JMHT Vol. XIX, (1): 1–10, April 2013
EISSN: 2089-2063
DOI: 10.7226/jtfm.19.1.1

Scientific Article
ISSN: 2087-0469

Biomass Distribution of Cajuput Stand in Central Kalimantan Swamp Forest

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Received April 5, 2012/Accepted January 18, 2013

Abstract

In Central Kalimantan, cajuput (Melaleuca cajuputi subsp. cumingiana) mostly can be found in the riptide swamp area. The present research was intended to determine the distribution of biomass based on the part of tree, position to the ground surface, growing stage, and allometric equation models to estimate the prospective of biomass in 2 different locations (A and B). The A and B locations were characterized by type B riptide peat swamp forest (high tide effected with peat thickness of 51–100 cm) and type C riptide peat swamp forest (tide unaffected shallow soil of < 50 cm with peat thickness of 101–200 cm), respectively. The distribution of cajuput biomass based on the part of tree, position to the ground surface, and growing stage in both locations indicated a similar pattern. Stem contained the highest biomass followed successively by that of root, branch, leave, fruit, and flower. Biomass above the ground was also higher than that of below the ground. Furthermore, biomass content of poles was the highest, followed successively by that of sapling, tree, and seedling. Allometric equation models used to estimate biomass of the A location in the state of green, air dry, and oven dry were $0.335D^{2,35}$, $0.143D^{2,42}$, *and* $0.128D^{2,41}$, *respectively. While those in the B location for green, air dry, and oven dry state were* $0.279D^{2,48}$, $0.127D^{2,58}$, *and* $0.114D^{2,56}$, *respectively. The potential of biomass in the A and B location were 144,100 and 127,212 ton* ha^{-1}, *respectively.*

Keywords: cajuput, distribution, biomass, allometric, swamp

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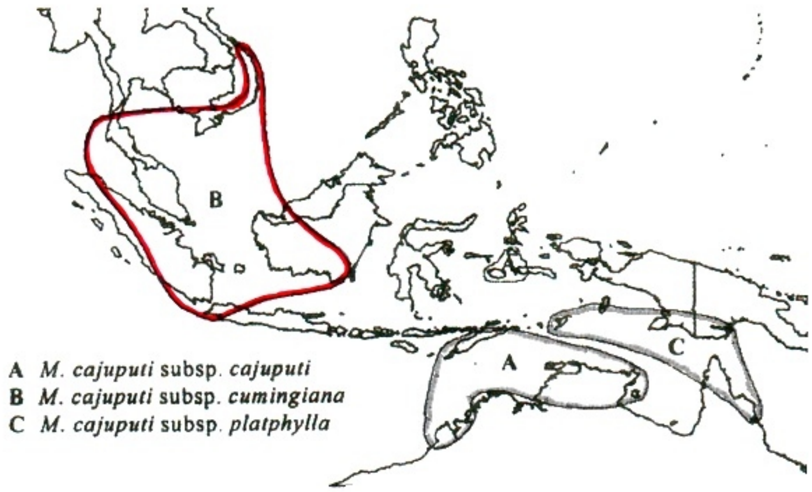
Introduction

Cajuput (*Melaleuca cajuputi subsp. cumingiana*) tree, a species of Myrtaceae family, predominantly grows in riptide swamp area. It is very tolerant and readily grows in highly acidic and saline water logged area and it is commonly found grouping in South and Central Kalimantan (Rachmanady *et al*. 2003). Cajuput other names include swamp tea-tree, *kayu putih* (Indonesia), *kayu putih* or *gelam* (Malaysia), *samet-kao* (Thailand), and *c(aa)ytr(af)m* (Vietnam) (Oyen & Dung 1999) and in South East Asia, its common growing niche includes the area of Western Indonesia (Sumatera, West Java, South Kalimantan), Malaysia, Myanmar, Thailand and Vietnam (Rimbawan & Susanto 2004). Figure 1 indicates the cajuput distribution map. In South-Kalimantan and Sumatera the wood has been mostly utilized for construction material. It is also commercially utilized for firewood, charcoal, pulp, and sawn timber (Chokkalingam *et al*. 2004). In Central Kalimantan, cajuput naturally grows in the disastrous and abandoned land of the former one million Peat Area Development Project (PAD) (Poniman *et al*. 2006). Peat swamp forest is an immense carbon stock area and it is an important element of global carbon cycle (Rochmayanto *et al*. 2010). Due to its important role in forest management, study on the potential of forest based on the biomass quantity is paramount (Pamoengkas *et al*. 2000). The report of the Watershed Management Unit (WMU) Kahayan (2007) and the result of a previously conducted survey in the research areas indicated that cajuput was considered a prospective biomass in riptide swamp area of the former PAD project. These were the basis of the present study on the distribution of cajuput biomass. It was expected that the study would complete the information related to the development of cajuput biomass utilization, either from economy and ecology point of view.

