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An Evaluation of The carbon stocks of The Tra Su Cajuputi Forests in An Giang Province of Southern Vietnam

Phan Truong Khanh
Faculty of Environment Technology Engineering
University of An Giang – Vietnam National University
Ho Chi Minh City, Vietnam

Nguyen Phu Vinh
Faculty of Environment Technology Engineering
University of An Giang – Vietnam National University
Ho Chi Minh City, Vietnam

Tran Thi Hong Ngoc
Faculty of Environment Technology Engineering
University of An Giang – Vietnam National University
Ho Chi Minh City, Vietnam

ABSTRACT

Forest aboveground biomass (AGB) plays an important role in the study of the carbon cycle and climate change in the global terrestrial ecosystem. Therefore, studying the CO_2 absorption capacity of forests through the accumulation of carbon in biomass is essential. Quantification of M. cajuputi forest biomass in the TraSu Cajuput forest was conducted to estimate the carbon storage capacity of M.cajuputi forest. Data were collected in 13 plots measurement cells in forests. The results showed that the average density, height and diameter respectively were 3,778 tree/ha, 11.54m±1.45m, 13.08cm±1.6cm. At the same time, analysis of 15 standard Melaleuca trees to establish 2 equations relating biomass and stem diameter (DBH 1,3) of M. cajuputi trees above ground and DBH 1,3 and height using the form of $y = ax^b$ and all two equations have correlative coefficients $R^2>0.90$. The average green biomass of the M. cajuputi populations in Tra Su forests was 404.38tons/ha and the dry biomass was 238.99tons/ha. Dry biomass ratio per green biomass is K = 0.56. The average carbon content of M. cajuputi forests is 116.15tons/ha. The total amount of CO_2 storage of M.cajuputi forests is 425.88tons/ha. The amount of carbon accumulated in M.cajuputi population of the Tra Su Park was 98,146 tons, equivalent to 359,868.6tons of CO_2.

Keywords: Biomass, Carbon, CO_2, M. cajuputi, Tra Su cajuputi forest.

INTRODUCTION

Melaleuca forests are very important ecological systems, especially in the wetlands and or peatlands of tropical and subtropical regions. In association with other plant species, Melaleuca dominated ecosystems can provide an important habitat for fauna, as well as protecting soil, peat and water and providing a significant carbon store (EPA, 2005). Secondly, from a human

socio-economic perspective, Melaleuca forests can provide timber for building and furniture. Other traditional uses, such as for fuel wood, charcoal, tea-tree oil, and honey are still employed today (Duong et al.,2005). Melaleuca forests can also store a large volume of soil organic carbon, especially in the peatlands (e.g. in Indonesia, Malaysia, Thailand, and Vietnam).

The quantity of biomass in a forest is a result of the difference between production through photosynthesis and consumption by respiration and harvest processes. Thus it is a useful measure for assessing changes in forest structure. Consequently, biomass represents the potential amount of carbon, that can be added to the atmosphere as carbon dioxide when the forest is cleared and/or burned. Attempts to estimate the biomass density of tropical forests have been made by the scientific community for use in models that assess the contribution of tropical deforestation and biomass burning to the increase in atmospheric carbon dioxide and other trace gases (Lu, D, 2005). Biomass density estimates also provide the means for calculating the amount of carbon dioxide that can be removed from the atmosphere by regrowing forests or by plantations because they establish the rates of biomass production and the upper bounds for carbon sequestering. This issue is receiving more attention of late as countries look to forests as a means of mitigating greenhouse gas emissions, particularly carbon dioxide, a major greenhouse gas and the one fixed during photosynthesis (Li, W., 2015). Practices such as sustainable forest management, slowing deforestation, and low-impact-logging decrease emissions or conserve carbon dioxide. Other practices such as plantation establishment or other tree planting programs on previously non-forested land sequester carbon dioxide (Brown et al. 2002). Furthermore, biomass density estimates of forests are extremely relevant for studying other global biogeochemical cycles, such as nitrogen, because the amount of other nutrient elements in forests is also related to the quantity of biomass present.

