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An Assessment Of The Carbon Stocks Of *Melaleuca* Forests In The Lower U Minh National Park In Ca Mau Province Of Southern Vietnam

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ABSTRACT:*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. Quantification of M. cajuputiforest biomass in the Lower U Minh National Park was conducted to estimate the carbon storage capacity of M. cajuputi forest. Data were collected in 45 plots measurement cells in natural and plantation forests. The results showed that the average density, height, and diameter respectively were: 528.65tree/ha, 14.73m±3.01m, 17.17cm±7.05cm for natural M. cajuputiforest and 6,285.71tree/ha, 11.45m±2.25m, 9.01cm±2.14cm for plantation forest. At the same time, analysis of 64 standard Melaleuca trees to establish 4 equations relating biomass and stem diameter (DBH 1,3) of M. cajuputi trees above ground and below ground using the form of $y = ax^b$ and all four equations have correlative coefficients $R^2 > 0.95$. The average green biomass of the M. cajuputipopulations in natural forests was 113.65tons/ha and the dry biomass was 68.52tons/ha. The green biomass of plantation forest was 274.36tons/ha and dry biomass were 179.16tons/ha. Dry biomass ratio per green biomass of natural forest is K = 0.60; for plantation forest is K = 0.65. The average carbon content of M. cajuputiforests is 56.18tons/ha. The total amount of CO_2 storage of M.cajuputi forests is 206.18tons/ha. The amount of carbon accumulated in M. cajuputipopulation of the National Park was 518,535.76tons, equivalent to 1,902,665.08tons of CO_2.*

KEYWORDS:*Biomass, Carbon, CO_2, M. cajuputi, the Lower U Minh National Park.*

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I INTRODUCTION

Global warming has become a major issue for the entire global community. One of the causes of global warming is an increase in the concentration of greenhouse gases generated by human activities such as fossil fuel burning and deforestation that made the Earth's temperature increase since the mid-twentieth century [8]. Forests and other terrestrial systems annually absorb approximately 2.6 gigatons of carbon (GtC), or 9.53 gigatons of carbon dioxide equivalent (GtCO2e) [9].Reduction of deforestation by 50% before 2020 would prevent the release of nearly 3 billion tons of CO_2 per year [10]. In tropical forests, approximately 50% of the carbon is stored in the biomass and 50% in the associated soil [2]; [8]. According to estimates, plantation activities and reforestation in the world have an absorption rate of CO_2 in the biomass above ground and below ground that is 0.4 to 1.2 tons/ha/year in the far north, 1.5-4.5 tons/ha/year in temperate climates, and 4-8 tons/ha/year in the tropics [8]. Brown (1997) estimated the maximum total amount of carbon that plantation activities around the world can absorb, within 55 years (1995-2050), is about 60-87 Gt C, with 70% in tropical forests, temperate forests 25% and 5% in the northernmost forest [2]. As a whole the forest, and forest plantations can absorb 11-15% of the total CO_2 emissions from fossil fuels in equivalent time.

Terrestrial carbon sequestration in above ground woody biomass has received attention as an immediate attempt to mitigate global warming. Biomass estimates provide a means of calculating the amount of carbon dioxide that could be removed/fixed from the atmosphere by re-growing vegetation. Many attempts have been made to estimate vegetation biomass and use of existing forest inventory can be identified as a key method. Researchers have developed various methods for the quantification of sequestered carbon. Study of assessing cumulative carbon plantations of eucalyptus species and Acacia, populations of shrubs and grass in a drought region, city NyaungUtown, Myanmar has been performed by Ha [6]. The ability of carbon absorb and commercial value of several major planted forest *(Pines, Acacias, Eucalyptus)* in Vietnam was done by Hai [7]. Estimating biomass and developing an algometric equation for biomass partioning of *M. cajuputi*species planted in Long An province was carried out by Pham [15]. Evaluation biomass and effect of submergence depth on growth of *M. cajuputi*planting on peat soil and acid sulfate soil in Ca Mau province was done by Le [12]. A study of Da was "the carbon stocks of *M. cajuputi*forests in the coastal regions of Southern Vietnam" [4]. Estimating biomassof *M. cajuputi*in Southern Florida was carried by Van [20]. The rapid assessment of carbon accumulation on the ground of a state of vegetation in Tay Nguyen was carried out by Chung [3].

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. Their biomass and carbon content is generally high, which influences their role in the global carbon cycle. Furthermore, tropical forests have the greatest potential for mitigation of CO_2 through conservation and management [1]and 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. For these reasons, the project "Evaluation of carbon accumulation of *M.cajuputi*forest in the Lower U Minh National Park, Ca Mau province" was made to contribute to providing a database of *M. cajuputi*forests 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.

The study was conducted with the objective of identification of the aboveground biomass and estimating the potential for carbon storage of *M. cajuputi*forests in the Lower U Minh National Park in Ca Mau province, Vietnam.

II METHODOLOGY

Characteristics the study area

The Lower U Minh National Park belongs to U Minh and Tran Van Thoi districts of Ca Mau province in Vietnam. The total extent of the park is estimated to be about 8,476 ha. It is located between $9^o12'30"$ to $9^o17'41"$ N and $104^o54'11"$ to $104^o59'29"$ E (Fig 1). The average temperature in the area is 26.5^0 C and the average annual precipitation is 2,360 mm. Its terrain is relatively flat and the average elevation varies from 1 to 1.5 m above sea level. The main soil types are peat and clay with alum sub-soils dominating in water logging areas.