The present research was intended to calculate the percent distribution of biomass based on stem division (root, branch, twig, leave, flower, and fruit), relative position to the ground (above the ground and below the ground), growing stage (seedling, sapling, pole, and tree), and allometric equation to estimate the biomass potential (green, air dry, and oven dry) of the cajuput stand in two different locations. Location A and B were respectively characterized by the influence of high tide with the peat thickness of 51–100 cm and tide unaffected shallow soil (<50 cm thickness) with peat thickness of 101–200 cm.

Methods

The present study was carried out in the area of 162,278 ha of the D block of previous PAD project (WMU Kahayan 2007). The block is located between Kahayan River and Kapuas River. The site was distinguished into 2 locations, i.e. location A that was type B riptide swamp (affected by high tide) with shallow peat thickness positioned at S 02°50.355'–S 02°50.520'; E 114°20.383'–E



Source: Rimbawan & Susanto (2004)

Figure 1 Distribution map of *Melaleuca cajuputi* subsp. *cumingiana* (B).

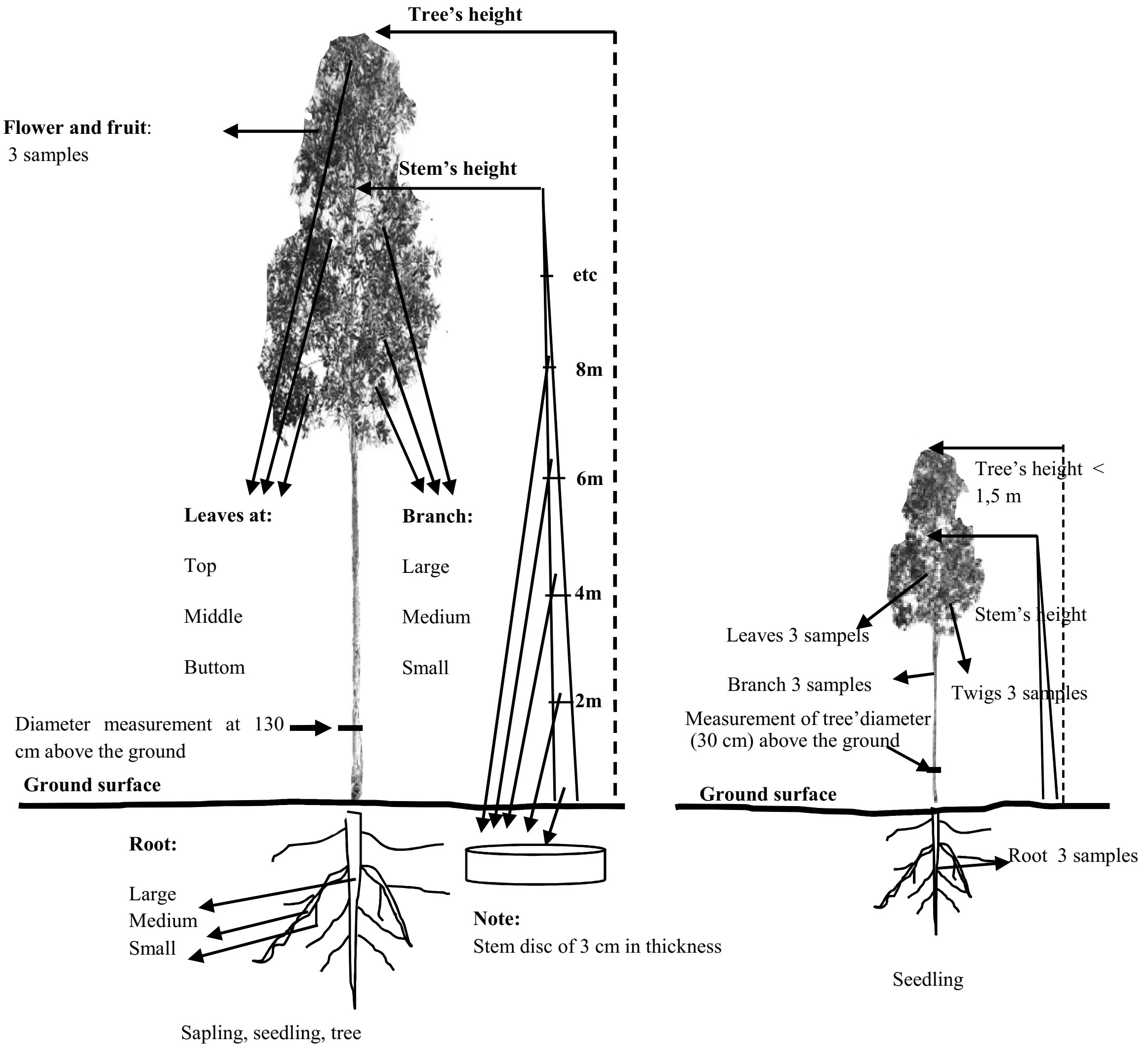


Figure 2 Samples procurement for laboratory testing (measurement of green, air dry, and oven dry moisture content and weight of biomass).

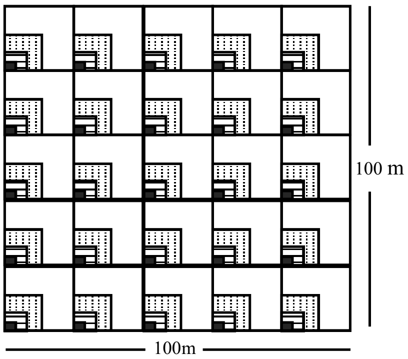


Figure 3 Singel plot method in studying the vegetation of forest stand (Soerianegara & Indrawan 2005). □ 20×20 m^2: trees (25 plots), ▦ 10×10m^2: poles (25 plots), ◼ 5×5m^2: sapling (25 plots), ■ 2×2m^2: seedling (25 plots).

114°20.544', and location B was type C riptide swamp, tide unaffected shallow soil (< 50 cm) with medium peat thickness positioned at S 02°49.369'–S 02°49.627'; E 114°17.462'–E 114°18.109'. These locations were preferred due to the area was dominated by cajuput stand and it was in accordance with the proposed research criteria.

The inventory of cajuput stand potential in the A and B locations was carried out using the method of single plot (Figure 3) in the D block of the former PAD project. The area of every location of the A and B was 5 ha. Figure 3 indicates survey activities in the area of 1 ha. The survey area of every location (A and B) was 5 ha. Therefore, the total number of studied for seedling, sapling, poles and tree was 25 plots × 5 = 125 plots. The diameter and number of tree were the measured variables.