In Viet Nam, equations for estimating forest biomass have taken place in the past, mostly for plantation species, triggered by the onset of the Clean Development Mechanism (CDM), while studies on biomass and equations for biomass estimation of natural forests have been limited. The first research on forest biomass (plantations) was conducted by Le Hong Phuc (1996) for pine forests in Lam Dong. This research developed models of biomass estimates based on variables of the forest inventory (DBH and H). Ngo Dinh Que (2007) studied the amount of carbon sequestrated in plantations of Acacia mangium, Acacia auriculiformis, Acacia hybrid, Pinus kesiya and eucalyptus. A numbers of comprehensive studies on biomass, carbon stock and equations for biomass estimation was then carried out for plantations of Acacia mangium, Acacia hybrid, Eucalyptus urophylla, mangletia glauca, Pinus massoniana, Pinus merkusii by Vu Tan Phuong (2009), Vo Dai Hai et al., (2009), Pham.T.D and Vu. D. H.,2014; Da B. T, 2015….Most studies have used DBH and H as predictor variables for biomass estimation.

Decisions by policy-makers regarding the management and use of forest and trees require accurate and precise information on the state and patterns and rates of change of the resource. To attain these needs, reliable estimates on the state and change of forest biomass for all countries over the long term must be made. Biomass estimates for forests of tropical countries, in particular, are needed because globally they are undergoing the greatest rates of change and reliable biomass estimates are few. For these reasons, the project "Evaluation of The carbon stocks of Tra Su Melaleuca Forests, An Giang province" was made to contribute to providing a database of M. cajuputiforests in reducing greenhouse gas. On that basis,

recommendations and orientation for the payment of environmental services are needed, as well as providing methodological or institutional of policies in the protection and using sustainable forest land because of environmental values in the context of global climate change.

METHODOLOGY

Characteristics the study area

Located in Van Giao Commune of Tinh Bien District in An Giang Province, Tra Su Cajeput Forest covers an area of 845ha, belonging to the national specialized forest system in the western region in Southern Vietnam. It is an ideal place for researchers and those who love wild animals. Tra Su Cajuput Forest is home to more than 140 types of plants, of which cajuput overwhelms. This place has become a popular tourist spot in the South of Vietnam recently.

The area stretches from 10°33 'to 10°36' north latitude; from 105°02 'to 105°04' east longitude (Figure 1). Just 10 km from the Vietnam-Cambodia border to the northwest and about 15 km from the Hau river to the northeast, on a tourist route connecting Cam mountain, Sam mountain, Tuc Dup hill.



Figure 1: Location of the study area and Layout of sample plots in Tra Su Cajeput forest

Data collection

Using the administrative map of the Tra Su forest combined with GPS, we established 13 plots of 25m*25m (Fig 2). In each main plot, we set up 5 subplots. They were placed at four corners of the main plot and one was placed in the center. The subplot area 100m^2 (10x10) to survey the parameters: Diameter at bread height of tree of 1.3m (DBH1,3), height (H) and density of trees, the tree number of standing and lying dead, and estimate liana species and vegetation on the ground.

The total number of trees have been counted for each DBH and height category for each species. In order to calculate the number of trees per ha, first the sample plot average values were calculated as shown in equation below:

$$\text{Average number of trees per plot} = \frac{number\ of\ these\ trees\ on\ all\ plots}{\text{number of plots}} \quad (1)$$

In order to convert a plot-average number of trees to a per ha value, the plot average equation 3.5 was used.

$$\text{Number of trees per ha} = average\ number\ of\ trees\ per\ plot\ x \frac{10{,}000}{1{,}600} \quad (2)$$

A total of 15 trees were cut down at five diameters in classes representing forest to build the relationship equations between the green biomass of standard tree and DBH(1.3) according to the exponential function y=axb. For calculate the biomass per ha for a given DBH and height category per tree biomass was determined. Then it multiply the biomass of one tree by the number of those trees per ha to get biomass per ha. An estimate of the total biomass or number of trees was obtained by multiplying the total area with the estimate biomass or trees per ha in each density class.

All samples were collected, chopped and dried at 105^0C from 48h-72h, periodically weighing the dry biomass of stems, branches, and leaves. Final measurements were recorded after the dry biomass had an unchanged value. Next, we calculated the ratio of dry biomass D(kg) to green biomass G(kg) by the formula: k = D/G. The dry biomass for each part of the tree and the entire study area were calculated by the formula D = G*k. We used SPSS Statistics 16.0 software to analyze the biomass differences between diameter classes by the Duncan-Anova test method.