Due to the presence of dyke systems in the area, Lower U Minh National Park is not affected by the diurnal tidal of the West Sea. However, the area is flooded from 0.1 to 1 m during the rainy season for 5-6 months from June to November in each year. The amount of water in the forest can be adjusted, lowered or stored in each zone by regulating water through culverts. The vegetation of the Lower U Minh National Parkdominates with *M. cajuputi*belongs to *Myrtaceae*family.

Data collection

Using the administrative map of the Lower U Minh National Park combined with GPS, we established 45 plots of 40mx40m. Out of 45, 33 plots were laid in the plantation *M. cajuputi*forest of various age classes (fom the P1 plot to the P33 plot) and 12 plots were laid in natural *M. cajuputi*forest area (fom the N1 plot to the N12 plot) (Fig 1). Data on diameter at breast height of tree of 1.3 m (DBH1,3), height (H) and density of trees plant were collected from those plots. A total of 64 trees were cut down at four diameters in classes representing plantation and natural forest to build the relationship equations between the green biomass of standard tree and DBH (1.3) according to the exponential function $y = ax^b$. 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 K(kg) to green biomass T(kg) by the formula k = K/T. The dry biomass for each part of the tree and the entire study area were calculated by the formula K = T*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). Where: Wcarbon = The amount of stored carbon in the biomass (tons/ha); Wdry biomass = The amount of above ground dry biomass (tons/ha) [13]. Carbon accumulation in below-ground biomass (roots) was calculated based on the dry biomass of below-ground and %C in below-ground was analyzed at the laboratory. 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 or CO_2 =3,67*C.

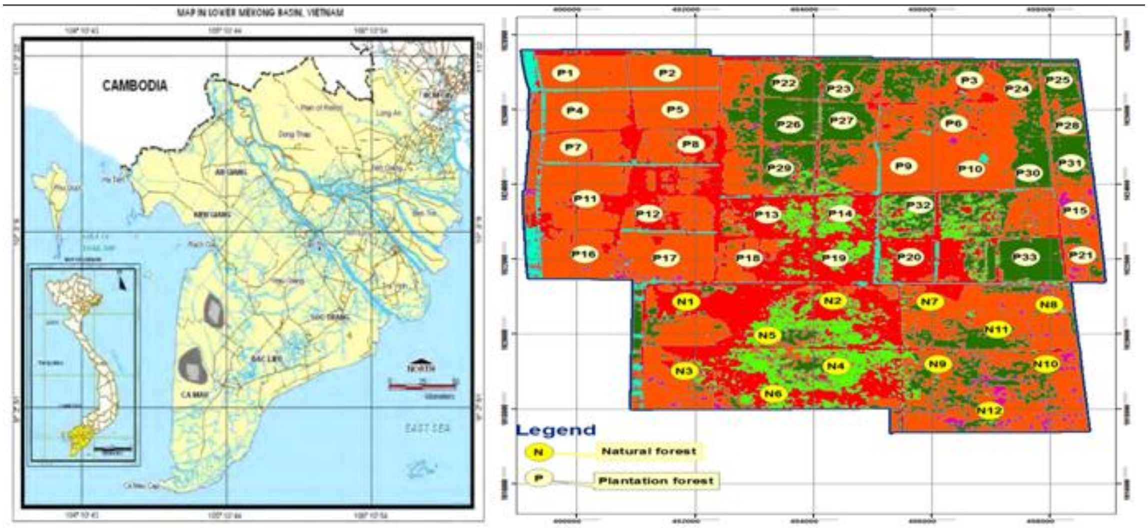


Fig 1: Mekong Delta map, Vietnam (left) and layout of sample plots in the U Minh National Park (right)

III RESULTS

The growth parameters of melaleuca forests

The Lower U Minh National Park has been dominated by *M. cajuputi* trees with a grass community and vines. The *M. cajuputi*forests is 88.64% of the total area of the Lower U Minh National Park in 2015 and rest was comprised of bare soil, canals and grassland. There are 104 plant species of natural plants belonging to 48 different families. Among them, grass and liana are the most dominant types. Although known as *M. cajuputi* forests, there are 11 other tree species (*Annonaglabra; Alstoniaspathulutablume; llexthoreliipiere; Tremaorientalis (L) blume*; *Acacia auriculiformis; Ficusmicrocarpa;Ficuspisocarpa*; *Morus alba; Eugenia cumini (L); Euodia lepta (Spreng.) Merr; Premmaintergrifolia*) found in small numbers. Apart from that, 4 shrub species, 4 herbaceous species, 38 grass species, 27 liana species, 13 aquatic weed species, and 6 fern species were recorded. The *M. cajuputi*area could be divided into two sub-zones as natural zone and plantation zone.

Natural forest: The *M. cajuputi* trees growing naturally covers a large area, i.e., 1,844.46 ha in 2015 which is accounted for 21.76% of the total area, which was distributed in the southwest of the National Park (Fig 1). Most of the natural *M. cajuputi* on peatland was older than 13 years, and it was the dominant tree, with average height of 14.73±3.01m, and the average diameter of 17.17±7.05cm (Table 1). The highest percentage at DBH greater than 20 cm was 31.03%. The highest trees were around 20 m with DBH > 62 cm was also found, but in small quantities. However, although the natural *M. cajuputi* forest on peatland in the Lower U Minh National Park was an old forest, it's tree density is low. The highest density of *M. cajuputi*was 675 trees/ha, the lowest density was 318.75 trees/ha, and the average density was 528.65 trees/ha. Average volume of main stem was 0.151±0.015 m^3/tree. The depth of the peat layer was 1.2m.

