

Moisture content, density, and allometric model for estimating above-ground biomass of *Peronema canescens* trees in the private forest

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Abstract. Khan K, Listyanto T, Soraya E. 2022. Moisture content, density, and allometric model for estimating above-ground biomass of *Peronema canescens* trees in the private forest. *Biodiversitas* 23: 1132-1139. The objectives of this study were to quantitatively measure the above-ground biomass (AGB) of *Peronema canescens* Jack species in a private forest in Indonesia using a destructive method and to develop an allometric model for the same. Six trees were sampled for above-ground biomass and their components (stem, branch, and leaves) were weighted and measured. Regression analysis was used for developing the allometric equation by using predictor variables of diameter at breast height (DBH), squared diameter at breast height together with height (DBH²H), and diameter and height separately (D & H). The average AGB of six sampled trees was 0.264 (26.38%) tons per tree. The fit allometric equation $AGB = 0.254(DBH^2H)^{0.886}$ was developed for estimating above-ground biomass of *P. canescens* and it had 99.2% accuracy. The implications and recommendations were provided based on the results of the study.

Keywords: AGB, biomass distribution, Kulon Progo district, harvesting method, private forest, Yogyakarta

INTRODUCTION

In many tropical countries like Indonesia, forest management is still delegated to community and private forests (Meijaard et al. 2020). Security of tenure and well-defined ownership rights play an essential role in sustainable forest management, according to country experiences. Therefore, when forests and trees are maintained sustainably, they benefit people and the environment by boosting livelihoods, providing clean air and water, protecting biodiversity, and dampening climate change effects.

With regards to climate change, quantifying the climate effects towards tree biomass harvesting becomes crucial to determine the impact of this harvesting on the growth of carbon stores at the landscape level (Berndes et al. 2020). Nevertheless, estimating forest biomass at greater scales sometimes involves determining generalized allometric equations in field biomass estimations (Huynh et al. 2021). Even though the destructive method is one of the most precise methods in obtaining biomass among other methods, measuring the total above-ground biomass (AGB) is expensive and time-consuming, particularly for private forests. Moreover, the necessity to estimate the biomass of private forests is inevitably needed since private forests are the type of social forestry that the Indonesian government is using as a strategy to cut carbon dioxide (CO₂) emissions by 26% by 2030 (Askar et al. 2018).

Moisture content (MC) and density are keys to help understanding tree biomass. MC (%) is the total amount of water in a block of wood, while density refers to the total amount of wood. Basic Wood Density (BWD) is mostly used to convert a volume of green lumber into the total

biomass in dry conditions. Both MC and BWD are also primary indicators for other wood characteristics such as mechanical properties and drying properties (Listyanto et al. 2016; Listyanto et al. 2020; Listyanto et al. 2021)

A private forest is that which is planted, maintained, or protected in any private land held by an individual (Kurniawan et al. 2018). Generally, the owners or the local farmers would plant the trees, which have benefits for their economy. For instance, in Indonesia, the most planted trees in their forests are usually the trees that have high commercial value, such as *Peronema canescens* Jack (Lamiaceae), *Tectona grandis* L.f., and *Falcataria moluccana* (Miq.) Barneby & J.W.Grimes). *Peronema canescens* or more well-known as Sungkai tree, is one of the fancy woods which is mostly found in Java, Kalimantan, and Sumatra islands. On the other hand, from 1990 to 1996, this species has grown its popularity in Java Island due to its high values in terms of building materials, furniture, and medical (Hatta 1999).

The objectives of this study were to quantitatively measure the total AGB of *P. canescens* using the destructive method and to develop the allometric model for the Sungkai tree in a private forest of Ngargosari village in Kulon Progo district and to develop an allometric equation to estimate the tree biomass of the tree in the study site.

MATERIALS AND METHODS

Study area

The study site is a private forest located in Kulon Progo district in the Special Region of Yogyakarta, Indonesia. Geographically, Kulon Progo Regency lies on

S 7° 38'42"– 7° 59'3" and E 110° 1'37" – 110° 16'26" (Figure 1) and has a total land area of around 58.627.5 ha. Since 2017, the average annual rainfall has been 2150 mm, with the lowest temperature in July 24.2°C and 25.4°C in April. The elevation of the study area is 600–900 meters above sea level. According to the Office of Environment and Forestry Yogyakarta (2019), the total land of private forest in the DIY province is 149,278.22 m³, while the total land of private forests in Kulon Progo itself is 58,404.37 m³.