The amount of accumulated carbon was estimated based on the total of above-ground dry biomass by the formula of Meine Van Noordwijk (2007):

Wcarbon= 0.46*Wdry biomass (tonsC/ha) (3)

Where;
Wcarbon = The amount of stored carbon in the biomass (tons/ha);
Wdry biomass = The amount of above ground dry biomass (tons/ha).

From there, we could calculate the absorbed CO_2 amount/ha for the whole study area. The relationship between carbon and CO_2 was shown by the equation:

Absorbed CO_2 amount = amount of accumulation C*44/12 (4)

RESULTS

The growth parameters of melaleuca forests

Tra Su forest has been dominated by M. cajuputi trees with a grass community and vines. The M. cajuputi forests is 85% of the total area of the Park in 2020 and rest was comprised of bare soil, canals and grassland. Here, there are 140 specified floral varieties with 22 varieties of trees, 25 varieties of shrubs, 10 varieties of vines, 70 varieties of grasses, 13 species of aquatic plants, 22 varieties of ornamental plants, 9 varieties of fruit trees and particularly many varieties of medicinal herbs of high value, 11 species of beasts belonging to 6 families and 4 orders, 70 species of birds belonging to 3 families and 13 orders, 2 rare and precious varieties of birds, including *Mycteria Leucocephala* and *Anhiga melanogaster,* 20 species of reptiles, 5 species of amphibians and 23 species of fish, including *Chitala ornata* and *Clarias batrachus* having the scientific value and being in danger of extinction.

Tra Su forest has 5 diameter classes, the average height ranges from 5.61 m - 16 m. The highest density (1,384.62 trees/ha, 36,64%) concentrated in a diameter of 10-15cm, with an average height of 12.4m ± 1.61. At diameter classes 5-10cm and 15-20cm, there are 886.15trees/ha

(23.45%), 806.15 trees/ha (21.33%) respectively. Diameter >20cm and <5cm occupies a small proportion (12,7% and 5,86%). The density of the whole park is 3.778,46 tree/ha (Table 1).

Table 1: The growth parameters of *M. cajuputi*

Diameter class (cm)	DBH (cm)	H(m)	N (tree/ha)
< 5	4,15 ± 0,61	5,61 ± 0,91	221,54
5-10 cm	8,21 ± 1,25	9,32 ± 1,82	886,15
10-15 cm	12,59 ± 1,47	12,4 ± 1,61	1.384,62
15-20 cm	17,28 ± 1,38	14,37 ± 1,34	806,15
> 20 cm	23,18 ± 3,26	16 ± 1,57	480
Total			**3.778,46**

Note: Average ±standard deviation; N:the density of M. cajuputi; DBH: Diameter at breast height of tree of 1.3 m; H: the average height of tree.

It was intenesting observe in the Tra Su forest that the many trees bent at the base at a height of around 1m. This could be caused due to genetic characteristics of the species, or due to their natural reaction to the impact of the wind. *M cajuputi* are planted by bare roots according to a floating implantation method. Therefore, after transplanting, the root system is weak and do not have the ingrained ability in the soil. Therefore, when encountering large impact force of the wind, the *M. cajuputi* roots can be separated from the soft soil. When they were separated from the soil layer, the root system is still had the ability to develop in the water environment. Under natural reaction, the *M.cajuputi* root system will develop gradually and is able to be established in the soil. However to stand firmly against mechanical forces, the *M.cajuputi* stems have to change morphology and bend at the base. This metamorphosis change could help to sustain the trees in the environment and to grow normally in soft soil with of prolonged flooding.

The above-ground biomass of M. cajuputi The above-ground biomass of the *M. cajuputi* tree consists of green biomass and dry biomass of the stems, branches and leaves. *M. cajuputi* trees of older ages are greater in DBH and therefore biomass should have high. The results of the biomass estimation are given in Table 2.

