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Biomass and Carbon Storage Estimation of Melaleuca Forests in Thanh Hoa District, Long An Province

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ABSTRACT

Forests play an important role in living on Earth by absorbing and storing carbon dioxide (CO_2), emitting oxygen for the atmosphere, and human life. Forests can digest about 1/12 of the CO_2 in the atmosphere and storage of about 72% of the total carbon in global sinks. Forest carbon credits are considered an important tool in reducing carbon emissions and global warming potential. This study aims to estimate the biomass and carbon storage of Melaleuca plantations in Thanh Hoa district, Long An province, Vietnam. The findings contribute to developing sustainable forest management mechanisms and carbon credit markets. Nine standard plots (10x10m) were established to collect data on number of tree, diameter at breast height, and select trees. The results showed that carbon storage (CO_2) was 689.13 kg/standard plot for 2-year-old Melaleuca forests and 2423.5 kg/standard plot for 6-year-old Melaleuca forests. The study provides valuable information for forest managers and policymakers in promoting sustainable Melaleuca forest management and carbon credit trading.

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1. Introduction

Forest carbon credits are considered an important tool in reducing carbon emissions and protecting the global environment. They are tradable certificates that represent the right to emit one ton of CO_2 or one ton of CO_2 equivalent through forest-related activities such as reforestation, conservation or sustainable forest management.

Forests play an irreplaceable role in sustaining life on Earth by absorbing and storing carbon dioxide (CO_2) [1], providing oxygen for the atmosphere, and sustaining human life. Forests can absorb about 1/12 of the CO_2 in the air and store about 72% of the total carbon in global sinks [2]. Of which, half is absorbed by tropical and subtropical forests [3].

Melaleuca sp, belonging to the *Myrtaceae* family, is common in tropical and subtropical climates. Globally, there are about 260 Melaleuca species distributed over 9 million hectares of land, mainly concentrated in Australia with about 200 species [4]. In Vietnam has only one recorded species, Melaleuca cajuputi, which is primarily found in the Mekong Delta, covering approximately 176,296 hectares. *Melaleuca cajuputi* in the MD is known for its good adaptability, strong natural regeneration ability and fast growth in waterlogged saline soil conditions. In many flooded areas, *Melaleuca cajuputi* forests play an important role as water reservoirs, acid sulfate soil filtration systems, fish farming areas and biodiversity conservation. *Melaleuca cajuputi* forests provide a large amount of biomass (mainly wood) for human activities such as firewood, charcoal, piles and construction materials. With an average density of about 6,500 trees/ha, *Melaleuca cajuputi* forests provide about 75.74 tons/ha of fresh biomass, equivalent to 35.99 tons/ha of dry biomass [5]. In addition, *Melaleuca cajuputi* forests also play an important role in regulating the climate, absorbing CO_2 and providing oxygen for the atmosphere.

In Vietnam, there have been many studies on the CO_2 absorption capacity of plants, including studies on the biomass and CO_2 absorption of *Melaleuca cajuputi* forests [6]–[8]. However, most of these studies focus on the three main areas of Dong Thap Muoi, Long Xuyen quadrangle, U Minh Thuong National Park and U Minh Ha National Park, where there is a large area of *Melaleuca cajuputi* forest conservation (about 20,000 ha), while no studies have been conducted on medium- and small-sized forest plantations.

To expand and enrich the scientific data source on carbon accumulation in forest ecosystems, especially in the *Melaleuca cajuputi* forest ecosystem in the Long Xuyen quadrangle, the research topic aims to assess the carbon storage capacity in Thanh Hoa district, Long An province, Vietnam. The objective of the topic is to provide new information on the carbon storage process in these forests, thereby contributing to the expansion of the database on growth and carbon storage in forest ecosystems in general. This study assessed the carbon storage capacity of Melaleuca forests in Thanh Hoa district, Long An province, Vietnam, using field measurements and data analysis.