Data collection

The destructive method (also called the direct method or harvesting method) was used for measuring the AGB of the trees. A total of six *Peronema canescens* trees were harvested with different diameters (13.2 cm, 18.5 cm, 22.3 cm, 29.1 cm, 30.2 cm and 31.5 cm). Furthermore, the above-ground components of each tree such as stem and branches (≥ 3 cm) volume were measured. Branches with less than 3 cm diameter and leaves were weighted in the field by weighing scale (Germany 25 kg Gold Hanging Weigh Scale, 0.5 kg error sensitivity). Four samples of the stem were collected from each tree at the base, DBH, mid and top point. The Crown of each tree was divided into three parts. Moreover, 250 grams of stem and branch samples were collected from each tree. The Crown of each tree was further divided into three parts and 200 grams of leaves were collected. Fresh samples of the stem, branches, and leaves were dried in the oven at temperature ± 102 °C until the constant dry weight was achieved.

Data analysis

Before finding the biomass of the tree, it was essential to find out the moisture content (MC %) of the samples. The value of MC was used to calculate the water content in the samples. The fresh weight of the sample indicated that

the ratio of water content was high. Moreover, the constant dry weight was determined by seeing the lowest value of moisture content. MC values of the sample were obtained following the formula of Shmulsky and Jones (2018) and Listyanto (2018).

$$MC \% = \frac{Fw - Ow}{Ow} \times 100 \quad [1]$$

Where:

MC : Moisture Content (%)

F_w : Fresh/green weight of sample (g)

O_w : Oven dry weight of sample (g)

Subsequently, the values of moisture content and constant dry weight were used to find out the basic wood density of the Sungkai tree. All the samples of stem and branches samples were also put in the oven for drying. Basic wood density, which is the ratio of oven-dry mass (at 0% moisture) to green volume in g/cm³ was calculated following the formula of Vieilledent et al. (2018), as follows.

$$BWD = \frac{Dw}{Fv} \quad [2]$$

Where:

BWD: Basic wood density (g/cm³)

Dw : Oven dry weight of sample (g)

F_v : Fresh volume of sample (cm³)

Stem and branches (≥ 3 cm) biomass were calculated directly from the volume of wood using a basic wood density. The formula 3 was used to calculate the biomass of stem and branches following Nizami (2012) and Vieilledent et al. (2018).

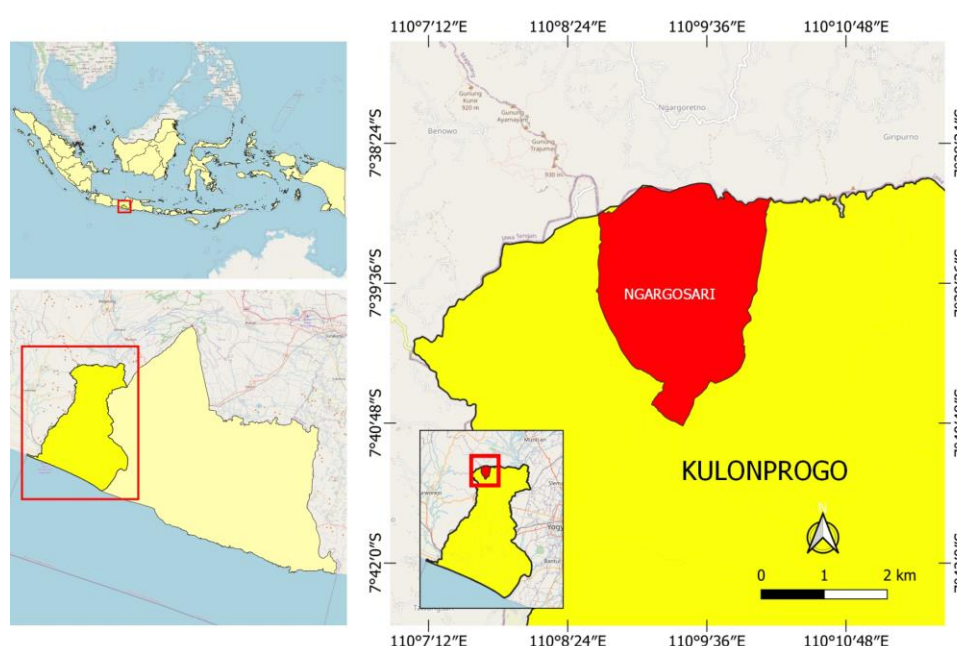


Figure 1. Location of the study site

$$Bs = Vs \times BWD \quad [3]$$

Whereas:

B_s : Total stem biomass of tree (kg)

V_s : Total volume of tree stem/branch (m^3)

BWD : Basic wood density (kg/m^3)

The value of total biomass was expressed in kilogram (kg) while the volume was in m^3 and basic wood density was in kg/m^3 . Furthermore, the following formula was applied to measure the branches (<3cm) and leaves biomass (Wani et al. 2012).

$$Bb = \frac{O_w}{G_w} \times T_g \quad [4]$$

Whereas:

B_b : Biomass of stem/leaves (kg)

O_w : Dry weight of branch/leaves sample (g)

G_w : Green weight of branch/leaves sample (g)

T_g : Total green weight of branch/leaves (kg)

Following Almay Widagdo et al. (2020) the total AGB of each tree was calculated by adding all the biomass of tree components such as bole, branches and leaves. The following formula was used for finding the total amount of dry tree biomass. Moreover, total AGB was calculated in Ton.

$$Tb = Bs + Bb + Bl \quad [5]$$

Whereas:

T_b : Total biomass of the tree (Ton)

B_s : Biomass of stem (Ton)

B_b : Biomass of Branches (Ton)

B_l : Biomass of leaves (Ton)

All the data were analyzed by using Excel Spreadsheet from Microsoft Office 2019. The results were further described to interpret the statistical data attributes such as mean, standard deviation, min and max values. The normality of data was evaluated by using Shapiro-Wilk test; meanwhile, the R^2 , Adj. R^2 , SSE, and P-values were obtained to validate the allometric model. Three general allometric equations were applied such as diameter at breast height (DBH), squared diameter at breast height together with tree height (DBH^2H), Diameter (D), and height (H) separately to estimate the total AGB of the samples (Dong et al. 2015; Altanzagas et al. 2019).

Whereas, in the above three equations, y represents estimated biomass in a ton (stem, branches, and leaves and AGB) and a , b and c represent fitted parameters. The unit of DBH was in centimeter (cm), while the total tree height was in meter (m). On the other hand, Manuri et al. (2016) and Zeng and Tang (2012) stated that, in most cases, nonlinear models for biomass experiments using arithmetical units did not have constant error variances overall observations. Heteroscedasticity was a term used to describe this phenomenon. As a result, when computing the parameters for equations, data transformation in natural

log-form was commonly used to turn the nonlinear model into a linear regression to minimize the influence of heteroscedasticity (He et al. 2018). Therefore, the three general allometric equations were converted into the models below.

$$\ln Y = \ln a + b \times \ln DBH \quad [6]$$

$$\ln Y = \ln a + b \times \ln (DBH^2H) \quad [7]$$

$$\ln Y = \ln a + b \times \ln DBH + c \times \ln H \quad [8]$$

The estimated biomass value in the logarithmic unit is $\ln Y$, and the fixed parameters were $\ln a$, b and c . Furthermore, the best allometric model was designed for stems, branches, leaves and total AGB. According to (Chaturvedi and Raghubanshi 2013; Zaenal et al. 2020) the best models were generated on the basis of statistical indicators such as the highest coefficient of determination value, Adj R^2 , lowest standard error (SSE) and P-value.

RESULTS AND DISCUSSION

Selected individual tree samples

Six trees of Sungkai with different diameters at breast height (DBH) were harvested for destructive method data. The DBH were range from 13.2 cm, 18.5 cm, 22.3 cm, 29.1 cm, 30.2 cm and 31.5 cm. The diameters were selected in consideration of the availability of the Sungkai tree in the study site.

Moisture content

The moisture content (MC) of each sample was determined before drying all samples in the oven. The purpose of finding the moisture content was to check the water percentage in the samples and to determine the ratio of fresh and dry weight. Moisture content and wood strength depended on each other. If the moisture content of the wood decreased, then the strength of the wood would be increased (Shmulsky and Jones 2018). In this present study, the moisture content also affected the fresh weight of the samples.