Sample trees The sample of trees was selected based on its growing stage, i.e. seedling (plant with < 1.5 cm in height), sapling (tree with > 1.5 cm in height and < 10 cm in diameter), pole (tree with the diameter of >10 cm ≤ 20 cm), and tree (tree with the diameter > 20 cm) (Soerianegara & Indrawan 2005). The number of seedling collected was 4 samples and 5 samples each for sapling, pole, and tree. Samples from the locations of A and B were the same in number, measured tree diameter and stem appearance (tree with relatively upright stem).

Samples procurement Seedling and sapling were acquired by destructive sampling method. Sampling area was cleared and the soil around the base of the samples was carefully excavated in order not to break the root. Seedling and sapling were then carefully pulled out. At first, the leaves, fruits, and flowers were procured, accumulated, and weighed. The branch and the stem was cut with knife or handsaw, accumulated, and weighed. In the A location, the root was cleaned and washed with water pump, and in the B location root was just carefully cleaned and then both groups of samples were cut, accumulated and weighed. The samples of pole and tree were procured in similar methods to these of seedling and sapling, except that they were fell down by the use of steel wire pulled out by 3 ton capacity habegge that fastened in a big and sturdy adjacent tree. After felling of the trees, leaves, fruits, flowers, branches, stem, and root were procured, accumulated, and weighed. The root was pulled out by the use of the habegge. The nature of peat structure was found very helpful in pulling out the roots. The roots from the A location were cleaned and washed with water pump and the root from the B location were just carefully cleaned before cutting, procuring, and weighing. Total weight of biomass samples were measured based on their fresh/green weight.

