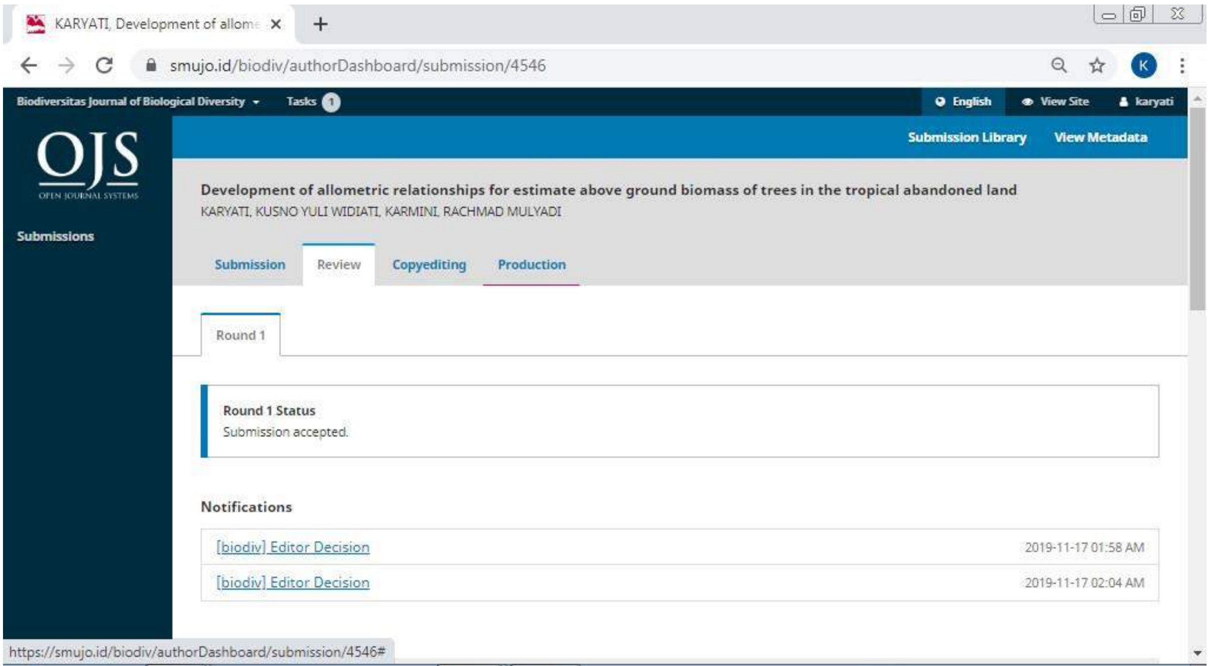
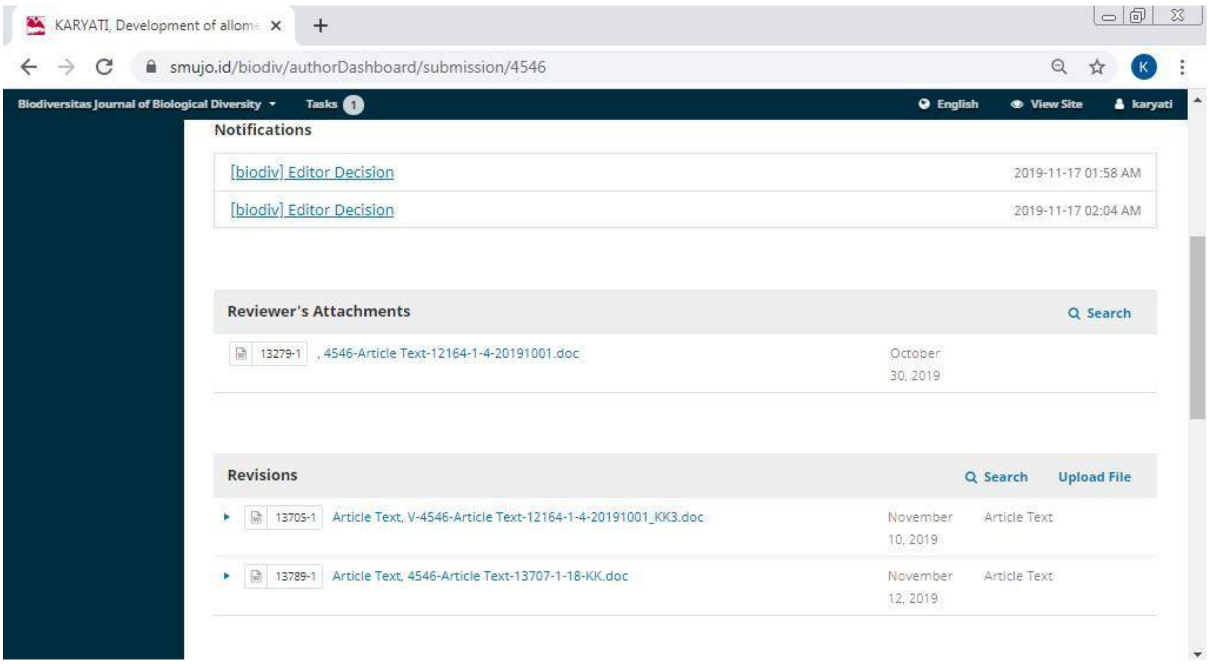
BUKTI-BUKTI PROSES REVIEW (KORESPONDENSI)

Judul	:	Development of Allometric Relationships for Estimate Above Ground Biomass of Trees in the Tropical Abandoned Land
Penulis	:	Karyati, Kusno Yuli Widiati, Karmini, dan Rachmad Mulyadi
Nama Jurnal	:	Biodiversitas
Volume/Nomor/Tahun/Halaman	:	20, 12, 2019, 3508-3516
ISSN	:	1412-033X/E-ISSN: 2085-4722
Penerbit	:	Society for Indonesian Biodiversity
DOI	:	10.13057/biodiv/d201207





KARYATI, Development of allom...

smujo.id/biodiv/authorDashboard/submission/4546

Biodiversitas Journal of Biological Diversity | Tasks 1 | English | View Site | karyati

Review Discussions Add discussion

Name	From	Last Reply	Replies	Closed
Review	aseptiasari 2019-10-03 04:39 AM	karyati 2019-10-26 03:17 AM	2	
Feedback for reviewer's comments	karyati 2019-11-10 06:54 AM	-	0	
Uncorrected Proof	editors 2019-11-10 10:30 AM	karyati 2019-11-15 05:31 PM	3	
BILLING	dewinurpratiwi 2019-11-11 01:52 AM	karyati 2019-11-12 05:30 AM	1	

https://smujo.id/biodiv/$$$call$$$/tab/author-dashboard/author-dashboard-tab/fetch-tab?submissionId=4546&stageId=3

Ahmad Dwi Setyawan <smujo.id@gmail.com> Wed, Sep 11, 2019 at 3:17 PM
To: Karyati Karyati

Karyati Karyati:

Thank you for submitting the manuscript, "D Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land: Development of allometric equations in abandoned land " to Biodiversitas Journal of Biological Diversity. With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal web site:

Submission URL: https://smujo.id/biodiv/authorDashboard/submission/4430
Username: karyati

If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

[biodiv] New notification from Biodiversitas Journal of Biological Diversity

Yahoo/Inbox

Nor Liza <smujo.id@gmail.com>
To: Karyati Karyati

Thu, Sep 12, 2019 at 1:28 PM

You have a new notification from Biodiversitas Journal of Biological Diversity:

You have been added to a discussion titled "Manuscript submission" regarding the submission "D Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land".

Link: https://smujo.id/biodiv/authorDashboard/submission/4430

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

Smujo Editors <smujo.id@gmail.com>
To: Karyati, Kusno Yuli Widiati, Karmini, Rachmad Mulyadi

Sun, Sep 15, 2019 at 7:50 AM

Karyati, Kusno Yuli Widiati, Karmini, Rachmad Mulyadi:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "D Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land: Development of allometric equations in abandoned land ".

Our decision is to: Decline Submission
Note:

Thank you very much for your mss submission.
Unfortunately, this mss is too brief to be published in Biodiversitas journal. At least, you need to compose a 2500 words article from intro to conclusion (table and figure are excluded).

Kindly resubmit when it meets the requirements.

Smujo Editors
editors@smujo.id

[biodiv] Submission Acknowledgement

Yahoo/Inbox

Ahmad Dwi Setyawan <smujo.id@gmail.com>
To: Karyati Karyati

Sun, Sep 29, 2019 at 11:58 PM

Karyati Karyati:

Thank you for submitting the manuscript, "D Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land: Development of allometric equations in abandoned land " to Biodiversitas Journal of Biological Diversity. With the online journal management system that we are using, you will be able to track its progress through the editorial process by logging in to the journal web site:

Submission URL: https://smujo.id/biodiv/authorDashboard/submission/4546
Username: karyati

If you have any questions, please contact me. Thank you for considering this journal as a venue for your work.

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

[biodiv] New notification from Biodiversitas Journal of Biological Diversity 2

Yahoo/Sent

Anisa Septiasari <smujo.id@gmail.com>
To: Karyati Karyati

Thu, Oct 3, 2019 at 12:39 PM

You have a new notification from Biodiversitas Journal of Biological Diversity:

You have been added to a discussion titled "Review" regarding the submission "D Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land".

Link: https://smujo.id/biodiv/authorDashboard/submission/4546

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

Karyati Hanapi <karyati.hanapi@yahoo.com>

Fri, Oct 4, 2019 at 6:43 AM

[biodiv] Editor Decision 3 Yahoo/Sent

Smujo Editors <smujo.id@gmail.com> Wed, Oct 30, 2019 at 12:05 PM

To: Karyati Karyati, Kusno Yuli Widiati, Karmini Karmini, Rachmad Mulyadi

Karyati Karyati, Kusno Yuli Widiati, Karmini Karmini, Rachmad Mulyadi:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "D Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land: Development of allometric equations in abandoned land ".

Our decision is: Revisions Required

Smujo Editors
editors@smujo.id

Reviewer V:

Based on the biomass data of 30 tree samples from destructive sampling, abovegroun biomass proportions were provided and biomass models were developed for different parts of trees in the tropical abandoned land, especially in Kalimantan, Indonesia. The topic of this manuscript is valuable, but some issues I concern are necessary to be revised for improving the MS.

1. What method was used in selecting sample trees both species and family? Please explain clearly

2. This model is for aboveground biomass, however, there is no flower and fruit parts. Why?

3. The model evaluation was only based on statistics for *R* square and *P* value, no including some statistics for errors, especially relative

Back Archive Move Delete Spam

relationships for estimate above ground biomass of trees in the tropical abandoned land: Development of allometric equations in abandoned land ".

Our decision is: Revisions Required

Smujo Editors
editors@smujo.id

Reviewer V:

Based on the biomass data of 30 tree samples from destructive sampling, abovegroun biomass proportions were provided and biomass models were developed for different parts of trees in the tropical abandoned land, especially in Kalimantan, Indonesia. The topic of this manuscript is valuable, but some issues I concern are necessary to be revised for improving the MS.

1. What method was used in selecting sample trees both species and family? Please explain clearly

2. This model is for aboveground biomass, however, there is no flower and fruit parts. Why?

3. The model evaluation was only based on statistics for *R* square and *P* value, no including some statistics for errors, especially relative errors. It is suggested to add some assessment indices such as mean relative error (MRE), mean absolute relative error (MARE) (Manuri et al., 2017), total relative error (TRE) and mean prediction error (MPE) (Zeng et al, 2017) for model evaluation.
Due to limited samples (only 30 trees) in this study, cross validation was not conducted. In this case, MPE an d others statistics are an important index for assessing the biomass models.

4. Please read and compare to Manuri et al. (2017) that it is related to effect of species grouping and site variables on aboveground biomass models for lowland tropical forests of the Indo-Malay region, including this reseach site.

Recommendation: Revisions Required

Karyati Hanapi <karyati.hanapi@yahoo.com> Wed, Oct 30, 2019 at 2:41 PM
To: Smujo Editors
Cc: Kusno Widiati, Karmini Kasiman, Rachmad Mulyadi

Dear Managing Editor,

We will revised the manuscript as soon as possible.

Thank you very much.

Regards,

Karyati

> Show original message

V-4546-Arti... .doc
8.5MB

Karyati Hanapi <karyati.hanapi@yahoo.com> Sun, Nov 10, 2019 at 3:02 PM
To: Smujo Editors
Cc: karmini.kasiman@yahoo.com, Kusno Widiati, Rachmad Mulyadi, Karyati Kasiman

Dear Managing Editor,

We would like to say thanks and appreciate for constructive suggestion from reviewer.

As attached below, our feedback for the reviewer's comments on our manuscript entitled "Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned lands"

No.	Page/ Line	Review	Feedback and revision
1	Page 5, line 207	What method was used in selecting sample trees both species and family?	Explaination had added ➔ Thirty sample trees with DBH of > 15 cm were selected in the study site, with consideration of the species. These selected trees didnot considering individuals with damaged crowns or broken trunks. Almost 90% of the selected trees were categorized as the dominant species in terms of density and Importance Value Index (IVi) as observed in the current study, while few selected trees represented the rare species (Page 5, line 214-217).

...

← Back Archive Move Delete Spam •••

2	Page 5, line 226	Is there no flower and fruit parts?	Explaination had added → The flower and fruit parts was not included in the observation, because very few sample trees that have flower and fruit during observation (Page 3, line 107-109)
3	Page 5, line 255	The model evaluation was only based on statistics for R^2 and P value, no including some statistics for errors, especially relative errors. It is suggested to add some assessment indices such as mean relative error (MRE), mean absolute relative error (MARE) (Manuri et al., 2017), total relative error (TRE) and mean prediction error (MPE) (Zeng et al, 2017) for model evaluation. Due to limited samples (only 30 trees) in this study, cross validation was not conducted. In this case, MPE and others statistics are an important index for assessing the biomass models.	Some assessment indices such as mean relative error (MRE), mean absolute relative error (MARE) (Manuri et al., 2017), total relative error (TRE) and mean prediction error (MPE) (Zeng et al, 2017) for model evaluation had added (Page 4, line 152-154; Page 7, Table 3)
4	Page 8, line 303	Please read and compare to Manuri *et al.* (2017) that it is related to effect of species grouping and site variables on aboveground biomass models for lowland tropical forests of the Indo-Malay region.	The comparison to Manuri et al. (2017) had added (Page 7, line 295; Page 8, line 313-316; Page 8,Tabel 4; Page 8, Figure 7)

mobile.yahoo.com...

← Back Archive Move Delete Spam •••

4	Page 8, line 303	Please read and compare to Manuri *et al.* (2017) that it is related to effect of species grouping and site variables on aboveground biomass models for lowland tropical forests of the Indo-Malay region.	The comparison to Manuri et al. (2017) had added (Page 7, line 295; Page 8, line 313-316; Page 8,Tabel 4; Page 8, Figure 7)

Thank you very much.

Regards,

Karyati

> Show original message

Download all attachments as a zip file

V-4546-Arti... .doc
8.8MB

feedback f... .docx
205.9kB

[biodiv] New notification from Biodiversitas Journal of Biological Diversity 5 Yahoo/Sent

Smujo Editors <smujo.id@gmail.com> Sun, Nov 10, 2019 at 6:32 PM
To: Karyati Karyati

You have a new notification from Biodiversitas Journal of Biological Diversity:

You have been added to a discussion titled "Uncorrected Proof" regarding the submission "Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land".

Link: https://smujo.id/biodiv/authorDashboard/submission/4546

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

Karyati Hanapi Dear Managing Editor, Bersama ini dilampirkan... Tue, Nov 12, 2019 at 12:12 PM

Karyati Hanapi Terlampir file bukti bayar atas penerbitan... Tue, Nov 12, 2019 at 1:28 PM

← Back Archive Move Delete Spam ...

You have a new notification from Biodiversitas Journal of Biological Diversity:

You have been added to a discussion titled "Uncorrected Proof" regarding the submission "Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land".

Link: https://smujo.id/biodiv/authorDashboard/submission/4546

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

Karyati Hanapi <karyati.hanapi@yahoo.com> Tue, Nov 12, 2019 at 12:12 PM
To: Smujo Editors, Dewi Nur Pratiwi

Dear Managing Editor,

Bersama ini dilampirkan file "*Uncorrected Proof*" yang telah kami setujui dengan sedikit perbaikan yaitu

- Nama institusi "Universitas Mulawarman" diganti menjadi "Mulawarman University" sebagaimana diinstruksikan oleh Pimpinan Universitas.

← Back Archive Move Delete Spam •••

4546-Article....doc
8.7MB

Karyati Hanapi <karyati.hanapi@yahoo.com> Tue, Nov 12, 2019 at 1:28 PM
To: Smujo Editors, Managing Editor, Dewi Nur Pratiwi
Cc: Karyati Kasiman, Kusno Widiati, Karmini Kasiman

Terlampir file bukti bayar atas penerbitan artikel kami yang berjudul "Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land".
Atas perhatian dan bantuannya diucapkan banyak terima kasih.

Karyati

› Show original message

bukti bayar .... .jpg
369.3kB

← Back Archive Move Delete Spam •••

Managing Editor <unsjournals@gmail.com> Tue, Nov 12, 2019 at 1:31 PM
To: Karyati Hanapi

Kami menggunakan nama universitas di Indonesia dengan nama asli dalam bahasa Indonesia (mohon periksa Guidance for Authors). Bila hal ini menjadi ganjalan, naskah tidak diterbitkan.

Thank you,
Regards,

Ahmad Dwi Setyawan
Managing Editor,

› Show original message

Karyati Hanapi <karyati.hanapi@yahoo.com> Tue, Nov 12, 2019 at 1:37 PM
To: Managing Editor

← Back Archive Move Delete Spam •••

Thank you,
Regards,

Ahmad Dwi Setyawan
Managing Editor,

› Show original message

Karyati Hanapi <karyati.hanapi@yahoo.com> Tue, Nov 12, 2019 at 1:37 PM
To: Managing Editor

Dear Managing Editor,

Kami mengikuti ketentuan dalam Guidance for Authors.
Terima kasih.

Karyati

← Back Archive Move Delete Spam •••

[biodiv] New notification from Biodiversitas Journal of Biological Diversity Yahoo/Inbox

Smujo Editors <smujo.id@gmail.com> Fri, Nov 15, 2019 at 11:45 AM
To: Karyati Karyati

You have a new notification from Biodiversitas Journal of Biological Diversity:

There is new activity in the discussion titled "Uncorrected Proof" regarding the submission "Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land".

Link: https://smujo.id/biodiv/authorDashboard/submission/4546

Ahmad Dwi Setyawan

Biodiversitas Journal of Biological Diversity

[biodiv] Editor Decision Yahoo/Inbox

Smujo Editors <smujo.id@gmail.com> Sun, Nov 17, 2019 at 9:58 AM
To: KARYATI, KUSNO YULI WIDIATI, KARMINI, RACHMAD MULYADI

KARYATI, KUSNO YULI WIDIATI, KARMINI, RACHMAD MULYADI:

We have reached a decision regarding your submission to Biodiversitas Journal of Biological Diversity, "Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land".

Our decision is to: Accept Submission

Smujo Editors
editors@smujo.id

Biodiversitas Journal of Biological Diversity

← Back Archive Move Delete Spam

[biodiv] Editor Decision 2 Yahoo/Sent

Smujo Editors <smujo.id@gmail.com> Sun, Nov 17, 2019 at 10:04 AM
To: KARYATI, KUSNO YULI WIDIATI, KARMINI, RACHMAD MULYADI

KARYATI, KUSNO YULI WIDIATI, KARMINI, RACHMAD MULYADI:

The editing of your submission, "Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land," is complete. We are now sending it to production.

Submission URL: https://smujo.id/biodiv/authorDashboard/submission/4546

Smujo Editors
editors@smujo.id

Biodiversitas Journal of Biological Diversity

Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land

Abstract. *Karyati, Widiati KY, Karmini, Mulyadi R. 2019. Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned lands. Biodiversitas x: xx-xx.* The abandoned lands have important role in the ecological fuction as well as carbon sequestration. The allometric equations to estimate above ground biomass in abandoned land are still limited available. This study objective was to develop allometric relationships between tree size variables (diameter at breast height (DBH) and tree height) and leaf, branch, trunk, and total above ground biomass (TAGB) in abandoned land in East Kalimantan, Indonesia. The correlation coefficients between stem DBH and tree height to leaf and branch indicating a relatively weak relationship. The moderately strong relationships were showed by DBH and tree height to trunk and TAGB. The specific allometric equation of above ground biomass for different land use and land type is needed to estimate the accurate TAGB in the site.

Key words: Abandoned land, allometric equation, biomass, destructive method

Running title: Development of allometric equations in abandoned land

INTRODUCTION

The National Land Affairs Agency identified 7.3 million hectares lands in Indonesia as abandoned lands in 2011 and about 4.8 million hectares was stated as abandoned lands. This area of abandoned lands increase from 2007 as much as 7.1 million hectares outside forest area (Nurlinda et al. 2014). The abandoned land area in East Kalimantan was about 3 million hectares. The abandoned lands provide habitat rotation to succession process in primary-secondary forest that will increase biodiversity (Chokkalingam et al. 2001). The plant composition, diversity, and growth during fallow periods after shifting cultivation was resulted from complex interaction between condition and factor before and after fallow periods, such as disturbance, land history, land management, tree and seed source composition from soil or surrounding forest, soil fertility, and climate factor (Awang Noor et al. 2008; Kendawang et al. 2007; Van Do et al. 2010).

Land use system on forest basis store CO_2 by carbon stock storage at their biomasss (Gorte 2007; Roshetko et al. 2002). The carbon stock in old age stand could different compared to carbon stock in second growth stand that replace it, cause woody biomass in an area could not describe in nett eosystem productivity (Janisch and Harmon 2002). Biomass dynamic in tropical forest play important role to evaluation of global carbon cycle and global climate change (Fearnside 1997; Seiler and Crutzen 1980). During the early succession process, amount of stand biomass increase fastly (Selaya et al. 2007). The carbon sequestration of forest area change constanly with vegetation growth, dead, and decomposition (Gorte 2007); species composition, age structur, and forest health (Harmon et al. 1990). Carbon stock at stand in the surface soil and standing tree mass could represented less than 1% to 60% from total carbon stock of forest ecosystem (Curtis 2008). Carbon stock of fertile soils is higher which could influence to carbon stock storage at vegetation biomass (Hairiah and Rahayu 2007).

Biomass is generally expressed in terms of dry weight and on occasion may be given in terms of ash free dry weight (Moore and Chapman 1986). The 'scaling' relationships, by which the ratios between different aspects of tree size change when small and large trees of the same species are compared generally known as 'allometric' relations (Hairiah et al. 2001). The previous studies had been developed allometric equations to estimate above ground biomass (AGB) in the secondary forests (Hashimoto et al. 2004; Kenzo et al. 2009a; Kenzo et al. 2009b; Ketterings et al. 2001; Kiyono and Hastaniah 2005; Nelson et al. 1999; Sierra et al. 2007; Karyati et al. 2019). However the allometric equations to estimate AGB in abandoned lands is still rare reported. The objective of this study was to develop allometric equations for estimation AGB in fallow lands. Information on the allometric relationships could predict biomass and carbon stock in lands after abandonment.

MATERIALS AND METHODS

Study site

The study was carried out in Salo Cella Village, Muara Badak Sub-district, Kutai Kartanegara Districts, East Kalimantan Province, Indonesia (Figure 1). This site was located in 0°17'18.7"S 117°18'08.2"E. Muara Badak Sub-district has 939.09 km^2 wide with population of 57,712 persons including 13 villages. Salo Cella Village is about 10 km from the capital of Sub-district. The capital of subdistrict was Muara Badak Ulu with 16 m height Above Mean Sea Level (AMSL). Muara Badak received average amount of 141 mm in rainfall and 11 raindays in 2017 (Statistics Kutai Kartanegara Regency 2018). Most of the population in this village were farmers' livelihoods. Muara Badak is administratively bordered with Marang Kayu Sub-district at north side, Anggana Sub-district Samarinda City at south side, Makassar Strait at east side, and Tenggarong Seberang Sub-district at west side. Muara Badak is one of oil and gas producer. This has also big potency in fishery and plantation sectors. The area was covered by lowland mixed dipterocarp forest.

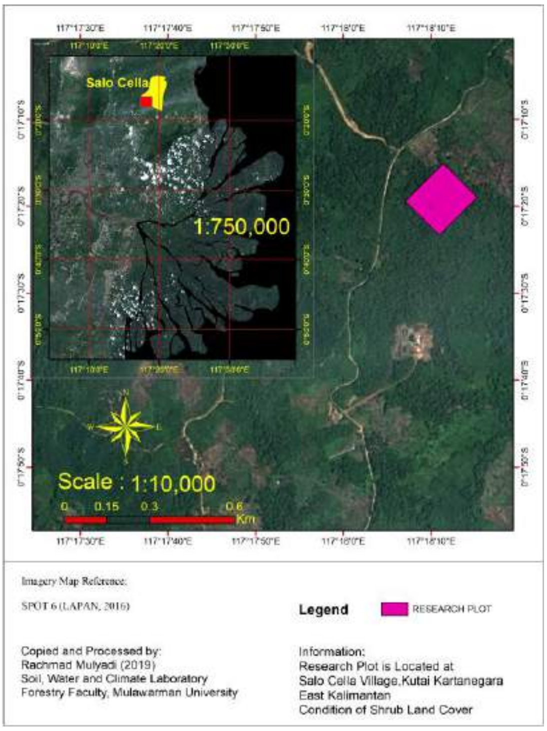


Figure 1. Map of study site in Salo Cella Village, Kutai Kartanegara Districts, East Kalimantan Province, Indonesia.