Table 1. Statistical summary of MC (%)

Tree	Unit	Stem	Branches	Leaves
1	Mean	87	93	161
	SD	8	2	2
2	Mean	82	72	156
	SD	10	20	18
3	Mean	80	62	145
	SD	3	1	10
4	Mean	79	80	201
	SD	2	21	14
5	Mean	77	63	185
	SD	3	7	3
6	Mean	79	77	181
	SD	3	9	4

The moisture content of each part could be seen from the mean of the data. The smallest moisture content of the stem was found in tree 5 ($M = 77\%$). Meanwhile, the highest moisture content of the stem was in tree 1 ($M = 87\%$). Furthermore, the tree 4 and 6 had the same amount of moisture content ($M = 79\%$). The tree 2 had the second-highest moisture content ($M = 82\%$), followed by tree 3 ($M = 80\%$). Moreover, the moisture content of the branch, which had the highest amount of 93%, was found in tree 1. In contrast, the smallest percentage of moisture content was found in tree branch 3 ($M = 62\%$) and followed by tree 5 ($M = 63\%$).

Referring to the moisture content of the leaves, tree branch 4 had the highest percentage of moisture content ($M = 201\%$). Furthermore, the second-highest amount of moisture content was stored in tree 5 ($M = 185\%$). Tree 6 had slightly less moisture content than tree 5, at 181%. Sequentially, the remaining three trees 1, 2, and 3 had moisture contents of 161%, 156%, and 145%

Basic wood density of each tree

Basic Wood Density (BWD) was needed to compute tree biomass. Importantly, the aim of calculating BWD was also to measure the oven-dried biomass of the tree. In this case, the BWD of the tree is one of the most important factors for wood quality attributes. Moreno-Fernández et al. (2018) pointed out that wood density affected mechanical properties, wood strength, stiffness, flexibility and physiological wood construction costs, carbon storage.

Table 2. Statistical summary of BWD (kg/m^3)

Tree	Basic wood density values (kg/m^3)	CV (%)
1	470.781	11.58
2	502.599	5.73
3	470.408	6.18
4	568.342	18.22
5	559.795	9.62
6	536.884	3.32
Mean	518.135	8.35
SD	43.288	

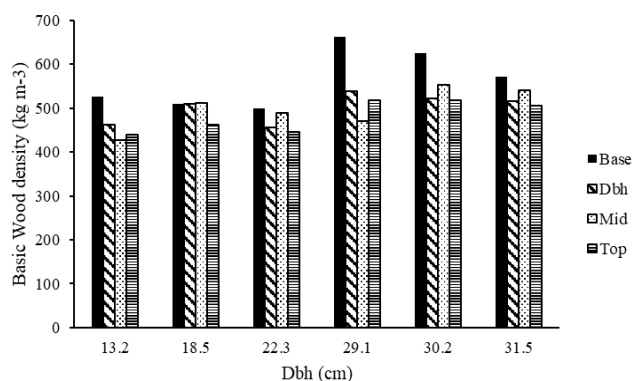


Figure 2. Basic wood density (kg/m^3) of six trees

The sequence of the six trees in Table 2, the highest basic wood density of the tree was found in tree 4 ($\text{BWD} = 568.342 \text{ kg}/\text{m}^3$) while the lowest one was stored in tree 3 ($\text{BWD} = 470.408 \text{ kg}/\text{m}^3$) and the mean of all BWD values were revealed as $518.135 \text{ kg}/\text{m}^3 (\pm 43.288)$. On the other hand, the value of coefficient variation (CV) was calculated for each tree by dividing the standard deviation value of each sample tree by the mean value of each sample tree then multiplied by 100. The value of CV was calculated for each tree then a mean value of 8.35 % was obtained. Meanwhile, the chart in Figure 2 describes the flow pattern of BWD in each tree in terms of base, DBH, mid and top points. The flow pattern of trees 1 and 4 showed that the line gradually went down from the base to midpoints of the tree yet slightly went up to the top point. Moreover, tree 2 had a different flow pattern where the line was stable from the base, DBH and midpoints. However, the line went down at the top point of the tree. The third tree had a zig-zag pattern, which declined from base to DBH points, then rose to mid before going down midpoint. Meanwhile, the two remaining trees (trees 5 and 6) had the same flow pattern. According to the chart, the line went down from base to the DBH point and slightly rose before going down to the top point. Therefore, the flow pattern of each tree was illustrated differently based on basic wood density values.

