouse gases are atmospheric compounds that trap heat by absorbing and re-emitting infrared radiation, thereby increasing the Earth's surface temperature. The primary GHGs include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), sulfur hexafluoride (SF_6), perfluorocarbons (PFCs), and other anthropogenic gases (Kusumaningtyas & Chofyan, 2011) (Kusumaningtyas & Chofyan, 2011; Nema et al., 2012; Tang et al., 2021).

Forests are an important component in the absorption of carbon dioxide (CO_2) in the atmosphere (Hurteau, 2021; Rahman et al., 2023; Raihan & Tuspekova, 2022; Rizki et al., 2024). With the composition in it, be it trees, stakes, pillars, seedlings and undergrowth and even dead parts play a role in absorbing carbon (Moomaw et al., 2020; Pan et al., 2024). The absorbed carbon will be stored into biomass (Hilyana & Rahman, 2022; Jannah et al., 2021). Thus, it can be interpreted that the greater the quality of the forest, the more carbon will be absorbed, and conversely, the more afforestation and forest burning, the more carbon in the atmosphere will also increase and in conditions the carbon can turn into organic molecules (CO_2, CH_4, N_2O) in the atmosphere in the form of greenhouse gases (GHGs) which will eventually cause global warming (Farmen et al., 2014; Markum & Lestari, 2022; Rahman & Hadi, 2021).

The forestry partnership in Mekarsari Village is located in the Mount Rinjani area which is directly adjacent to the protected forest area and is located in the Pohgading Sunggang

Watershed sub-watershed. The village borders a protected forest covering an area of 601 ha. Of this amount, 350 ha have been cultivated by residents. The Mekarsari Forestry Partnership has a profit-sharing cooperation system where all NTFP (Non-Timber Forest Products) proceeds are shared. The revenue sharing between the community and the permit holder or FMU has a ratio of 75% for the public and 25% for the permit holder or FMU. The Mekarsari Forestry Partnership is planted with agroforestry plants such as *Durio zibethinus*, avocado (*Persea americana*), *Manilkara zapota*, and others.

The purpose of this study is to analyze the biodiversity of vegetation species, estimate stored carbon reserves and determine the relationship between carbon stocks and plant density and biodiversity.

RESEARCH METHODS

This research was conducted in August 2022 in the Forest Management Unit (KPH) of East Rinjani, specifically in Mekarsari Village, Suele District, East Lombok Regency. The study employed both quantitative and descriptive methods, using observation and survey techniques. The descriptive method was used to describe existing phenomena—both natural and anthropogenic (Linarwati et al., 2016). The quantitative method involved the collection and analysis of numerical data using statistical tools (Wahidmurni, 2017).

The instruments used in this study included Avenza Maps, writing tools, hagameters, compasses, roll meters, measuring tapes, and ropes. The materials used for data collection were questionnaires and tally sheets.

The research location was selected within the Forestry Partnership area of Mekarsari Village, under the East Rinjani KPH. The partnership area covers approximately 380 hectares and includes eight Forest Farmer Groups (*Kelompok Tani Hutan* or KTH). The specific study site was determined using purposive sampling, with research conducted in the Tempos Sodot KTH—selected based on its status as the largest among the eight KTHs in the area. The determination of the sample farmer was determined using the Slovin formula with an error rate of 15% so that the sample number was obtained as follows:

$$n = \frac{N}{N \times E^2 + 1}$$

Information:
n = Number of samples
N = Total population
E = Error rate (15%)

In the study, the determination of respondents to be interviewed was carried out by simple random sampling by way of lots. The number of plots was determined using the census method from the number of respondents obtained totaling 30 respondents. Biomass measurement uses a rectangular sample plot measuring 20x20 meters with an area of 400 meters. Furthermore, the plot is divided into sub-sub-plots, namely: trees, poles and stakes.

RESULTS AND DISCUSSION

General Gambaan Research Location

Mekarsari Village is located in the Mount Rinjani area which is directly adjacent to the protected forest area and is located in the Pohgading Sunggang Watershed Sub-Watershed. The village is bordered to the north by a protected forest covering an area of 601.00 ha. Of this amount, 380 ha have been cultivated by the community.