Data collection

Assessment on biomass in the field

Thirty sample trees were chosen in abandoned land. The sample trees were selected to obtain the representative species of land after abandonment. The selection of sample trees was based on consideration of the species and DBH. The standing DBH (1.3 m) of selected trees were measured using diameter tape. Measurement of the total height of the sample tree was completed once the tree had fallen. Fellings sample trees were conducted by following the harvesting rules. The harvested trees were divided into several fractions which every tree fraction was 1 meter length. Then, parts of trees were separated into leaves and twigs (hereafter called leaves), branches, and main stems in the field as shown in Figure 2.

Dividing sample tree fractions was accomplished with the following criteria (Ministry of Forestry Indonesia, 2011):

1) Dividing sample tree fractions was done to separate parts of tree biomass including leaves, branches, and stem.
2) Dividing sample tree fraction to be weighed needs to consider the capacity of the available scales.

3) Especially for the stem fraction, the stem was divided into several sections (sub-fractions of the stem) taking into account the shape, uniformity, and weight of the pieces.

The fresh weight of all fractions were taken by the suitable scale in the field. The disk samples of trunk with 2-5 cm thick were were collected as many as three disk sample if the harvested trees had less than 10 fractions and four disk samples if more than 10 fractions. Five branch samples of 20-30 cm in length and five leaf samples of 100-300 grams in weight were taken from each sample tree. Figure 3 illustrates tree components and the position of sub-sample being taken for AGB assessment. The wood density of each sample tree was conducted from the various literatures.

Analysis of dry-weight in the laboratory

Before oven-dried, all samples were air-dried in the laboratory to determine the moisture content. Then, samples of stem and branch fractions were dried in an oven at a temperature 105ºC for 96 hours until reaching a constant weight. Samples of leaves were dried in an oven at temperature of 80ºC for 48 hours until constant weight was reached. Weighing the samples of each fraction was performed using an analytical digital weighing scale after drying them in an oven.

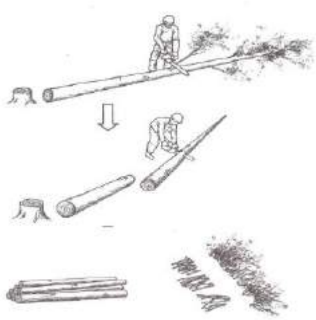


Figure 2. Dividing the trees (Source: Ministry of Forestry Indonesia, 2011).

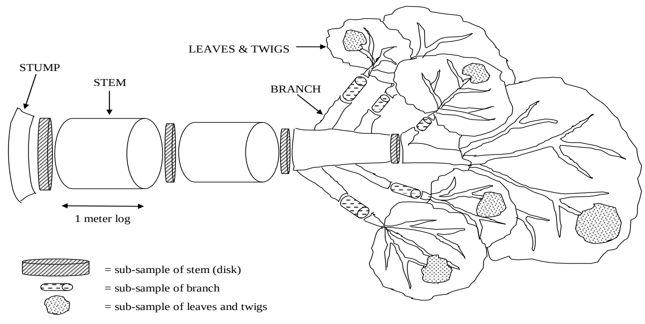


Figure 3. Illustration of tree components and the position of sub-sample being taken (Karyati 2013).

Data analysis

The total oven-dry weight of each seedling-sapling and tree part were determined using the following formula (Hairiah et al. 2001; Hairiah & Rahayu 2007; Ministry of Forestry Indonesia, 2011):

$$dw = (sdw \times fw) / sfw \quad (1)$$

where: dw = total dry weight (kg); sdw = dry weight of the sample (g); fw = total fresh weight (kg); sfw = fresh weight of the sample (g).

The five selected allometric equations of AGB were tested (Equations 2-6):

$$y = a + b x \quad (2)$$

$$y = ax^b \quad (3)$$

$$y = a + b\,(\ln x) \quad (4)$$
$$(\ln y) = a + b\,x \quad (5)$$
$$(\ln y) = a + b\,(\ln x) \quad (6)$$

where: y = total dry weight or biomass of each plant part, such as trunk, branch, leaf, and total above ground biomass (TAGB) (kg); x = diameter at breast height (DBH, cm), total height (H, meter), and ($DBH^2 \times H$) (cm^2 m); 'a' and 'b' = coefficients estimated by regression.

All regression analysis was carried out using SPSS version 18 for windows (SPSS Japan, Tokyo, Japan). The R^2 value was determined to evaluate precision among all tested allometric equations.

RESULTS AND DISCUSSION

Selected samples of trees

Thirty trees with DBH of $\geq$ 5 cm were harvested and measured to determine above ground parts in the study site as represent in Table 1. The DBH and height classes of selected sample trees for assessment AGB are illustrated in Figure 4. The DBH range was 5.0-17.4 cm and height was 5.0-12.5 m for selective sample trees. The relationship between DBH and total height of sample trees for assessment AGB in the study sites is presented in Figure 5. The illustration showed that an increase in DBH was followed by an increase in total height. The equations of this relationship was "H=0.4898 (DBH)+3.3254" (n=30; R^2=0.608). As stated 'H' is total height (m) and 'DBH' is diameter at breast height (cm).

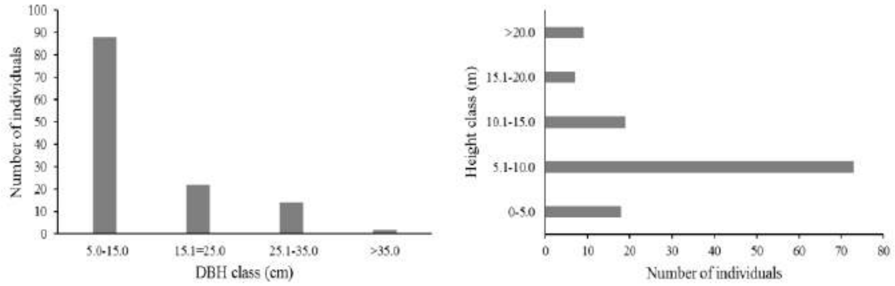


Figure 4. The distributions of (a) DBH classes and (b) height classes of sample trees to developed allometric equations.

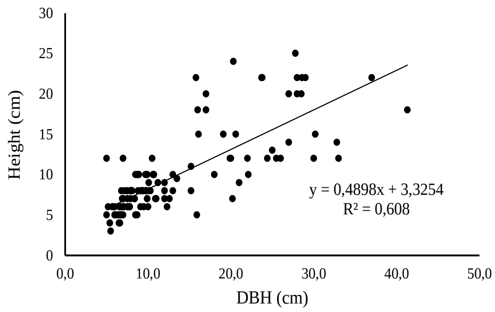


Figure 5. The DBH and total height of sample trees to developed allometric equations.

Tree variables

Pearson's correlation between DBH, height, wood density and branches biomass, trunk biomass, TAGB and parameters of destructive biomass are summarized in Table 1. The minimum and maxiu weight of branches biomass, trunk biomass, and TAGB were 3.92-34.18 kg; 12.84-296.72 kg, and 34.28-308.98 respectively. The DBH of sample trees ranged 16.00-32.00 cm,with the the height ranged 9.30-22.70 m. The wood densites of sample trees ranged 0.37-0.69 g cm^{-3}. The result showed that there were strong correlation (P < 0.01) among trunk biomass to DBH and tree height as well as TAGB and tree height. The correlation (P<0.05) was showed by TAGB and DBH. The strong correlation (P<0.01) was also showed between DBH and tree height. However, the leaf and branch biomass were not correlated with DBH and tree height significantly (P>0.05). In addition, the wood density was not also correlated to plant part biomass (leaf, branch, trunk, and TAGB) and tree dimensions (DBH and height).

Table 1. Pearson's correlation between DBH, height, wood density and branches biomass, trunk biomass, TAGB and parameters of destructive biomass

	Pearson's correlation			Mean	Range
	DBH (cm)	H (m)	WD (g cm^{-3})		
Leaf biomass (kg)	-0.303^{ns}	-0.198^{ns}	0.262^{ns}	12.43	1.37 - 45.59
Branch biomass (kg)	0.205^{ns}	-0.072^{ns}	0.208^{ns}	16.99	3.92 - 34.18
Trunk biomass (kg)	0.527**	0.768**	0.027^{ns}	116.55	12.84 - 296.72
TAGB (kg)	0.494*	0.710**	0.098^{ns}	145.97	34.28 - 308.98
DBH (cm)	1	0.578**	-0.357^{ns}	24.35	16.00 - 32.00
H (m)	0.578**	1	-0.184^{ns}	14.54	9.30 - 22.70
WD (g cm^{-3})	-0.357^{ns}	-0.184^{ns}	1	0.53	0.37 - 0.69

Note: ^{ns} is not significant at the 0.05 level (P>0.05) ; * and **Correlation are significant at the 0.05 and 0.01 level (2-tailed) respectively

There were 10 species of 10 genera of 9 families selected in study site. Eight sample trees were *Pterospermum javanicum* ~~including~~ (Malvaceae). There were 5 sample trees of *Glochidion obscurum* (Euphorbiaceae) and 4 sample trees of *Bridelia glauca* (Phyllanthaceae). Three sample trees were *Vatica javanica* (Dipterocarpacea). The species of *Ficus septica* (Moraceae), *Trema orientalis* (Cannabaceae), *Archidendron jiringa* (Fabaceae), *Vernonia arborea* (Asteraceae) were selected for two sample trees respectively. One sampe tree was *Heliciopsis artocarpoides* (Proteaceae) as well as *Artocarpus elasticus* (Moraceae). The range of dry weight was 1.37-45.59 kg for leaf, 3.92-34.18 kg for branch, 12.84-296.72 kg for trunk, and 34.28-308.98 kg for TAGB in this site (Table 2). The result showed that there are diverse variation among different species. The different tree species tends to has the different structure (growth, stratification, and crown cover) and physiognomy. The largest sample tree was *Artocarpus elasticus* with DBH of 32.60 cm. This species had the dry weight of leaf, branch, trunk, and TAGB were 14.15, 20.23, 183.51, and 217.89 kg respectively. On the other hand, the smallest selected tree was *Archidendron jiringa* with DBH of 16.00 cm. This species obtained 22.95 kg of leaf dry biomass, 9.27 kg of branch dry biomass, 24.09 kg of trunk dry biomass, and 56.30 kg of TAGB. *Pterospermum javanicum* with 22.70 m height was the tallest sample trees. This sample tree had the highest trunk dry biomass (296.72 kg) and TAGB (308.98 kg). Contrasly, the other sample tree of *Pterospermum javanicum* had the lowest trunk dry biomass (12.84 kg) and TAGB (34.28 kg). The shortest sampe tree with 9.30 m height was *Bridelia glauca*. The lowest leaf dry biomass (1.37 kg) and branch dry biomass (3.92 kg) were showed by *Vernonia arborea*. Meanwhile, the other sample tree of *Archidendron jiringa* had the highest leaf dry biomass (45.59 kg). The highest branch dry biomass (34.18 kg) was showed by *Glochidion obscurum*.

Commented [SV1]: What method was used in selecting sample trees both species and family?

Table 2. All data sets for develop allometric equations in abandoned lands

Commented [SV2]: Is there no flower and fruit parts?

Tree No.	Family	Species	DBH (cm)	H (m)	Leaves (kg)	Branches (kg)	Trunk (kg)	TAGB (kg)	WD (g cm^{-3})
1	Malvaceae	*Pterospermum javanicum*	31.85	18.10	5.68	32.61	249.73	288.01	0.53
2	Malvaceae	*Pterospermum javanicum*	20.06	17.10	9.31	9.39	119.09	137.80	0.53
3	Malvaceae	*Pterospermum javanicum*	28.98	22.70	3.86	8.39	296.72	308.98	0.53
4	Moraceae	*Ficus septica*	32.17	20.20	5.70	19.70	166.63	192.03	0.39
5	Moraceae	*Ficus septica*	28.03	15.60	1.92	10.47	93.98	106.38	0.39
6	Cannabaceae	*Trema orientalis*	26.75	14.16	7.37	22.89	86.11	116.36	0.44
7	Proteaceae	*Heliciopsis artocarpoides*	21.97	9.70	9.95	9.88	57.62	77.44	0.65
8	Phyllanthaceae	*Bridelia glauca*	28.66	13.90	6.78	12.37	80.76	99.91	0.50
9	Phyllanthaceae	*Bridelia glauca*	20.70	12.50	6.93	16.74	71.55	95.22	0.50
10	Cannabaceae	*Trema orientalis*	26.11	10.80	13.97	29.02	58.17	101.16	0.44
11	Malvaceae	*Pterospermum javanicum*	29.62	16.00	8.76	10.12	77.63	96.52	0.53
12	Malvaceae	*Pterospermum javanicum*	16.88	10.60	6.88	14.56	12.84	34.28	0.53
13	Phyllanthaceae	*Bridelia glauca*	26.75	15.80	12.89	33.00	89.17	135.07	0.50
14	Euphorbiaceae	*Glochidion obscurum*	26.00	15.30	10.65	8.34	114.02	133.01	0.67
15	Euphorbiaceae	*Glochidion obscurum*	20.40	13.70	11.88	9.24	89.41	110.53	0.67
16	Fabaceae	*Archidendron jiringa*	16.00	10.36	22.95	9.27	24.09	56.30	0.42
17	Dipterocarpaceae	*Vatica javanica*	19.95	13.00	38.71	32.40	43.01	114.11	0.69
18	Euphorbiaceae	*Glochidion obscurum*	19.70	14.65	8.64	14.25	78.32	101.21	0.67
19	Fabaceae	*Archidendron jiringa*	24.60	16.00	45.59	22.73	160.89	229.21	0.42
20	Dipterocarpaceae	*Vatica javanica*	20.70	12.00	39.17	16.92	129.92	186.01	0.69
21	Euphorbiaceae	*Glochidion obscurum*	20.39	9.50	20.97	34.18	104.42	159.57	0.67
22	Dipterocarpaceae	*Vatica javanica*	28.60	13.90	7.66	29.95	184.53	222.14	0.69
23	Euphorbiaceae	*Glochidion obscurum*	21.50	10.90	11.24	21.63	142.13	175.00	0.67

Tree No.	Family	Species	DBH (cm)	H (m)	Leaves (kg)	Branches (kg)	Trunk (kg)	TAGB (kg)	WD (g cm^{-3})
24	Moraceae	*Artocarpus elasticus*	32.60	20.70	14.15	20.23	183.51	217.89	0.46
25	Asteraceae	*Vernonia arborea*	23.30	9.82	1.37	3.92	52.70	57.99	0.37
26	Asteraceae	*Vernonia arborea*	29.40	13.50	3.79	9.83	121.02	134.64	0.37
27	Phyllanthaceae	*Bridelia glauca*	21.50	9.30	14.28	17.31	67.24	98.83	0.50
28	Malvaceae	*Pterospermum javanicum*	20.29	16.10	4.04	3.94	163.39	171.38	0.53
29	Malvaceae	*Pterospermum javanicum*	20.36	18.50	6.66	8.55	189.90	205.12	0.53
30	Malvaceae	*Pterospermum javanicum*	26.60	21.70	11.19	17.72	187.95	216.85	0.53
Average			24.35	14.54	12.43	16.99	116.55	145.96	0.53
Minimum			16.00	9.30	1.37	3.92	12.84	34.28	0.37
Maximum			32.60	22.70	45.59	34.18	296.72	308.98	0.69
Standard deviation			4.66	3.75	10.93	9.13	65.59	66.98	0.11

Note: DBH=diameter at breast height; H=total height; TAGB=total above ground biomass; WD=wood density.

The allometric equations for Above Ground Biomass (AGB) of trees

The results of regression analyses for predicting plant part biomass of subject trees from diameter at breast height (DBH) and total height (H) using data all studied individuals are shown in Table 3. The relationships between DBH, ($DBH^2 \times H$), and height of trees as independent variables were not significant to related leaf and branch dry biomasss (*P* value > 0.05) as well as DBH to trunk dry biomass. This means that the DBH, ($DBH^2 \times H$), height of trees were not a good predictor to leaf and branch dry biomass based on the goodness of fit. Similarly DBH was not also good predictor to trunk dry biomass. The correlations between ($DBH^2 \times H$) and height of trees to trunk dry biomass and TAGB showed moderately strong relationships as well as DBH to TAGB (*P* value < 0.001).

The selected allometric equations to estimate above ground biomass of trees were dominated by log-linear model (ln y=a+b ln x) and linear model (y=a+bx). These equations were fitting model to relate dependent variables (leaf, branch, trunk, and AGB) and independent variables (DBH, ($DBH^2 \times H$), and H) for tree stage. From all tested regression, there are only four equations wih relatively high R^2 (>0.400). These equations are "ln (trunk dry biomass) = 0.837 × ln ($DBH^2 \times H$) – 29.45" (R^2=0.500), "ln (trunk dry biomass) = 1.812 × ln (H) – 0.217" (R^2=0.461), "ln (AGB) = 0.576 × ln ($DBH^2 \times H$) – 0.301" (R^2=0.431), and "ln (AGB) = 1.331 × ln (H) – 1.350" (R^2=0.455). However, the result showed there are very weak relationships between leaves and branches dry biomass of trees and plant dimensions in the abandoned land. The trunk dry biomass and AGB in the tropical secondary forests of different ages (5, 10 and 20 years after abandonment) showed strong correlations (adjusted R^2= 0.59-0.95) with diameter at breast height (DBH) and height. The leaf and branch dry biomass had weak correlations with height (adjusted R^2=0.36-0.50) (Karyati et al. 2019). The mixed-species allometric equations showed AGB correlates significantly with diameter at stump height (R^2=0.78; P<0.01) and tree height (R^2=0.41, P<0.05) (Mokria et al. 2018). Generally, the developed allometric equations showed relatively low R^2 (<0.60). This may caused by the high variation sample trees. The variation sample trees lead the variation on wood density, structure, and physiognomy. Parlucha (2017) stated that comparing growth performance for different level of species type (native or exotic) is not conclusive since the growth of trees varies. It is happen from specific species character level and matching with the existing site condition. The regression between the trunk biomass and TAGB and the product of square DBH and height (cm^2 m) and the natural logarithm of height was illustrated in Figure 6.

Table 3. The allometric equations for predicting plant part biomass of subject trees in the study site

Dependent variable (y)	Independent variable (x)	Equation	*P* value	R^2
Leaf dry biomass (kg)	DBH (cm)	ln (y) = 0.054 × (x) – 3.524	>0.05	0.099
	($DBH^2 \times H$) (cm^2m)	ln (y) = 0.4132 × ln (x) – 5.932	>0.05	0.086
	H (m)	(y) = 0.001 × (x) – 17.614	>0.05	0.074
Branch dry biomass (kg)	DBH (cm)	ln (y) = 0.695 × ln (x) + 0.4687	>0.05	0.060
	($DBH^2 \times H$) (cm^2m)	ln (y) = 0.001 × (x) + 2.5228	>0.05	0.023
	H (m)	(y) = 0.001 × (x) + 15.097	>0.05	0.014
Trunk dry biomass (kg)	DBH (cm)	ln (y) = 1.910 × ln (x) – 1.501	>0.05	0.347
	($DBH^2 \times H$) (cm^2m)	ln (y) = 0.837 × ln (x) – 2.945	<0.001	0.500
	H (m)	ln (y) = 1.812 × ln (x) – 0.217	<0.001	0.461
Above ground biomass (kg)	DBH (cm)	ln (y) = 1.277 × ln (x) + 0.808	<0.001	0.283
	($DBH^2 \times H$) (cm^2m)	ln (y) = 0.576 × ln (x) – 0.301	<0.001	0.431
	H (m)	ln (y) = 1.331 × ln (x) – 1.350	<0.001	0.455

Note: *P* values of the regression analysis are shown, R^2 denotes multiple coefficient of determination.

Commented [SV3]: The model evaluation was only based on statistics for R^2 and *P* value, no including some statistics for errors, especially relative errors. It is suggested to add some assessment indices such as mean relative error (MRE), mean absolute relative error (MARE) (Manuri et al., 2017), total relative error (TRE) and mean prediction error (MPE) (Zeng et al, 2017) for model evaluation.
Due to limited samples (only 30 trees) in this study, cross validation was not conducted. In this case, MPE an d others statistics are an important index for assessing the biomass models.

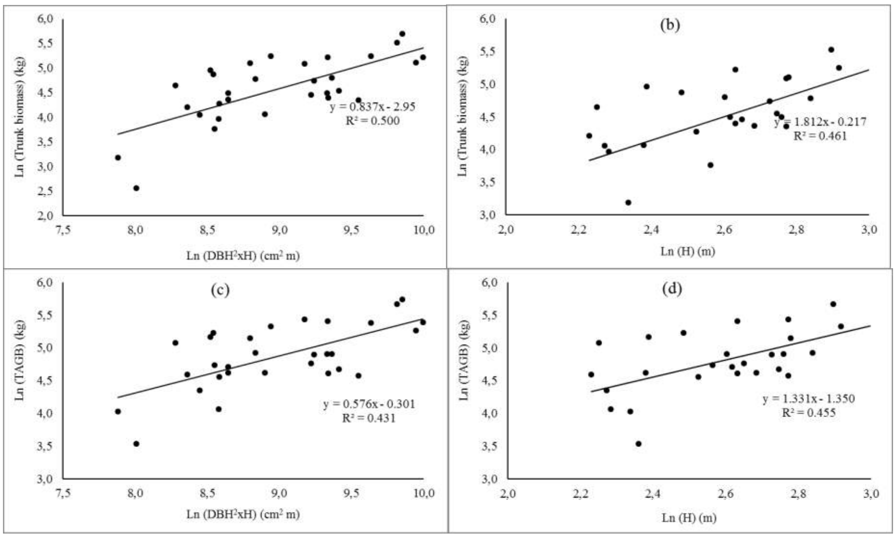


Figure 6. Regression between the trunk biomass (kg) and the product of square DBH and height (cm^2 m) (a) and the natural logarithm of height (m) (b); Regression between total above ground biomass (TAGB) (kg) and the product of square DBH and height (cm^2 m) (c) and the natural logarithm of height (m) (d).

Comparison among various allometric equations

The estimation of AGB using the developed allometric equation in this study was lower than using the previous developed equations as presented in Table 3. The AGB estimation of 33.31 Mg ha^{-1} was lower than 115.90, 91.65, 85.60, 76.31, 68.08, 63.99, 60.32 Mg ha^{-1} of AGB calculated using the formulas of Rai and Proctor (1986), Chambers et al. (2001), Yamakura et al. (1986), Brown (1997), Basuki et al. (2009), Kiyono and Hastaniah (2008), and Nelson et al. (1999) respectively. The value resulted by the developed allometric equation was similar than those using other previous reported equations, i.e., 38.86 Mg ha^{-1} (Kenzo et al. 2009a), 39.31 Mg ha^{-1} (Hashimoto et al. 2004), 49.05 Mg ha^{-1} (Sierra et al. (2007), 49.63 Mg ha^{-1} (Kettering et al. 2001), 50.31Mg ha^{-1} (Karyati et al. 2019), and 5.94 Mg ha^{-1} (Kenzo et al. 2009b). The comparison between AGB and DBH estimated by previously reported relationships was illustrated in Figure 7.

The calculation using equations of Rai and Proctor (1986), Chambers et al. (2001), Yamakura et al. (1986), Brown (1997), Basuki et al. (2009), and Kiyono and Hastaniah (2008) resulted the overestimation than the developed allometric equation. This might be caused the low wood density (0.37-0.69) of trees in the study site, because tree species observed in the abandoned land was dominated by pioneer species. The allometric equations for pioneer species may differ significantly caused usually these species has the low wood (Hashimoto et al. 2004). The wood densities of trees were 0.40-0.79 for Brown's equation, 0.32-0.86 for Basuki et al.'s equation, and 0.67 for Kiyono and Hastaniah's equation. The similar values of AGB were estimated by using equations of Kenzo et al. (2009a) with wood density of 0.35, Kettering et al. (2001) with wood density of 0.35 to 0.91, Karyati et al. (2019) with wood density of 0.24-0.44, and Kenzo et al. (2009b) with wood density of 0.35. Kenzo et al. (2009a), Hashimoto et al. (2004), and Karyati et al. (2019) developed allometric equation for mixed species in tropical forest of Kalimantan, while Kettering et al. (2001) developed allometric for mixed secondary forest in Sumatra. Sierra et al. (2007) reported allometric equation for tropical forest in Colombia. The similar tree species in abandoned land of study site and the mixed secondary forest caused the similar estimation of AGB by using the developed equations.