It could be inferred from Figure 2 that trees 1 and 4 had a similar pattern of wood density. It was shown that the bar decreased from the base to the top point. Similar to the result of the previous study, the BWD had the tendency to decrease to the top of the tree in *P. sylvestris* species (Ikonen et al. 2008). According to (Ramanantoandro 2016), the finding also showed the tree diameter did not have a relationship with the wood density values. It could be seen in Table 2 that the BWD values were high and low in both small and large tree diameters. In contrast, the study conducted by Deng et al. (2014) found that the more mature the tree, the higher the wood density value while the younger tree had a lower BWD value. The result in this previous study indicated that there was a positive relationship between tree age with BWD values which was different from the present study. Djomo et al. (2017) also found a similar result, who revealed that there was no massive gap between the tree's base and top in terms of basic wood density.

Above-ground biomass of *P. canescens*

The basic data of the six trees and DBH, basal area, height, DBH²h, stems, branches, leaves and AGB are represented in Table 3. It could be seen that the basal area values of all six trees were progressively increased from a minimum value of 0.0137 m^2 to a maximum value of 0.0779 m^2 . Meanwhile, Table 5 reported the average values of biomass in each part of the tree ranged from $0.212 \text{ ton tree}^{-1}$. The lowest AGB value was stored in tree 1 ($0.064 \text{ ton tree}^{-1}$), while the highest AGB value was found in tree 6 ($0.479 \text{ ton tree}^{-1}$). Moreover, it could be seen from Table 4 that the variation of stem biomass values was not significantly different.

Table 3. Summary of each tree

DBH (cm)	Height (m)	DBH ² H (m)	Stem (ton)	Branches (ton)	Leaves (ton)	AGB (ton)
13.2	12.2	0.213	0.045	0.011	0.007	0.064
18.5	14.5	0.496	0.112	0.015	0.011	0.138
22.3	17.7	0.880	0.189	0.025	0.021	0.234
29.1	14.9	1.262	0.268	0.032	0.024	0.323
30.2	17.8	1.623	0.272	0.044	0.029	0.345
31.5	19.2	1.905	0.384	0.057	0.038	0.479

Table 4. Statistical summary of each tree

Parameters	Unit	Min	Max	Mean	SD	SE
DBH	cm	13.2	31.5	24.13	7.35	3.00
Basal area	m ² tree ⁻¹	0.01	0.08	0.05	0.03	0.01
Height	m	12.2	19.2	16.05	2.62	1.07
Stem biomass	Ton tree ⁻¹	0.045	0.384	0.212	0.12	0.05
Branch biomass	Ton tree ⁻¹	0.011	0.057	0.031	0.02	0.01
Leaves' biomass	Ton tree ⁻¹	0.007	0.038	0.022	0.01	0.00
AGB	Ton tree ⁻¹	0.064	0.479	0.264	0.15	0.06

Table 5. Ratio of tree components to AGB. SCR=Stem Crown Ratio

Diameter	Ratio of tree component to AGB			SCR (%)
	Stem (%)	Branch (%)	Leaves (%)	
13.2	71	18	12	42
18.5	81	11	08	23
22.3	80	11	09	24
29.1	83	10	07	21
30.2	79	13	08	27
31.5	80	12	08	25

In accordance with Table 5, the stem crown ratio (SCR) values were obtained. It could be seen that the highest SCR value was found in a tree with a diameter of 13.2 cm (SCR = 42). The lowest SCR values were noted in the tree with a diameter of 29.1 cm (SCR = 21). In line with that, trees with diameters 18.5 cm and 22.3 cm had SCR values 23 and 24, which had slightly increased. Lastly, the trees with diameter 30.2 cm and 31.5 cm contained of SCR values 27 and 25. It was concluded that the tree with a small diameter had a higher SCR value compared to the tree with the biggest diameter. In line with these results, the previous study conducted by Hemery et al. (2005) also revealed that the SCR value was reduced from the younger tree to the tree with a bigger diameter.