Plantation forest: The*M. cajuputi* plantation area is 5,668.87 ha in 2015, accounted for 66.88% of the total area of the Lower U Minh National Park and this forest type usually appears at the outer edge of the peatland (Fig 1). The regenerated *M. cajuputi* after fires seared away on the layers of primitive peats with the area total of 1,653.97 ha, accounted for 19.51% of the area total of the Lower U Minh National Park, was distributed in the north and east locations.The plantation *M. cajuputi*trees (4,014.9 ha) were 5 to 13 years. The average density of plantation *M. cajuputi*was 6,285.71 trees/ha with the average ground cover of 72.87%. The average height was 11.45±2.25m, and the average DBH of 9.01±2.14 cm (Table 1). Average volume of stem was 0.028 ± 0.016 m^3/tree.

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

Type of soil	Diameter class (cm)	N (tree/ha)	DBH (cm)	H (m)
Natural forest	5-10	114.07	7.90 ± 1.48	9.94 ± 2.05
	10-15	139.06	12.55 ± 1.57	13.16 ± 0.95
	15-20	111.46	17.36 ± 1.40	15.56 ± 1.19
	>20	164.06	25.53 ± 4.87	17.75 ± 1.34
	< 5	112.12	4.68 ± 0.20	5.51 ± 1.11
Plantation forest	5-10	5,169.70	7.90 ± 1.39	10.44 ± 1.77

10-15	1,024.24	11.24 ± 1.00	13.65 ± 0.53
15-20	6.06	15.62 ± 0.58	13.78 ± 0.67

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.*

The results also showed that, the stem DBH of plantation *M. cajuputi*growing on clay soilswassmaller than the DBH of natural *M. cajuputi* growing on peatland. However, the density of plantation *M. cajuputi*growingon clay soilswas significantly higher than the natural *M. cajuputi*growing on peatland. This could be due to the characteristics of peatland such as very thick and soft soil and covering of the ground with many weeds and vines. In contrast, clay soil was alkaline had a thinner and harder surface soil layer because there was more clay soil. Weeds and vines were less growing on the ground.

In order to adapt to the loose soils on the peatland, *M. cajuputi* stems became harder at the base. However on the other hand, due to strong competition with weeds and vines, the seedlings of naturally *M. cajuputi* trees grow on peatland did not survive. Therefore the density of the natural *M. cajuputi* grow on peatland was lower than the plantation *M. cajuputi*grown on clay soil.

It was intenesting observe in the Lower U Minh National Park that the many trees bent at the base at a height of around 1 m. 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. For the natural *M. cajuputi* forests, both green biomass and dry biomass increased very slowly within 5-15cm DBH, then increased rapidly from DBH >15cm (Table 2). The average green biomass of *M. cajuputi* trees in the DBH range of 5 cm to >20cm was from 25.34 kg/tree to 414.41kg/tree. Average biomass was 169.79 kg/tree. Meanwhile, green biomass of individual trees in plantations forest at DBH >5 cm increased rapidly (Table 2). Green biomass of plants grown trees of DBH <5cm to 20cm varied from 6.94 kg/tree to 144.74 kg/tree, having the average of 64.68 kg/tree.

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

Diameter (cm)	**Green biomass (kg/tree) (Nnatural Forest)**				**Dry biomass (kg/tree) (Natural Forest)**			
	Stems	**branches**	**Leaf**	**Total**	**Stems**	**branches**	**Leaf**	**Total**
5-10	17.37	4.77	3.20	25.34^{a}	9.83	3.11	2.16	15.10^{a}
10-15	50.80	12.30	5.23	68.33^{a}	29.11	8.66	3.67	41.44^{a}
15-20	123.03	34.67	13.40	171.10^{b}	71.23	23.75	9.30	104.28^{b}
> 20	330.47	59.47	24.47	414.41^{c}	215.75	24.80	8.15	248.70^{c}
Diameter (cm)	**Green biomass (kg/tree) (Plantation Forest)**				**Dry biomass (kg/tree) (Plantation Forest)**			
	Stems	**branches**	**Leaves**	**Total**	**Stems**	**branches**	**Leaves**	**Total**
< 5	4.87	1.27	0.80	6.94^{a}	3.19	0.80	0.59	4.58^{a}
5-10	25.84	5.10	2.57	33.51^{b}	15.01	3.57	1.67	20.25^{b}
10-15	56.30	11.08	6.17	73.55^{c}	36.67	8.29	4.67	49.63^{c}
15-20	120.43	16.44	7.87	144.74^{d}	79.63	9.44	5.43	94.50^{d}

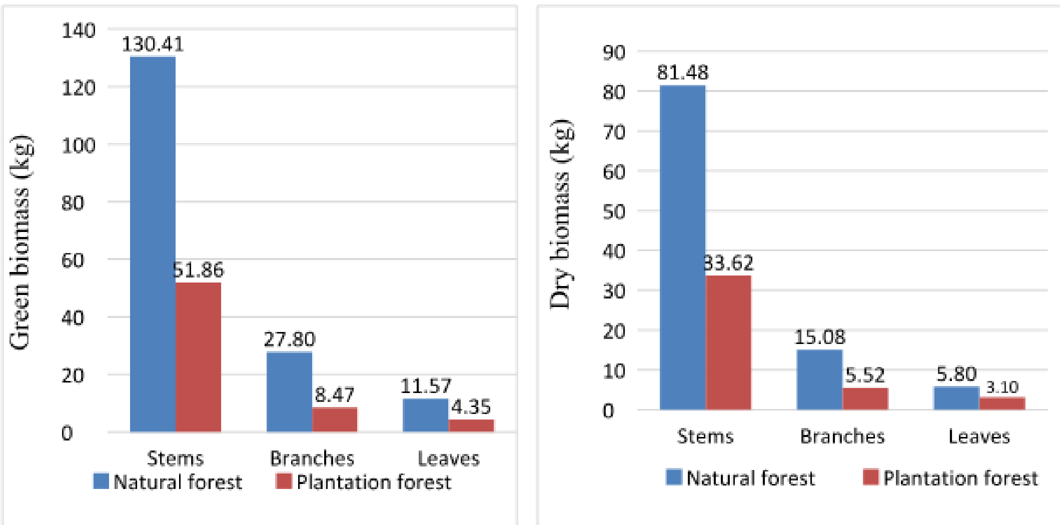
Note:*a,b,c,d: In the same column, the letters (a, b, c, d) following the numbers are significantly different at 5% by Duncan's test.*