Laboratory samples preparation Samples for laboratory measurements were grouped based on the growing stage of tree, i.e. the stage of seedling, sapling, pole, and tree. Samples were collected in the form of leaves, flowers, fruits, chips, and wood disc. Figure 2 exemplify the method of samples procurement for laboratory testing. The green weight of every sample type was weighed in the felling site. The green weight is used to determine the moisture content of samples. Air dry moisture content was determined after exposing the samples indoor at 22.3–33.6 °C for a month (Government of Central Kalimantan Province 2006). Air dry and oven dry moisture content of samples was calculated based on ASTM D2016 standard procedure. Green and oven dried weight of biomass were calculated based on the following equations (Bowyer *et al.* 2003):

$$ODW = \frac{GW}{\left(1 + \frac{MC_G}{100}\right)} \qquad [1]$$

$$ADW = ODW \times \left(1 + \frac{MC_{AD}}{100}\right) \qquad [2]$$

note:
OD = oven dried weight
ADW= air dried weight
GW = green weight
MC_G = green moisture content
MC_{AD} = air dried moisture

Allometric equation models Allometric equation model *[3]* was formulated based on the diameter of tree. The resulting model was then applied to the data obtained from the inventory activities of cajuput stand. Estimation of biomass in green, air dry, and oven dry conditions was carried out by the application of SPSS 12 program.

$$Y = aX^b \qquad [3]$$

note:
Y = biomass of cajuput
X = diameter at breast height (Dbh) of sapling, pole, and tree (diameter of seedling was measured at 30 cm above the ground)
a, b = coefficient

Results and Discussion

Description of cajuput tree samples Measured parameters of sample trees of the A and B locations are listed in Table 1. The average height of cajuput grown in location B was 10.896 m. It was higher than that grown in location A (9.967

m). The average values of crown height, crown diameter, root depth, and root diameter of trees in both locations (A and B) were relatively the same.

Biomass distribution of cajuput Biomass composition in the stem division of the trees was difference. Brown *et al.* (1986) also found that biomass of tree was tended to vary among the tree's component. Table 2 indicates the percentage and weight distribution of cajuput biomass in location A and B. The pattern of biomass percentage distribution of tree from location A and B was found to be the

Table 1 Measured parameters of cajuput sample trees in A and B locations

Location A (cm)							
Stage of growth	KP	ØP	TP	TT	ØT	DA	ØA
Seedling	0.63	0.20	70.00	32.83	9.85	9.97	9.37
	1.26	0.40	112.00	38.57	12.67	12.90	11.58
	1.89	0.60	129.00	39.67	13.62	14.80	14.23
	2.51	0.80	146.00	49.53	16.47	19.23	18.13
Poles	4.50	1.43	288.63	134.50	59.50	42.50	65.00
	9.50	3.02	715.00	250.00	100.00	40.00	80.00
	13.00	4.14	872.00	300.00	150.00	55.00	90.00
	19.00	6.05	1020.00	400.00	170.00	75.00	110.00
Saplings	26.00	8.28	1050.00	400.00	180.00	80.00	150.00
	32.00	10.19	1071.00	406.00	238.00	85.00	180.00
	38.00	12.10	1173.00	553.00	243.00	90.00	200.00
	44.00	14.01	1289.00	570.00	250.00	95.00	215.00
	50.00	15.92	1341.00	575.00	332.00	98.00	240.00
	56.00	17.83	1343.00	600.00	358.00	99.00	248.00
Tree	63.00	20.05	1347.00	634.00	379.00	100.00	270.00
	75.00	23.87	1490.00	800.00	386.00	115.00	275.00
	83.00	26.42	1750.00	820.00	570.00	118.00	304.00
	94.00	29.92	1850.00	850.00	600.00	133.00	327.00
	100.00	31.83	1880.00	800.00	600.00	139.00	353.00
Total	713.29	227.06	18936.63	8253.10	4668.11	1421.40	3160.31
Average	37.54	11.95	996.67	434.37	245.69	74.81	166.33

Location B (cm)							
Stage of growth	KP	ØP	TP	TT	ØT	DA	ØA
Seedling	0.63	0.20	62.00	29.08	8.07	9.05	7.97
	1.26	0.40	106.00	43.33	12.17	15.50	11.83
	1.89	0.60	131.00	51.30	15.37	19.33	14.52
	2.51	0.80	144.00	53.67	18.90	21.73	18.90
Poles	4.50	1.43	331.75	136.00	62.00	54.00	61.25
	9.50	3.02	622.00	250.00	90.00	70.00	100.00
	13.00	4.14	780.00	270.00	100.00	80.00	110.00
	19.00	6.05	1100.00	300.00	120.00	80.00	120.00
	26.00	8.28	1190.00	350.00	155.00	80.00	130.00
Sapling	32.00	10.19	1370.00	530.00	220.00	90.00	170.00
	38.00	12.10	1430.00	550.00	250.00	90.00	200.00
	44.00	14.01	1450.00	560.00	300.00	100.00	220.00
	50.00	15.92	1460.00	580.00	330.00	100.00	230.00
	56.00	17.83	1620.00	660.00	340.00	110.00	235.00
Tree	63.00	20.05	1650.00	670.00	350.00	110.00	250.00
	75.00	23.87	1720.00	690.00	400.00	130.00	250.00
	83.00	26.42	1740.00	720.00	430.00	135.00	260.00
	94.00	29.92	1850.00	770.00	450.00	140.00	300.00
	100.00	31.83	1945.00	795.00	450.00	140.00	320.00
Total	713.29	227.06	20701.75	8008.38	4101.51	1574.61	3009.47
Average	37.54	11.95	1089.57	421.49	215.87	82.87	158.39