Overall, the average AGB of Sungkai trees in Ngargosari village, as mentioned in Table 4 was 0.264 tons per tree. Therefore, there was 26.38% of AGB estimated in every single tree of Sungkai. This value was considered as higher compared to other species which had the same commercial value and were planted in the same location, such as *T. grandis*, *F. molucana* or Sengon. According to Santosa et al. (2020), the average AGB of *T. grandis* species was 0.0114 tons in each tree which meant that 1.14% tree biomass was found in Teak species. Meanwhile,

the average AGB of *F. molucana* species was 0.0480 tons or 4.79% was found in each tree of Sengon. Further, Table 3 conveyed that the AGB of Sungkai increased with the increase of tree diameter. The bigger the diameter, the more the AGB was accumulated. Bareke and Addi (2021) also stated that DBH and crown area significantly influenced the AGB of *Galiniera saxifrage*. Furthermore, the previous study had revealed that the Sungkai tree highly increased its stand biomass until reaching the 16th year and started to flat from the ages of 16th to 20th (Akmalluddin et al. 2019).

Allometric model development

Table 6 provided the finding of the best allometric models for the biomass of stems, branches, leaves and especially for AGB. Table 6 revealed that each allometric model had P-value < 0.005, which explained all four models. From the three models of stems biomass, it could be seen that the second model was the fit allometric model to predict the AGB of the tree ($\ln Y = \ln a + b \times \ln \text{DBH}^2 H$) and to generate the highest accuracy in predicting the total AGB estimation. Therefore, the result recorded that the best model for the stem biomass had the most suitable findings which was selected in terms of $R^2 = 0.987$, adjusted $R^2 = 0.984$, SSE = 0.100 and P-value = 0.000. On the other hand, the best allometric model for tree branches was also obtained from the second model among three others. The data showed that the model of $\ln Y = \ln a + b \times \ln \text{DBH}^2 H$ generated the best results of the values of $R^2 = 0.946$, adjusted $R^2 = 0.933$, SSE = 0.161 and P-value = 0.001. In line with that, the suitable allometric model for leaves biomass was $\ln Y = \ln a + b \times \ln \text{DBH}^2 H$ gained the best model of the values of $R^2 = 0.968$, adjusted $R^2 = 0.960$, SSE = 0.124 and P-value = 0.000. Therefore, all the relationships of tree components biomass (stems, branches and leaves) with the best allometric models were

significant ($P < 0.005$).

Lastly, the best allometric model for AGB was similar to previous tree components. The log-linear formula was $\ln Y = \ln a + b \times \ln DBH^2H$ with revealed the result of $R^2 = 0.992$, adjusted $R^2 = 0.990$ and $SSE = 0.074$. The result showed a significant relationship between total AGB with the best allometric model ($P < 0.005$). Moreover, the study obtained the log-linear equation and converted it to exponential form to calculate the above-ground biomass (AGB) of *P. canescens* in the study area. The best equation for estimating the total above-ground biomass of individual trees was presented below:

$$AGB = 0.254(DBH^2H)^{0.886}$$

The above formula was generated to find the total AGB (kg), whereas the value of 0.254 was obtained by converting -1.370 to exponential form (a). On the other hand, the best allometric model indicated that DBH^2H was the greatest model for the Sungkai tree. DBH indicated diameter at breast height (cm) and H showed a height of the tree (m). Meanwhile, the value of 0.886 was represented by the power value of the exponential formula (b). The formula mentioned above was specifically designed for the Sungkai tree in Ngargosari village, Kulon Progo District. However, this formula could reference the total AGB of another Sungkai tree in different locations.

Validation of the best allometric model

The models based on DBH and DBH^2H derived from Table 6 were validated based upon Mean Absolute Biased (MAB), Root-Mean Squared Error (RMSE) and P-values. The assessment of best model was treated as the one having the values of MAB and RMSE were closest one to zero (0), the P-value < 0.0005 and the highest values of R^2 and Adj. R^2 (Guangyi et al. 2017). The model validation details of DBH are presented in Table 7 and DBH^2H in Table 8.

The model of DBH met the requirements of the fit model since the P-value < 0.0005 . However, the average values of MAB and RMSE were higher compared to DBH^2H model. Furthermore, for more details, the equation from Table 6 was applied by inserting the values of $a = 0.000272096$ and $b = 2.131446$, resulting in $y = 0.000272D^{2.131446}$, which was not valid and could not be used as the best allometric model.