Averagegreen biomass of branches and leaves of *M. cajuputi* in natural forests are 27.80±4.71 kg/tree (18.56 %) and 11.57±1.46 kg/tree (8.85%) respectively. Meanwhile, in the plantation forest, green branches biomass of trees was 8.47±2.42 kg/tree (15.45%) and green leaf biomass was only 4.35±1.03 kg/tree (9.07%) (Fig 2a). The green biomass structure of the parts of individual *M. cajuputi*trees was arranged in the following order: stems > branches > leaves.

There was a significant difference of average biomass value of each part of *M. cajuputi* in natural forest and plantation forest (Fig 2a). The largest biomass was concentrated in the stem (including bark), forming an average of 130.41±15.82 kg/tree (72.59%) in natural forest and 51.86±8.85 kg/tree in plantation forest (75.48%).

According to the results of the Duncan's test conducted to compare average biomass values among different DBH classes in the same forest category, a significant difference was observed in average green biomass (as well as in average dry biomass) between DBH groups at 95% confidence level in both types of forest (Table 2), except in the natural forest where there was no significant difference in average green biomass (as well as in average dry biomass) between the two DBH groups of 5-10cm and 10-15cm (Table 2). This suggests that in natural forest, *M. cajuputi* trees have slower growth compared to that in plantation forests in these two DBH groups. The reason is that in natural forests, due to the thick, soft peat soils, the ground is covered by many weeds and vines, many young *M. cajuputi* trees are less adaptive and grow slowly because the roots do not developing strong manner. On the other hand, *M. cajuputi* still have to compete with weeds and vines. In contrast, grass and liana in plantation forests are less so than in natural forests because soils in plantation forest are more alkaline, thinner, and harder than soils in natural forests. Therefore, *M. cajuputi* in plantation forests in early stages will grow faster than *M. cajuputi* in natural forests. On the other hand, the significant difference between the DBH classes in two types of forests indicates that the choice of step between diameters classes (distance between DBH classes) of the standard *M. cajuputi* trees is appropriate because each diameter class represents the whole study area, leading to the calculation of biomass and carbon content of *M. cajuputi* forests in the study area reducing the error significantly.

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 results of the present study showed that the average dry biomass of *M. cajuputi*trees in natural forest is 102.36 kg/tree, ranging from 15.1 kg/tree to 248.7 kg/tree (Table 2), and in plantation forest is 42.24 kg/tree, ranging from 4.58 kg/tree to 94.5kg/tree (Table 2). The dry stem biomass is the largest, with an average of 81.48±14.24 kg/tree for natural forest and 33.62±8.14 kg/tree for plantation forest. Average branch dry biomass was 15.08±6,29 kg/tree for natural forest and which was 5.52±3.85 kg/tree for plantation forest. Leaf biomass decreased heavily, with average 5.80±1.42 kg/tree for natural forest and 3.10±1.07 kg/tree for plantation forest (Fig 2b). Dry biomass structure of the parts of *M. cajuputi* trees is arranged in the following order: stems > branches > leaves.



(a) **(b)**

Fig 2: The green (a) and dry biomass (b) of stems, branches and leaves of *M.cajuputi*

The ratio of dry biomass to green biomass of stems, branches and leaves is 0.62; 0.54; 0.50 for natural forests and 0.67; 0.62; 0.55 respectively for plantation forest. Of this, the ratio of stems biomass is higher than the ratio of branches and leaves biomass in both types of forest. 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 in natural forests was 0.603 and the ratio of dry biomass to green biomass of individual trees in the plantation forest was 0.65.

Estimation of below-ground biomass of M.cajuputi

Results of shows that, average green below-ground biomass of *M. cajuputi* tree in natural forest was 13.11 kg/tree which ranges from 2.42-26.83 kg/tree, equivalent from 1.23-13.68 kg/tree dry biomass. Average green below-ground biomass of *M. cajuputi* tree was 5.85 kg/tree, ranges from 0.69-12.27 kg/tree, equivalent from 0.36-6.38kg/tree dry biomass for plantation *M. cajuputi* forest (Fig 3).