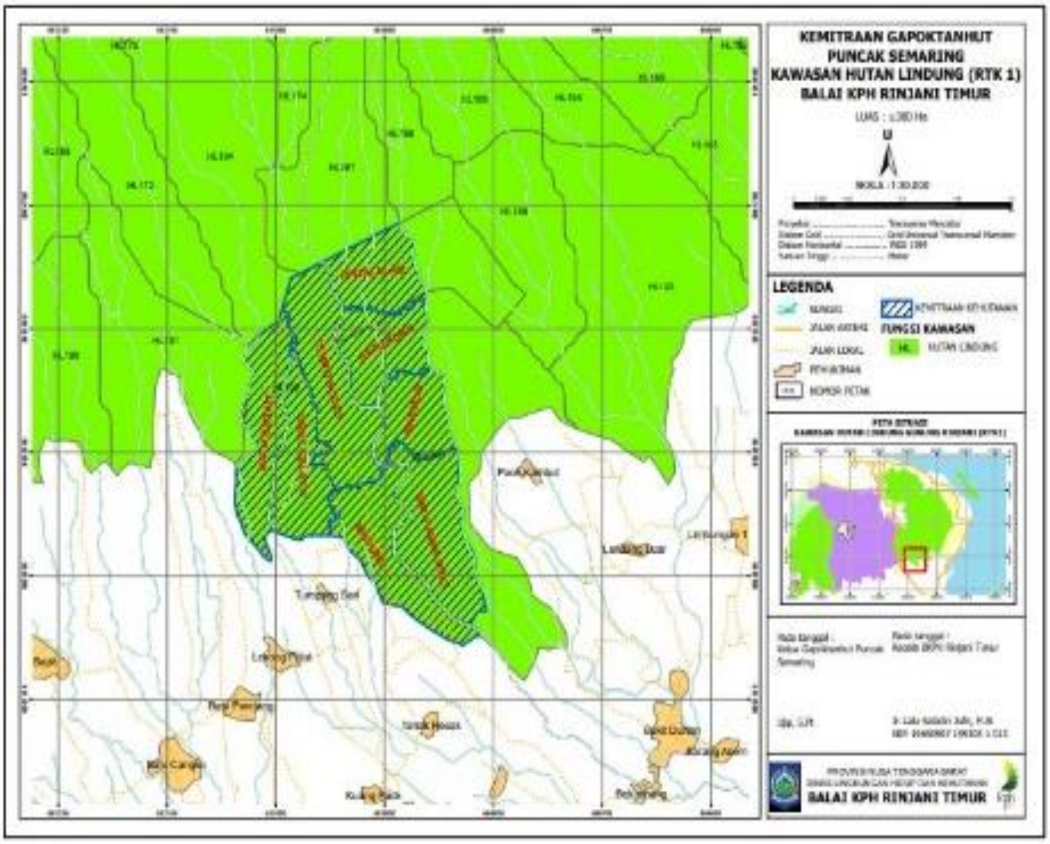

Figure 1. Mekarsari village partnership map

Overview of Mekarsari Forestry Partnership

One of the government's policies to increase community participation in forest management is through forestry partnerships. The combined group of Semaring peak forest farmers is one of the groups in partnership with the East Rinjani BKPH which is located in Mekarsari Village, Suele District, East Lombok Regency, in the Mount Rinjani area and directly adjacent to the protected forest.

Overview of Respondent Characteristics

A farmer is someone who manages land with the aim of growing and maintaining plants to obtain the results of the plant. Mekarsari Village has an average community whose main job is as forest farmers/cultivators, where they collaborate with East Rinjani FMU with the status of forestry partnership. The number of farmers recorded in Mekarsari Village is 591 members and the average age of farmers is 30-70 years.