KP: tree's perimeter ; ØP: diameter at breast height (Dbh) for sapling, poles, and tree, diameter at 30 cm above the ground of seedling; TP: the height of tree (cm) ; PB: the length of free branch stem; TT: the height of crown; ØT: the diameter of crown ; DA: the depth of root; ØA: the diameter of root.

same. Table 2 indicates that the distribution of biomass percentage, successively from the highest to the lowest, was found at the stem, root, branch, leaves, fruit, and flower. Table 3 indicates a similar distribution between oven dried biomass in the A and B locations, i.e. successively from the highest to the lowest was at the stem, root, branch, leaves, fruit, and flower. The present findings were different with the results of previous works on *Acacia mangium* carried out by Elias *et al.* (2010). The authors reported that the percentage distribution of biomass, successively from the highest to the lowest, was at stem division (51.84%), leaves (17.79%), branch/twigs (16.96%), and root (13.36%). Heriyanto and Siregar (2007) found that in 5 years old pine tree, the highest percentage of biomass was in the stem (42.15%), successively followed by leaves (23.45%), branch/twigs (21.98%), and root (12.42%). Elias *et al.* (2010) and Heriyanto and Siregar (2007) explained that leave biomass was the second in the amount after that of the branches. The present result indicated that leaves biomass was the fourth in amount after that of the branches. Lower leave biomass of cajuput was thought due to its less expansive crown diameter, relatively less branching, and con-shaped crown (Table 1, Figure 4, and Figure 5). Distribution pattern of cajuput biomass was comparable to that of juvenile scots pine with the biomass percentage of branches, twigs, leaves and root was 33.90, 25.00, 22.00, and 19.10%, respectively (Xiao & Ceulemans 2004). The present finding indicated that the amount of root biomass was the second after that of the branch, while Xiao and Ceulemans (2004) reported that the amount of root biomass was fourth after that of the leave.

Biomass can also be classified into the above and below the ground biomass. Table 3 indicates that oven dried biomass of cajuput in both locations showing a similar percentage distribution, in which the percentage of above the ground biomass was higher than that of below the ground. These results are in agreement to these found by Siregar (2007b) for 6 age classes of pine, i.e. at the age of 1, 4, 5, 11, 19, and 24 years with above the ground biomass of 86.67, 87.88, 83.98, 84.25, 83.52, and 83.77%, respectively, and below the ground of 13.33, 12.12, 16.02, 15.75, 16.48, and 16.23%, respectively. Furthermore, Siregar (2007a) found that above the ground and below the ground biomass of sengon with the dbh diameter in the range of 16.6–31.2 cm was 87.32 and 12.68%, respectively.

Allometric relationship among plant divisions can be explained by the formula of $Y = aX^b$, in which Y is dependent variables, X is independent variables, and a,b are constant (Purwanto & Shiba 2005). Allometric equation can be used to correlate between tree's diameter and other variables such

Table 2 The distribution of percentage and weight (kg) of green, air dry and oven dry of the biomass based on the part of tree

Description	Root	Stem	Branch	Leave	Flower	Fruit	Total
Total weight of green biomass A	1422.189	2574.635	867.502	93.010	12.770	30.600	5000.707
Percentage of green biomass A	28.440	51.485	17.348	1.860	0.255	0.612	100.000
Total weight of green biomass B	1480.617	3023.342	856.906	163.841	0.920	11.030	5536.655
Percentage of green biomass B	26.742	54.606	15.477	2.959	0.017	0.199	100.000
Total weight of air dry biomass A	602.475	1587.940	487.746	35.567	4.127	17.816	2735.670
Percentage of air dry biomass A	22.023	58.046	17.829	1.300	0.151	0.651	100.000
Total weight of air dry biomass B	739.040	2123.834	490.888	63.230	0.317	10.063	3427.373
Percentage of air dry biomass B	21.563	61.967	14.323	1.845	0.009	0.294	100.000
Total weight of oven dry biomass A	526.768	1368.562	425.586	32.073	3.671	15.650	2372.308
Percentage of oven dry biomass A	22.205	57.689	17.940	1.352	0.155	0.660	100.000
Total weight of oven dry biomass B	639.620	1831.344	422.907	56.478	0.271	8.881	2952.502
Percentage of oven dry biomass B	21.612	61.880	14.290	1.908	0.009	0.300	100.000