The using appropriate allometric equations to estimate AGB is needed, because it will give accurate estimation on AGB in the study site. When specific allometric equation for different land use and land coverage was developed, the users will choose suitable alternative equations.

Table 4. Estimation of AGB using various reported relationships for trees in the study site

No.	Equation	Author	Estimate of AGB (Mg ha^{-1})
1	ln(AGB)=2.12×ln(DBH)-0.435	Rai and Proctor (1986)	115.90
2	ln(AGB)=2.62×ln(DBH)-2.30	Yamakura et al. (1986)	85.60
3	ln(AGB)=2.53×ln(DBH)-2.13	Brown (1997)	76.31
4	ln(AGB)=2.413×ln(DBH)-1.997	Nelson et al. (1999)	60.32
5	ln(AGB)=2.55×ln(DBH)-2.010	Chambers et al. (2001)	91.65
6	ln(AGB)=2.59×ln(DBH)-2.75	Kettering et al. (2001)	49.63
7	ln(AGB)=2.44×ln(DBH)-2.51	Hashimoto et al. (2004)	39.31
8	ln(AGB)=2.422×ln(DBH)-2.232	Sierra et al. (2007)	49.05
9	$AGB=0.1008\times DBH^{2.5264}$	Kiyono and Hastaniah (2008)	63.99
10	ln(AGB)=2.196×ln(DBH)-1.201	Basuki et al. (2009)	68.08
11	$AGB=0.0829\times DBH^{2.43}$	Kenzo et al. (2009a)	38.86
12	$AGB=0.1525\times DBH^{2.34}$	Kenzo et al. (2009b)	53.94
13	ln(AGB)=2.3207×ln(DBH)-1.89	Karyati et al. (2019)	50.31
14	$(AGB) = 12.683\times(DBH^2\times H)-38.403$	This study	33.31

Note: AGB = above ground biomass ; DBH = diameter at breast height.

Commented [SV4]: Please read and compare to Manuri *et al.* (2017) that it is related to effect of species grouping and site variables on aboveground biomass models for lowland tropical forests of the Indo-Malay region

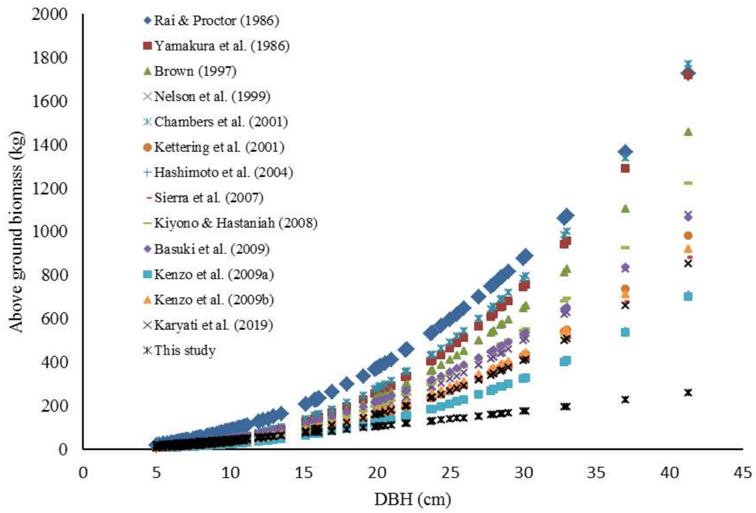


Figure 7. Comparison among various allometric relationships between above ground biomass (AGB) and diameter at breast height (DBH) in the study site

ACKNOWLEDGEMENTS

We express our thanks to Ministry of Research, Technology and Higher Education, Republic of Indonesia for supporting *Hibah Penelitian Dasar Unggulan Perguruan Tinggi* Contract No.: 183/SP2H/LT/DRPM/2019.

REFERENCES

Awang Noor AG, Faridah Hanum I, Tuan Marina TI. 2008. Relationship between economic value and species diversity of timber resources in a hill forest in Peninsular Malaysia. Journal of Sustainable Development 1(2): 17-26.
Chokkalingam U, Smith J, de Jong W. 2001. A conceptual framework for the assessment of tropical secondary forest dynamics and sustainable development potential in Asia. Journal of Tropical Forest Science 13(4): 577-600.
Curtis PS. 2008. Estimating Aboveground Carbon in Live and Standing Dead Trees. In: Hoover CM (ed). Field Measurements for Forest Carbon Monitoring: a Landscape-Scale Approach. Springer, USA.
Fearnside PM. 1997. Greenhouse gases emissions from deforestation in Brazillian Amazonia: Net committed emissions. Climatic Change 35: 321-360.
Gorte RW. 2007. Carbon Sequestration in Forests. CRS Report for Congress. Congressional Research Service.

Hairiah K, Rahayu S. 2007. Pengukuran "Karbon Tersimpan" di Berbagai Macam Penggunaan Lahan. World Agroforestry Centre-ICRAF, Indonesia.

Hairiah K, Sitompul SM, Van Noordwijk M, Palm C. 2001. Methods for Sampling Carbon Stocks Above and Below Ground. ASB Lecture Note 4B. International Centre for Research in Agroforestry, Indonesia.

Harmon EH, Ferrell WK, Frankli JF. 1990. Effects on carbon storage of conservation of old growth forests to young forest. Science 297: 699-702.

Hashimoto T, Tange T, Masumori M, Yagi H, Sasaki S, Kojima K. 2004. Allometric equations for pioneer tree species and estimation of the aboveground biomass of a tropical secondary forest in East Kalimantan. Tropics 14: 123-130.

Janisch JE, Harmon ME. 2002. Successional changes in live and dead wood carbon stores: Implications for net ecosystem productivity. Tree Physiology 22: 77-89.

Karyati. 2013. Ecology and Carbon Sequestration of Secondary Forests at Sabal, Sarawak. [Dissertation]. Universiti Malaysia Sarawak, Malaysia.

Karyati, Ipor IB, Jusoh I, Wasli ME. 2019. Allometric equations to estimate the above-ground biomass of trees in the tropical secondary forests of different ages. Biodiversitas 20(9): 2427-2436.

Kendawang JJ, Ninomiya I, Tanaka K, Ozawa T, Hattori D, Tanaka S, Sakurai K. 2007. Effects of burning strength in shifting cultivation on the early stage of secondary succession in Sarawak, Malaysia. Tropics 16: 309-321.

Kenzo T, Furutani R, Hattori D, Kendawang JJ, Tanaka S, Sakurai K, Ninomiya I. 2009a. Allometric equations for accurate estimation of above-ground biomass in logged-over tropical rainforests in Sarawak, Malaysia. J For Res 14 (6): 365-372.

Kenzo T, Ichie T, Hattori D, Itioka T, Handa C, Ohkubo T, Kendawang JJ, Nakamura M, Sakaguchi M, Takahashi N, Okamoto M, Tanaka-Oda A, Sakurai K, Ninomiya I. 2009b. Development of allometric relationships for accurate estimation of above- and below-ground biomass in tropical secondary forests in Sarawak, Malaysia. J Trop Ecol 25: 371-386.

Ketterings QM, Coe R, Van Noordwijk M, Ambagau Y, Palm CA. 2001. Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. For Ecol Manag 146:199-209.

Kiyono Y, Hastaniah. 2005. Pattern of slash-and-burn land use and their effects on forest succession. swidden-land forests in Borneo. Bull For For Prod Res Inst 4: 259-282.

Ministry of Forestry Indonesia. 2011. Development of Allometric Equations for Estimating Forest Carbon Stocks Based on Field Measurement (Ground Based Forest Carbon Accounting). Centre for Standardization and Environment, Ministry of Forestry, Indonesia.

Moore PD, Chapman SB. 1986. Methods in Plant Ecology, 2nd Ed. Blackwell Scientific Publications, Oxford.

Mokria M, Mekuria W, Gebrekirstos A, Aynekulu E, Belay B, Gashaw T, Brauning A. 2018. Mixed-species allometric equations and estimation of aboveground bioass and carbon stocks in restoring degraded landscape in northern Ethiopia. Environmental Research Letters 13: 1-14.

Nelson BW, Mesquita R, Pereira JLG, De Souza SGA, Batista T, Couto LB. 1999. Allometric regressions for improved estimate of secondary forest biomass in the Central Amazon. For Ecol Manag 117:149-167.

Nurlinda I, Pujiwati Y, Ishak M. 2014. Perbandingan penanganan tanah terlantar di Kabupaten Tasikmalaya dan Kabupaten Sukabumi dalam mewujudkan ketahanan pangan Provinsi Jawa Barat. Jurnal Hukum IUS Quia Iustum 21(1): 120-138. [Indonesian]

Parlucha J, Barbadillo N, Sedenio P. 2017. Species-site matching based on growth performance evaluation of mixed native and exotic secondary forest in Musuan Bukidnon. Journal of Biodiversity and Environmental Sciences (JBES). 10(3): 62-70.

Roshetko JM, Delaney M, Hairiah K, Purnomosidhi P. 2002. Carbon stocks in Indonesian homegarden systems: Can smallholder systems be targeted for increased carbon storage. American Journal of Alternative Agriculture 17(2): 1-11.

Seiler W, Crutzen PJ. 1980. Estimates of gross and net fluxes of carbon between the biosphere and the atmosphere from biomass burning. Climatic Change 2: 207-247.

Selaya NG, Anten NPR, Oomen RJ, Matthies M, Werger MJA. 2007. Above-ground biomass investments and light interception of tropical forest trees and lianas early in succession. Annals of Botany 99: 141-51.

Sierra CA, Del Valle JI, Orrego SA, Moreno FH, Harmon MA, Zapata M, Colorado GJ, Herrera MA, Lara W, Restrepo DE, Berrouet LM, Loaiza LM, Benjumea JF. 2007. Total carbon stocks in a tropical forest landscape of the Porce Region, Colombia. For Ecol Manag 243: 299-309.

Statistics Kutai Kartanegara Regency. 2018. Kutai Kartanegara Regency in Figures 2018. Tenggarong.

Van Do T, Osawa A, Thang NT. 2010. Recovery process of a mountain forest after shifting cultivation in Northwestern Vietnam. For Ecol Manag 259: 1650-1659.

Dear Managing Editor,

We would like to say thanks and appreciate for constructive suggestion from reviewer.

As attached below, our feedback for the reviewer’s comments on our manuscript entitled “Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned lands”

No.	Page/ Line	Review	Feedback and revision
1	Page 5, line 207	What method was used in selecting sample trees both species and family?	Explaination had added ➔ Thirty sample trees with DBH of > 15 cm were selected in the study site, with consideration of the species. These selected trees didnot considering individuals with damaged crowns or broken trunks. Almost 90% of the selected trees were categorized as the dominant species in terms of density and Importance Value Index (IVi) as observed in the current study, while few selected trees represented the rare species (Page 5, line 214-217).
2	Page 5, line 226	Is there no flower and fruit parts?	Explaination had added ➔ The flower and fruit parts was not included in the observation, because very few sample trees that have flower and fruit during observation (Page 3, line 107-109)
3	Page 5, line 255	The model evaluation was only based on statistics for R^2 and P value, no including some statistics for errors, especially relative errors. It is suggested to add some assessment indices such as mean relative error (MRE), mean absolute relative error (MARE) (Manuri et al., 2017), total relative error (TRE) and mean prediction error (MPE) (Zeng et al, 2017) for model evaluation. Due to limited samples (only 30 trees) in this study, cross validation was not conducted. In this case, MPE and others statistics are an important index for assessing the biomass models.	Some assessment indices such as mean relative error (MRE), mean absolute relative error (MARE) (Manuri et al., 2017), total relative error (TRE) and mean prediction error (MPE) (Zeng et al, 2017) for model evaluation had added (Page 4, line 152-154; Page 7, Table 3)
4	Page 8, line 303	Please read and compare to Manuri *et al.* (2017) that it is related to effect of species grouping and site variables on aboveground biomass models for lowland tropical forests of the Indo-Malay region.	The comparison to Manuri et al. (2017) had added (Page 7, line 295; Page 8, line 313-316; Page 8,Tabel 4; Page 8, Figure 7)

Samarinda, 10 November 2019

Karyati

Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land

Abstract. *Karyati, Widiati KY, Karmini, Mulyadi R. 2019. Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned lands. Biodiversitas x: xx-xx.* The abandoned lands have important role in the ecological fuction as well as carbon sequestration. The allometric equations to estimate above ground biomass in abandoned land are still limited available. This study objective was to develop allometric relationships between tree size variables (diameter at breast height (DBH) and tree height) and leaf, branch, trunk, and total above ground biomass (TAGB) in abandoned land in East Kalimantan, Indonesia. The correlation coefficients between stem DBH and tree height to leaf and branch indicating a relatively weak relationship. The moderately strong relationships were showed by DBH and tree height to trunk and TAGB. The specific allometric equation of above ground biomass for different land use and land type is needed to estimate the accurate TAGB in the site.

Key words: Abandoned land, allometric equation, biomass, destructive method

Running title: Development of allometric equations in abandoned land

INTRODUCTION

The National Land Affairs Agency identified 7.3 million hectares lands in Indonesia as abandoned lands in 2011 and about 4.8 million hectares was stated as abandoned lands. This area of abandoned lands increase from 2007 as much as 7.1 million hectares outside forest area (Nurlinda et al. 2014). The abandoned land area in East Kalimantan was about 3 million hectares. The abandoned lands provide habitat rotation to succession process in primary-secondary forest that will increase biodiversity (Chokkalingam et al. 2001). The plant composition, diversity, and growth during fallow periods after shifting cultivation was resulted from complex interaction between condition and factor before and after fallow periods, such as disturbance, land history, land management, tree and seed source composition from soil or surrounding forest, soil fertility, and climate factor (Awang Noor et al. 2008; Kendawang et al. 2007; Van Do et al. 2010).

Land use system on forest basis store CO_2 by carbon stock storage at their biomasss (Gorte 2007; Roshetko et al. 2002). The carbon stock in old age stand could different compared to carbon stock in second growth stand that replace it, cause woody biomass in an area could not describe in nett eosystem productivity (Janisch and Harmon 2002). Biomass dynamic in tropical forest play important role to evaluation of global carbon cycle and global climate change (Fearnside 1997; Seiler and Crutzen 1980). During the early succession process, amount of stand biomass increase fastly (Selaya et al. 2007). The carbon sequestration of forest area change constanly with vegetation growth, dead, and decomposition (Gorte 2007); species composition, age structur, and forest health (Harmon et al. 1990). Carbon stock at stand in the surface soil and standing tree mass could represented less than 1% to 60% from total carbon stock of forest ecosystem (Curtis 2008). Carbon stock of fertile soils is higher which could influence to carbon stock storage at vegetation biomass (Hairiah and Rahayu 2007).

Biomass is generally expressed in terms of dry weight and on occasion may be given in terms of ash free dry weight (Moore and Chapman 1986). The ‘scaling’ relationships, by which the ratios between different aspects of tree size change when small and large trees of the same species are compared generally known as ‘allometric’ relations (Hairiah et al. 2001). The previous studies had been developed allometric equations to estimate above ground biomass (AGB) in the secondary forests (Hashimoto et al. 2004; Kenzo et al. 2009a; Kenzo et al. 2009b; Ketterings et al. 2001; Kiyono and Hastaniah 2005; Nelson et al. 1999; Sierra et al. 2007; Karyati et al. 2019). However the allometric equations to estimate AGB in abandoned lands is still rare reported. The objective of this study was to develop allometric equations for estimation AGB in fallow lands. Information on the allometric relationships could predict biomass and carbon stock in lands after abandonment.

MATERIALS AND METHODS

Study site

The study was carried out in Salo Cella Village, Muara Badak Sub-district, Kutai Kartanegara Districts, East Kalimantan Province, Indonesia (Figure 1). This site was located in 0°17'18.7"S 117°18'08.2"E. Muara Badak Sub-district has 939.09 km^2 wide with population of 57,712 persons including 13 villages. Salo Cella Village is about 10 km from the capital of Sub-district. The capital of subdistrict was Muara Badak Ulu with 16 m height Above Mean Sea Level (AMSL). Muara Badak received average amount of 141 mm in rainfall and 11 raindays in 2017 (Statistics Kutai Kartanegara Regency 2018). Most of the population in this village were farmers' livelihoods. Muara Badak is administratively bordered with Marang Kayu Sub-district at north side, Anggana Sub-district Samarinda City at south side, Makassar Strait at east side, and Tenggarong Seberang Sub-district at west side. Muara Badak is one of oil and gas producer. This has also big potency in fishery and plantation sectors. The area was covered by lowland mixed dipterocarp forest.

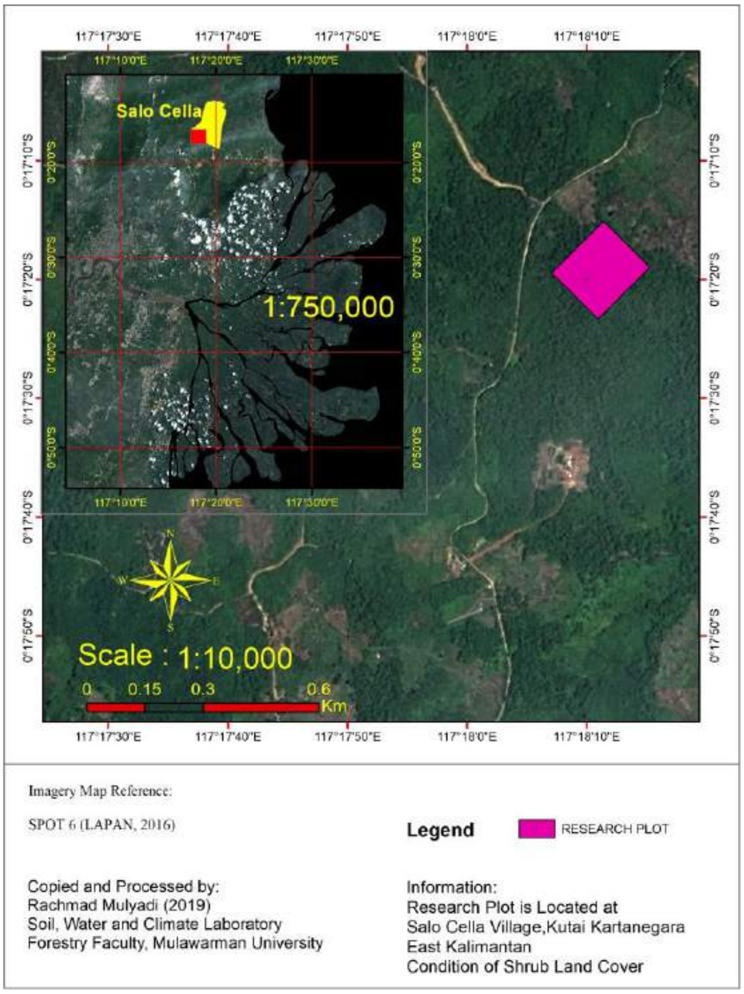


Figure 1. Map of study site in Salo Cella Village, Kutai Kartanegara Districts, East Kalimantan Province, Indonesia.

Data collection

Assessment on biomass in the field

Thirty sample trees were chosen in abandoned land. The sample trees were selected to obtain the representative species of land after abandonment. The selection of sample trees was based on consideration of the species and DBH. The standing DBH (1.3 m) of selected trees were measured using diameter tape. Measurement of the total height of the sample tree was completed once the tree had fallen. Fellings sample trees were conducted by following the harvesting rules. The harvested trees were divided into several fractions which every tree fraction was 1 meter length. Then, parts of trees were separated into leaves and twigs (hereafter called leaves), branches, and main stems in the field as shown in Figure 2.

Dividing sample tree fractions was accomplished with the following criteria (Ministry of Forestry Indonesia, 2011):

1) Dividing sample tree fractions was done to separate parts of tree biomass including leaves, branches, and stem. The flower and fruit parts was not included in the observation, because very few sample trees that have flower and fruit during observation.

2) Dividing sample tree fraction to be weighed needs to consider the capacity of the available scales.

3) Especially for the stem fraction, the stem was divided into several sections (sub-fractions of the stem) taking into account the shape, uniformity, and weight of the pieces.

The fresh weight of all fractions were taken by the suitable scale in the field. The disk samples of trunk with 2-5 cm thick were were collected as many as three disk sample if the harvested trees had less than 10 fractions and four disk samples if more than 10 fractions. Five branch samples of 20-30 cm in length and five leaf samples of 100-300 grams in weight were taken from each sample tree. Figure 3 illustrates tree components and the position of sub-sample being taken for AGB assessment. The wood density of each sample tree was conducted from the various literatures.

Analysis of dry-weight in the laboratory

Before oven-dried, all samples were air-dried in the laboratory to determine the moisture content. Then, samples of stem and branch fractions were dried in an oven at a temperature 105ºC for 96 hours until reaching a constant weight. Samples of leaves were dried in an oven at temperature of 80ºC for 48 hours until constant weight was reached. Weighing the samples of each fraction was performed using an analytical digital weighing scale after drying them in an oven.

Figure 2. Dividing the trees (Source: Ministry of Forestry Indonesia, 2011).

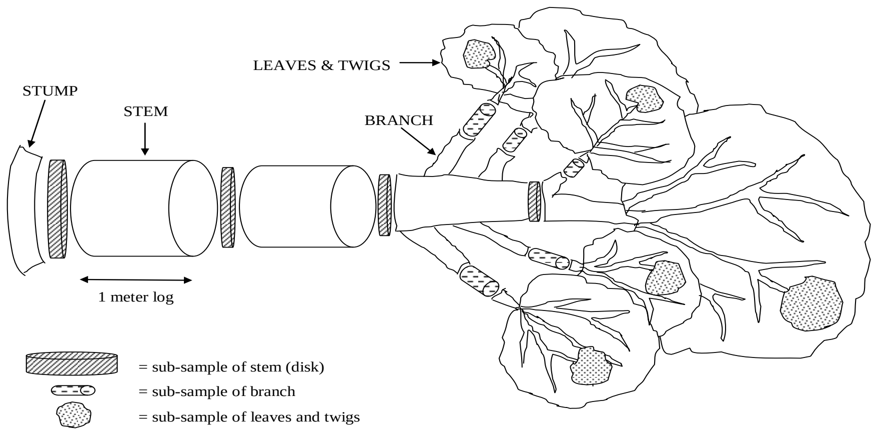


Figure 3. Illustration of tree components and the position of sub-sample being taken (Karyati 2013).

Data analysis

The total oven-dry weight of each tree part were determined using the following formula (Hairiah et al. 2001; Hairiah & Rahayu 2007; Ministry of Forestry Indonesia, 2011):

$$dw = (sdw \times fw) / sfw \quad (1)$$

where: dw = total dry weight (kg); sdw = dry weight of the sample (g); fw = total fresh weight (kg); sfw = fresh weight of the sample (g).

The five selected allometric equations of AGB were tested (Equations 2-6):

$$y = a + b\,x \quad (2)$$

$$y = ax^b \quad (3)$$

$$y = a + b (\ln x) \quad (4)$$

$$(\ln y) = a + b x \quad (5)$$

$$(\ln y) = a + b (\ln x) \quad (6)$$

where: y = total dry weight or biomass of each plant part, such as trunk, branch, leaf, and total above ground biomass (TAGB) (kg); x = diameter at breast height (DBH, cm), total height (H, meter), and ($DBH^2 \times H$) (cm^2 m); 'a' and 'b' = coefficients estimated by regression.

All regression analysis was carried out using SPSS version 18 for windows (SPSS Japan, Tokyo, Japan). The R^2 value was determined to evaluate precision among all tested allometric equations.

RESULTS AND DISCUSSION

Selected samples of trees

Thirty trees with DBH of $\geq$ 15 cm were harvested and measured to determine above ground parts in the study site as represent in Table 1. The DBH and height classes of selected sample trees for assessment AGB are illustrated in Figure 4. The DBH range was 16.0-32.6 cm and height was 9.3-22.7 m for selective sample trees. The relationship between DBH and total height of sample trees for assessment AGB in the study site is presented in Figure 5. The illustration showed that an increase in DBH was followed by an increase in total height. The equations of this relationship was "H=0.4642 (DBH)+3.2344" (n=30; R^2=0.3339). As stated 'H' is total height (m) and 'DBH' is diameter at breast height (cm).

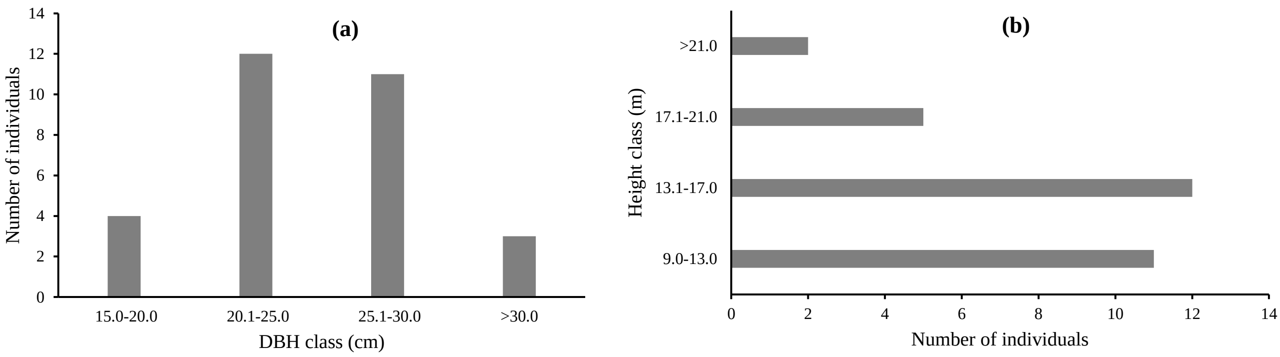


Figure 4. The distributions of (a) DBH classes and (b) height classes of sample trees to developed allometric equations.