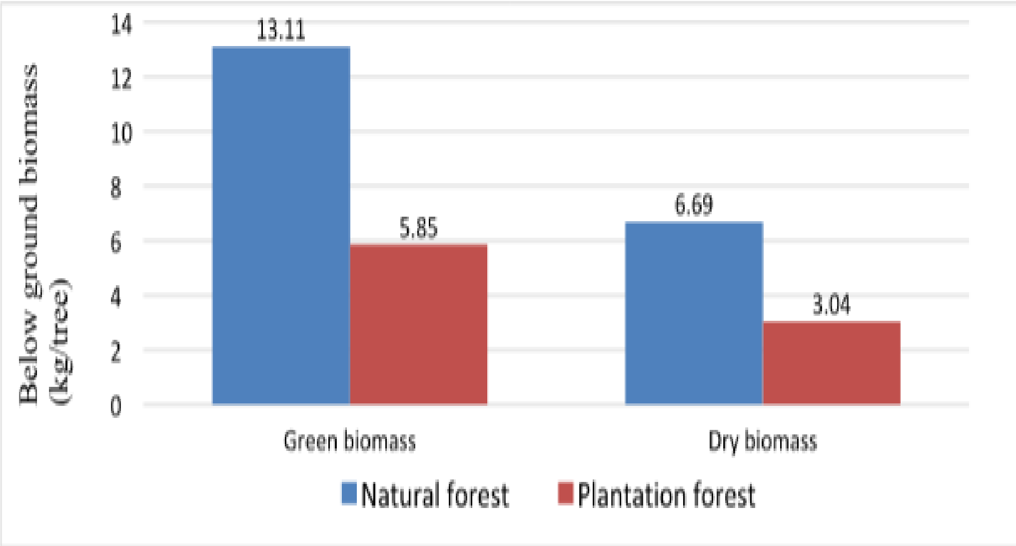


Fig 3: Below-ground biomass of *M.cajuputi* tree

Mathematical models built for the relationship of biomass and DBH

Four equations were constructed to predict the total green above and below-ground biomass with the DBH for both plantation and natural forest. All four equations (Table 3) are of the form $y = ax^b$ and have a very strong correlation between biomass and diameter, because the correlation coefficients of all four equations were higher than 0.95.

Table 3: List of allometric equations applied to estimate biomass of the *M.cajuputi* forests in the Lower U Minh National Park, Vietnam.

Type of forest	Allometric equation	R^2
Natural forest	$W_{above} = 0.1412 DBH^{2.4369}$ (1)	0.9957
	$W_{below} = 0.0079 DBH^{2.7318}$ (2)	0.9817
Plantation forest	$W_{above} = 0.3457 DBH^{2.127}$ (3)	0.9488
	$W_{below} = 0.0083 DBH^{2.7328}$ (4)	0.9649

***Where:** Wabove = above-ground biomass (kg/tree), Wbelow = below-ground biomass (kg/tree), DBH = diameter at breast height (cm)*

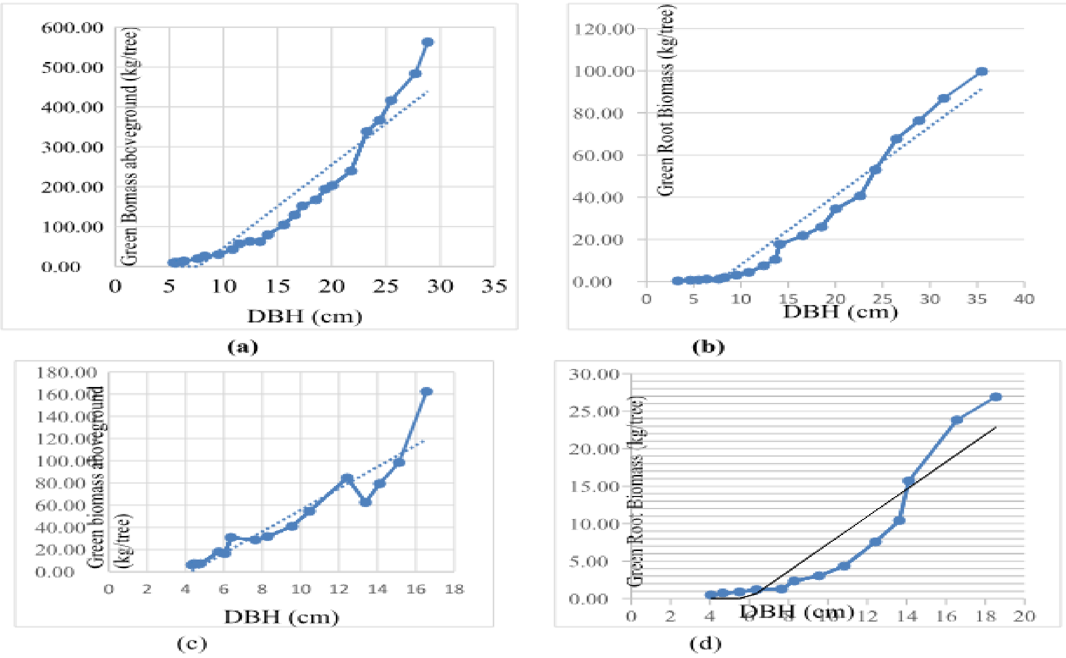


Fig 4: Relationship between observed values results of biomass predicting equation, natural forest, above-ground biomass (a) and plantation forest (c); Relationship between observed values results of biomass predicting equation, natural forest, below-ground biomass (b) and plantation forest (d).

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 because the average error in planted forest was 5.51% and in natural forest it was 4.86%. This value was still acceptable in the forestry sector.

The above and below- ground biomass of M. cajuputi populations

In order to determine above and below-ground green biomass of *M. cajuputi*populations between diameter classes, the equations developed as this study were used between DBH coupling with stand density in each class. The results showed that natural *M. cajuputi* forests at the time of study, provided 99.56 tons/ha of above-ground green biomass equivalent to 60.03 tons/ha of dry biomass and 14.09 tons/ha of green below-ground biomass equivalent to 8.49 tons/ha of dry below-ground biomass. Meanwhile, the above-ground biomass of plantation forests was 250.20 tons/ha, equivalent to 163.38 tons/ha of dry biomass and below-ground biomass was 24.16 tons/ha, equivalent to 15.78 tons/ha of dry biomass. In general, in the same acreage unit, the biomass of plantation forest was 2.51 times higher than the biomass of natural *M. cajuputi* forests, and due to the high tree density of plantation forest was 12 times thicker than natural forest. Results of T-test analyses showed that there were a significant difference about above ground green biomass (as well as below ground) between natural and plantation forests in 95% confidence level (Fig 5). The total green biomass of the natural *M. cajuputi*population was 209,622.88 tons (126,382.40 tons dry biomass) and the total green biomass of plantation forest was 1,555,311.17 tons (1,015,634.75 tons of dry biomass). The total green biomass for the two forest types was 1,764,934.05 tons (1,142,017.15 tons of dry biomass) (Table 4).