2. Methods

The study was conducted in *Melaleuca sp* forests managed by Thanh Hoa district, Long An province, in March 2024. The study area covers approximately 50 hectares and primarily consists of two Melaleuca species, *Melaleuca cajuputi* and *Melaleuca leucadendron*, ranging in age from 2 to 8 years.

2.1. The study Area and Data Collection

The study area was divided into 9 standard plots, including 4 plots for *Melaleuca cajuputi* and 5 plots for *Melaleuca leucadendron*, with each plot having an area of 100 m^2 (10 m x 10 m), and the arrangement was randomized (Figure 1). Each standard plot was used to collect the following indicators:

(i) Diameter at breast height (DBH) of the tree trunk at a height of 1.3 m above the ground, using the method for measuring individual tree biomass prescribed in the UNREDD Viet Nam Programme (2012) [9].

(ii) Tree density in each standard plot. In each standard plot, a representative tree was selected and cut down at the base, with the cut being 5-10 cm above the ground. The biomass of the tree was then divided and weighed for each separate part, including the stem (SKTt), branches (SKTc), and leaves (SKTl). Samples of each part of the tree were also collected.

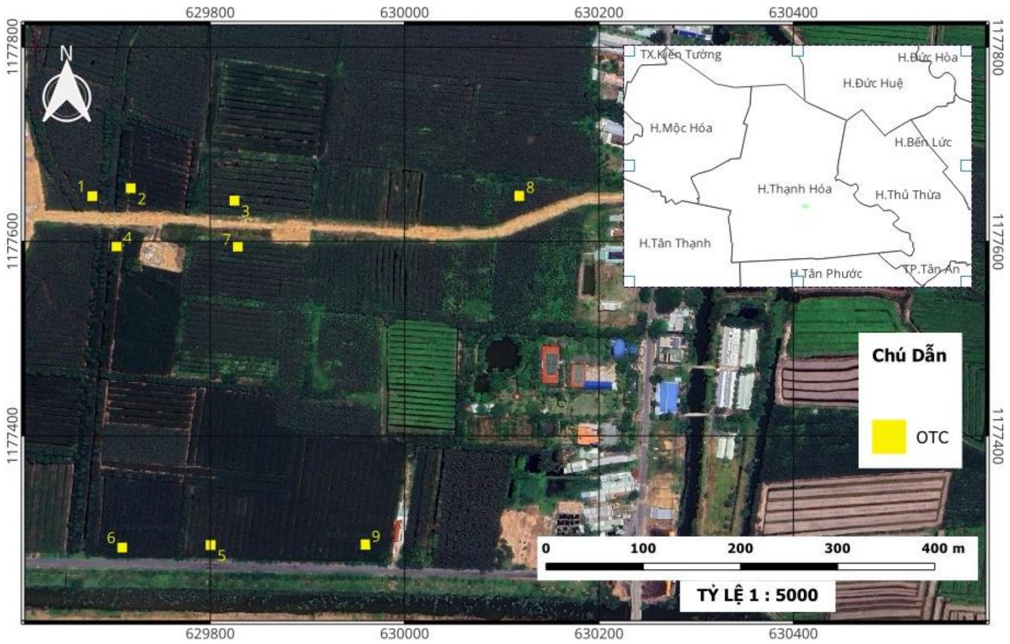

Figure 1. *Standard plot in the study area.*

2.2. Laboratory Analysis

Collected samples were cut into small pieces, oven-dried at 105^0C until the sample weight reached a constant value (drying time ranged from 24 to 48 hours depending on the tree component).

Dry biomass of Melaleuca trees was determined for each component: stem (SKTt), branches (SKTc), and leaves (SKTl).

Samples of each component were also collected.

Ratio of Below-ground Biomass to Above-ground Biomass (R) [10]:

$$\mathbf{BGB = R/S \times AGB} \tag{1}$$

Trong đó: BGB: Below-ground Biomass(kg);

AGB: Above-ground Biomass (kg);

R/S: Proportionality factor between below-ground and above-ground biomass of a plant. Almost all plants grown under normal conditions have an R/S coefficient of 1/5 to 1/6. For melaleuca roots, the R/S coefficient of 1/6 was selected for calculation [11].