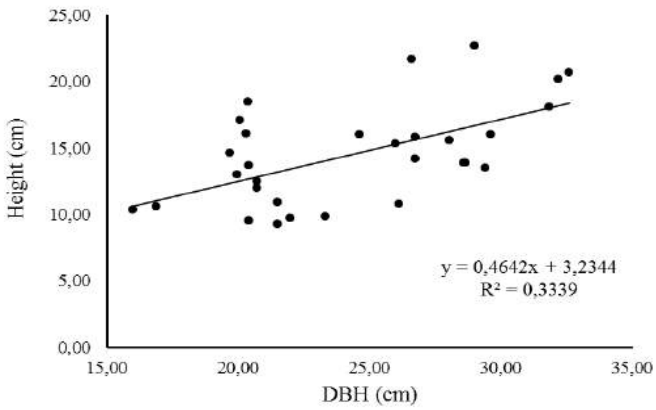


Figure 5. The DBH and total height of sample trees to developed allometric equations.

Tree variables

Pearson's correlation between DBH, height, wood density and branches biomass, trunk biomass, TAGB and parameters of destructive biomass are summarized in Table 1. The minimum and maxiu weight of branches biomass, trunk biomass, and TAGB were 3.92-34.18 kg; 12.84-296.72 kg, and 34.28-308.98 respectively. The DBH of sample trees ranged 16.00-32.00 cm,with the the height ranged 9.30-22.70 m. The wood densites of sample trees ranged 0.37-0.69 g cm^{-3}. The result showed that there were strong correlation (P < 0.01) among trunk biomass to DBH and tree height as well as TAGB and tree height. The correlation (P<0.05) was showed by TAGB and DBH. The strong correlation (P<0.01) was also showed between DBH and tree height. However, the leaf and branch biomass were not correlated with DBH and tree height significantly (*P*>0.05). In addition, the wood density was not also correlated to plant part biomass (leaf, branch, trunk, and TAGB) and tree dimensions (DBH and height).

Table 1. Pearson's correlation between DBH, height, wood density and branches biomass, trunk biomass, TAGB and parameters of destructive biomass

	Pearson's correlation			Mean	Range
	DBH (cm)	**H (m)**	**WD (g cm^{-3})**		
Leaf biomass (kg)	-0.303^{ns}	-0.198^{ns}	0.262^{ns}	12.43	1.37 - 45.59
Branch biomass (kg)	0.205^{ns}	-0.072^{ns}	0.208^{ns}	16.99	3.92 - 34.18
Trunk biomass (kg)	0.527**	0.768**	0.027^{ns}	116.55	12.84 - 296.72
TAGB (kg)	0.494*	0.710**	0.098^{ns}	145.97	34.28 - 308.98
DBH (cm)	1	0.578**	-0.357^{ns}	24.35	16.00 - 32.00
H (m)	0.578**	1	-0.184^{ns}	14.54	9.30 - 22.70
WD (g cm^{-3})	-0.357^{ns}	-0.184^{ns}	1	0.53	0.37 - 0.69

Note: ^{ns} is not significant at the 0.05 level (P>0.05) ; * and **Correlation are significant at the 0.05 and 0.01 level (2-tailed) respectively

Thirty sample trees with DBH of > 15 cm were selected in the study site, with consideration of the species. These selected trees didnot considering individuals with damaged crowns or broken trunks. Almost 90% of the selected trees were categorized as the dominant species in terms of density and Importance Value Index (IVi) as observed in the preminilary study, while few selected trees represented the rare species. There were 10 species of 10 genera of 9 families selected in study site. Eight sample trees were *Pterospermum javanicum* ~~including~~ (Malvaceae). There were 5 sample trees of *Glochidion obscurum* (Euphorbiaceae) and 4 sample trees of *Bridelia glauca* (Phyllanthaceae). Three sample trees were *Vatica javanica* (Dipterocarpacea). The species of *Ficus septica* (Moraceae), *Trema orientalis* (Cannabaceae), *Archidendron jiringa* (Fabaceae), *Vernonia arborea* (Asteraceae) were selected for two sample trees respectively. One sampe tree was *Heliciopsis artocarpoides* (Proteaceae) as well as *Artocarpus elasticus* (Moraceae). The range of dry weight was 1.37-45.59 kg for leaf, 3.92-34.18 kg for branch, 12.84-296.72 kg for trunk, and 34.28-308.98 kg for TAGB in this site (Table 2). The result showed that there are diverse variation among different species. The different tree species tends to has the different structure (growth, stratification, and crown cover) and physiognomy. The largest sample tree was *Artocarpus elasticus* with DBH of 32.60 cm. This species had the dry weight of leaf, branch, trunk, and TAGB were 14.15, 20.23, 183.51, and 217.89 kg respectively. On the other hand, the smallest selected tree was *Archidendron jiringa* with DBH of 16.00 cm. This species obtained 22.95 kg of leaf dry biomass, 9.27 kg of branch dry biomass, 24.09 kg of trunk dry biomass, and 56.30 kg of TAGB. *Pterospermum javanicum* with 22.70 m height was the tallest sample trees. This sample tree had the highest trunk dry biomass (296.72 kg) and TAGB (308.98 kg). Contrasly, the other sample tree of *Pterospermum javanicum* had the lowest trunk dry biomass (12.84 kg) and TAGB (34.28 kg). The shortest sampe tree with 9.30 m height was *Bridelia glauca*. The lowest leaf dry biomass (1.37 kg) and branch dry biomass (3.92 kg) were showed by *Vernonia arborea*. Meanwhile, the other sample tree of *Archidendron jiringa* had the highest leaf dry biomass (45.59 kg). The highest branch dry biomass (34.18 kg) was showed by *Glochidion obscurum*.

Table 2. All data sets for develop allometric equations in abandoned lands

Tree No.	Family	Species	DBH (cm)	H (m)	Leaves (kg)	Branches (kg)	Trunk (kg)	TAGB (kg)	WD (g cm^{-3})
1	Malvaceae	*Pterospermum javanicum*	31.85	18.10	5.68	32.61	249.73	288.01	0.53
2	Malvaceae	*Pterospermum javanicum*	20.06	17.10	9.31	9.39	119.09	137.80	0.53
3	Malvaceae	*Pterospermum javanicum*	28.98	22.70	3.86	8.39	296.72	308.98	0.53
4	Moraceae	*Ficus septica*	32.17	20.20	5.70	19.70	166.63	192.03	0.39
5	Moraceae	*Ficus septica*	28.03	15.60	1.92	10.47	93.98	106.38	0.39
6	Cannabaceae	*Trema orientalis*	26.75	14.16	7.37	22.89	86.11	116.36	0.44
7	Proteaceae	*Heliciopsis artocarpoides*	21.97	9.70	9.95	9.88	57.62	77.44	0.65
8	Phyllanthaceae	*Bridelia glauca*	28.66	13.90	6.78	12.37	80.76	99.91	0.50
9	Phyllanthaceae	*Bridelia glauca*	20.70	12.50	6.93	16.74	71.55	95.22	0.50
10	Cannabaceae	*Trema orientalis*	26.11	10.80	13.97	29.02	58.17	101.16	0.44
11	Malvaceae	*Pterospermum javanicum*	29.62	16.00	8.76	10.12	77.63	96.52	0.53
12	Malvaceae	*Pterospermum javanicum*	16.88	10.60	6.88	14.56	12.84	34.28	0.53
13	Phyllanthaceae	*Bridelia glauca*	26.75	15.80	12.89	33.00	89.17	135.07	0.50
14	Euphorbiaceae	*Glochidion obscurum*	26.00	15.30	10.65	8.34	114.02	133.01	0.67
15	Euphorbiaceae	*Glochidion obscurum*	20.40	13.70	11.88	9.24	89.41	110.53	0.67
16	Fabaceae	*Archidendron jiringa*	16.00	10.36	22.95	9.27	24.09	56.30	0.42
17	Dipterocarpaceae	*Vatica javanica*	19.95	13.00	38.71	32.40	43.01	114.11	0.69
18	Euphorbiaceae	*Glochidion obscurum*	19.70	14.65	8.64	14.25	78.32	101.21	0.67

Tree No.	Family	Species	DBH (cm)	H (m)	Leaves (kg)	Branches (kg)	Trunk (kg)	TAGB (kg)	WD (g cm^{-3})
19	Fabaceae	*Archidendron jiringa*	24.60	16.00	45.59	22.73	160.89	229.21	0.42
20	Dipterocarpaceae	*Vatica javanica*	20.70	12.00	39.17	16.92	129.92	186.01	0.69
21	Euphorbiaceae	*Glochidion obscurum*	20.39	9.50	20.97	34.18	104.42	159.57	0.67
22	Dipterocarpaceae	*Vatica javanica*	28.60	13.90	7.66	29.95	184.53	222.14	0.69
23	Euphorbiaceae	*Glochidion obscurum*	21.50	10.90	11.24	21.63	142.13	175.00	0.67
24	Moraceae	*Artocarpus elasticus*	32.60	20.70	14.15	20.23	183.51	217.89	0.46
25	Asteraceae	*Vernonia arborea*	23.30	9.82	1.37	3.92	52.70	57.99	0.37
26	Asteraceae	*Vernonia arborea*	29.40	13.50	3.79	9.83	121.02	134.64	0.37
27	Phyllanthaceae	*Bridelia glauca*	21.50	9.30	14.28	17.31	67.24	98.83	0.50
28	Malvaceae	*Pterospermum javanicum*	20.29	16.10	4.04	3.94	163.39	171.38	0.53
29	Malvaceae	*Pterospermum javanicum*	20.36	18.50	6.66	8.55	189.90	205.12	0.53
30	Malvaceae	*Pterospermum javanicum*	26.60	21.70	11.19	17.72	187.95	216.85	0.53
Average			24.35	14.54	12.43	16.99	116.55	145.96	0.53
Minimum			16.00	9.30	1.37	3.92	12.84	34.28	0.37
Maximum			32.60	22.70	45.59	34.18	296.72	308.98	0.69
Standard deviation			4.66	3.75	10.93	9.13	65.59	66.98	0.11

Note: DBH=diameter at breast height; H=total height; TAGB=total above ground biomass; WD=wood density.

The allometric equations for Above Ground Biomass (AGB) of trees

The results of regression analyses for predicting plant part biomass of subject trees from diameter at breast height (DBH) and total height (H) using data all studied individuals are shown in Table 3. The relationships between DBH, ($DBH^2 \times H$), and height of trees as independent variables were not significant to related leaf and branch dry biomasss (*P* value > 0.05) as well as DBH to trunk dry biomass. This means that the DBH, ($DBH^2 \times H$), height of trees were not a good predictor to leaf and branch dry biomass based on the goodness of fit. Similarly DBH was not also good predictor to trunk dry biomass. The correlations between ($DBH^2 \times H$) and height of trees to trunk dry biomass and TAGB showed moderately strong relationships as well as DBH to TAGB (*P* value < 0.001).

The selected allometric equations to estimate above ground biomass of trees were dominated by log-linear model (ln y=a+b ln x) and linear model (y=a+bx). These equations were fitting model to relate dependent variables (leaf, branch, trunk, and AGB) and independent variables (DBH, ($DBH^2 \times H$), and H) for tree stage. From all tested regression, there are only four equations wih relatively high R^2 (>0.400). These equations are "ln (trunk dry biomass) = 0.837 × ln ($DBH^2 \times H$) – 29.45" (R^2=0.500), "ln (trunk dry biomass) = 1.812 × ln (H) – 0.217" (R^2=0.461), "ln (AGB) = 0.576 × ln ($DBH^2 \times H$) – 0.301" (R^2=0.431), and "ln (AGB) = 1.331 × ln (H) – 1.350" (R^2=0.455). However, the result showed there are very weak relationships between leaves and branches dry biomass of trees and plant dimensions in the abandoned land. The trunk dry biomass and AGB in the tropical secondary forests of different ages (5, 10 and 20 years after abandonment) showed strong correlations (adjusted R^2= 0.59-0.95) with diameter at breast height (DBH) and height. The leaf and branch dry biomass had weak correlations with height (adjusted R^2=0.36-0.50) (Karyati et al. 2019). The mixed-species allometric equations showed AGB correlates significantly with diameter at stump height (R^2=0.78; $P<0.01$) and tree height (R^2=0.41, $P<0.05$) (Mokria et al. 2018). Generally, the developed allometric equations showed relatively low R^2 (<0.60). This may caused by the high variation sample trees. The variation sample trees lead the variation on wood density, structure, and physiognomy. Parlucha (2017) stated that comparing growth performance for different level of species type (native or exotic) is not conclusive since the growth of trees varies. It is happen from specific species character level and matching with the existing site condition. The regression between the trunk biomass and TAGB and the product of square DBH and height (cm^2 m) and the natural logarithm of height was illustrated in Figure 6.

Table 3. The allometric equations for predicting plant part biomass of subject trees in the study site

Dependent variable (y)	Independent variable (x)	Equation	*P* value	R^2	MRE	MARE
Leaf dry biomass (kg)	DBH (cm)	ln (y) = 0.054 × (x) – 3.524	>0.05	0.099		
	($DBH^2 \times H$) (cm^2m)	ln (y) = 0.4132 × ln (x) – 5.932	>0.05	0.086		
	H (m)	(y) = 0.001 × (x) – 17.614	>0.05	0.074		
Branch dry biomass (kg)	DBH (cm)	ln (y) = 0.695 × ln (x) + 0.4687	>0.05	0.060		
	($DBH^2 \times H$) (cm^2m)	ln (y) = 0.001 × (x) + 2.5228	>0.05	0.023		
	H (m)	(y) = 0.001 × (x) + 15.097	>0.05	0.014		
Trunk dry biomass (kg)	DBH (cm)	ln (y) = 1.910 × ln (x) – 1.501	>0.05	0.347		
	($DBH^2 \times H$) (cm^2m)	ln (y) = 0.837 × ln (x) – 2.945	<0.001	0.500		
	H (m)	ln (y) = 1.812 × ln (x) – 0.217	<0.001	0.461		
Above ground biomass (kg)	DBH (cm)	ln (y) = 1.277 × ln (x) + 0.808	<0.001	0.283		
	($DBH^2 \times H$) (cm^2m)	ln (y) = 0.576 × ln (x) – 0.301	<0.001	0.431		
	H (m)	ln (y) = 1.331 × ln (x) – 1.350	<0.001	0.455		

Note: *P* values of the regression analysis are shown, R^2 denotes multiple coefficient of determination.

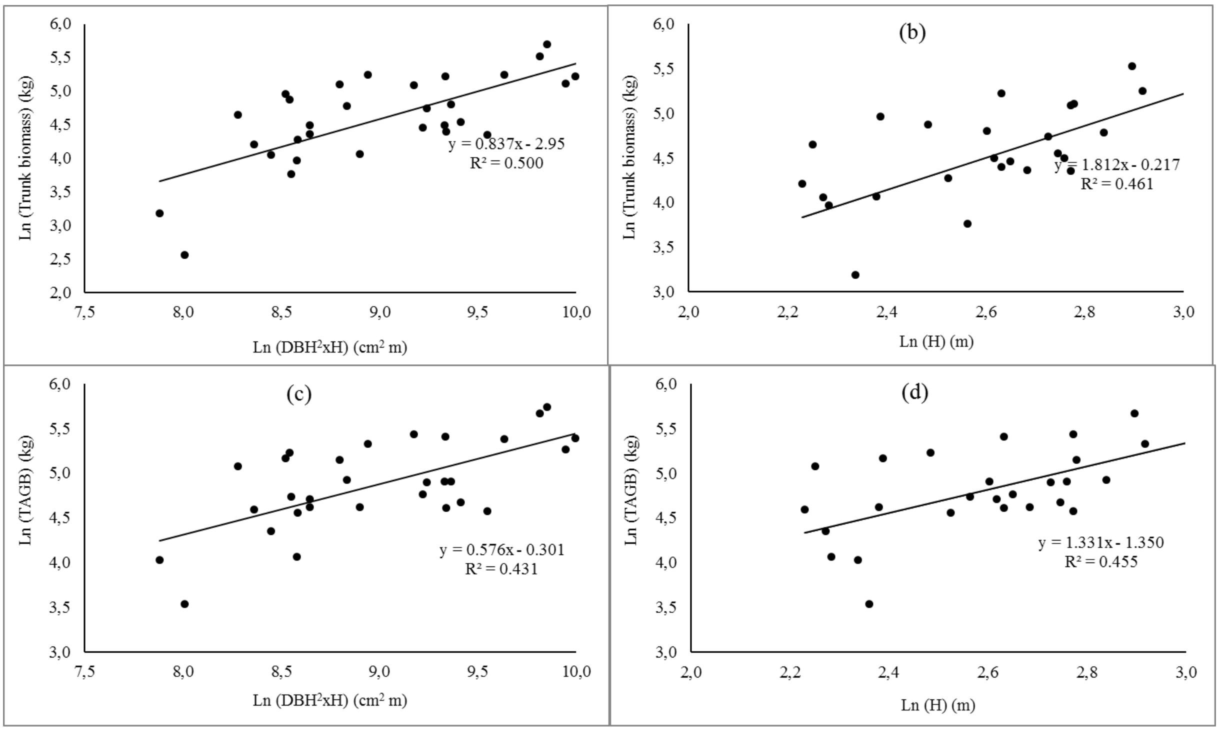


Figure 6. Regression between the trunk biomass (kg) and the product of square DBH and height (cm^2 m) (a) and the natural logarithm of height (m) (b); Regression between total above ground biomass (TAGB) (kg) and the product of square DBH and height (cm^2 m) (c) and the natural logarithm of height (m) (d).

Comparison among various allometric equations

The estimation of AGB using the developed allometric equation in this study was lower than using the previous developed equations as presented in Table 3. The AGB estimation of 33.31 Mg ha^{-1} was lower than 115.90, 91.65, 85.60, 76.31, 68.08, 63.99, 60.32 Mg ha^{-1} of AGB calculated using the formulas of Rai and Proctor (1986), Chambers et al. (2001), Yamakura et al. (1986), Brown (1997), Basuki et al. (2009), Kiyono and Hastaniah (2008), and Nelson et al. (1999) respectively. The value resulted by the developed allometric equation was similar than those using other previous reported equations, i.e., 38.86 Mg ha^{-1} (Kenzo et al. 2009a), 39.31 Mg ha^{-1} (Hashimoto et al. 2004), 49.05 Mg ha^{-1} (Sierra et al. (2007), 49.63 Mg ha^{-1} (Kettering et al. 2001), 50.31Mg ha^{-1} (Karyati et al. 2019), and 5.94 Mg ha^{-1} (Kenzo et al. 2009b). The comparison between AGB and DBH estimated by previously reported relationships was illustrated in Figure 7.

The calculation using equations of Rai and Proctor (1986), Chambers et al. (2001), Yamakura et al. (1986), Brown (1997), Basuki et al. (2009), and Kiyono and Hastaniah (2008) resulted the overestimation than the developed allometric equation. This might be caused the low wood density (0.37-0.69) of trees in the study site, because tree species observed in the abandoned land was dominated by pioneer species. The allometric equations for pioneer species may differ significantly caused usually these species has the low wood (Hashimoto et al. 2004). The wood densities of trees were 0.40-0.79 for Brown's equation, 0.32-0.86 for Basuki et al.'s equation, and 0.67 for Kiyono and Hastaniah's equation. The similar values of AGB were estimated by using equations of Kenzo et al. (2009a) with wood density of 0.35, Kettering et al. (2001) with wood density of 0.35 to 0.91, Karyati et al. (2019) with wood density of 0.24-0.44, and Kenzo et al. (2009b) with wood density of 0.35. Kenzo et al. (2009a), Hashimoto et al. (2004), and Karyati et al. (2019) developed allometric equation for mixed species in tropical forest of Kalimantan, while Kettering et al. (2001) developed allometric for mixed secondary forest in Sumatra. Sierra et al. (2007) reported allometric equation for tropical forest in Colombia. The similar tree species in abandoned land of study site and the mixed secondary forest caused the similar estimation of AGB by using the developed equations.

The using appropriate allometric equations to estimate AGB is needed, because it will give accurate estimation on AGB in the study site. When specific allometric equation for different land use and land coverage was developed, the users will choose suitable alternative equations.

Table 4. Estimation of AGB using various reported relationships for trees in the study site

No.	Equation	Author	Estimate of AGB (Mg ha^{-1})
1	ln(AGB)=2.12×ln(DBH)-0.435	Rai and Proctor (1986)	115.90
2	ln(AGB)=2.62×ln(DBH)-2.30	Yamakura et al. (1986)	85.60
3	ln(AGB)=2.53×ln(DBH)-2.13	Brown (1997)	76.31
4	ln(AGB)=2.413×ln(DBH)-1.997	Nelson et al. (1999)	60.32
5	ln(AGB)=2.55×ln(DBH)-2.010	Chambers et al. (2001)	91.65
6	ln(AGB)=2.59×ln(DBH)-2.75	Kettering et al. (2001)	49.63
7	ln(AGB)=2.44×ln(DBH)-2.51	Hashimoto et al. (2004)	39.31
8	ln(AGB)=2.422×ln(DBH)-2.232	Sierra et al. (2007)	49.05
9	$AGB=0.1008\times DBH^{2.5264}$	Kiyono and Hastaniah (2008)	63.99
10	ln(AGB)=2.196×ln(DBH)-1.201	Basuki et al. (2009)	68.08
11	$AGB=0.0829\times DBH^{2.43}$	Kenzo et al. (2009a)	38.86
12	$AGB=0.1525\times DBH^{2.34}$	Kenzo et al. (2009b)	53.94
13	ln(AGB)=2.3207×ln(DBH)-1.89	Karyati et al. (2019)	50.31
14	$(AGB) = 12.683\times(DBH^2\times H)–38.403$	This study	33.31

Note: AGB = above ground biomass ; DBH = diameter at breast height.

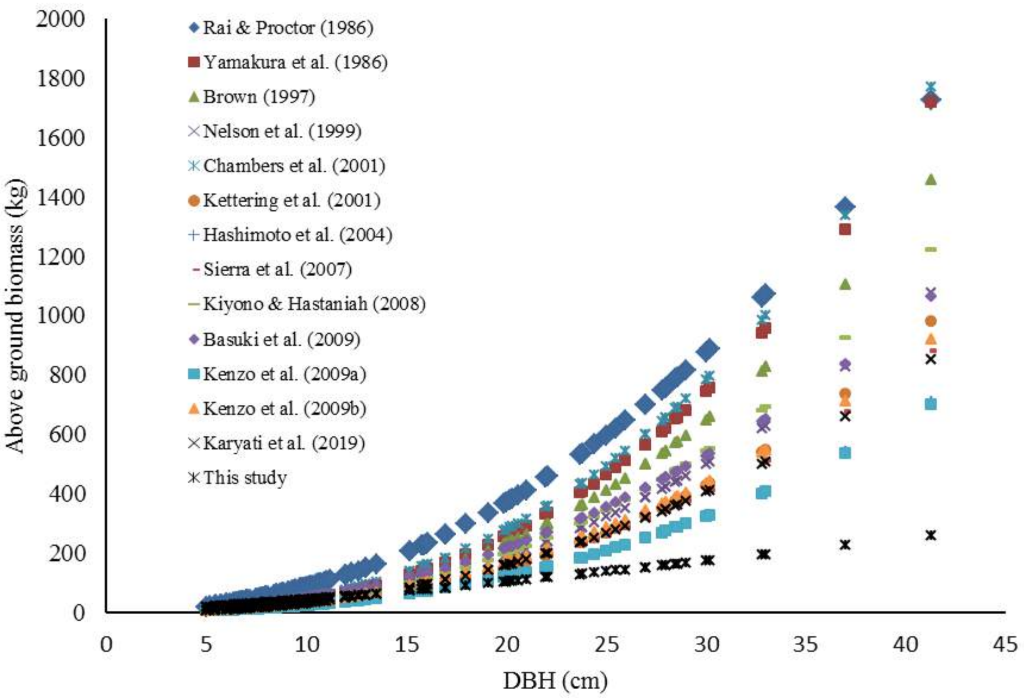


Figure 7. Comparison among various allometric relationships between above ground biomass (AGB) and diameter at breast height (DBH) in the study site

ACKNOWLEDGEMENTS

We express our thanks to Ministry of Research, Technology and Higher Education, Republic of Indonesia for supporting *Hibah Penelitian Dasar Unggulan Perguruan Tinggi* Contract No.: 183/SP2H/LT/DRPM/2019.