Table 3 Above and below the ground cajuput biomass distribution of the A and B locations (kg)

Description	Below the ground biomass	Above the ground biomass
Total weight of green biomass A	1422.189	3578.517
Percentage of green biomass A	28.440	71.560
Total weight of green biomass B	1480.617	4056.038
Percentage of green biomass B	26.742	73.258
Total weight of air dry biomass A	602.475	2133.196
Percentage of air dry biomass A	22.023	77.977
Total weight of air dry biomass B	739.040	2680.288
Percentage of air dry biomass B	21.563	78.437
Total weight of oven dry biomass A	526.768	1845.541
Percentage of oven dry biomass A	22.205	77.795
Total weight of oven dry biomass B	639.620	2319.882
Percentage of oven dry biomass B	21.612	78.388

Figure 4 Cajuput stand in the B location.

Figure 5 Cajuput stand in the A location.

Table 4 Total weight of biomass (kg) in the A and B locations

DP	BB A	BB B	BKU A	BKU B	BKT A	BKT B
0.20	0.016	0.007	0.006	0.003	0.006	0.003
0.40	0.034	0.025	0.014	0.010	0.012	0.009
0.60	0.060	0.051	0.025	0.021	0.022	0.019
0.80	0.105	0.093	0.044	0.040	0.038	0.035
1.43	0.892	0.980	0.394	0.462	0.346	0.406
3.02	6.250	5.600	2.830	2.834	2.482	2.475
4.14	9.930	10.890	4.814	5.738	4.218	5.010
6.05	25.210	30.660	12.294	17.407	10.733	15.045
8.28	48.980	61.920	24.334	35.408	21.174	30.562
10.19	70.940	93.060	35.373	53.321	30.764	46.189
12.10	128.900	143.670	64.351	80.886	55.723	69.956
14.01	132.110	200.360	67.899	114.428	58.889	98.955
15.92	236.590	320.040	121.735	188.334	105.351	163.257
17.83	269.450	332.460	140.188	197.840	121.212	170.199
20.05	321.160	412.710	167.995	247.882	145.955	214.562
23.87	631.350	616.080	340.959	375.923	295.821	324.977
26.42	912.950	920.180	508.988	575.799	440.388	497.731
29.92	1116.020	1122.050	620.458	705.389	539.036	611.691
31.83	1089.760	1265.820	622.972	825.646	540.138	708.424
Total	5000.707	5536.655	2735.670	3427.373	2372.308	2959.502

DP: the diameter of tree; BB : green weight; BKU: air dry weight ; BKT: oven dry weight.

as volume, biomass, and carbon stock of forest stands (Martin *et al.* 1998). Equal diameters of the samples tree were chosen from the locations of A and B. The samples were weighed to determine the total weight of biomass based on green, air dry, and oven dry conditions. Biomass data in Table 4 were used to formulate the allometric equation of biomass, and the resulting equations are listed in Table 5.

The resulting data from inventory survey of both locations (A and B) are listed in Table 6. The survey area of every location (A and B) was 5 ha. The higher number of tree in the B location compared to that of the A location was thought due to the effect of forest fire. Santri (2006) found that forest fire in Rawa Lebak Teluk, South Sumatera stimulated seed germination and seedling growth of cajuput stand. Forest fire previously occurred in the B location cleared the forest floor (Figure 4), and this opening prepared an appropriate growing site for the cajuput seedling. On the other hand, the A location is repeatedly influenced by high tide that brought about the forest floor was dominated by bush and weed, thus reduced the growing number of cajuput seedling (Figure 5).