The total dry weight of the plant is equal to the total dry weight of the parts. Determine accumulated carbon reserves and accumulated CO_2 amount [12].

$$\mathbf{Cacbon_{accumulation} = 0{,}5 \times AGB\ (kg\ C/OTC)} \tag{2}$$

$$\mathbf{CO_2\ accumulation} = \frac{Cacbon_{accumulation}\ x\ 44}{12}\ \mathbf{x\ density/OTC\ (kg\ CO_2/OTC)} \tag{3}$$

2.3. Data Processing

Measured data was summarized on fresh and dry biomass for each representative Melaleuca tree in each standard plot (OTC). The tools in Excel software were used to calculate the total fresh and dry biomass of the components of the Melaleuca forest. The data were then transferred to SPSS software (version 26) for processing and statistical analysis, enabling detailed and accurate data analysis.

3. Results and Discussion

3.1. Results of Forest Stand Growth Parameters

The results of the analysis of forest stand growth parameters regarding diameter and density in the standard plots are presented in Table 1.

Table 1. *Forest Growth Parameters of Melaleuca Trees.*

OTC (Standard plots)	Age	$D_{1.3}$	Density (trees/100m^2)	Type
1	7	5.8	115	*Melaleuca cajuputi*
2	4	4.6	153	*Melaleuca leucadendron*
3	5	5.9	98	*Melaleuca cajuputi*
4	2	3.2	154	*Melaleuca leucadendron*
5	6	5.5	175	*Melaleuca leucadendron*
6	6	5.4	185	*Melaleuca leucadendron*
7	5	4.4	158	*Melaleuca cajuputi*
8	8	6.6	87	*Melaleuca cajuputi*
9	6	4.0	140	*Melaleuca leucadendron*

In general, the results of Table 1 and Figure 2 show a clear difference in diameter and density between the plots as well as the ages, as follows:

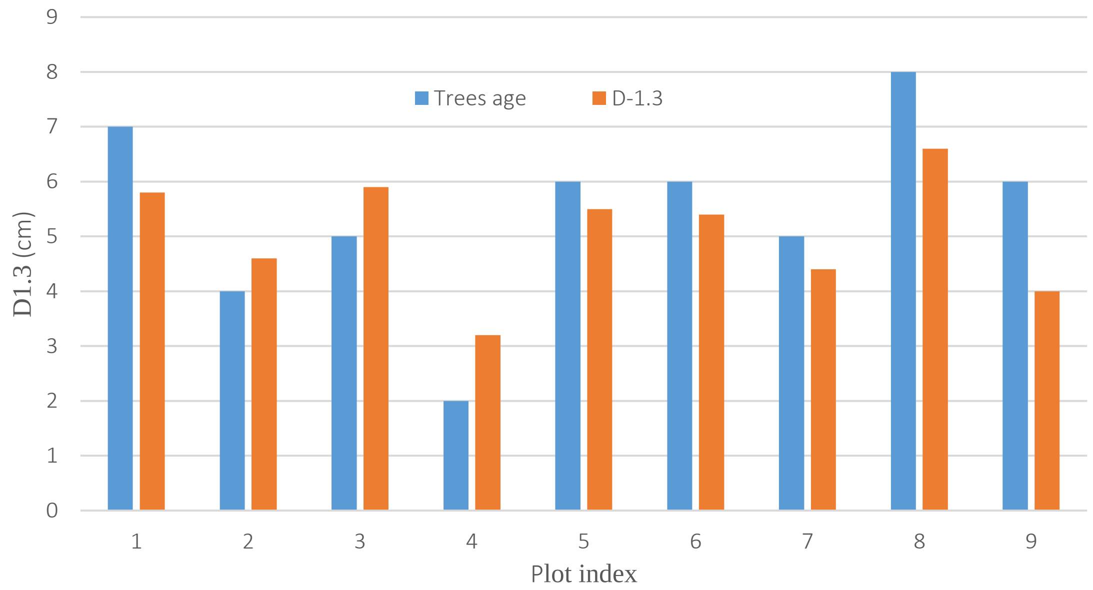

Figure 2. *Graph between age and diameter at breast height of Malaleuca tree*

3.1.1. Density

The density of *Malaleuca* trees in the standard plots varies, with the highest average density recorded in standard plot number 6, with an age of about 6 years, with about 185 trees/100m², which is higher than the standard plot with the lowest density of about 0.87 trees/m² at an age of about 8 years. According to the afforestation design of some scientific and environmental documents, the optimum initial planting density is 100 trees/100m². However, during the growth process, *Malaleuca* trees and other plants on the same soil substrate compete for space, nutrients, and light, leading to the elimination of poorly growing trees, creating a difference in tree density between the sample plots.

According to the Forest Business Design Code, *Malaleuca* forests with a density of less than 1,000 trees/ha are considered sparse, from 1,000 to 2,000 trees/ha are considered medium, and *Malaleuca* forests with a density greater than 2,000 trees/ha are considered dense. Based on the above data, the *Malaleuca* forests in the standard plots (3,8) are classified as sparse and the remaining standard plots are classified as medium density.

3.1.2. Diameter at breast height (DBH) of the tree trunk at a height of 1.3 m

The breast diameter of Melaleuca trees typically falls between 3.2 cm and 6.6 cm on average, with considerable variation depending on tree age. A distinct pattern shows that older Melaleuca trees generally have larger breast diameters.

3.2. Results of cajuput forest biomass

3.2.1. Results of fresh biomass

Biomass is mainly concentrated in the stem of the tree and increases with diameter (Table 2). For *Malaleuca* trees in the study area, the average weight of the fresh stem accounts for the highest proportion (78.4%), followed by the fresh leaves (12.9%) and fresh branches (8.7%). The older the *Malaleuca* tree, the greater the tendency to accumulate total fresh biomass. Specifically, the *Malaleuca* tree at the oldest age has a higher accumulated fresh biomass (24.15 kg/tree) than the tree at the youngest age (5.1 kg/tree). There is no significant difference in the fresh biomass of the tree parts at different ages ($p > 0.05$). Younger *Malaleuca* forests can be explained by the fact that the trees have reached maturity

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and focus on the dense development of branches and leaves. For older, low-density *Malaleuca* forests, the area of branches and leaves receives more sunlight, and it is possible that the *Malaleuca* trees will develop dense branches and leaves but slow stem growth.

Table 2. *Fresh biomass results (kg).*

OTC (Standard box)	SKT_t	SKT_c	SKT_l	SKT_{tong}
1	1621.5	149.5	184	1955
2	994.5	64.26	237.15	1295.91
3	1092.7	269.5	147.98	1510.18
4	548.24	36.96	200.2	785.4
5	1452.5	136.5	287	1876
6	1951.75	129.5	342.25	2423.5
7	960.64	211.72	165.9	1338.26
8	1744.35	200.1	156.6	2101.05
9	988	64.6	142.5	1195.1

3.2.2. Dry Biomass Results

The analysis of the data shows that *Malaleuca* trees in older stands generally have a higher total dry biomass than *Malaleuca* trees in younger stands (see Table 3). Specifically, the accumulated dry biomass of *Malaleuca* trees at the youngest age is 2.44 kg/tree, which is lower than that of *Malaleuca* trees at the oldest age, which is 13.18 kg/tree. At the time of the study, *Malaleuca* forests in Thanh Hoa district had the potential to provide about 2423.5 kg/OTC total fresh biomass, equivalent to 1287.18 kg/OTC total dry biomass for *Malaleuca* trees with the highest biomass. There was no significant difference in the dry biomass of stem, branches, leaves, and roots, as well as total dry biomass, between ages ($p > 0.05$). This can be explained by the fact that *Malaleuca* forests in Thanh Hoa, Long An grow on acid sulfate soils, similar to *Malaleuca* forests in Lung Ngọc Hoang Nature Reserve. In addition, during the sampling process, the above-ground components were calculated for the biomass of cajuput forests in Lung Ngọc Hoang Nature Reserve, and as in Thanh Hoa, Long An, the dry biomass included the below-ground root portion. Since the tree felling method was carried out at a position 5-10 cm above the ground (see Figure 1), the fresh biomass of the root portion was not displayed. When calculating the dry biomass, the study applied the R/S ratio to estimate the dry biomass of the root portion (see Table 3).