REFERENCES

Awang Noor AG, Faridah Hanum I, Tuan Marina TI. 2008. Relationship between economic value and species diversity of timber resources in a hill forest in Peninsular Malaysia. Journal of Sustainable Development 1(2): 17-26.

Chokkalingam U, Smith J, de Jong W. 2001. A conceptual framework for the assessment of tropical secondary forest dynamics and sustainable development potential in Asia. Journal of Tropical Forest Science 13(4): 577-600.

Curtis PS. 2008. Estimating Aboveground Carbon in Live and Standing Dead Trees. In: Hoover CM (ed). Field Measurements for Forest Carbon Monitoring: a Landscape-Scale Approach. Springer, USA.

Fearnside PM. 1997. Greenhouse gases emissions from deforestation in Brazillian Amazonia: Net committed emissions. Climatic Change 35: 321-360.

Gorte RW. 2007. Carbon Sequestration in Forests. CRS Report for Congress. Congressional Research Service.

Hairiah K, Rahayu S. 2007. Pengukuran "Karbon Tersimpan" di Berbagai Macam Penggunaan Lahan. World Agroforestry Centre-ICRAF, Indonesia.

Hairiah K, Sitompul SM, Van Noordwijk M, Palm C. 2001. Methods for Sampling Carbon Stocks Above and Below Ground. ASB Lecture Note 4B. International Centre for Research in Agroforestry, Indonesia.

Harmon EH, Ferrell WK, Frankli JF. 1990. Effects on carbon storage of conservation of old growth forests to young forest. Science 297: 699-702.

Hashimoto T, Tange T, Masumori M, Yagi H, Sasaki S, Kojima K. 2004. Allometric equations for pioneer tree species and estimation of the aboveground biomass of a tropical secondary forest in East Kalimantan. Tropics 14: 123-130.

Janisch JE, Harmon ME. 2002. Successional changes in live and dead wood carbon stores: Implications for net ecosystem productivity. Tree Physiology 22: 77-89.

Karyati. 2013. Ecology and Carbon Sequestration of Secondary Forests at Sabal, Sarawak. [Dissertation]. Universiti Malaysia Sarawak, Malaysia.

Karyati, Ipor IB, Jusoh I, Wasli ME. 2019. Allometric equations to estimate the above-ground biomass of trees in the tropical secondary forests of different ages. Biodiversitas 20(9): 2427-2436.

Kendawang JJ, Ninomiya I, Tanaka K, Ozawa T, Hattori D, Tanaka S, Sakurai K. 2007. Effects of burning strength in shifting cultivation on the early stage of secondary succession in Sarawak, Malaysia. Tropics 16: 309-321.

Kenzo T, Furutani R, Hattori D, Kendawang JJ, Tanaka S, Sakurai K, Ninomiya I. 2009a. Allometric equations for accurate estimation of above-ground biomass in logged-over tropical rainforests in Sarawak, Malaysia. J For Res 14 (6): 365-372.

Kenzo T, Ichie T, Hattori D, Itioka T, Handa C, Ohkubo T, Kendawang JJ, Nakamura M, Sakaguchi M, Takahashi N, Okamoto M, Tanaka-Oda A, Sakurai K, Ninomiya I. 2009b. Development of allometric relationships for accurate estimation of above- and below-ground biomass in tropical secondary forests in Sarawak, Malaysia. J Trop Ecol 25: 371-386.

Ketterings QM, Coe R, Van Noordwijk M, Ambagau Y, Palm CA. 2001. Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. For Ecol Manag 146:199-209.

Kiyono Y, Hastaniah. 2005. Pattern of slash-and-burn land use and their effects on forest succession. swidden-land forests in Borneo. Bull For For Prod Res Inst 4: 259-282.

Ministry of Forestry Indonesia. 2011. Development of Allometric Equations for Estimating Forest Carbon Stocks Based on Field Measurement (Ground Based Forest Carbon Accounting). Centre for Standardization and Environment, Ministry of Forestry, Indonesia.

Moore PD, Chapman SB. 1986. Methods in Plant Ecology, 2nd Ed. Blackwell Scientific Publications, Oxford.

Mokria M, Mekuria W, Gebrekirstos A, Aynekulu E, Belay B, Gashaw T, Brauning A. 2018. Mixed-species allometric equations and estimation of aboveground bioass and carbon stocks in restoring degraded landscape in northern Ethiopia. Environmental Research Letters 13: 1-14.

Nelson BW, Mesquita R, Pereira JLG, De Souza SGA, Batista T, Couto LB. 1999. Allometric regressions for improved estimate of secondary forest biomass in the Central Amazon. For Ecol Manag 117:149-167.

Nurlinda I, Pujiwati Y, Ishak M. 2014. Perbandingan penanganan tanah terlantar di Kabupaten Tasikmalaya dan Kabupaten Sukabumi dalam mewujudkan ketahanan pangan Provinsi Jawa Barat. Jurnal Hukum IUS Quia Iustum 21(1): 120-138. [Indonesian]

Parlucha J, Barbadillo N, Sedenio P. 2017. Species-site matching based on growth performance evaluation of mixed native and exotic secondary forest in Musuan Bukidnon. Journal of Biodiversity and Environmental Sciences (JBES). 10(3): 62-70.

Roshetko JM, Delaney M, Hairiah K, Purnomosidhi P. 2002. Carbon stocks in Indonesian homegarden systems: Can smallholder systems be targeted for increased carbon storage. American Journal of Alternative Agriculture 17(2): 1-11.

Seiler W, Crutzen PJ. 1980. Estimates of gross and net fluxes of carbon between the biosphere and the atmosphere from biomass burning. Climatic Change 2: 207-247.

Selaya NG, Anten NPR, Oomen RJ, Matthies M, Werger MJA. 2007. Above-ground biomass investments and light interception of tropical forest trees and lianas early in succession. Annals of Botany 99: 141-51.

Sierra CA, Del Valle JI, Orrego SA, Moreno FH, Harmon MA, Zapata M, Colorado GJ, Herrera MA, Lara W, Restrepo DE, Berrouet LM, Loaiza LM, Benjumea JF. 2007. Total carbon stocks in a tropical forest landscape of the Porce Region, Colombia. For Ecol Manag 243: 299-309.

Statistics Kutai Kartanegara Regency. 2018. Kutai Kartanegara Regency in Figures 2018. Tenggarong.

Van Do T, Osawa A, Thang NT. 2010. Recovery process of a mountain forest after shifting cultivation in Northwestern Vietnam. For Ecol Manag 259: 1650-1659.

Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land

Abstract. *Karyati, Widiati KY, Karmini, Mulyadi R. 2019. Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned lands. Biodiversitas x: xx-xx.* The abandoned lands have important role in the ecological fuction as well as carbon sequestration. The allometric equations to estimate above ground biomass in abandoned land are still limited available. This study objective was to develop allometric relationships between tree size variables (diameter at breast height (DBH) and tree height) and leaf, branch, trunk, and total above ground biomass (TAGB) in abandoned land in East Kalimantan, Indonesia. The correlation coefficients between stem DBH and tree height to leaf and branch indicating a relatively weak relationship. The moderately strong relationships were showed by DBH and tree height to trunk and TAGB. The specific allometric equation of above ground biomass for different land use and land type is needed to estimate the accurate TAGB in the site.

Key words: Abandoned land, allometric equation, biomass, destructive method

Running title: Development of allometric equations in abandoned land

INTRODUCTION

The National Land Affairs Agency identified 7.3 million hectares lands in Indonesia as abandoned lands in 2011 and about 4.8 million hectares was stated as abandoned lands. This area of abandoned lands increase from 2007 as much as 7.1 million hectares outside forest area (Nurlinda et al. 2014). The abandoned land area in East Kalimantan was about 3 million hectares. The abandoned lands provide habitat rotation to succession process in primary-secondary forest that will increase biodiversity (Chokkalingam et al. 2001). The plant composition, diversity, and growth during fallow periods after shifting cultivation was resulted from complex interaction between condition and factor before and after fallow periods, such as disturbance, land history, land management, tree and seed source composition from soil or surrounding forest, soil fertility, and climate factor (Awang Noor et al. 2008; Kendawang et al. 2007; Van Do et al. 2010).

Land use system on forest basis store CO_2 by carbon stock storage at their biomasss (Gorte 2007; Roshetko et al. 2002). The carbon stock in old age stand could different compared to carbon stock in second growth stand that replace it, cause woody biomass in an area could not describe in nett eosystem productivity (Janisch and Harmon 2002). Biomass dynamic in tropical forest play important role to evaluation of global carbon cycle and global climate change (Fearnside 1997; Seiler and Crutzen 1980). During the early succession process, amount of stand biomass increase fastly (Selaya et al. 2007). The carbon sequestration of forest area change constanly with vegetation growth, dead, and decomposition (Gorte 2007); species composition, age structur, and forest health (Harmon et al. 1990). Carbon stock at stand in the surface soil and standing tree mass could represented less than 1% to 60% from total carbon stock of forest ecosystem (Curtis 2008). Carbon stock of fertile soils is higher which could influence to carbon stock storage at vegetation biomass (Hairiah and Rahayu 2007).

Biomass is generally expressed in terms of dry weight and on occasion may be given in terms of ash free dry weight (Moore and Chapman 1986). The ‘scaling’ relationships, by which the ratios between different aspects of tree size change when small and large trees of the same species are compared generally known as ‘allometric’ relations (Hairiah et al. 2001). The previous studies had been developed allometric equations to estimate above ground biomass (AGB) in the secondary forests (Hashimoto et al. 2004; Kenzo et al. 2009a; Kenzo et al. 2009b; Ketterings et al. 2001; Kiyono and Hastaniah 2005; Nelson et al. 1999; Sierra et al. 2007; Karyati et al. 2019). However the allometric equations to estimate AGB in abandoned lands is still rare reported. The objective of this study was to develop allometric equations for estimation AGB in fallow lands. Information on the allometric relationships could predict biomass and carbon stock in lands after abandonment.

MATERIALS AND METHODS

Study site

The study was carried out in Salo Cella Village, Muara Badak Sub-district, Kutai Kartanegara Districts, East Kalimantan Province, Indonesia (Figure 1). This site was located in 0°17'18.7"S 117°18'08.2"E. The study site was abandoned land after selective cutting about 20 years ago. Muara Badak Sub-district has 939.09 km^2 wide with population of 57,712 persons including 13 villages. Salo Cella Village is about 10 km from the capital of Sub-district. The capital of subdistrict was Muara Badak Ulu with 16 m height Above Mean Sea Level (AMSL). Muara Badak received average amount of 141 mm in rainfall and 11 raindays in 2017 (Statistics Kutai Kartanegara Regency 2018). Most of the population in this village were farmers' livelihoods. Muara Badak is administratively bordered with Marang Kayu Sub-district at north side, Anggana Sub-district Samarinda City at south side, Makassar Strait at east side, and Tenggarong Seberang Sub-district at west side. Muara Badak is one of oil and gas producer. This has also big potency in fishery and plantation sectors. The area was covered by lowland mixed dipterocarp forest.

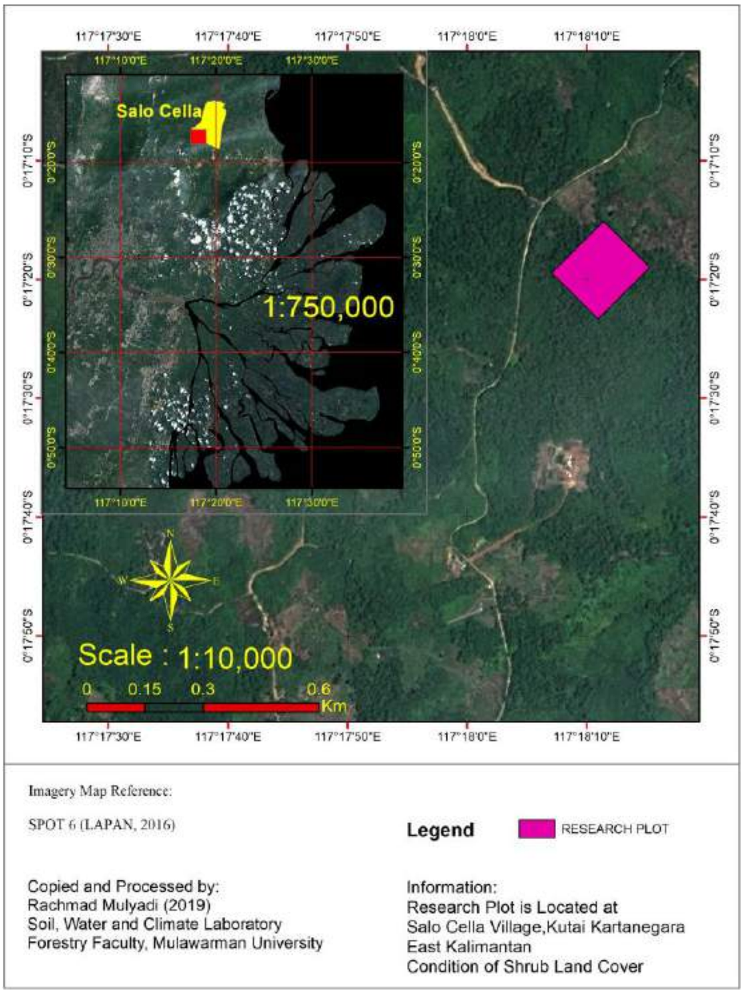


Figure 1. Map of study site in Salo Cella Village, Kutai Kartanegara Districts, East Kalimantan Province, Indonesia.

Data collection

Assessment on biomass in the field

Thirty sample trees were chosen in abandoned land. The sample trees were selected to obtain the representative species of land after abandonment. The selection of sample trees was based on consideration of the species and DBH. The standing DBH (1.3 m) of selected trees were measured using diameter tape. Measurement of the total height of the sample tree was completed once the tree had fallen. Fellings sample trees were conducted by following the harvesting rules. The harvested trees were divided into several fractions which every tree fraction was 1 meter length. Then, parts of trees were separated into leaves and twigs (hereafter called leaves), branches, and main stems in the field as shown in Figure 2.

Dividing sample tree fractions was accomplished with the following criteria (Ministry of Forestry Indonesia, 2011):

1) Dividing sample tree fractions was done to separate parts of tree biomass including leaves, branches, and stem. The flower and fruit parts was not included in the observation, because very few sample trees that have flower and fruit during observation.
2) Dividing sample tree fraction to be weighed needs to consider the capacity of the available scales.
3) Especially for the stem fraction, the stem was divided into several sections (sub-fractions of the stem) taking into account the shape, uniformity, and weight of the pieces.

The fresh weight of all fractions were taken by the suitable scale in the field. The disk samples of trunk with 2-5 cm thick were were collected as many as three disk sample if the harvested trees had less than 10 fractions and four disk samples if more than 10 fractions. Five branch samples of 20-30 cm in length and five leaf samples of 100-300 grams in weight were taken from each sample tree. Figure 3 illustrates tree components and the position of sub-sample being taken for AGB assessment. The wood density of each sample tree was conducted from the various literatures.

Analysis of dry-weight in the laboratory

Before oven-dried, all samples were air-dried in the laboratory to determine the moisture content. Then, samples of stem and branch fractions were dried in an oven at a temperature 105ºC for 96 hours until reaching a constant weight. Samples of leaves were dried in an oven at temperature of 80ºC for 48 hours until constant weight was reached. Weighing the samples of each fraction was performed using an analytical digital weighing scale after drying them in an oven.

Figure 2. Dividing the trees (Source: Ministry of Forestry Indonesia, 2011).

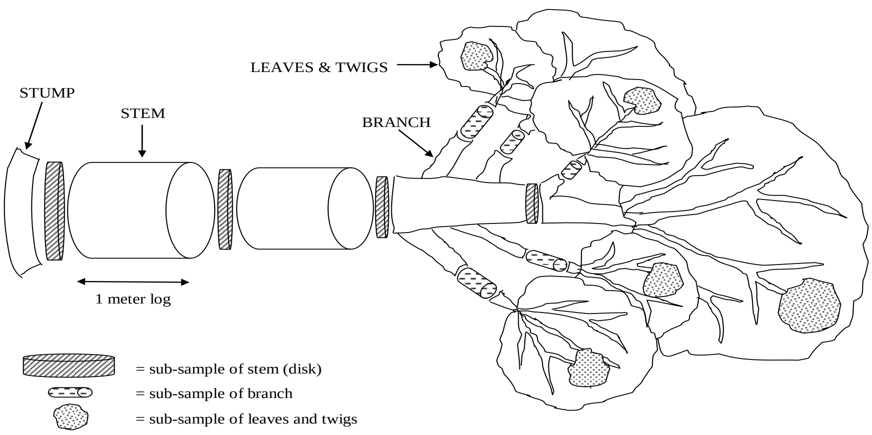


Figure 3. Illustration of tree components and the position of sub-sample being taken (Karyati 2013).

Data analysis

The total oven-dry weight of each tree part were determined using the following formula (Hairiah et al. 2001; Hairiah & Rahayu 2007; Ministry of Forestry Indonesia, 2011):

$$dw = (sdw \times fw) / sfw \quad (1)$$

where: dw = total dry weight (kg); sdw = dry weight of the sample (g); fw = total fresh weight (kg); sfw = fresh weight of the sample (g).

The five selected allometric equations of AGB were tested (Equations 2-6):

$$y = a + b\,x \quad (2)$$

$$y = ax^b \quad (3)$$

$$y = a + b\,(\ln x) \quad (4)$$

$$(\ln y) = a + b\,x \quad (5)$$

$$(\ln y) = a + b\,(\ln x) \quad (6)$$

where: y = total dry weight or biomass of each plant part, such as trunk, branch, leaf, and total above ground biomass (TAGB) (kg); x = diameter at breast height (DBH, cm), total height (H, meter), and ($DBH^2 \times H$) (cm^2 m); ‘a’ and ‘b’ = coefficients estimated by regression.

All regression analysis was carried out using SPSS version 18 for windows (SPSS Japan, Tokyo, Japan). The R^2 value and *P* value were determined to evaluate precision among all tested allometric equations. The indices of relative errors such as mean prediction error (MPE), total relative error (TRE), mean relative error (MRE), and mean relative absolute error (MRAE) were also assessed for model evaluation.

RESULTS AND DISCUSSION

Selected samples of trees

Thirty trees with DBH of ≥ 15 cm were harvested and measured to determine above ground parts in the study site as represent in Table 1. The DBH and height classes of selected sample trees for assessment AGB are illustrated in Figure 4. The DBH range was 16.0-32.6 cm and height was 9.3-22.7 m for selective sample trees. The relationship between DBH and total height of sample trees for assessment AGB in the study site is presented in Figure 5. The illustration showed that an increase in DBH was followed by an increase in total height. The equations of this relationship was “H=0.4642 (DBH)+3.2344” (n=30; R^2=0.3339). As stated ‘H’ is total height (m) and ‘DBH’ is diameter at breast height (cm).

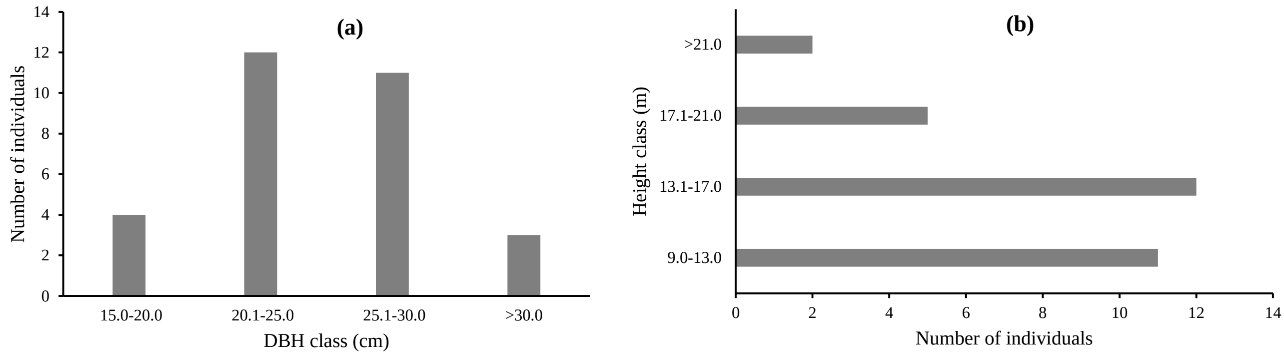


Figure 4. The distributions of (a) DBH classes and (b) height classes of sample trees to developed allometric equations.

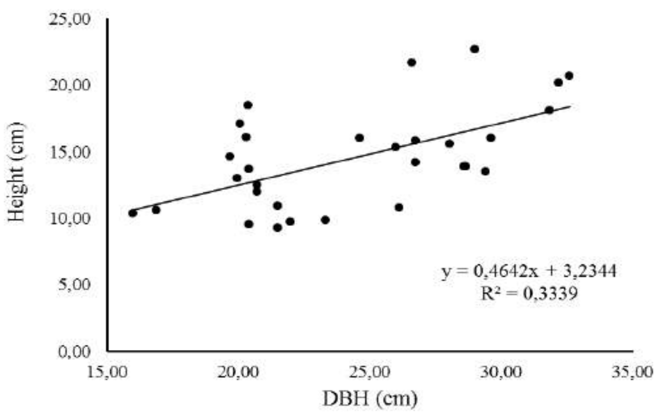


Figure 5. The DBH and total height of sample trees to developed allometric equations.

Tree variables

Pearson's correlation between DBH, height, wood density and branches biomass, trunk biomass, TAGB and parameters of destructive biomass are summarized in Table 1. The minimum and maxiu weight of branches biomass, trunk biomass, and TAGB were 3.92-34.18 kg; 12.84-296.72 kg, and 34.28-308.98 respectively. The DBH of sample trees ranged 16.00-32.00 cm,with the the height ranged 9.30-22.70 m. The wood densites of sample trees ranged 0.37-0.69 g cm^{-3}. The result showed that there were strong correlation (P < 0.01) among trunk biomass to DBH and tree height as well as TAGB and tree height. The correlation (P<0.05) was showed by TAGB and DBH. The strong correlation (P<0.01) was also showed between DBH and tree height. However, the leaf and branch biomass were not correlated with DBH and tree height significantly (P>0.05). In addition, the wood density was not also correlated to plant part biomass (leaf, branch, trunk, and TAGB) and tree dimensions (DBH and height).

Table 1. Pearson's correlation between DBH, height, wood density and branches biomass, trunk biomass, TAGB and parameters of destructive biomass

	Pearson's correlation			Mean	Range
	DBH (cm)	H (m)	WD (g cm^{-3})		
Leaf biomass (kg)	-0.303^{ns}	-0.198^{ns}	0.262^{ns}	12.43	1.37 - 45.59
Branch biomass (kg)	0.205^{ns}	-0.072^{ns}	0.208^{ns}	16.99	3.92 - 34.18
Trunk biomass (kg)	0.527^{**}	0.768^{**}	0.027^{ns}	116.55	12.84 - 296.72
TAGB (kg)	0.494^{*}	0.710^{**}	0.098^{ns}	145.97	34.28 - 308.98
DBH (cm)	1	0.578^{**}	-0.357^{ns}	24.35	16.00 - 32.00
H (m)	0.578^{**}	1	-0.184^{ns}	14.54	9.30 - 22.70
WD (g cm^{-3})	-0.357^{ns}	-0.184^{ns}	1	0.53	0.37 - 0.69

Note: ^{ns} is not significant at the 0.05 level (P>0.05) ; * and **Correlation are significant at the 0.05 and 0.01 level (2-tailed) respectively

Thirty sample trees with DBH of > 15 cm were selected in the study site, with consideration of the species. These selected trees didnot considering individuals with damaged crowns or broken trunks. Almost 90% of the selected trees were categorized as the dominant species in terms of density and Importance Value Index (IVi) as observed in the current study, while few selected trees represented the rare species. There were 10 species of 10 genera of 9 families selected in study site. Eight sample trees were *Pterospermum javanicum* ~~including~~ (Malvaceae). There were 5 sample trees of *Glochidion obscurum* (Euphorbiaceae) and 4 sample trees of *Bridelia glauca* (Phyllanthaceae). Three sample trees were *Vatica javanica* (Dipterocarpacea). The species of *Ficus septica* (Moraceae), *Trema orientalis* (Cannabaceae), *Archidendron jiringa* (Fabaceae), *Vernonia arborea* (Asteraceae) were selected for two sample trees respectively. One sampe tree was *Heliciopsis artocarpoides* (Proteaceae) as well as *Artocarpus elasticus* (Moraceae). The range of dry weight was 1.37-45.59 kg for leaf, 3.92-34.18 kg for branch, 12.84-296.72 kg for trunk, and 34.28-308.98 kg for TAGB in this site (Table 2). The result showed that there are diverse variation among different species. The different tree species tends to has the different structure (growth, stratification, and crown cover) and physiognomy. The largest sample tree was *Artocarpus elasticus* with DBH of 32.60 cm. This species had the dry weight of leaf, branch, trunk, and TAGB were 14.15, 20.23, 183.51, and 217.89 kg respectively. On the other hand, the smallest selected tree was *Archidendron jiringa* with DBH of 16.00 cm. This species obtained 22.95 kg of leaf dry biomass, 9.27 kg of branch dry biomass, 24.09 kg of trunk dry biomass, and 56.30 kg of TAGB. *Pterospermum javanicum* with 22.70 m height was the tallest sample trees. This sample tree had the highest trunk dry biomass (296.72 kg) and TAGB (308.98 kg). Contrasly, the other sample tree of *Pterospermum javanicum* had the lowest trunk dry biomass (12.84 kg) and TAGB (34.28 kg). The shortest sampe tree with 9.30 m height was *Bridelia glauca*. The lowest leaf dry biomass (1.37 kg) and branch dry biomass (3.92 kg) were showed by *Vernonia arborea*. Meanwhile, the other sample tree of *Archidendron jiringa* had the highest leaf dry biomass (45.59 kg). The highest branch dry biomass (34.18 kg) was showed by *Glochidion obscurum*.