Vegetation Diversity

a. Tree level

The results of vegetation gratification at the tree level are known, that the tree-level plants at the research site consist of 12 species with the number of species in the entire plot of 220 trees and the number of individuals as many as 183 individuals per Ha. The plant that has the highest number of individuals for the tree level is the sonokeling type (*Dalbergia latiolia*) with a number of individuals as much as 54 per hectare.

b. Pole Level

The results of observation of vegetation at the pole level are known, that the pole level plants in the research site consist of 16 species with the number of species in the entire plot of

97 trees and the number of individuals as many as 162 individuals per Ha. The plant that has the highest number of individuals for the pole level is the avocado (*Persea americana*) with a number of individuals as much as 52 individuals per hectare.

c. Pile Level

The results of vegetation observation at the pile level are known, that there are 15 types of vegetation at the research site with a total of 69 species and a total of 920 individuals per hectare. The plant that has the highest number of individuals for the stake level is the coffee type (Coffea) with a number of individuals as much as 280 per hectare.

INP (Vital Value Index)

The Important Value Index or Impontant Value Index is an index that describes the importance of the role of a type of vegetation in its ecosystem (Parmadi, 2016). From the results of the research that has been carried out, it can be seen that the type of vegetation that has the highest INP value is sonokeling at the tree level of 74.863%. Meanwhile, at the pole level there is the highest INP is avocado at 104.4%. And at the highest level of indigo inp is avocado at 86.56%. This shows that at the tree level with the highest INP value, it does not always have the highest INP value at the pole level or pile level. As well as the value of the summing component to determine the INP value of each vegetation, not all components have the same level value.

Carbon Reserves

Stored carbon is the content of stored carbon, whether it is on the soil surface as plant biomass, dead plant residues or biomass in the soil. Biomass is an organic material obtained from the results of photosynthesis, in the form of land cover in the Forestry Partnership of Mekarsari Village, KPH Rinjani Timur which obtained the amount of carbon reserves at each level of trees, poles and piles shown in Table 1.

a. Tree level

The average carbon stock at the tree level was estimated at 30.93 tonnes per hectare. Among the sample plots, the highest carbon stock was recorded in Plot 7, with a total of 96.69 tonnes per hectare, while the lowest was observed in Plot 10, amounting to 7.22 tonnes per hectare**.**

b. Pole level

The average carbon stock at the pole level was estimated at 6.08 tonnes per hectare. Among the sample plots, the highest carbon stock was recorded in Plot 7, reaching 16.01 tonnes per hectare, while the lowest was observed in Plot 19, with a value of 0 tonnes per hectare. The zero value in Plot 19 is attributed to the absence of vegetation that met the size criteria for classification at the pole level within the plot.

c. Pile level

For the average pile level, the carbon stock obtained is 2,280 tons/ha. The highest amount of carbon reserves based on plots is 12,004 tons/ha. And the lowest amount of carbon reserves was obtained in plot 8, plot 13 and plot 30 with the same amount of 0 tons/ha. The value of 0 in the three plots is because the three plots do not have plants that have the size for the level of piles found in the location of the three plots.

The average value of carbon reserves in Mekarsari Village, KPH Rinjani Timur is 39,287 Tons/Ha from all components such as at the level of trees, poles and stakes as shown in table 4.6.1. Each level has a different average score. At the tree level, it has a higher stored carbon value than the value at the pole and stake level. At the tree level, it has an average value of 30,928 tons/ha. At the pole level, it has an average value of 6,080 tons/ha. Meanwhile, at the pile level, it has the lowest average value of 2,280 tons/ha. From the average value above, the average carbon reserves in Mekarsari village are still relatively low. According to the Intergovernmental Panel on Climate (IPCC, 2006), forests that are good at storing carbon stocks are those that store an average of >135 tons/ha.

Table 1. Carbon reserves

Number of Plot	Surface stored carbon (tons/ha)			Totals C (tonnes/ha)
	Tree	Post	Stake	
1	24.74	6.65	1.62	33.01
2	20.96	3.91	7.65	32.53
3	16.97	7.36	1.03	25.36
4	19.52	11.41	2.31	33.24
5	12.67	5.09	1.44	19.21
6	25.75	7.35	2.97	36.08
7	96.68	10.59	2.05	109.33
8	25.46	8.84	0	34.30
9	95.96	5.35	0.21	101.52
10	7.22	2.38	2.18	11.78
11	70.73	7.83	0.28	78.83
12	30.64	3.56	1.74	35.94
13	14.14	2.67	0	16.80
14	11.15	13.01	2.29	26.45
15	12.97	10.54	4.35	27.86
16	40.42	5.52	3.85	49.79
17	32.59	1.09	0.26	33.93
18	40.57	16.01	1.79	58.37
19	12.85	0	12.00	24.85
20	25.00	1.94	2.08	29.03
21	9.02	5.94	1.57	16.53
22	26.82	7.15	0.77	34.74
23	31.78	3.07	0.43	35.29
24	17.44	3.76	2.72	23.92
25	62.88	4.07	5.27	72.22
26	36.19	10.43	2.27	48.89
27	36.53	1.05	0.97	38.54
28	22.02	1.26	2.42	25.69
29	14.68	10.48	1.89	27.05
30	33.45	4.11	0	37.56
Totals	30.93	6.08	2.28	39.29