Estimation of biomass potential (Table 7, Table 8, and Table 9) was carried out by the application of the resulting allometric equations (Table 6) to the data from the inventory survey of locations A and B. Coefficient determination (R^2) is a measure of regression line accuracy (Sutaryo 2009). The present research indicated that the R^2 values of allometric equations was in the range of 0.994–0.996 indicating a significant influence of tree diameter on the green, air dry, and oven dry of biomass. R^2 indicates the level of data variability explained by regression model. Northupa *et al.* (2005) found that crown and stem dimension significantly ($p < 0.05$) influenced the content of above the ground biomass, carbon, and nitrogen of 10 bush species of Texas. They found that the R^2 of the regression line was in the range of

Table 5 Allometric equation models used to estimate the weight of cajuput stand biomass in the A and B locations

Relationship	Criteria	Allometric equation
The diameter of tree-green biomass A Biomassa Basah A	R^2 = 0.994	BB = $0.335D^{2.35}$
The diameter of tree-air dry biomass A	R^2 = 0.994	BKU = $0.143D^{2.42}$
The diameter of tree-oven dry biomass A	R^2 = 0.994	BKT = $0.128D^{2.41}$
The diameter of tree-green biomass B	R^2 = 0.996	BB = $0.279D^{2.48}$
The diameter of tree-air dry biomass B	R^2 = 0.996	BKU = $0.127D^{2.58}$
The diameter of tree-oven dry biomass B	R^2 = 0.996	BKT = $0.114D^{2.56}$

BB: green weight; BKU: air dry weight; BKT: oven dry weight.

Table 6 The distribution of cajuput stand data resulted from inventory survey in the A and B locations

Growing stage	Location A			Location B		
	The number of stem ha^{-1}	The average of tree's perimeter (cm)	The average of tree's diameter (cm)	The number of tree ha^{-1}	The average of tree's perimeter (cm)	The average of tree's diameter (cm)
Seedling	14,400	1.600	0.509	23,900	1.165	0.371
Sapling	7,082	13.014	4.141	1,837	18.738	5.962
Poles	1,029	39.450	12.552	944	41.952	13.348
Tree	65	75.036	23.875	70	74.566	23.726
Total	22,575	129.099	41.077	26,751	136.420	43.406
Average		32.275	10.269		34.105	10.852

The diameter of tree (cm) = the perimeter of tree/Л (3.142857); the area of every location (A and B) was 5 ha.

Table 7 Biomass distribution (t ha^{-1}) based on the part of tree

Description	Root	Stem	Branch	Leave	Flower	Fruit	Total
Biomass KT A	28.247	73.387	22.822	1.720	0.197	0.840	127.212
Percentage BKT A	22.205	57.689	17.940	1.352	0.155	0.660	100.000
Biomass BKT B	31.143	89.169	20.592	2.750	0.013	0.432	144.100
Percentage BKT B	21.612	61.880	14.290	1.908	0.009	0.300	100.000

0.77–0.98. The range of R^2 for the allometric equation models of biomass of the low altitude tropical forest of dipterocarp in East Kalimantan (Basuki *et al.* 2009), 11 species of tree in Sudanian savanna forest of West Africa (Sawadogo *et al.* 2010) and organic carbon stock of forest vegetation in Bangladesh (Alamgir & Al-Amin 2008) were 0.963–0.989, 0.700–0.905, and 0.737–0.879, respectively.

Oven dried biomass potential of root, stem, branch, leave, and flower of the A and B locations were listed in Table 7. Data in Table 7 were calculated based on the data of Table 2 and allometric equations in Table 5. It can be seen that the highest biomass potential is obtained from the stem, successively followed by that of the root, branch, leave, flower, and fruit. Biomass potential of the above the ground and below the ground was calculated based on the data of Table 3 and the allometric equations in Table 5. Table 8 indicates that biomass potential above the ground was higher than that of below the ground for both locations. Oven dried biomass of A location was found 127.212 t ha^{-1} similar to that found by Tresnawan & Rosalina (2002) in the log over area**.** These authors found that the biomass potential in the year of 2001 of the area harvested in 2000 and 1998 was 119.129 and 116.676 t ha^{-1}, respectively. The weight of the biomass of every growing stage of cajuput shown in Table 9 was calculated based on the allometric equations (Table 5) and data in Table 6. It can be seen (Table 9) that in both locations, the highest oven dry biomass was in the pole stage followed successively by sapling, tree, and seedling stage. Furthermore, biomass in the B location was found higher than that of in the A location and both was lower than that found in secondary peat swamp natural forest (as high as 166.93 t ha^{-1}) by Rochmayanto *et al.* (2010). Green and air dry weight of biomass are required to calculate oven dry biomass. Information on weight reduction from green to oven dry weight of biomass is important for business sectors in the development and utilization of cajuput related to weight unit such as raw material transportation, calculation of required raw material and production capacity of sawn timber (transportation), charcoal material (renewable energy), and active charcoal (absorbent material). The height of water lodge did not influence the growth of cajuput. On the other hand, Yamanoshita *et. al* (2001) found a