Table 2: The aboveground biomass of individual M. cajuputi tree

Diameter $_{1.3}$ (cm)	Green biomass (kg/tree)				Dry biomass (kg/tree)			
	Stems	Branches	Leaf	Total	Stems	Branches	Leaf	Total
< 5	7,33	0,93	0,63	**8,9**	3,69	0,41	0,26	**4,36**
5-10	22,27	3,37	1,57	**27,2**	11,69	1,66	0,73	**14,08**
10-15	71,33	5,5	3,13	**79,97**	42,86	3,14	1,66	**47,66**
15-20	142,17	10,6	5,47	**158,23**	85,54	6,17	2,99	**94,69**
>20	257,67	22,47	11,6	**291,73**	154,81	12,18	6,36	**173,36**

Table 2 showed that both green biomass and dry biomass increased very slowly within 5-10cm DBH, then increased rapidly from DBH >10cm (Table 2). The average green biomass of *M. cajuputi* trees in the DBH range of 5cm to >20cm was from 8.9kg/tree to 291kg/tree. Dry biomass ranged from 4.36-173kg/tree. Having the average of 113,2kg/tree for green biomass and 66.83kg/tree for dry biomass.

Average green biomass of Stems, branches and leaves of M. cajuputi are 100.15kg/tree (72.57%); 8.57kg/tree (18.56%) and 4.48kg/tree (8.85%) respectively. The green biomass structure of the parts of individual M. cajuputitrees was arranged in the following order: stems > branches > leaves. In fact that the majority of Melaleuca in Tra Su has few leaves, the canopy is not large, so the biomass of two these parts are small rate. Quy (2010) established a biomass equation for M.cajuputi growing in the South of Vietnam. The results showed that the total biomass and above-ground biomass components of M. cajuputi plant fluctuated greatly in the same DBH class. In which the biomass variability of the small DBH trees was much higher than the larger DBH trees. Quy's calculations in 2010 also showed that, compared to total green biomass (100%), The average percentage of green stems biomass was 75.6%, green branches biomass and green leaves biomass were 14.8% and 9.6% respectively. This showed that the results of Quy were similar to the findings of ours (2010).

The relationship between dry biomass and green biomass was expressed by K coefficient. The ratio of dry biomass to green biomass of stems, branches and leaves is 0.59; 0.55; 0.54. Of this, the ratio of stems biomass is higher than the ratio of branches and leaves biomass. The ratio of dry biomass to green biomass of the leaf is the lowest because the leaf is an organ that transports organic matter and is also the main organ of the plant's evapotranspiration through stomata. Therefore, the water content is easily lost when dried. The ratio of dry biomass to green biomass of individual trees was 0.56. Two equations were constructed to predict the DBH with total green above-ground biomass and with height. All two equations are decivations of equation $y=ax^b$ and have very strong correlation between biomass and diameter, between diameter and height because correlation coefficients (R^2) of all equations were higher than 0.9.

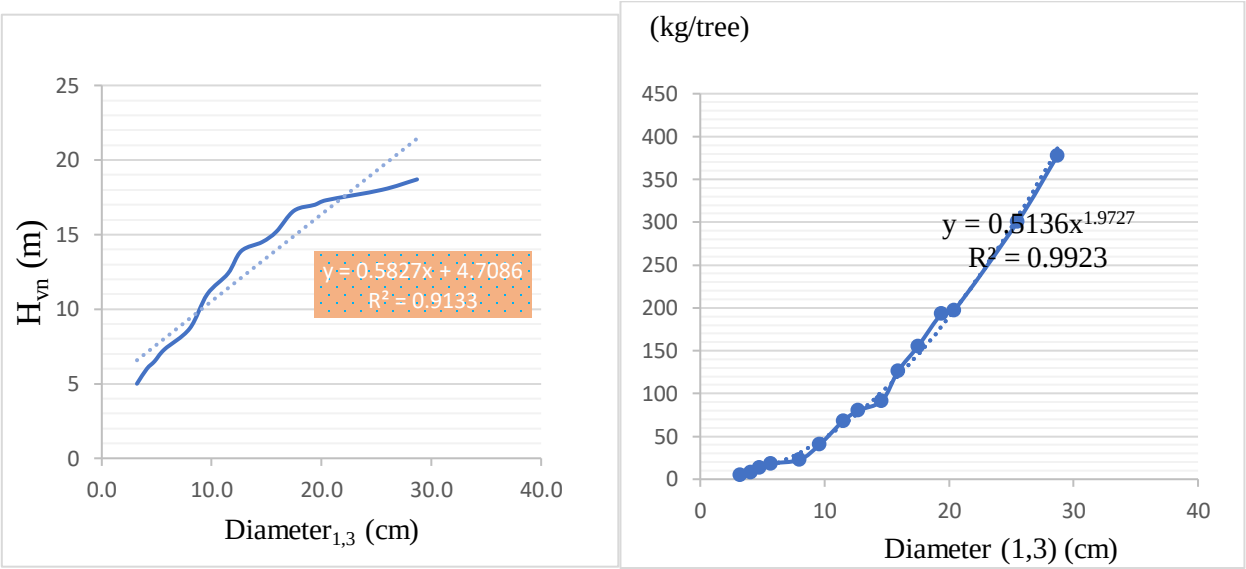


Figure 2: Relationship between DBH $_{(1,3)}$ and green biomass; DBH $_{(1,3)}$ and height H.