Table 4: Estimated the total biomass of *M.cajuputi* forests

Kind of forest	**Green biomass**	**Tree/ha**	**Green biomass (tons/ha)**	**Green biomass total (tons)**	**Dry biomass (tons/ha)**	**Dry biomass total (tons)**
Natural forest	Above-ground	528.65	99.56	183,634.44	60.03	110,722.93
	Below-ground	528.65	14.09	25,988.44	8.49	15,659.47
	Total	528.65	113.65	**209,622.88**	68.52	**126,382.40**
Plantation of forest	Above-ground	6,312.12	250.20	1,418,351.27	163.38	926,179.98
	Below-ground	6,312.12	24.16	136,959.90	15.78	89,454.77
	Total	6,312.12	274.36	**1,555,311.17**	179.16	**1,015,634.75**
Total				**1,764,934.05**		**1,142,017.15**

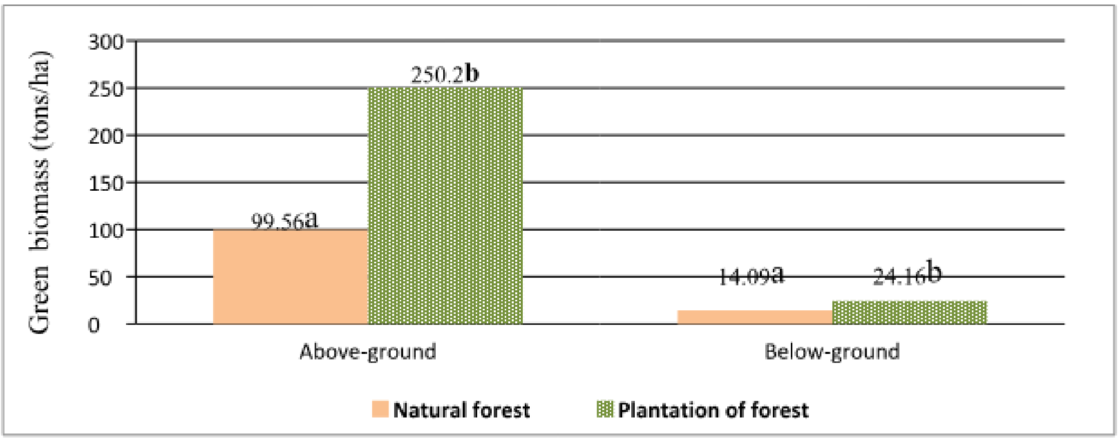


Fig 5: Difference of green biomass between natural and plantation forest

Carbon content and CO_2 storage in the M.cajuputi populations

The total amount of carbon was calculated based on the total of aboveground dry biomass. Carbon accumulation in below ground biomass of *M. cajuputi* was calculated from the dry biomass of the roots. The weight of carbon in the roots was calculated based on equation of Meine Van Noordwijk (2007): Wcarbon =0.46 x Wroot dry biomass (tons/ha). Results of the carbon content and CO_2 storage in the Lower U Minh National Park are showed in table 5.

Table 5: The carbon content and CO_2 storage in the Lower U Minh National Park.

Kind of forest		Carbon (tons/ha)	Carbon (tons)	CO_2 (tons/ha)	CO_2 (tons)
Natural forest	Above-ground	27.61	50,925.54	101.33	186,899.13
	Below-ground	3.38	6,334.27	12.40	22,871.30
Plantation forest	Above-ground	75.15	426,015.58	275.80	1,563,474.35
	Below-ground	6.22	35,260.37	22.83	129,420.30
Total			**518,535.76**		**1,902,665.08**

For the natural *M. cajuputi* forests, the average carbon content above-ground was 27.61 (tons C/ha), below-ground was 3.38 (tonsC/ha), while the above-ground carbon content in plantations was 75.15 (tonsC/ha), and below-ground was 6.22 (tonsC/ha) (Table 5). There was a large difference in carbon content between plantations and natural forests, due to the fact that the plantation forest had a high density of *M. cajuputi* trees, leading to the average carbon content in plantations being 2.72 times higher than the carbon content of natural 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 National Park was estimated 518,535.76tons. Of this, the above-ground cumulative carbon in natural and plantation forests was 50,925.54 tons and 426,015.58 tons respectively; The below-ground was 6,334.27 tons for natural forest and 35,260.37tons for plantation forests.

Based on the carbon content data, the CO_2 content of the *M. cajuputi* population was estimated through the carbon conversion factor of 3.67. In natural forests, the total CO_2 concentration of above-ground *M. cajuputi* population was 101.33 tons/ha, the roots was 12.40 tons/ha, the plantation forest was 275.80 tonsCO_2/ha above-ground, and the roots was 22.83 tonsCO_2/ha.

The total of CO_2 absorption capacity of *M. cajuputi* populations in the Lower U Minh National Park was 1,902,665.08 tons. Of this, natural forests were (186,899.13 tons CO_2 above-ground biomass+ 22,871.30 tonsCO_2 below-ground); and plantations forest were (1,563,474.35 tons CO_2 above-ground + 129,420.30 tons CO_2 below-ground) (Table 5).