Table 2. All data sets for develop allometric equations in abandoned lands

Tree No.	Family	Species	DBH (cm)	H (m)	Leaves (kg)	Branches (kg)	Trunk (kg)	TAGB (kg)	WD (g cm^{-3})
1	Malvaceae	*Pterospermum javanicum*	31.85	18.10	5.68	32.61	249.73	288.01	0.53
2	Malvaceae	*Pterospermum javanicum*	20.06	17.10	9.31	9.39	119.09	137.80	0.53
3	Malvaceae	*Pterospermum javanicum*	28.98	22.70	3.86	8.39	296.72	308.98	0.53
4	Moraceae	*Ficus septica*	32.17	20.20	5.70	19.70	166.63	192.03	0.39
5	Moraceae	*Ficus septica*	28.03	15.60	1.92	10.47	93.98	106.38	0.39
6	Cannabaceae	*Trema orientalis*	26.75	14.16	7.37	22.89	86.11	116.36	0.44
7	Proteaceae	*Heliciopsis artocarpoides*	21.97	9.70	9.95	9.88	57.62	77.44	0.65
8	Phyllanthaceae	*Bridelia glauca*	28.66	13.90	6.78	12.37	80.76	99.91	0.50
9	Phyllanthaceae	*Bridelia glauca*	20.70	12.50	6.93	16.74	71.55	95.22	0.50
10	Cannabaceae	*Trema orientalis*	26.11	10.80	13.97	29.02	58.17	101.16	0.44
11	Malvaceae	*Pterospermum javanicum*	29.62	16.00	8.76	10.12	77.63	96.52	0.53
12	Malvaceae	*Pterospermum javanicum*	16.88	10.60	6.88	14.56	12.84	34.28	0.53

Tree No.	Family	Species	DBH (cm)	H (m)	Leaves (kg)	Branches (kg)	Trunk (kg)	TAGB (kg)	WD (g cm^{-3})
13	Phyllanthaceae	*Bridelia glauca*	26.75	15.80	12.89	33.00	89.17	135.07	0.50
14	Euphorbiaceae	*Glochidion obscurum*	26.00	15.30	10.65	8.34	114.02	133.01	0.67
15	Euphorbiaceae	*Glochidion obscurum*	20.40	13.70	11.88	9.24	89.41	110.53	0.67
16	Fabaceae	*Archidendron jiringa*	16.00	10.36	22.95	9.27	24.09	56.30	0.42
17	Dipterocarpaceae	*Vatica javanica*	19.95	13.00	38.71	32.40	43.01	114.11	0.69
18	Euphorbiaceae	*Glochidion obscurum*	19.70	14.65	8.64	14.25	78.32	101.21	0.67
19	Fabaceae	*Archidendron jiringa*	24.60	16.00	45.59	22.73	160.89	229.21	0.42
20	Dipterocarpaceae	*Vatica javanica*	20.70	12.00	39.17	16.92	129.92	186.01	0.69
21	Euphorbiaceae	*Glochidion obscurum*	20.39	9.50	20.97	34.18	104.42	159.57	0.67
22	Dipterocarpaceae	*Vatica javanica*	28.60	13.90	7.66	29.95	184.53	222.14	0.69
23	Euphorbiaceae	*Glochidion obscurum*	21.50	10.90	11.24	21.63	142.13	175.00	0.67
24	Moraceae	*Artocarpus elasticus*	32.60	20.70	14.15	20.23	183.51	217.89	0.46
25	Asteraceae	*Vernonia arborea*	23.30	9.82	1.37	3.92	52.70	57.99	0.37
26	Asteraceae	*Vernonia arborea*	29.40	13.50	3.79	9.83	121.02	134.64	0.37
27	Phyllanthaceae	*Bridelia glauca*	21.50	9.30	14.28	17.31	67.24	98.83	0.50
28	Malvaceae	*Pterospermum javanicum*	20.29	16.10	4.04	3.94	163.39	171.38	0.53
29	Malvaceae	*Pterospermum javanicum*	20.36	18.50	6.66	8.55	189.90	205.12	0.53
30	Malvaceae	*Pterospermum javanicum*	26.60	21.70	11.19	17.72	187.95	216.85	0.53
Average			24.35	14.54	12.43	16.99	116.55	145.96	0.53
Minimum			16.00	9.30	1.37	3.92	12.84	34.28	0.37
Maximum			32.60	22.70	45.59	34.18	296.72	308.98	0.69
Standard deviation			4.66	3.75	10.93	9.13	65.59	66.98	0.11

Note: DBH=diameter at breast height; H=total height; TAGB=total above ground biomass; WD=wood density.

The allometric equations for Above Ground Biomass (AGB) of trees

The results of regression analyses for predicting plant part biomass of subject trees from diameter at breast height (DBH) and total height (H) using data all studied individuals are shown in Table 3. The relationships between DBH, (DBH^2×H), and height of trees as independent variables were not significant to related leaf and branch dry biomasss (*P* value > 0.05) as well as DBH to trunk dry biomass. This means that the DBH, (DBH^2×H), height of trees were not a good predictor to leaf and branch dry biomass based on the goodness of fit. Similarly DBH was not also good predictor to trunk dry biomass. The correlations between (DBH^2×H) and height of trees to trunk dry biomass and TAGB showed moderately strong relationships as well as DBH to TAGB (*P* value < 0.001).

The selected allometric equations to estimate above ground biomass of trees were dominated by log-linear model (ln y=a+b ln x) and linear model (y=a+bx). These equations were fitting model to relate dependent variables (leaf, branch, trunk, and AGB) and independent variables (DBH, (DBH^2×H), and H) for tree stage. From all tested regression, there are only four equations wih relatively high R^2 (>0.400). These equations are "ln (trunk dry biomass) = 0.837 × ln (DBH^2×H) – 29.45" (R^2=0.500), "ln (trunk dry biomass) = 1.812 × ln (H) – 0.217" (R^2=0.461), "ln (AGB) = 0.576 × ln (DBH^2×H) – 0.301" (R^2=0.431), and "ln (AGB) = 1.331 × ln (H) – 1.350" (R^2=0.455). However, the result showed there are very weak relationships between leaves and branches dry biomass of trees and plant dimensions in the abandoned land. The trunk dry biomass and AGB in the tropical secondary forests of different ages (5, 10 and 20 years after abandonment) showed strong correlations (adjusted R^2= 0.59-0.95) with diameter at breast height (DBH) and height. The leaf and branch dry biomass had weak correlations with height (adjusted R^2=0.36-0.50) (Karyati et al. 2019). The mixed-species allometric equations showed AGB correlates significantly with diameter at stump height (R^2=0.78; P<0.01) and tree height (R^2=0.41, P<0.05) (Mokria et al. 2018). Generally, the developed allometric equations showed relatively low R^2 (<0.60). This may caused by the high variation sample trees. The variation sample trees lead the variation on wood density, structure, and physiognomy. Parlucha (2017) stated that comparing growth performance for different level of species type (native or exotic) is not conclusive since the growth of trees varies. It is happen from specific species character level and matching with the existing site condition. The regression between the trunk biomass and TAGB and the product of square DBH and height (cm^2 m) and the natural logarithm of height was illustrated in Figure 6.

Results showed that mean prediction errors (MPEs) of the developed one- and two-variable aboveground biomass models were less than 4% and MPEs of the three-component (stem, branch, and foliage) and belowground biomass models were less than 10%.

Table 3. The allometric equations for predicting plant part biomass of subject trees in the study site

Dependent variable (y)	Independent variable (x)	Equation	*P* value	R^2	MPE	TRE	MRE	MRAE
Leaf dry biomass (kg)	DBH (cm)	ln y = 0.054 – 3.524 x	>0.05	0.099	-4.65	89.67	2.99	0.97
	(DBH^2×H) (cm^2m)	ln y = 0.4132 – 5.932 ln x	>0.05	0.086	55.16	96.26	3.21	0.97
	H (m)	y = 0.001 – 17.614 x	>0.05	0.074	26.85	11.78	3.93	1.02
Branch dry biomass (kg)	DBH (cm)	ln y = 0.695 + 0.4687 ln x	>0.05	0.060	0.50	6.63	0.22	1.28
	(DBH^2×H) (cm^2m)	ln y = 0.001 + 2.5228 x	>0.05	0.023	-7.24	87.45	2.91	0.97
	H (m)	y = 0.001 + 15.097 x	>0.05	0.014	-20.25	50.84	1.70	1.04
Trunk dry biomass (kg)	DBH (cm)	ln y = 1.910 – 1.501 ln x	>0.05	0.347	7.43	48.99	1.63	0.96
	(DBH^2×H) (cm^2m)	ln y = 0.837 – 2.945 ln x	<0.001	0.500	3.02	20.12	3.71	0.97
	H (m)	ln y = 1.812 – 0.217 ln x	<0.001	0.461	3.34	21.63	0.72	0.96
Above ground biomass (kg)	DBH (cm)	ln y = 1.277 + 0.808 ln x	<0.001	0.283	1.03	6.16	0.21	1.19
	(DBH^2×H) (cm^2m)	ln y = 0.576 – 0.301 ln x	<0.001	0.431	7.00	43.19	1.44	0.97
	H (m)	ln y = 1.331 – 1.350 ln x	<0.001	0.455	7.11	43.79	1.46	0.97

Note: *P* values of the regression analysis are shown, R^2 coefficient of determination, MPE mean prediction error, TRE total relative error, MRE mean relative error, MRAE mean relative absolute error, DBH diameter at breast height, H tree height.

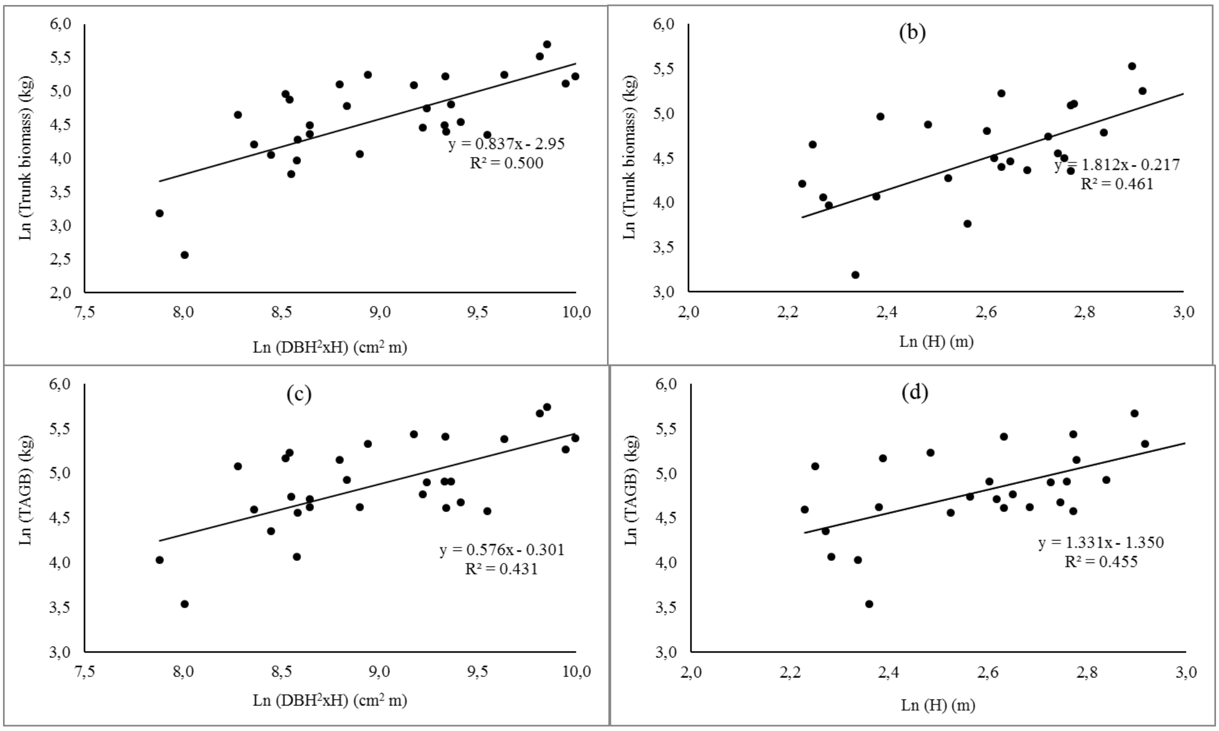


Figure 6. Regression between the trunk biomass (kg) and the product of square DBH and height (cm^2 m) (a) and the natural logarithm of height (m) (b); Regression between total above ground biomass (TAGB) (kg) and the product of square DBH and height (cm^2 m) (c) and the natural logarithm of height (m) (d).

Comparison among various allometric equations

The estimation of AGB using the developed allometric equation in this study was lower than using the previous developed equations as presented in Table 3. The AGB estimation of 33.31 Mg ha^{-1} was lower than 115.90, 91.65, 85.60, 76.31, 70.39, 68.08, 63.99, 60.32 Mg ha^{-1} of AGB calculated using the formulas of Rai and Proctor (1986), Chambers et al. (2001), Yamakura et al. (1986), Brown (1997), Manuri et al. (2017), Basuki et al. (2009), Kiyono and Hastaniah (2008), and Nelson et al. (1999) respectively. The value resulted by the developed allometric equation was similar than those using other previous reported equations, i.e., 38.86 Mg ha^{-1} (Kenzo et al. 2009a), 39.31 Mg ha^{-1} (Hashimoto et al. 2004), 49.05 Mg ha^{-1} (Sierra et al. (2007), 49.63 Mg ha^{-1} (Kettering et al. 2001), 50.31Mg ha^{-1} (Karyati et al. 2019), and 5.94 Mg ha^{-1} (Kenzo et al. 2009b). The comparison between AGB and DBH estimated by previously reported relationships was illustrated in Figure 7.

The calculation using equations of Rai and Proctor (1986), Chambers et al. (2001), Yamakura et al. (1986), Brown (1997), Basuki et al. (2009), and Kiyono and Hastaniah (2008) resulted the overestimation than the developed allometric equation. This might be caused the low wood density (0.37-0.69) of trees in the study site, because tree species observed in the abandoned land was dominated by pioneer species. The allometric equations for pioneer species may differ significantly caused usually these species has the low wood (Hashimoto et al. 2004). The wood densities of trees were 0.40-0.79 for Brown's equation, 0.32-0.86 for Basuki et al.'s equation, and 0.67 for Kiyono and Hastaniah's equation. The similar values of AGB were estimated by using equations of Kenzo et al. (2009a) with wood density of 0.35, Kettering et al. (2001) with wood density of 0.35 to 0.91, Karyati et al. (2019) with wood density of 0.24-0.44, and Kenzo et al. (2009b) with wood density of 0.35. Kenzo et al. (2009a), Hashimoto et al. (2004), and Karyati et al. (2019) developed allometric equation for mixed species in tropical forest of Kalimantan, while Kettering et al. (2001) developed allometric for mixed secondary forest in Sumatra. Sierra et al. (2007) reported allometric equation for tropical forest in Colombia. The similar tree species in abandoned land of study site and the mixed secondary forest caused the similar estimation of AGB by using the developed equations. In addition, the species and stand characteristics such as wood density and tree height effected to AGB variation directly, compare than biogeographical effect to those (Manuri et al. 2017).

Furthermore, the effects of main climate variables on above- and below-ground biomass were analyzed. Aboveground biomass was related to mean annual temperature (MAT), while belowground biomass had no significant relationship with either MAT or mean annual precipitation (MAP).

Table 4. Estimation of AGB using various reported relationships for trees in the study site

No.	Equation	Author	Estimate of AGB (Mg ha^{-1})
1	ln(AGB)=2.12×ln(DBH)-0.435	Rai and Proctor (1986)	115.90
2	ln(AGB)=2.62×ln(DBH)-2.30	Yamakura et al. (1986)	85.60
3	ln(AGB)=2.53×ln(DBH)-2.13	Brown (1997)	76.31
4	ln(AGB)=2.413×ln(DBH)-1.997	Nelson et al. (1999)	60.32
5	ln(AGB)=2.55×ln(DBH)-2.010	Chambers et al. (2001)	91.65
6	ln(AGB)=2.59×ln(DBH)-2.75	Kettering et al. (2001)	49.63
7	ln(AGB)=2.44×ln(DBH)-2.51	Hashimoto et al. (2004)	39.31
8	ln(AGB)=2.422×ln(DBH)-2.232	Sierra et al. (2007)	49.05
9	$AGB=0.1008 \times DBH^{2.5264}$	Kiyono and Hastaniah (2008)	63.99
10	ln(AGB)=2.196×ln(DBH)-1.201	Basuki et al. (2009)	68.08
11	$AGB=0.0829 \times DBH^{2.43}$	Kenzo et al. (2009a)	38.86
12	$AGB=0.1525 \times DBH^{2.34}$	Kenzo et al. (2009b)	53.94
13	$AGB=0.071 \times DBH^{2.667}$	Manuri et al. (2017)	70.39
14	ln(AGB)=2.3207×ln(DBH)-1.89	Karyati et al. (2019)	50.31
15	$(AGB) = 12.683 \times (DBH^2 \times H) – 38.403$	This study	33.31

Note: AGB = above ground biomass ; DBH = diameter at breast height.

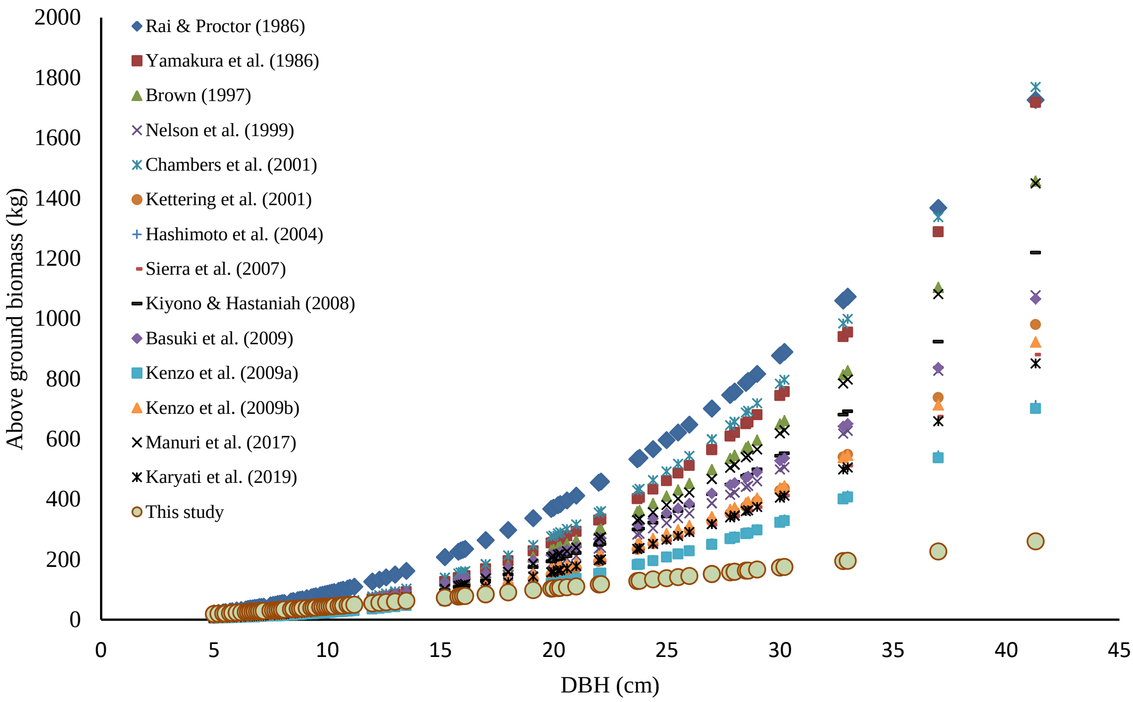


Figure 7. Comparison among various allometric relationships between above ground biomass (AGB) and diameter at breast height (DBH) in the study site

CONCLUSION

The using appropriate allometric equations to estimate AGB is needed, because it will give accurate estimation on AGB in the study site. When specific allometric equation for different land use and land coverage was developed, the users will choose suitable alternative equations.

ACKNOWLEDGEMENTS

We express our thanks to Ministry of Research, Technology and Higher Education, Republic of Indonesia for supporting *Hibah Penelitian Dasar Unggulan Perguruan Tinggi* Contract No.: 183/SP2H/LT/DRPM/2019.

REFERENCES

Awang Noor AG, Faridah Hanum I, Tuan Marina TI. 2008. Relationship between economic value and species diversity of timber resources in a hill forest in Peninsular Malaysia. Journal of Sustainable Development 1(2): 17-26.

Chokkalingam U, Smith J, de Jong W. 2001. A conceptual framework for the assessment of tropical secondary forest dynamics and sustainable development potential in Asia. Journal of Tropical Forest Science 13(4): 577-600.

Curtis PS. 2008. Estimating Aboveground Carbon in Live and Standing Dead Trees. In: Hoover CM (ed). Field Measurements for Forest Carbon Monitoring: a Landscape-Scale Approach. Springer, USA.

Fearnside PM. 1997. Greenhouse gases emissions from deforestation in Brazillian Amazonia: Net committed emissions. Climatic Change 35: 321-360.

Gorte RW. 2007. Carbon Sequestration in Forests. CRS Report for Congress. Congressional Research Service.

Hairiah K, Rahayu S. 2007. Pengukuran "Karbon Tersimpan" di Berbagai Macam Penggunaan Lahan. World Agroforestry Centre-ICRAF, Indonesia.

Hairiah K, Sitompul SM, Van Noordwijk M, Palm C. 2001. Methods for Sampling Carbon Stocks Above and Below Ground. ASB Lecture Note 4B. International Centre for Research in Agroforestry, Indonesia.

Harmon EH, Ferrell WK, Frankli JF. 1990. Effects on carbon storage of conservation of old growth forests to young forest. Science 297: 699-702.

Hashimoto T, Tange T, Masumori M, Yagi H, Sasaki S, Kojima K. 2004. Allometric equations for pioneer tree species and estimation of the aboveground biomass of a tropical secondary forest in East Kalimantan. Tropics 14: 123-130.

Janisch JE, Harmon ME. 2002. Successional changes in live and dead wood carbon stores: Implications for net ecosystem productivity. Tree Physiology 22: 77-89.

Karyati. 2013. Ecology and Carbon Sequestration of Secondary Forests at Sabal, Sarawak. [Dissertation]. Universiti Malaysia Sarawak, Malaysia.

Karyati, Ipor IB, Jusoh I, Wasli ME. 2019. Allometric equations to estimate the above-ground biomass of trees in the tropical secondary forests of different ages. Biodiversitas 20(9): 2427-2436.

Kendawang JJ, Ninomiya I, Tanaka K, Ozawa T, Hattori D, Tanaka S, Sakurai K. 2007. Effects of burning strength in shifting cultivation on the early stage of secondary succession in Sarawak, Malaysia. Tropics 16: 309-321.

Kenzo T, Furutani R, Hattori D, Kendawang JJ, Tanaka S, Sakurai K, Ninomiya I. 2009a. Allometric equations for accurate estimation of above-ground biomass in logged-over tropical rainforests in Sarawak, Malaysia. J For Res 14 (6): 365-372.

Kenzo T, Ichie T, Hattori D, Itioka T, Handa C, Ohkubo T, Kendawang JJ, Nakamura M, Sakaguchi M, Takahashi N, Okamoto M, Tanaka-Oda A, Sakurai K, Ninomiya I. 2009b. Development of allometric relationships for accurate estimation of above- and below-ground biomass in tropical secondary forests in Sarawak, Malaysia. J Trop Ecol 25: 371-386.

Ketterings QM, Coe R, Van Noordwijk M, Ambagau Y, Palm CA. 2001. Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. For Ecol Manag 146:199-209.

Kiyono Y, Hastaniah. 2005. Pattern of slash-and-burn land use and their effects on forest succession. swidden-land forests in Borneo. Bull For For Prod Res Inst 4: 259-282.

Manuri S, Brack C, Rusolono T, Noor'an F, Verchot L, Maulana SI, Adinugroho WC, Kurniawan H, Sukisno DW, Kusuma GA, Budiman A, Anggono RS, Siregar CA, Onrizal O, Yuniati D, Soraya E. 2017. Effect of species grouping and site variables on aboveground biomass models for lowland tropical forests of the Indo-Malay region. Annals of Forest Science 74(23): 1-14.