Table 3. *Dry biomass results (kg).*

OTC (Standard box)	SKK_t	SKK_c	SKK_l	SKK_r	SKK_{total}
1	903.41	79.73	66.24	174.90	1224.28
2	485.01	29.07	76.50	98.43	689.01
3	546.35	175.49	59.19	130.17	911.20
4	235.95	16.94	69.30	53.70	375.89
5	741.07	75.83	112.30	154.87	1084.08
6	873.92	71.94	157.44	183.88	1287.18
7	480.32	114.33	69.68	110.72	775.05
8	814.03	109.15	59.51	163.78	1146.46

9	414.96	28.50	44.05	81.25	568.76

3.3. Results of CO_2 Sequestration Potential of Malaleuca Forests

The research results summarized in Figure 3 show the carbon accumulation of *Malaleuca* trees in forests at different ages, with the highest accumulation of 643.59 kg/OTC.

The carbon accumulation values recorded in the study area were determined to be higher than those reported for studies conducted in the northern regions of Vietnam [13]. This difference can be explained by the different light conditions in the study areas, as green plants absorb CO_2 and produce biomass through photosynthesis under the influence of sunlight. Compared to the study of *Malaleuca* forests in Lung Ngọc Hoang Nature Reserve, our study area has a lower carbon value due to the fact that the acid sulfate soils in the Hau River Delta provide better conditions for organic matter accumulation than other acid sulfate soils in the Mekong Delta [14].

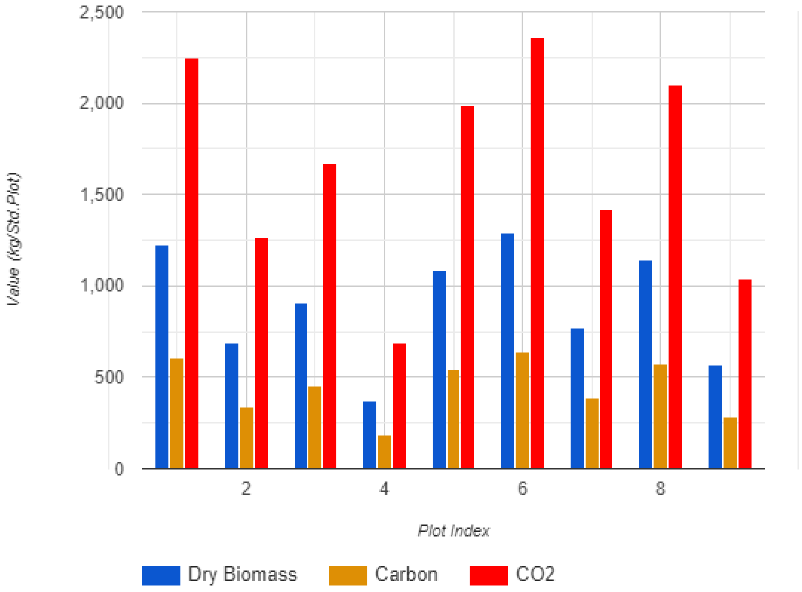

Figure 3. *Carbon sequestration of Melaleuca Forest*

4. Conclusion

The CO_2 sequestration potential of *Malaleuca* trees corresponds to the increase in their biomass. *Malaleuca* forests in the study area have the highest CO_2 sequestration potential of 2359.83 kg/OTC and the lowest of 689.13 kg/OTC. This is related to the different development of stems, branches, and leaves of cajuput trees, which in turn affects their CO_2 sequestration potential.