Table 8 The distribution of above and below the ground biomass

Location	Above the ground biomass (t ha^{-1})	Above the ground biomass (%)	Below the ground biomass (t ha^{-1})	Below the ground biomass (%)	Biomass (t ha^{-1})
A	98.965	77.795	28.247	22.205	127.212
B	112.957	78.388	31.143	21.612	144.100

Table 9 Biomass distribution based on the growing stage

Growing stage	Green biomass (t ha^{-1})	Percentage (%)	Air dry biomass (t ha^{-1})	Percentage (%)	Oven dry biomass (t ha^{-1})	Percentage (%)
Location A						
Seedling	1.246	0.434	0.516	0.353	0.463	0.364
Sapling	109.545	38.160	53.908	36.828	47.103	37.027
Poles	137.059	47.745	70.735	48.324	61.368	48.240
Tree	39.217	13.661	21.219	14.496	18.278	14.368
Total	287.068	100.000	146.378	100.000	127.212	100.000
Location B						
Seedling	0.973	0.341	0.424	0.254	0.386	0.268
Sapling	58.504	20.529	32.427	19.441	28.287	19.630
Poles	172.576	60.555	101.196	60.672	87.408	60.658
Tree	52.936	18.575	32.745	19.632	28.019	19.444
Total	284.989	100.000	166.792	100.000	144.100	100.000

tendency that the higher the water lodge the higher was the height growth of cajuput (*Melaleuca cajuputi*).

The difference of biomass between the location of A and B was thought due to forest fire occurred in the B location. Forest fire prepared a better growing space, diminished weeds, and brought about thinning process for seedling and sapling while leaving pole and tree survived, thus resulted in a better stand growth. Frequent forest fire change the land condition of mature swamp forest into fire resistant cajuput dominated forest (Chokkalingam *et al.* 2005; Li 1997). Following forest fire in the B location, more young seedling with smaller diameter than that in the A location was growing. The influence of high tide in the A location prevented forest fire and brought about slower cajuput growing rate due to competition with thick bushes species such as Kalakai (*Stenochlaena palustris*) (Figure 5).

Previous explanation indicates that cajuput will grow better when planted in a better growing space through thinning and maintenance (eliminate weeds). Cajuput (*Melaleuca cajuputi*) can be developed and used in the rehabilitation of peat swamp forest.

Conclusion

Similar pattern of biomass distribution was found in the type B (A location) and type C (B location) riptide peat swamp cajuput forest of Central Kalimantan. Stem contained the highest amount of biomass, successively followed by root, branch, leave, fruit, and flower. Biomass percentage above the ground was also higher than that of below the ground. Furthermore, biomass percentage of pole was the highest, followed successively by that in sapling, tree, and seedling. In the type B riptide peat swamp cajuput forest, allometric equation of green, air dry, and oven dry biomass was BB = $0.335D^{2,35}$, BKU = $0.143D^{2,42}$, and BKT = $0.128D^{2,41}$, respectively. While in the type C riptide peat swamp cajuput forest, allometric equation of green, air dry and oven dry biomass was BB = $0.279D^{2,48}$, BKU = $0.127D^{2,58}$, and BKT = $0.114D^{2,56}$, respectively. The potential of Cajuput stand in the type C and type B riptide peat swamp forest was found as much as 144.100 and 127.212 t ha^{-1}, respectively. This differences was thought to be brought about by forest fire previously occurred in the type C riptide peat swamp forest. Forest fire opened a better growing space, diminished weeds, and brought about thinning process in the seedling and sapling stage leaving pole and tree survived brought about better growth of cajuput stand. Biomass calculation based on growing site, growing stage, tree division, and allometric equations resulted in the present research can be referred for the utilization development of cajuput biomass either from economy and ecological aspects in Indonesia and specifically in Central Kalimantan.

Recomendations

Development of cajuput tree in the types B and C riptide peat swamp area requires maintenance through weed cleaning and thinning to create a better growing space. Prevention of forest fire by fire breaker belt in the type C riptide swamp area should be carried out to avoid burning of the cajuput stand. The biomass prospective and allometric equations resulted from the present study can be referred to estimate the capacity of cajuput stand from ecological aspect, i.e. in absorbing CO_2 and releasing O_2.

Acknowledgement

The authors wish to sincerely acknowledge DIKTI and DP3M of Ministry of National Education who through the LPPM of Gadjah Mada University has funded the present study.

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