Ministry of Forestry Indonesia. 2011. Development of Allometric Equations for Estimating Forest Carbon Stocks Based on Field Measurement (Ground Based Forest Carbon Accounting). Centre for Standardization and Environment, Ministry of Forestry, Indonesia.

Moore PD, Chapman SB. 1986. Methods in Plant Ecology, 2nd Ed. Blackwell Scientific Publications, Oxford.

Mokria M, Mekuria W, Gebrekirstos A, Aynekulu E, Belay B, Gashaw T, Brauning A. 2018. Mixed-species allometric equations and estimation of aboveground bioass and carbon stocks in restoring degraded landscape in northern Ethiopia. Environmental Research Letters 13: 1-14.

Nelson BW, Mesquita R, Pereira JLG, De Souza SGA, Batista T, Couto LB. 1999. Allometric regressions for improved estimate of secondary forest biomass in the Central Amazon. For Ecol Manag 117:149-167.

Nurlinda I, Pujiwati Y, Ishak M. 2014. Perbandingan penanganan tanah terlantar di Kabupaten Tasikmalaya dan Kabupaten Sukabumi dalam mewujudkan ketahanan pangan Provinsi Jawa Barat. Jurnal Hukum IUS Quia Iustum 21(1): 120-138. [Indonesian]

Parlucha J, Barbadillo N, Sedenio P. 2017. Species-site matching based on growth performance evaluation of mixed native and exotic secondary forest in Musuan Bukidnon. Journal of Biodiversity and Environmental Sciences (JBES). 10(3): 62-70.

Roshetko JM, Delaney M, Hairiah K, Purnomosidhi P. 2002. Carbon stocks in Indonesian homegarden systems: Can smallholder systems be targeted for increased carbon storage. American Journal of Alternative Agriculture 17(2): 1-11.

Seiler W, Crutzen PJ. 1980. Estimates of gross and net fluxes of carbon between the biosphere and the atmosphere from biomass burning. Climatic Change 2: 207-247.

Selaya NG, Anten NPR, Oomen RJ, Matthies M, Werger MJA. 2007. Above-ground biomass investments and light interception of tropical forest trees and lianas early in succession. Annals of Botany 99: 141-51.

Sierra CA, Del Valle JI, Orrego SA, Moreno FH, Harmon MA, Zapata M, Colorado GJ, Herrera MA, Lara W, Restrepo DE, Berrouet LM, Loaiza LM, Benjumea JF. 2007. Total carbon stocks in a tropical forest landscape of the Porce Region, Colombia. For Ecol Manag 243: 299-309.

Statistics Kutai Kartanegara Regency. 2018. Kutai Kartanegara Regency in Figures 2018. Tenggarong.

Van Do T, Osawa A, Thang NT. 2010. Recovery process of a mountain forest after shifting cultivation in Northwestern Vietnam. For Ecol Manag 259: 1650-1659.

Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned land

Abstract. *Karyati, Widiati KY, Karmini, Mulyadi R. 2019. Development of allometric relationships for estimate above ground biomass of trees in the tropical abandoned lands. Biodiversitas x: xx-xx.* The abandoned lands have important role in the ecological fuction as well as carbon sequestration. The allometric equations to estimate above ground biomass in abandoned land are still limited available. This study objective was to develop allometric relationships between tree size variables (diameter at breast height (DBH) and tree height) and leaf, branch, trunk, and total above ground biomass (TAGB) in abandoned land in East Kalimantan, Indonesia. The correlation coefficients between stem DBH and tree height to leaf and branch indicating a relatively weak relationship. The moderately strong relationships were showed by DBH and tree height to trunk and TAGB. The specific allometric equation of above ground biomass for different land use and land type is needed to estimate the accurate TAGB in the site.

Key words: Abandoned land, allometric equation, biomass, destructive method

Running title: Development of allometric equations in abandoned land

INTRODUCTION

The forest degradation process with respect to selective logging, forest fire, and abandonment dynamics occurs over large areas in tropical forests (Pinheiro et al. 2016). The National Land Affairs Agency identified 7.3 million hectares lands in Indonesia as abandoned lands in 2011 and about 4.8 million hectares was stated as abandoned lands. This area of abandoned lands increase from 2007 as much as 7.1 million hectares outside forest area (Nurlinda et al. 2014). The abandoned land area in East Kalimantan was about 3 million hectares. The abandoned lands provide habitat rotation to succession process in primary-secondary forest that will increase biodiversity (Chokkalingam et al. 2001). The plant composition, diversity, and growth during fallow periods after shifting cultivation was resulted from complex interaction between condition and factor before and after fallow periods, such as disturbance, land history, land management, tree and seed source composition from soil or surrounding forest, soil fertility, and climate factor (Awang Noor et al. 2008; Kendawang et al. 2007; Van Do et al. 2010).

Forest-based land use systems sequester carbon dioxide by storing carbon stored in their biomass (Gorte 2007; Roshetko et al. 2002). The carbon stock in old age stand could different compared to carbon stock in second growth stand that replace it, cause woody biomass in an area could not describe in nett eosystem productivity (Janisch and Harmon 2002). Biomass dynamic in tropical forest play important role to evaluation of global carbon cycle and global climate change (Fearnside 1997; Seiler and Crutzen 1980). During the early succession process, amount of stand biomass increase fastly (Selaya et al. 2007). The carbon sequestration of forest area change constanly with vegetation growth, dead, and decomposition (Gorte 2007); species composition, age structur, and forest health (Harmon et al. 1990). Carbon stock at stand in the surface soil and standing tree mass could represented less than 1% to 60% from total carbon stock of forest ecosystem (Curtis 2008). Carbon stock of fertile soils is higher which could influence to carbon stock storage at vegetation biomass (Hairiah and Rahayu 2007).

Biomass is generally expressed in terms of dry weight and on occasion may be given in terms of ash free dry weight (Moore and Chapman 1986). The ‘scaling’ relationships, by which the ratios between different aspects of tree size change when small and large trees of the same species are compared generally known as ‘allometric’ relations (Hairiah et al. 2001). The previous studies had been developed allometric equations to estimate above ground biomass (AGB) in the secondary forests (Hashimoto et al. 2004; Kenzo et al. 2009a; Kenzo et al. 2009b; Ketterings et al. 2001; Kiyono and Hastaniah 2005; Nelson et al. 1999; Sierra et al. 2007; Karyati et al. 2019). However the allometric equations to estimate AGB in abandoned lands is still rare reported. The objective of this study was to develop allometric equations for estimation AGB in fallow lands. Information on the allometric relationships could predict biomass and carbon stock in lands after abandonment.

MATERIALS AND METHODS

Study site

The study was carried out in Salo Cella Village, Muara Badak Sub-district, Kutai Kartanegara Districts, East Kalimantan Province, Indonesia (Figure 1). This site was located in 0°17'18.7"S 117°18'08.2"E. The study site was abandoned land after selective logging about 30 years ago. Muara Badak Sub-district has 939.09 km^2 wide with population of 57,712 persons including 13 villages. Salo Cella Village is about 10 km from the capital of Sub-district. The capital of subdistrict was Muara Badak Ulu with 16 m height Above Mean Sea Level (AMSL). Muara Badak received average amount of 141 mm in rainfall and 11 raindays in 2017 (Statistics Kutai Kartanegara Regency 2018). Most of the population in this village were farmers' livelihoods. Muara Badak is administratively bordered with Marang Kayu Sub-district at north side, Anggana Sub-district Samarinda City at south side, Makassar Strait at east side, and Tenggarong Seberang Sub-district at west side. Muara Badak is one of oil and gas producer. This has also big potency in fishery and plantation sectors. The area was covered by lowland mixed dipterocarp forest.

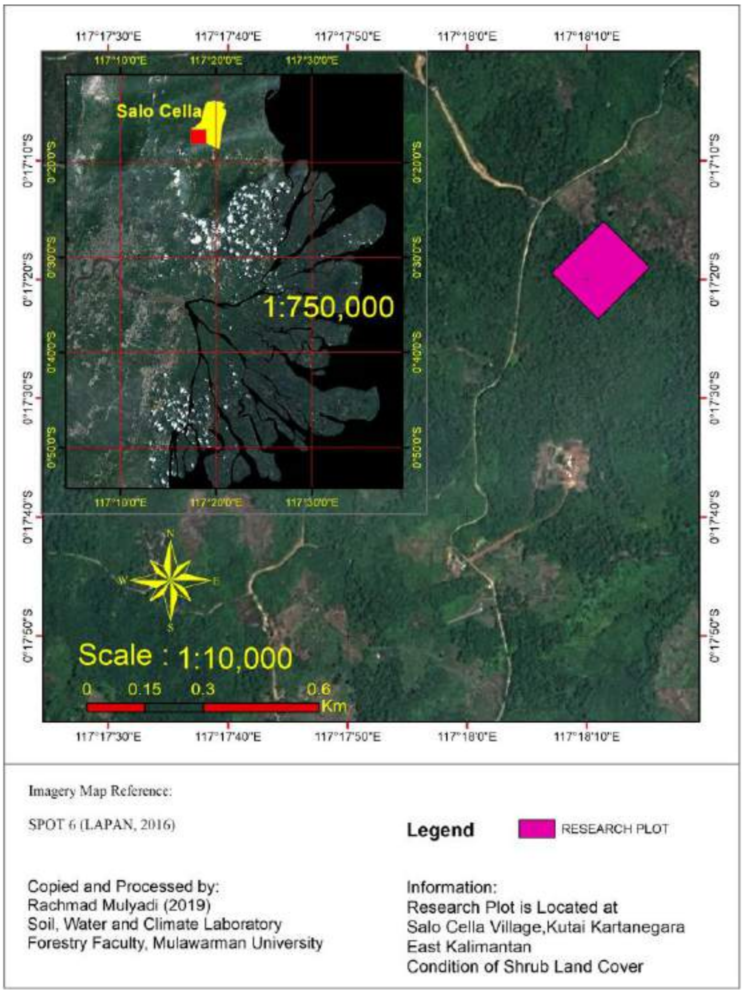


Figure 1. Map of study site in Salo Cella Village, Kutai Kartanegara Districts, East Kalimantan Province, Indonesia.

Data collection

Assessment on biomass in the field

Thirty sample trees were chosen in abandoned land. The sample trees were selected to obtain the representative species of land after abandonment. The selection of sample trees was based on consideration of the species and DBH. The standing DBH (1.3 m) of selected trees were measured using diameter tape. Measurement of the total height of the sample tree was completed once the tree had fallen. Fellings sample trees were conducted by following the harvesting rules. The harvested trees were divided into several fractions which every tree fraction was 1 meter length. Then, parts of trees were separated into leaves and twigs (hereafter called leaves), branches, and main stems in the field as shown in Figure 2.

Dividing sample tree fractions was accomplished with the following criteria (Ministry of Forestry Indonesia, 2011):

1) Dividing sample tree fractions was done to separate parts of tree biomass including leaves, branches, and stem. The flower and fruit parts was not included in the observation, because very few sample trees that have flower and fruit during observation.
2) Dividing sample tree fraction to be weighed needs to consider the capacity of the available scales.
3) Especially for the stem fraction, the stem was divided into several sections (sub-fractions of the stem) taking into account the shape, uniformity, and weight of the pieces.

The fresh weight of all fractions were taken by the suitable scale in the field. The disk samples of trunk with 2-5 cm thick were were collected as many as three disk sample if the harvested trees had less than 10 fractions and four disk samples if more than 10 fractions. Five branch samples of 20-30 cm in length and five leaf samples of 100-300 grams in weight were taken from each sample tree. Figure 3 illustrates tree components and the position of sub-sample being taken for AGB assessment. The wood density of each sample tree was conducted from the various literatures.

Analysis of dry-weight in the laboratory

Before oven-dried, all samples were air-dried in the laboratory to determine the moisture content. Then, samples of stem and branch fractions were dried in an oven at a temperature 105ºC for 96 hours until reaching a constant weight. Samples of leaves were dried in an oven at temperature of 80ºC for 48 hours until constant weight was reached. Weighing the samples of each fraction was performed using an analytical digital weighing scale after drying them in an oven.

Figure 2. Dividing the trees (Source: Ministry of Forestry Indonesia, 2011).

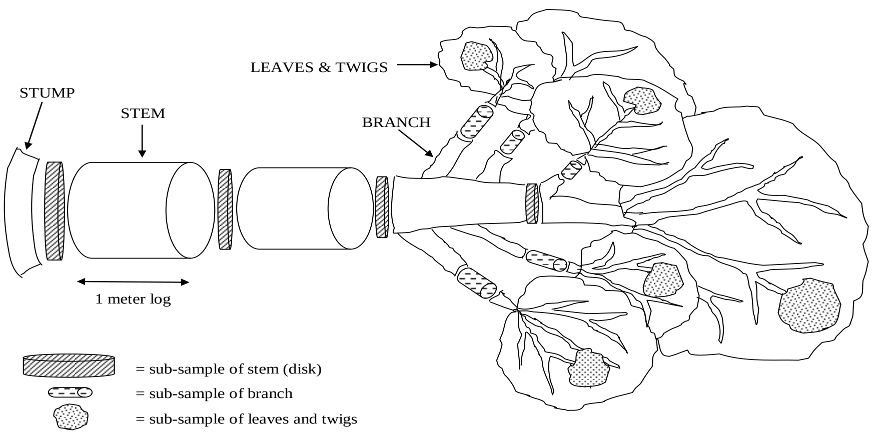


Figure 3. Illustration of tree components and the position of sub-sample being taken (Karyati 2013).

Data analysis

The total oven-dry weight of each tree part were determined using the following formula (Hairiah et al. 2001; Hairiah & Rahayu 2007; Ministry of Forestry Indonesia, 2011):

$$dw = (sdw \times fw) / sfw \quad (1)$$

where: dw = total dry weight (kg); sdw = dry weight of the sample (g); fw = total fresh weight (kg); sfw = fresh weight of the sample (g).

The five selected allometric equations of AGB were tested (Equations 2-6):

$$y = a + b\,x \quad (2)$$

$$y = ax^{b} \quad (3)$$

$$y = a + b\,(\ln x) \quad (4)$$

$$(\ln y) = a + b\,x \quad (5)$$

$$(\ln y) = a + b\,(\ln x) \quad (6)$$

where: y = total dry weight or biomass of each plant part, such as trunk, branch, leaf, and total above ground biomass (TAGB) (kg); x = diameter at breast height (DBH, cm), total height (H, meter), and ($DBH^2 \times H$) (cm^2 m); ‘a’ and ‘b’ = coefficients estimated by regression.

All regression analysis was carried out using SPSS version 18 for windows (SPSS Japan, Tokyo, Japan). The R^2 value and *P* value were determined to evaluate precision among all tested allometric equations. The indices of relative errors such as mean prediction error (MPE), mean relative error (MRE), and mean relative absolute error (MRAE) were also assessed for model evaluation.

RESULTS AND DISCUSSION

Selected samples of trees

Thirty trees with DBH of ≥ 15 cm were harvested and measured to determine above ground parts in the study site as represent in Table 1. The DBH and height classes of selected sample trees for assessment AGB are illustrated in Figure 4. The DBH range was 16.0-32.6 cm and height was 9.3-22.7 m for selective sample trees. The relationship between DBH and total height of sample trees for assessment AGB in the study site is presented in Figure 5. The illustration showed that an increase in DBH was followed by an increase in total height. The equations of this relationship was “H=0.4642 (DBH)+3.2344” (n=30; R^2=0.3339). As stated ‘H’ is total height (m) and ‘DBH’ is diameter at breast height (cm).

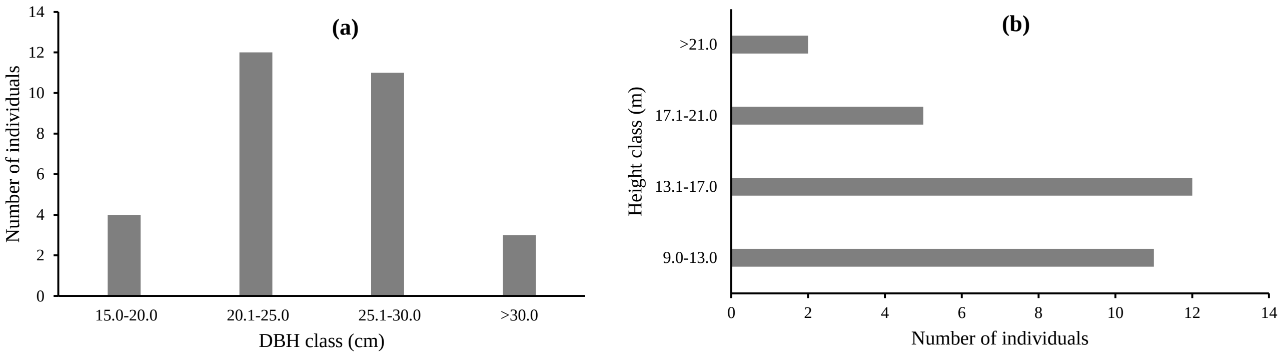


Figure 4. The distributions of (a) DBH classes and (b) height classes of sample trees to developed allometric equations.

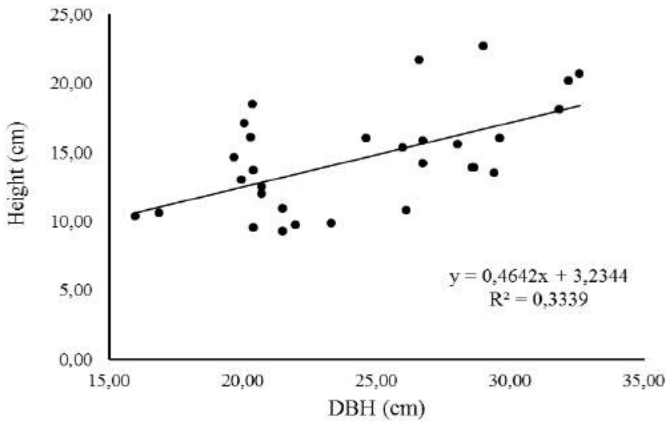


Figure 5. The DBH and total height of sample trees to developed allometric equations.

Tree variables

Pearson's correlation between DBH, height, wood density and branches biomass, trunk biomass, TAGB and parameters of destructive biomass are summarized in Table 1. The minimum and maxiu weight of branches biomass, trunk biomass, and TAGB were 3.92-34.18 kg; 12.84-296.72 kg, and 34.28-308.98 respectively. The DBH of sample trees ranged 16.00-32.00 cm,with the the height ranged 9.30-22.70 m. The wood densites of sample trees ranged 0.37-0.69 g cm^{-3}. The result showed that there were strong correlation ($P < 0.01$) among trunk biomass to DBH and tree height as well as TAGB and tree height. The correlation ($P<0.05$) was showed by TAGB and DBH. The strong correlation ($P<0.01$) was also showed between DBH and tree height. However, the leaf and branch biomass were not correlated with DBH and tree height significantly ($P>0.05$). In addition, the wood density was not also correlated to plant part biomass (leaf, branch, trunk, and TAGB) and tree dimensions (DBH and height).

Table 1. Pearson's correlation between DBH, height, wood density and branches biomass, trunk biomass, TAGB and parameters of destructive biomass

	Pearson's correlation			Mean	Range
	DBH (cm)	H (m)	WD (g cm^{-3})		
Leaf biomass (kg)	-0.303^{ns}	-0.198^{ns}	0.262^{ns}	12.43	1.37 - 45.59
Branch biomass (kg)	0.205^{ns}	-0.072^{ns}	0.208^{ns}	16.99	3.92 - 34.18
Trunk biomass (kg)	0.527^{**}	0.768^{**}	0.027^{ns}	116.55	12.84 - 296.72
TAGB (kg)	0.494^{*}	0.710^{**}	0.098^{ns}	145.97	34.28 - 308.98
DBH (cm)	1	0.578^{**}	-0.357^{ns}	24.35	16.00 - 32.00
H (m)	0.578^{**}	1	-0.184^{ns}	14.54	9.30 - 22.70
WD (g cm^{-3})	-0.357^{ns}	-0.184^{ns}	1	0.53	0.37 - 0.69

Note: ^{ns} is not significant at the 0.05 level (P>0.05) ; * and **Correlation are significant at the 0.05 and 0.01 level (2-tailed) respectively

Thirty sample trees with DBH of > 15 cm were selected in the study site, with consideration of the species. These selected trees didnot considering individuals with damaged crowns or broken trunks. Almost 90% of the selected trees were categorized as the dominant species in terms of density and Importance Value Index (IVi) as observed in the current study, while few selected trees represented the rare species. There were 10 species of 10 genera of 9 families selected in study site. Eight sample trees were *Pterospermum javanicum* (Malvaceae). There were 5 sample trees of *Glochidion obscurum* (Euphorbiaceae) and 4 sample trees of *Bridelia glauca* (Phyllanthaceae). Three sample trees were *Vatica javanica* (Dipterocarpacea). The species of *Ficus septica* (Moraceae), *Trema orientalis* (Cannabaceae), *Archidendron jiringa* (Fabaceae), *Vernonia arborea* (Asteraceae) were selected for two sample trees respectively. One sampe tree was *Heliciopsis artocarpoides* (Proteaceae) as well as *Artocarpus elasticus* (Moraceae). The range of dry weight was 1.37-45.59 kg for leaf, 3.92-34.18 kg for branch, 12.84-296.72 kg for trunk, and 34.28-308.98 kg for TAGB in this site (Table 2). The result showed that there are diverse variation among different species. The different tree species tends to has the different structure (growth, stratification, and crown cover) and physiognomy. The largest sample tree was *Artocarpus elasticus* with DBH of 32.60 cm. This species had the dry weight of leaf, branch, trunk, and TAGB were 14.15, 20.23, 183.51, and 217.89 kg respectively. On the other hand, the smallest selected tree was *Archidendron jiringa* with DBH of 16.00 cm. This species obtained 22.95 kg of leaf dry biomass, 9.27 kg of branch dry biomass, 24.09 kg of trunk dry biomass, and 56.30 kg of TAGB. *Pterospermum javanicum* with 22.70 m height was the tallest sample trees. This sample tree had the highest trunk dry biomass (296.72 kg) and TAGB (308.98 kg). Contrasly, the other sample tree of *Pterospermum javanicum* had the lowest trunk dry biomass (12.84 kg) and TAGB (34.28 kg). The shortest sampe tree with 9.30 m height was *Bridelia glauca*. The lowest leaf dry biomass (1.37 kg) and branch dry biomass (3.92 kg) were showed by *Vernonia arborea*. Meanwhile, the other sample tree of *Archidendron jiringa* had the highest leaf dry biomass (45.59 kg). The highest branch dry biomass (34.18 kg) was showed by *Glochidion obscurum*.

Table 2. All data sets for develop allometric equations in abandoned lands

Tree No.	Family	Species	DBH (cm)	H (m)	Leaves (kg)	Branches (kg)	Trunk (kg)	TAGB (kg)	WD (g cm^{-3})
1	Malvaceae	*Pterospermum javanicum*	31.85	18.10	5.68	32.61	249.73	288.01	0.53
2	Malvaceae	*Pterospermum javanicum*	20.06	17.10	9.31	9.39	119.09	137.80	0.53
3	Malvaceae	*Pterospermum javanicum*	28.98	22.70	3.86	8.39	296.72	308.98	0.53
4	Moraceae	*Ficus septica*	32.17	20.20	5.70	19.70	166.63	192.03	0.39
5	Moraceae	*Ficus septica*	28.03	15.60	1.92	10.47	93.98	106.38	0.39
6	Cannabaceae	*Trema orientalis*	26.75	14.16	7.37	22.89	86.11	116.36	0.44
7	Proteaceae	*Heliciopsis artocarpoides*	21.97	9.70	9.95	9.88	57.62	77.44	0.65
8	Phyllanthaceae	*Bridelia glauca*	28.66	13.90	6.78	12.37	80.76	99.91	0.50
9	Phyllanthaceae	*Bridelia glauca*	20.70	12.50	6.93	16.74	71.55	95.22	0.50
10	Cannabaceae	*Trema orientalis*	26.11	10.80	13.97	29.02	58.17	101.16	0.44
11	Malvaceae	*Pterospermum javanicum*	29.62	16.00	8.76	10.12	77.63	96.52	0.53

Tree No.	Family	Species	DBH (cm)	H (m)	Leaves (kg)	Branches (kg)	Trunk (kg)	TAGB (kg)	WD (g cm^{-3})
12	Malvaceae	*Pterospermum javanicum*	16.88	10.60	6.88	14.56	12.84	34.28	0.53
13	Phyllanthaceae	*Bridelia glauca*	26.75	15.80	12.89	33.00	89.17	135.07	0.50
14	Euphorbiaceae	*Glochidion obscurum*	26.00	15.30	10.65	8.34	114.02	133.01	0.67
15	Euphorbiaceae	*Glochidion obscurum*	20.40	13.70	11.88	9.24	89.41	110.53	0.67
16	Fabaceae	*Archidendron jiringa*	16.00	10.36	22.95	9.27	24.09	56.30	0.42
17	Dipterocarpaceae	*Vatica javanica*	19.95	13.00	38.71	32.40	43.01	114.11	0.69
18	Euphorbiaceae	*Glochidion obscurum*	19.70	14.65	8.64	14.25	78.32	101.21	0.67
19	Fabaceae	*Archidendron jiringa*	24.60	16.00	45.59	22.73	160.89	229.21	0.42
20	Dipterocarpaceae	*Vatica javanica*	20.70	12.00	39.17	16.92	129.92	186.01	0.69
21	Euphorbiaceae	*Glochidion obscurum*	20.39	9.50	20.97	34.18	104.42	159.57	0.67
22	Dipterocarpaceae	*Vatica javanica*	28.60	13.90	7.66	29.95	184.53	222.14	0.69
23	Euphorbiaceae	*Glochidion obscurum*	21.50	10.90	11.24	21.63	142.13	175.00	0.67
24	Moraceae	*Artocarpus elasticus*	32.60	20.70	14.15	20.23	183.51	217.89	0.46
25	Asteraceae	*Vernonia arborea*	23.30	9.82	1.37	3.92	52.70	57.99	0.37
26	Asteraceae	*Vernonia arborea*	29.40	13.50	3.79	9.83	121.02	134.64	0.37
27	Phyllanthaceae	*Bridelia glauca*	21.50	9.30	14.28	17.31	67.24	98.83	0.50
28	Malvaceae	*Pterospermum javanicum*	20.29	16.10	4.04	3.94	163.39	171.38	0.53
29	Malvaceae	*Pterospermum javanicum*	20.36	18.50	6.66	8.55	189.90	205.12	0.53
30	Malvaceae	*Pterospermum javanicum*	26.60	21.70	11.19	17.72	187.95	216.85	0.53
Average			24.35	14.54	12.43	16.99	116.55	145.96	0.53
Minimum			16.00	9.30	1.37	3.92	12.84	34.28	0.37
Maximum			32.60	22.70	45.59	34.18	296.72	308.98	0.69
Standard deviation			4.66	3.75	10.93	9.13	65.59	66.98	0.11

Note: DBH=diameter at breast height; H=total height; TAGB=total above ground biomass; WD=wood density.