The results of this study are an important initial basis for forest managers to calculate carbon credits and environmental service payments. At the same time, it also contributes to the completion of the sustainable development mechanism map and proposes sustainable development methods for cajuput forests.

The research process only focused on determining the above-ground carbon accumulation content of cajuput trees. A recommendation for further research is to clarify the carbon accumulation content in the root part of cajuput trees, as well as the carbon accumulation content in the shrub layer. This will help to better understand the contribution of roots and shrubs to the carbon accumulation process of the cajuput forest ecosystem.

Conflict of Interest

The authors declare no conflict of interest

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REFERENCES

[1] D. Brack, *Background Analytical Study: Forests and Climate Change*, 2019.

[2] I. R. Swingland, E. C. Bettelheim, J. Grace, G. T. Prance, L. S. Saunders, and Y. Malhi, "Forests, carbon and global climate," *Philos. Trans. R. Soc. Lond. A: Math. Phys. Eng. Sci.*, vol. 360, pp. 1567–1591, 2002, doi: 10.1098/rsta.2002.1020.

[3] J. G. Canadell and M. R. Raupach, "Managing forests for climate change mitigation," *Science*, vol. 320, pp. 1456–1457, 2008, doi: 10.1126/science.1155458.

[4] D. B. Tran, P. Dargusch, P. Moss, and T. V. Hoang, "An assessment of potential responses of *Melaleuca* genus to global climate change," *Mitig. Adapt. Strateg. Glob. Change*, vol. 18, pp. 851–867, 2013, doi: 10.1007/s11027-012-9394-2.

[5] T. T. K. Hong, Q. T. Xuan, and T. T. N. Hang, "Biomass of *Melaleuca* forest in U Minh Thuong National Park, Kien Giang Province," *Can Tho Univ. J. Sci.*, pp. 63–68, 2015. (in Vietnamese)

[6] T. H. Dan, B. T. Tho, and L. H. Tat, "Assessment of carbon accumulation in biomass of *Melaleuca* forest on clay soil in U Minh Thuong National Park," *Can Tho Univ. J. Sci.*, pp. 125–135, 2014. (in Vietnamese)

[7] B. T. T. Thao and L. A. Tuan, "Biomass and CO_2 absorption capacity of *Melaleuca* forest in Lung Ngoc Hoang Nature Reserve," *Can Tho Univ. J. Sci.*, pp. 58–65, 2017, doi: 10.22144/ctu.jvn.2017.067. (in Vietnamese)

[8] P. X. Quy, "Developing a biomass prediction model for *Melaleuca cajuputi* forests in the Southwest region of Vietnam," *J. Agric. Rural Dev.*, no. 5, pp. 36–46, 2010. (in Vietnamese)

[9] *Final Report of the Viet Nam National Programme on REDD+*, 2012.

[10] V. T. Phuong and V. D. Hai, "Biomass structure of monoculture *Pinus kesiya* plantations in Lam Dong Province," Technical Report, 2011. (in Vietnamese)

[11] T. O. Perry, "The ecology of tree roots and the practical significance thereof," *Arboric. Urban For.*, vol. 8, p. 197, 1982, doi: 10.48044/jauf.1982.047.

[12] J. Penman, *Good Practice Guidance for Land Use, Land-Use Change and Forestry*, Inst. for Global Environmental Strategies for the IPCC, 2003.

[13] D. T. Trieu, "Carbon sequestration capacity of monoculture *Pinus massoniana Lambert* plantations on different soil classes in Northeast Vietnam," *J. Agric. Rural Dev.*, no. 11, pp. 94–99, 2008. (in Vietnamese)

[14] D. T. Nha, L. V. Phat, L. Q. Tri, V. Q. Minh, and N. N. Hung, "Some morphological characteristics of acid sulfate soils in the Mekong Delta," *Can Tho Univ. J. Sci.*, pp. 243–249, 2010. (in Vietnamese)

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