Source: Processed Data Results 2022

Carbon Reserve Relationship

a. carbon reserves against crop density

The causative factor of carbon stocks in Mekarsari Village is classified as poor, due to low plant density and lack of maximization by farmers to prioritize planting forestry crops. The average plant density in Mekarsari Village has a density of 1445 plants/ha. Based on references from the Decree. The Minister of State for the Environment, No. 201 of 2004, said that the density is high ≥1500 trees/ha, medium ≥1000-<1500 trees/ha, and low < 1000 trees/ha. So, the density of plants in Mekarsari Village according to the Decree. The Minister of State for the Environment is moderate.

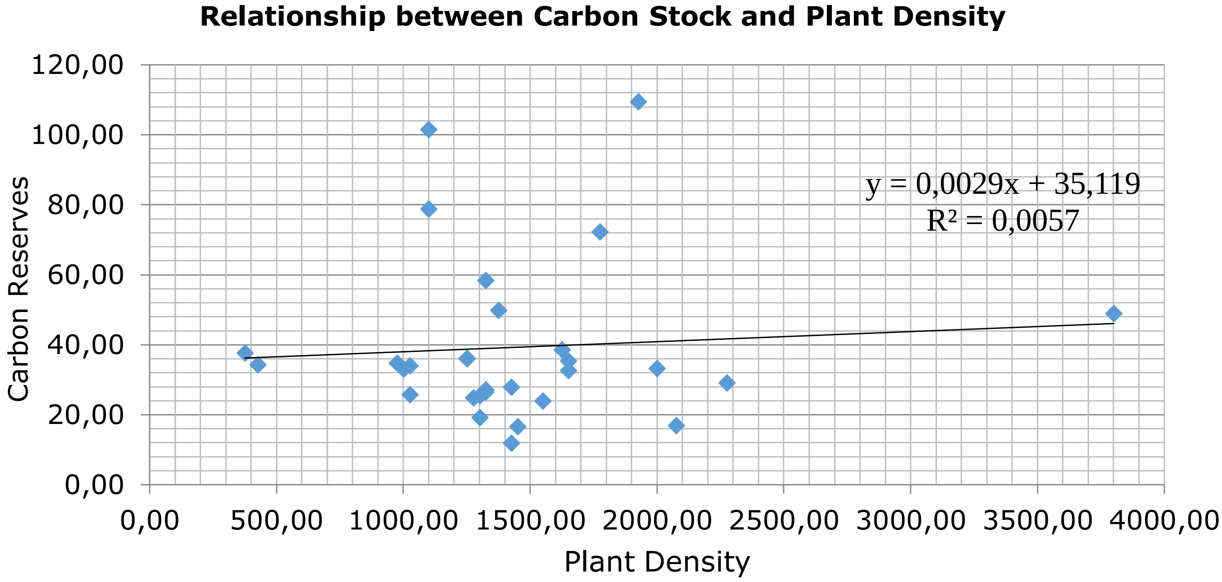

Figure 2. Regression of carbon reserves by plant density

The regression between carbon stocks and plant density in forestry partnerships in Mekarsari Village, KPH East Rinjani yielded a regression equation: Y = 0.0029x + 35.119 with a determination coefficient of R = 0.0057. This equation is able to explain 0.57% of the relationship between carbon stocks and plant density as seen in Figure 2 above.

b. Carbon Reserves for Biodiversity

The decline in biodiversity has an impact on the resilience of ecosystems due to climate change. High biodiversity is an insurance to be able to recover from various kinds of disturbances so that it can still store carbon in the long term (Arianty, 2018). According to the CBD in 2006, forests with high biodiversity are more productive and provide greater carbon reserves, especially in old established forests.