In order to test the reliability of the above equations, a comparison was made between the measured values and simulated values. The results showed that the simulated biomass value was slightly different than the survey biomass value. However, this is very small and therefore negligible the difference (Table 3) because the average error was 0.39% .

Table 3: The percentage of green biomass difference between the survey value and the simulation value

Diameter ($_{1.3}$) (cm)	Survey biomass value (kg)	Simulation biomass value (kg)
3,2	4,7	5,09
4,1	8,3	8,31
4,8	13,7	11,34
5,7	18,3	15,91
8,0	22,8	31,06
9,6	40,5	44,50
11,5	68,1	63,54
12,7	80,2	77,29
14,6	91,6	101,75
15,9	126,2	120,40
17,5	155,2	145,47
19,4	193,3	178,27
20,4	197,1	196,85
25,5	300,5	305,71
28,7	377,6	386,00
Average	**113,20**	**112,76**

In order to determine above-ground green biomass of M. cajuputi populations between diameter classes, the equation developed as this study were used between DBH coupling with stand density in each class. The results showed that the M. cajuputi forest at the time of study, provided 404 tons/ha of above-ground green biomass equivalent to 238 tons/ha of dry biomass. The total green biomass of *M. cajuputi* population was 341,701 tons (201,946 tons dry biomass) (Table 4).

Table 4: Estimated the total biomass of Melaleuca cajuputi forests

Diameter$_{(1,3)}$	Tree/ha	Green biomass (tons/ha)	Green biomass total (tons)	Dry biomass (tons/ha)	Dry biomass total (tons)
< 5 cm	221,54	1,97	1.664,65	0,97	819,65
5-10 cm	886,15	24,10	20.364,5	12,48	10.545,60
10-15 cm	1.384,62	110,72	93.558,4	65,99	55.761,55
15-20 cm	806,15	127,56	107.788,2	76,34	64.507,30
>20 cm	480,00	140,03	118.325,4	83,21	70.312,45
Total	**3.778,46**	**404,38**	**341.701,1**	**238,99**	**201.946,5**

Dry biomass is also an important parameter to determine the dry yield of a plant, and from which allows to determine the amount of carbon accumulated in individual trees. The total amount of carbon was calculated based on the total of aboveground dry biomass. Results of the carbon content and CO_2 storage in the Tra Su Park are showed in Table 5.

Table 5: The carbon content and CO_2 storage in the Tra Su forest

	Carbon (KgC/tree)	Carbon (tons/ha)	Carbon (tons)	CO_2 (tons/ha)	CO_2 (tons)
Above -ground	30.74	116.15	98,146.75	425.88	359,868.6

The results showed that, the average carbon content above-ground was 116.15 (tons C/ha), There was a difference in carbon content between plantations in The lower U Minh National Park (75 tons/ha) of Khanh's Author, due to the fact that the TraSu forest had a high density of *M.cajuputi* trees, leading to the average carbon content in TraSu forest being 1.54 times higher than the carbon content of UMinh forest. It is obvious that forest densities substantially impact the carbon storage potential of the forest. From the carbon content in one ha, the total carbon content of the M. cajuputi forests in the TraSu Park was estimated 98,146.75 tons. The total of CO_2 absorption capacity of M. cajuputi populations in the Tra Su Park was 359,868.6 tons.

CONCLUSIONS

Climate change is caused by the increase of greenhouse gases, of which the increase in CO_2 is one of the important factors. Therefore, studying the CO_2 absorption capacity of forests through the accumulation of carbon in biomass is essential. In study area, the wood density of the tree further affects the carbon content of the plants and hence that of the stand of vegetation. The relationship between the size of trees and their biomass is linear–meaning that as the diameter and height of the tree increases its biomass increases in a proportionally greater way.

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