Estimate the cost of CO_2

Scientists are today certain that up to 90 percent of climate change is man-made through the massive emissions caused by industrialization. The question now is whether we should consider a highly effective solution for improving the environment? Global carbon prices are a solution many economists support in terms of its effectiveness. According to the European carbon market in 2017, the cost of 1 ton of CO_2 was around €6. The price of 1,902,665.08tons CO_2 storage in the Lower U Minh National Park is €11,415,990.48.

A new report today by analysts Reuters Thomson Point Carbon estimates that by 2020, the reforms could nudge carbon prices up to €20 per ton. The price of CO_2 of the Lowe U Minh National Park will be €38,053,301.6.

IV DISCUSSION

The law of natural forest development, especially for woody plants, their growth and development depends very much on the interrelationship within a certain nutrient space. In general, forest tree density decreases with age due to competition of nutrient space while DBH and stem height increase over time. On the other hand, light-loving plants generally have a tendency to develop foliage under permissible spatial conditions. Therefore, at the same age, the ratio of above-ground biomass components is highly dependent on the density of forest trees. At high densities, the ratio of stem biomass will be high and low leaf, branches biomass (due to narrow nutrient space). In contrast, in the lower density, the proportion of branches will be higher and the biomass of these components will be higher, and the ratio of stem biomass will be lower (due to the wider nutrient space). Understanding the biomass structure of forest trees , it will be easy to make plan measures for forest business. Depending on the mark of the product can adjust the density of forest trees to achieve the highest biomass product.

Plant plays an important role in an ecosystem and biomass of plant strongly affects structure and function of ecosystem. Determination of above-ground biomass (AGB) is an important step in planning the protection and sustainable use of forest resources. Biomass determination can be done in a direct way, by cutting and weighing all the plants in sample areas. This requires considerable effort and time, destroys the vegetation in these areas and, in some situations, is not desirable or may even be illegal. Therefore, the application of correlative equations in predicting biomass by measuring stem diameter with permissible errors, this is the work of practical significant. This has also been applied in many biomass research works at home and abroad [11]; [20]; [12].

This study therefore developed accurate, predictive equations for determination of *M. cajuputi* and mangrove tree weights based on stem DBH so that within is not required for future estimations. These equations act as a useful tool for rapid estimation of above-ground biomass of *M. cajuputi* in Vietnam. In general, the average biomass difference between the actual value and the simulated value of *M. cajuputi* mostly negative and is less than 10%. In the forestry sector, the normal level of error allowed in the stand is about 10%. It is therefore expected that the biomass predictions of *M. cajuputi* trees based on DBH is a good method for rapid assessment of the biomass of Lower U Minh National Park *M. cajuputi* forests.

The results showed that in the same DBH class, green biomass and dry biomass of individual *M. cajuputi* grown on peatland was higher than that of individual *M. cajuputi* grown in clay soil in the Lower U Minh National Park. Further the biomass difference between *M. cajuputi* tree growing on peat soil and growing on clay soil is statistically significant at 95% confidence level. On both types of soil, the biomass of the parts (green and dried) of the stems, branches and leaves were increasing with DBH classes and great fluctuations. Different soil types also have an effect on total biomass (green and dry) and woody productivity of *M. cajuputi* forest. The reason of this biomass difference is that peatland has a deeper soil layer, better moisturizing keeping, especially in the dry season. In contrast, the total average biomass (gree and dry) on peatland was lower than that of on clay due to differences in forest density. The above facts were also observed by Le (2005). Further, 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. Similarly, compared to total dry biomass (100%), The average percentage of dry stems biomass, dry branches biomass and dry leaves biomass were 77.4%, 14.1% and 8.5%, respectively [16]. This showed that the results of the present study were similar to the findings of Quy (2010).

It is obvious that forest density has an impact on its carbon storage potential. The results of the present study are similar with the study conducted by Toan (2017) who found that the average carbon storage in plantation forest which was 27.54 ± 4.12 tons/ha [17] and with the study of Dan (2014) on natural forest on peatland in the upper U Minh (> 10 years) that ranged from 25.64 to 35.07 tonsC/ha [5].

However, carbon stocks of *M. cajuputi* forests are generally considered to be low, i.e., about 27.8 tC/ha estimated by Australian Government Office [14]. However, Tran (2013b) suggested that this has been grossly under-estimated and that *M. cajuputi* forests grown on peatland soils in Vietnam, Indonesia and Malaysia are likely to have slightly high potential for carbon sequestration [18]. The carbon densities of stands of the various *M. cajuputi* forests types in Southern Vietnam were 110.67, 44.27, 22.79, 48.25, and 37.20 tC/ha for primary *M. cajuputi* forests grown on sandy soil, regenerating *M.cajuputi* forests grown on sandy soil, degraded secondary *M. cajuputi* forests grown on clay soil with peatland, regenerating *M. cajuputi* forests grown on clay soil with peatland, and regenerating *M. cajuputi* forests grown on clay soil without peatlandrepectively [19].

V 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 the 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.

On both peatland and acid soils DBH distributions was wider as the tree age increases. The average density of *M. cajuputi* forests grown on peatland is lower than that of acid sulphate soil; the average DBH of *M. cajuputi* forests grown on peatland is significantly higher than that of acid sulphate soils; The average tree height of *M. cajuputi* forests grown on peatland is higher than that of *M. cajuputi* grown on acid soil.

The equations relating biomass and stem DBH of *M. cajuputi* trees for above-ground biomass and below-ground biomass used the general form of $y = ax^b$ and all four equations had coefficient of determinations (R^2) > 0.95. Total green biomass and total dry biomass are closely related to each other via dry/green factor. Dry biomass ratio per green biomass of natural forest is 0.60 and 0.65 for plantation forest. The biomass structure of the parts of individual tree is in the following order: stems > branches > leaves.