The developed allometric equations

The results of regression analyses for predicting plant part biomass of subject trees from diameter at breast height (DBH) and total height (H) using data all studied individuals are shown in Table 3. The relationships between DBH, ($DBH^2 \times H$), and height of trees as independent variables were not significant to related leaf and branch dry biomasss (*P* value > 0.05) as well as DBH to trunk dry biomass. This means that the DBH, ($DBH^2 \times H$), height of trees were not a good predictor to leaf and branch dry biomass based on the goodness of fit. Similarly DBH was not also good predictor to trunk dry biomass. The correlations between ($DBH^2 \times H$) and height of trees to trunk dry biomass and TAGB showed moderately strong relationships as well as DBH to TAGB (*P* value < 0.001).

The selected allometric equations to estimate above ground biomass of trees were dominated by log-linear model (ln y=a+b ln x) and linear model (y=a+bx). These equations were fitting model to relate dependent variables (leaf, branch, trunk, and AGB) and independent variables (DBH, ($DBH^2 \times H$), and H) for tree stage. From all tested regression, there are only four equations wih relatively high R^2 (>0.400). These equations are "ln (trunk dry biomass) = 0.837 × ln ($DBH^2 \times H$) – 29.45" (R^2=0.500), "ln (trunk dry biomass) = 1.812 × ln (H) – 0.217" (R^2=0.461), "ln (AGB) = 0.576 × ln ($DBH^2 \times H$) – 0.301" (R^2=0.431), and "ln (AGB) = 1.331 × ln (H) – 1.350" (R^2=0.455). However, the result showed there are very weak relationships between leaves and branches dry biomass of trees and plant dimensions in the abandoned land. The trunk dry biomass and AGB in the tropical secondary forests of different ages (5, 10 and 20 years after abandonment) showed strong correlations (adjusted R^2= 0.59-0.95) with diameter at breast height (DBH) and height. The leaf and branch dry biomass had weak correlations with height (adjusted R^2=0.36-0.50) (Karyati et al. 2019). The mixed-species allometric equations showed AGB correlates significantly with diameter at stump height (R^2=0.78; P<0.01) and tree height (R^2=0.41, P<0.05) (Mokria et al. 2018). Generally, the developed allometric equations showed relatively low R^2 (<0.60). This may caused by the high variation sample trees. The variation sample trees lead the variation on wood density, structure, and physiognomy. Parlucha (2017) stated that comparing growth performance for different level of species type (native or exotic) is not conclusive since the growth of trees varies. It is happen from specific species character level and matching with the existing site condition. The regression between the trunk biomass and TAGB and the product of square DBH and height (cm^2 m) and the natural logarithm of height was illustrated in Figure 6.

The results showed that mean prediction errors (MPEs) of the developed aboveground biomass models ranged 4.7% to 26.9%%. These values were higher than reported by Zeng et al. (2017). Zeng et al. (2017) stated that mean prediction errors (MPEs) of the developed one- and two-variable aboveground biomass models were less than 4%. The mean relative errors (MRE) for predicting plant part biomass of subject trees in the study site ranged 7.2% to 39.3%. These MRE were also higher than reported for lowland tropical forests of the Indo-Malay region (MRE ranged 3.2% to 33.6%) (Manuri et al. 2017). The mean relative absolute error (MRAE) of developed allometric equations ranged 28.4% to 35.7%. Similarly, the range of MRAE for aboveground biomass models were 26.6-41.5% as reported by Manuri et al. (2017).

Table 3. The allometric equations for predicting plant part biomass of subject trees in the study site

Dependent variable (y)	Independent variable (x)	Equation	*P* value	R^2	MPE	MRE	MRAE
Leaf dry biomass (kg)	DBH (cm)	ln y = 0.054 – 3.524 x	>0.05	0.099	0.047	0.299	0.292
	(DBH^2×H) (cm^2m)	ln y = 0.4132 – 5.932 ln x	>0.05	0.086	0.252	0.321	0.291
	H (m)	y = 0.001 – 17.614 x	>0.05	0.074	0.269	0.393	0.306
Branch dry biomass (kg)	DBH (cm)	ln y = 0.695 + 0.4687 ln x	>0.05	0.060	0.150	0.220	0.284
	(DBH^2×H) (cm^2m)	ln y = 0.001 + 2.5228 x	>0.05	0.023	0.172	0.291	0.290
	H (m)	y = 0.001 + 15.097 x	>0.05	0.014	0.202	0.170	0.311
Trunk dry biomass (kg)	DBH (cm)	ln y = 1.910 – 1.501 ln x	>0.05	0.347	0.174	0.163	0.289
	(DBH^2×H) (cm^2m)	ln y = 0.837 – 2.945 ln x	<0.001	0.500	0.030	0.371	0.291
	H (m)	ln y = 1.812 – 0.217 ln x	<0.001	0.461	0.033	0.072	0.289
Above ground biomass (kg)	DBH (cm)	ln y = 1.277 + 0.808 ln x	<0.001	0.283	0.130	0.210	0.357
	(DBH^2×H) (cm^2m)	ln y = 0.576 – 0.301 ln x	<0.001	0.431	0.070	0.144	0.289
	H (m)	ln y = 1.331 – 1.350 ln x	<0.001	0.455	0.071	0.146	0.290

Note: *P* values of the regression analysis are shown, R^2 coefficient of determination, MPE mean prediction error, MRE mean relative error, MRAE mean relative absolute error, DBH diameter at breast height, H tree height.

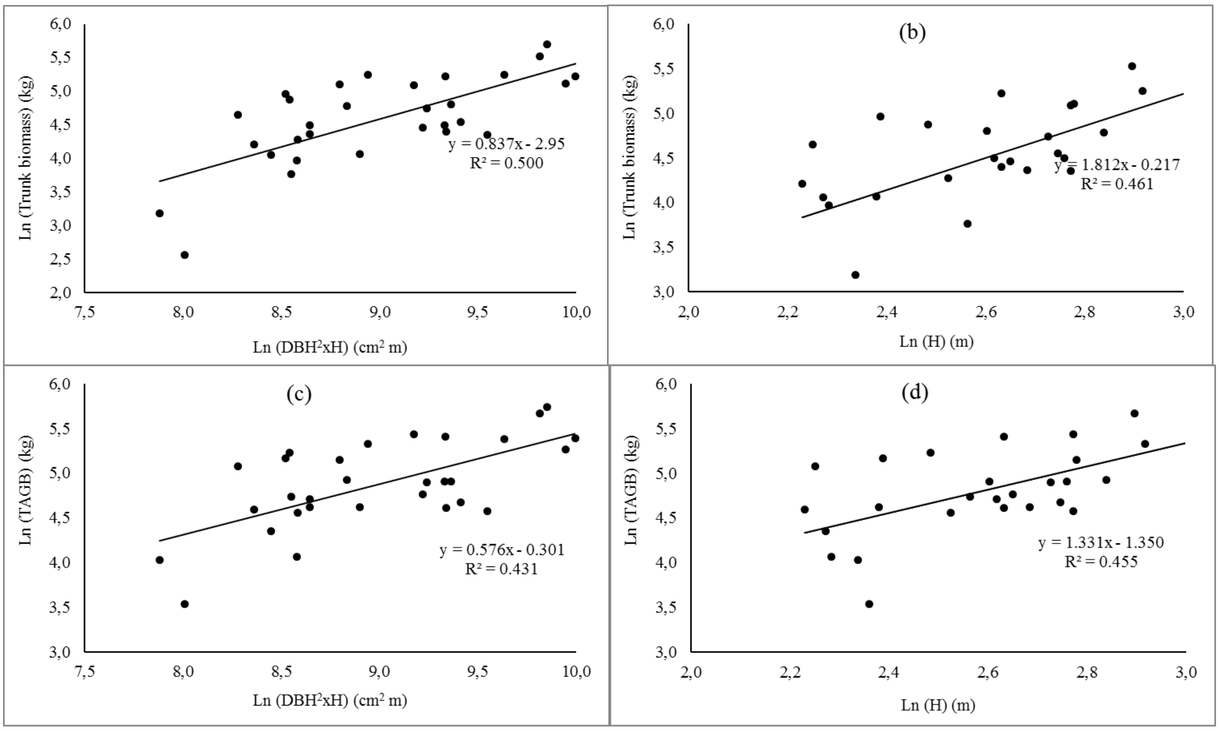


Figure 6. Regression between the trunk biomass (kg) and the product of square DBH and height (cm^2 m) (a) and the natural logarithm of height (m) (b); Regression between total above ground biomass (TAGB) (kg) and the product of square DBH and height (cm^2 m) (c) and the natural logarithm of height (m) (d).

Comparison among various allometric equations

The estimation of AGB using the developed allometric equation in this study was lower than using the previous developed equations as presented in Table 3. The AGB estimation of 33.31 Mg ha^{-1} was lower than 115.90, 91.65, 85.60, 76.31, 70.39, 68.08, 63.99, 60.32 Mg ha^{-1} of AGB calculated using the formulas of Rai and Proctor (1986), Chambers et al. (2001), Yamakura et al. (1986), Brown (1997), Manuri et al. (2017), Basuki et al. (2009), Kiyono and Hastaniah (2008), and Nelson et al. (1999) respectively. The value resulted by the developed allometric equation was similar than those using other previous reported equations, i.e., 38.86 Mg ha^{-1} (Kenzo et al. 2009a), 39.31 Mg ha^{-1} (Hashimoto et al. 2004), 49.05 Mg ha^{-1} (Sierra et al. (2007), 49.63 Mg ha^{-1} (Kettering et al. 2001), 50.31Mg ha^{-1} (Karyati et al. 2019), and 5.94 Mg ha^{-1} (Kenzo et al. 2009b). The comparison between AGB and DBH estimated by previously reported relationships was illustrated in Figure 7.

The calculation using equations of Rai and Proctor (1986), Chambers et al. (2001), Yamakura et al. (1986), Brown (1997), Basuki et al. (2009), and Kiyono and Hastaniah (2008) resulted the overestimation than the developed allometric equation. This might be caused the low wood density (0.37-0.69) of trees in the study site, because tree species observed in the abandoned land was dominated by pioneer species. The allometric equations for pioneer species may differ significantly caused usually these species has the low wood (Hashimoto et al. 2004). The wood densities of trees were 0.40-0.79 for Brown's equation, 0.32-0.86 for Basuki et al.'s equation, and 0.67 for Kiyono and Hastaniah's equation. The similar values of AGB were estimated by using equations of Kenzo et al. (2009a) with wood density of 0.35, Kettering et al. (2001) with wood density of 0.35 to 0.91, Karyati et al. (2019) with wood density of 0.24-0.44, and Kenzo et al. (2009b) with wood density of 0.35. Kenzo et al. (2009a), Hashimoto et al. (2004), and Karyati et al. (2019) developed allometric equation for mixed species in tropical forest of Kalimantan, while Kettering et al. (2001) developed allometric for mixed secondary forest in Sumatra. Sierra et al. (2007) reported allometric equation for tropical forest in Colombia. The similar tree species in abandoned land of study site and the mixed secondary forest caused the similar estimation of AGB by using the developed equations. The species and stand characteristics such as wood density and tree height effected to AGB variation directly, meanwhile biogeographical region only slightly effected to the accuracy of AGB equations (Manuri et al. 2017). In addition, aboveground biomass was also related to mean annual temperature (MAT) (Zeng et al. 2017).

Table 4. Estimation of AGB using various reported relationships for trees in the study site

No.	Equation	Author	Estimate of AGB (Mg ha^{-1})
1	ln(AGB)=2.12×ln(DBH)-0.435	Rai and Proctor (1986)	115.90
2	ln(AGB)=2.62×ln(DBH)-2.30	Yamakura et al. (1986)	85.60
3	ln(AGB)=2.53×ln(DBH)-2.13	Brown (1997)	76.31
4	ln(AGB)=2.413×ln(DBH)-1.997	Nelson et al. (1999)	60.32
5	ln(AGB)=2.55×ln(DBH)-2.010	Chambers et al. (2001)	91.65
6	ln(AGB)=2.59×ln(DBH)-2.75	Kettering et al. (2001)	49.63
7	ln(AGB)=2.44×ln(DBH)-2.51	Hashimoto et al. (2004)	39.31
8	ln(AGB)=2.422×ln(DBH)-2.232	Sierra et al. (2007)	49.05
9	$AGB=0.1008\times DBH^{2.5264}$	Kiyono and Hastaniah (2008)	63.99
10	ln(AGB)=2.196×ln(DBH)-1.201	Basuki et al. (2009)	68.08
11	$AGB=0.0829\times DBH^{2.43}$	Kenzo et al. (2009a)	38.86
12	$AGB=0.1525\times DBH^{2.34}$	Kenzo et al. (2009b)	53.94
13	$AGB=0.071\times DBH^{2.667}$	Manuri et al. (2017)	70.39
14	ln(AGB)=2.3207×ln(DBH)-1.89	Karyati et al. (2019)	50.31
15	$(AGB) = 12.683\times(DBH^2\times H)–38.403$	This study	33.31

Note: AGB = above ground biomass ; DBH = diameter at breast height.

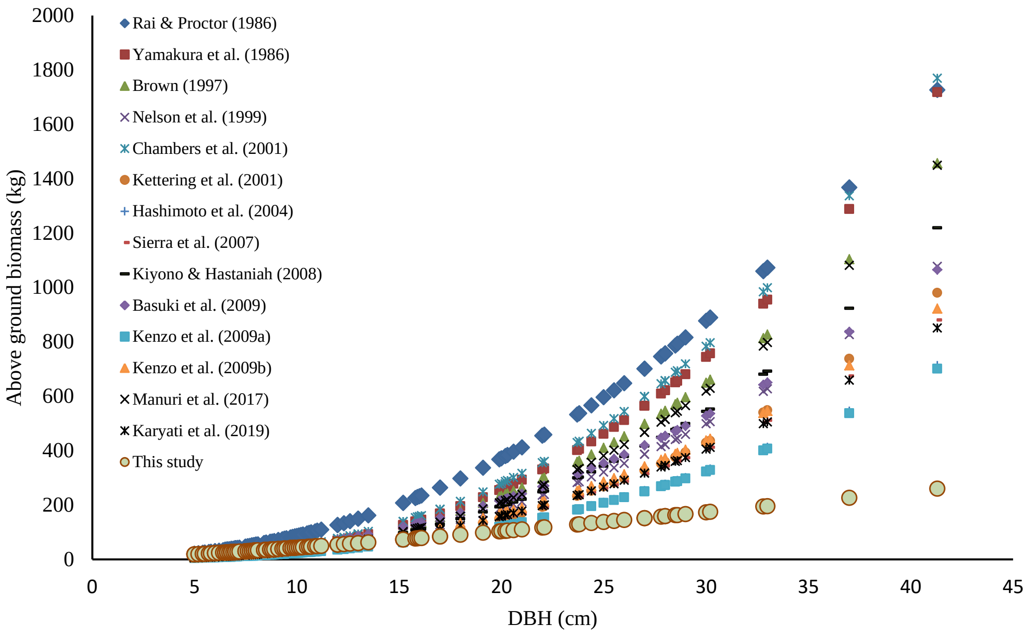


Figure 7. Comparison among various allometric relationships between above ground biomass (AGB) and diameter at breast height (DBH) in the study site

CONCLUSION

This study provides allometric equations to estimate above ground biomass in the tropical abandoned lands after selective logging that characterized by mixed species. The specific allometric equation for different types of abandoned lands was needed. Because the using appropriate allometric model will determine the accurate estimation of above ground biomass in the site.

ACKNOWLEDGEMENTS

We express our thanks to Ministry of Research, Technology and Higher Education, Republic of Indonesia for supporting *Hibah Penelitian Dasar Unggulan Perguruan Tinggi* Contract No.: 183/SP2H/LT/DRPM/2019.

REFERENCES

Awang Noor AG, Faridah Hanum I, Tuan Marina TI. 2008. Relationship between economic value and species diversity of timber resources in a hill forest in Peninsular Malaysia. Journal of Sustainable Development 1(2): 17-26.

Chokkalingam U, Smith J, de Jong W. 2001. A conceptual framework for the assessment of tropical secondary forest dynamics and sustainable development potential in Asia. Journal of Tropical Forest Science 13(4): 577-600.

Curtis PS. 2008. Estimating Aboveground Carbon in Live and Standing Dead Trees. In: Hoover CM (ed). Field Measurements for Forest Carbon Monitoring: a Landscape-Scale Approach. Springer, USA.

Fearnside PM. 1997. Greenhouse gases emissions from deforestation in Brazillian Amazonia: Net committed emissions. Climatic Change 35: 321-360.

Gorte RW. 2007. Carbon Sequestration in Forests. CRS Report for Congress. Congressional Research Service.

Hairiah K, Rahayu S. 2007. Pengukuran "Karbon Tersimpan" di Berbagai Macam Penggunaan Lahan. World Agroforestry Centre-ICRAF, Indonesia.

Hairiah K, Sitompul SM, Van Noordwijk M, Palm C. 2001. Methods for Sampling Carbon Stocks Above and Below Ground. ASB Lecture Note 4B. International Centre for Research in Agroforestry, Indonesia.

Harmon EH, Ferrell WK, Frankli JF. 1990. Effects on carbon storage of conservation of old growth forests to young forest. Science 297: 699-702.

Hashimoto T, Tange T, Masumori M, Yagi H, Sasaki S, Kojima K. 2004. Allometric equations for pioneer tree species and estimation of the aboveground biomass of a tropical secondary forest in East Kalimantan. Tropics 14: 123-130.

Janisch JE, Harmon ME. 2002. Successional changes in live and dead wood carbon stores: Implications for net ecosystem productivity. Tree Physiology 22: 77-89.

Karyati. 2013. Ecology and Carbon Sequestration of Secondary Forests at Sabal, Sarawak. [Dissertation]. Universiti Malaysia Sarawak, Malaysia.

Karyati, Ipor IB, Jusoh I, Wasli ME. 2019. Allometric equations to estimate the above-ground biomass of trees in the tropical secondary forests of different ages. Biodiversitas 20(9): 2427-2436.

Kendawang JJ, Ninomiya I, Tanaka K, Ozawa T, Hattori D, Tanaka S, Sakurai K. 2007. Effects of burning strength in shifting cultivation on the early stage of secondary succession in Sarawak, Malaysia. Tropics 16: 309-321.

Kenzo T, Furutani R, Hattori D, Kendawang JJ, Tanaka S, Sakurai K, Ninomiya I. 2009a. Allometric equations for accurate estimation of above-ground biomass in logged-over tropical rainforests in Sarawak, Malaysia. J For Res 14 (6): 365-372.

Kenzo T, Ichie T, Hattori D, Itioka T, Handa C, Ohkubo T, Kendawang JJ, Nakamura M, Sakaguchi M, Takahashi N, Okamoto M, Tanaka-Oda A, Sakurai K, Ninomiya I. 2009b. Development of allometric relationships for accurate estimation of above- and below-ground biomass in tropical secondary forests in Sarawak, Malaysia. J Trop Ecol 25: 371-386.

Ketterings QM, Coe R, Van Noordwijk M, Ambagau Y, Palm CA. 2001. Reducing uncertainty in the use of allometric biomass equations for predicting above-ground tree biomass in mixed secondary forests. For Ecol Manag 146:199-209.

Kiyono Y, Hastaniah. 2005. Pattern of slash-and-burn land use and their effects on forest succession. swidden-land forests in Borneo. Bull For For Prod Res Inst 4: 259-282.

Manuri S, Brack C, Rusolono T, Noor'an F, Verchot L, Maulana SI, Adinugroho WC, Kurniawan H, Sukisno DW, Kusuma GA, Budiman A, Anggono RS, Siregar CA, Onrizal O, Yuniati D, Soraya E. 2017. Effect of species grouping and site variables on aboveground biomass models for lowland tropical forests of the Indo-Malay region. Annals of Forest Science 74(23): 1-14.

Ministry of Forestry Indonesia. 2011. Development of Allometric Equations for Estimating Forest Carbon Stocks Based on Field Measurement (Ground Based Forest Carbon Accounting). Centre for Standardization and Environment, Ministry of Forestry, Indonesia.

Moore PD, Chapman SB. 1986. Methods in Plant Ecology, 2nd Ed. Blackwell Scientific Publications, Oxford.

Mokria M, Mekuria W, Gebrekirstos A, Aynekulu E, Belay B, Gashaw T, Brauning A. 2018. Mixed-species allometric equations and estimation of aboveground bioass and carbon stocks in restoring degraded landscape in northern Ethiopia. Environmental Research Letters 13: 1-14.

Nelson BW, Mesquita R, Pereira JLG, De Souza SGA, Batista T, Couto LB. 1999. Allometric regressions for improved estimate of secondary forest biomass in the Central Amazon. For Ecol Manag 117:149-167.

Nurlinda I, Pujiwati Y, Ishak M. 2014. Perbandingan penanganan tanah terlantar di Kabupaten Tasikmalaya dan Kabupaten Sukabumi dalam mewujudkan ketahanan pangan Provinsi Jawa Barat. Jurnal Hukum IUS Quia Iustum 21(1): 120-138. [Indonesian]

Parlucha J, Barbadillo N, Sedenio P. 2017. Species-site matching based on growth performance evaluation of mixed native and exotic secondary forest in Musuan Bukidnon. Journal of Biodiversity and Environmental Sciences (JBES). 10(3): 62-70.

Pinheiro TF, Escada MIS, Valeriano DN, Hostert P, Gollnow F, Müller H. 2016. Forest Degradation Associated with Logging Frontier Expansion in the Amazon: The BR-163 Region in Southwestern Pará, Brazil. Earth Interactions 20(17): 1-26.

Roshetko JM, Delaney M, Hairiah K, Purnomosidhi P. 2002. Carbon stocks in Indonesian homegarden systems: Can smallholder systems be targeted for increased carbon storage. American Journal of Alternative Agriculture 17(2): 1-11.

Seiler W, Crutzen PJ. 1980. Estimates of gross and net fluxes of carbon between the biosphere and the atmosphere from biomass burning. Climatic Change 2: 207-247.

Selaya NG, Anten NPR, Oomen RJ, Matthies M, Werger MJA. 2007. Above-ground biomass investments and light interception of tropical forest trees and lianas early in succession. Annals of Botany 99: 141-51.

Sierra CA, Del Valle JI, Orrego SA, Moreno FH, Harmon MA, Zapata M, Colorado GJ, Herrera MA, Lara W, Restrepo DE, Berrouet LM, Loaiza LM, Benjumea JF. 2007. Total carbon stocks in a tropical forest landscape of the Porce Region, Colombia. For Ecol Manag 243: 299-309.

Statistics Kutai Kartanegara Regency. 2018. Kutai Kartanegara Regency in Figures 2018. Tenggarong.

Van Do T, Osawa A, Thang NT. 2010. Recovery process of a mountain forest after shifting cultivation in Northwestern Vietnam. For Ecol Manag 259: 1650-1659.
Zeng WS, Zhang LJ, Chen XY, Cheng ZC, Ma KX, Li ZH. 2017. Construction of compatible and additive individual-tree biomass models for *Pinus tabulaeformis* in China. Canadian Journal of Forest Research 47(4): 467-475.