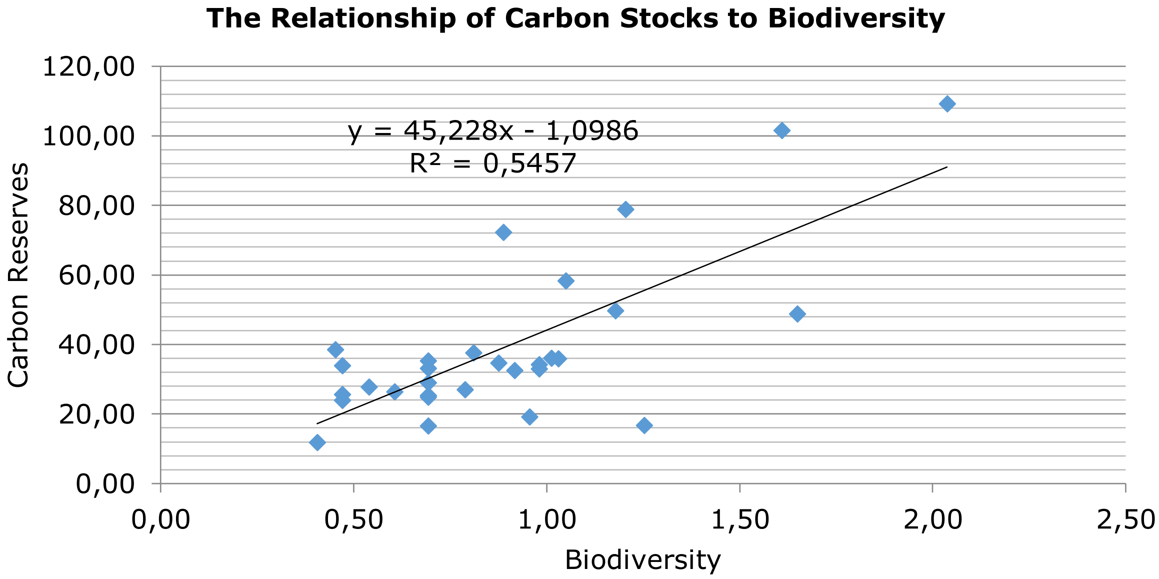

Figure 3. Regression of carbon reserves with biodiversity

The regression between carbon stocks and biodiversity index in forestry partnerships in Mekarsari Village, KPH Rinjani Timur yielded a regression equation: Y = 45.228x − 1.0986 with a determination coefficient of R = 0.5457. This equation is able to explain 54.57% of the relationship between carbon stocks and biodiversity indexes (Figure 3).

CONCLUSION

The research on carbon stock estimation in the agroforestry system of the Mekarsari Village Forestry Partnership in KPH East Rijani reveals several key findings. The area is home to 23 plant species namely Avocado (*Persea americana*), Banten (Lannea coromandelika), Durian (*Durio zibethinus*), Gamal (*Gliricidia sepium*), Jamblang (*Syzygium cumini*), Guava (*Anacardium occidentale*), Teak (Tectona grandis), Orange (Citrus), Cocoa (*Theobroma cacao*), Longan (*Dimocarpus longan*), Moringa (*Moringa oliefera*), Walnut (*Aleurites moluccanus*), Cherry (*Muntinga calabura*), Coffee (Coffea), Mahogany (Swietenia mahagoni), Mango (*Mangifera indica*), Jackfruit (*Artocarpus heterophyllus*), Palm (Arecaceae), Bananas (Musa), Milk Sabo (Manilkara zapota), Salam (Syzygium *polyanthum*), Sawo (Manikara zapota), and Sonokeling (*Dalbergia latiolia*). The total above-ground carbon reserves are estimated at 39.29 tons/ha, with the majority found in tree-level plants (30.928 tons/ha), followed by poles (6.080 tons/ha) and piles (2.280 tons/ha). The composition of plant species in each land use is influenced by management practices, with plant density and biodiversity playing a critical role. Higher density and biodiversity lead to greater carbon sequestration, thus increasing carbon reserve values.

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