The green biomass of the individual *M. cajuputi* trees in natural forest (169.79 kg/tree) is higher in plantation forests (64.68 kg/tree). However, the density of *M. cajuputi* plantation is much higher than (12 times) that of natural forests. Therefore, the total of above-ground biomass of planted forest is larger than 2.5 times that of natural forest.

The amount of CO_2 storage in the natural *M. cajuputi* forests is also lower by 2.72 times that of plantation *M.cajuputi* forest. The amount of carbon accumulated in *M.cajuputi* population of the Lower U Minh National Park was 518,469.76 tons (56.18 tonsC/ha), equivalent to 1,902,784.03 tons of CO_2 (206.2 tonsCO_2/ha).

It was evident that if forest destruction occurs due to fire or human exploitation for many purposes leads to the decline of biomass and CO_2 storage in the forest areas. In order to enhance the level of biomass, and subseqent carbon storage within *M.cajuputi* forests in the Lower U Minh National Park, efforts to protect the forest will be conducted. Protection and restoration of the forest is important for climate change mitigation strategies and will also confer considerable economic benefits to Ca Mau province. The results in this research provide further scientific information to support better *M.cajuputi* ecosystems management. The results should help policy makers make better decisions in an era of global change.

REFERENCES

[1]. Brown, S., 1996. Tropical forests and the global carbon cycle: estimating state and change in biomass density. Pages 135-144 in M. Apps and D. Price (eds.), The role of forest ecosystems and forest management in the global carbon cycle. NATO Series. Springer Verlag. NY.

[2]. Brown, S., 1997. Estimating Biomass and Biomass Change of Tropical Forests: a Primer. For the Food and Agriculture Organization of the United Nations. Rome, 1997. FAO Forestry Paper – 134. ISBN 92-5-103955-0.

[3]. Chung, D.H., 2010. Research of the rapid assessment of carbon accumulation on the ground of the vegetation in Tay Nguyen.

[4]. Da, T.B., 2015. An assessment of the carbon stocks and sodicity tolerance of disturbed Melaleuca forests in Southern Vietnam. Carbon Balance Manage (2015) 10:15 DOI 10.1186/s13021-015-0025-6.

[5]. Dan, T.H., Xuan, Q.T., and Tho, T.T., 2014. The assessment of carbon accumulation of Melaleuca forest on peat soil at U Minh Thuong National Park. Journal of Can Tho University. 30 (2014), 105-114.

[6]. Ha, N.T., 2007. Research of biomass, as a basis for determining the ability of absorb CO_2 of *Acacia auriculiformis x A.mangium* in the 9 th District, Ho Chi Minh City. Master theses Agricultural Sciences, University of Agriculture and Forestry, Ho Chi Minh City.

[7]. Hai, V.D., 2009.Research carbon absorption capacity of eucalyptus planted forest. Journal of Agricultural and Rural Development, 1(2009).

[8]. IPCC, 2000. Special Report on Emissions Scenarios-IPCC:http://www.ipcc.ch/ipccreports/sres/emission/index.php?idp=0

[9]. IPCC, 2007a. Forest and Climate Change 2007: https://www.ipcc.ch/pdf/assessment-report/ar4/wg3/ar4-wg3-chapter9.pdf

[10]. IPCC, 2007d. Summary for policymakers, In: Climate change 2007: The Physical Science Basic. Contribution of working group 1 to the fourth Assessment report of the Intergovernmental Panel on Climate Change, 2007. B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds) Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[11]. Komiyama, A., Ong, J.E. and Poungparn, S., 2008. Allometry biomass and productivity of mangrove forests. *Journal of Aquatic Botany*, 89: 128-137.

[12]. Le, M.L., 2005. Evaluation of biomass and effect of submergence depth on growth of Melaleuca planting on peatsoil and acid sulfate soil in the Lower U Minh National Park, in Ca Mau province. Master thesis, University of Can Tho.

[13]. Meine Van Noordwijk., 2007. Rapid Carbon Stock Appraisal (RaCSA). ICRAF, Bogor, Indonesia.

[14]. MIG, 2008. Australia's State of the Forests Report: Five-yearly report 2008, in: Biotext Canberra (Ed.). Montreal Process Implementation Group for Australia, Bureau of Rural Sciences, Canberra.

[15]. Pham. T. D and Vu. D. H., 2014. Biomass and the energy value of Melaleuca forest in Long An, Vietnam. Journal KHLN 2/2014 (3318 - 3323); Institute KHLNVN – VAFS, ISSN: 1859 – 0373.

[16]. Quy, P.X., 2010. The Building prediction models of the *Melaleuca* forests biomass in the Southwest of Vietnam. *Journal of Agriculture and Rural Development*, 5: 36-46.

[17]. Toan, N.K, and Nam, V.N., 2017. Carbon stocks of Melaleuca forest (Melaleucacajuputi Powell) at Soc Trang Forest Company, Soc Trang province, Journal of Forests and Environment, No 81 + 82/2017, p. 31-35.
[18]. Tran, D.B., Dargusch, P., Moss, P. and Hoang, T.V., 2013b. An assessment of potential responses of *Melaleuca* genus to global climate change. *Mitigation and Adaptation Strategies for Global Change*, 18: 851-867.
[19]. Tran, D. B and et al., 2015. An assessment of the carbon stocks and sodicity tolerance of disturbed *Melaleuca* forests in Southern Vietnam. *Journal of Carbon Balance and Management* (2015) 10:15. DOI 10.1186/s13021-015-0025-6.
[20]. Van, T.K., Rayachhetry, B.M., and Center, D.T., 2000. Estimating Above-ground Biomass of Melaleucaquinquenerviain Florida, USA. J. Aquat. Plant Manage.38: 62-67.

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