On the other hand, the findings showed that DBH^2H derived model ($y = 0.254DBH^2H^{0.886}$) was the finest to meet all the requirements of the best allometric model in terms of $MAB = 0.016$, $RMSE = 0.307$ and P-value $= < 0.0005$. Moreover, it could be seen from Table 6 that this model had the highest R^2 and Adj. R^2 values. Thus, from all of the studied models, $AGB = 0.254(DBH^2H)^{0.886}$ was found to be valid and fit as the best allometric model for *P. canescens*.

Table 6. Assessment of various AGB Allometric models for identifying the best model

Tree component	Equation form	Lna	b	c	R ² (%)	Adj R ² (%)	SSE	P-value
Stem biomass	$\ln Y = \ln a + b \times \ln DBH$	-8.826	2.253	-	0.974	0.968	0.141	0.000
	$\ln Y = \ln a + b \times \ln DBH^2H$	-1.598	0.935	-	0.987	0.984	0.100	0.000
	$\ln Y = \ln a + b \times \ln DBH + c \ln H$	-8.826	2.253	0.931	0.974	0.968	0.141	0.000
Branches biomass	$\ln Y = \ln a + b \times \ln DBH$	-9.114	1.747		0.925	0.907	0.190	0.002
	$\ln Y = \ln a + b \times \ln DBH^2H$	-3.508	0.729		0.946	0.933	0.161	0.001
	$\ln Y = \ln a + b \times \ln DBH + c \ln H$	-10.554	1.351	0.970	0.947	0.912	0.184	0.012
Leaf's biomass	$\ln Y = \ln a + b \times \ln DBH$	-9.499	1.758		0.938	0.923	0.173	0.001
	$\ln Y = \ln a + b \times \ln DBH^2H$	-3.857	0.737		0.968	0.960	0.124	0.000
	$\ln Y = \ln a + b \times \ln DBH + c \ln H$	-11.323	1.257	1.229	0.974	0.956	0.130	0.004
Total AGB	$\ln Y = \ln a + b \times \ln DBH$	-8.209	2.131		0.977	0.972	0.124	0.000
	$\ln Y = \ln a + b \times \ln DBH^2H$	-1.370	0.886		0.992	0.990	0.074	0.000
	$\ln Y = \ln a + b \times \ln DBH + c \ln H$	-9.598	1.750	0.936	0.992	0.987	0.085	0.001

Table 7. Validation of first model (DBH)

DBH (cm)	Height (m)	Actual AGB	Model AGB	MAB	RMSE	P-value
13.2	12.2	0.064	0.067	0.003	0.232	0.0001
18.5	14.5	0.138	0.137	0.001	0.174	
22.3	17.7	0.234	0.203	0.031	0.419	
29.1	14.9	0.323	0.359	0.035	0.434	
30.2	17.8	0.345	0.388	0.043	0.456	
31.5	19.2	0.479	0.425	0.054	0.483	
Average				0.028	0.366	

Table 8. Validation of second model (DBH²H)

DBH (cm)	Height (m)	Actual AGB	Model AGB	MAB	RMSE	P-value
13.2	0.213	0.064	0.064	0.001	0.167	0.0000
18.5	0.496	0.138	0.137	0.001	0.177	
22.3	0.880	0.234	0.227	0.008	0.294	
29.1	1.262	0.323	0.312	0.011	0.326	
30.2	1.623	0.345	0.390	0.045	0.461	
31.5	1.905	0.479	0.450	0.029	0.414	
Average				0.016	0.307	

In conclusion, it was found that the average above-ground biomass of six trees of *P. canescens* species was 0.264 tons per tree. There was 26.38% of AGB estimated in each Sungkai tree of in Ngargosari village, Kulon Progo district. It also demonstrated that the biomass of the Sungkai tree was generally found in the stem, branches, and leaves. The total AGB of the Sungkai tree was higher than that of teak and *P. falcataria*. The allometric model for AGB = $0.254(\text{DBH}^2\text{H})^{0.886}$ is the proper formula designed for Sungkai trees in the private forest in Kulon Progo district, Special Region of Yogyakarta.

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