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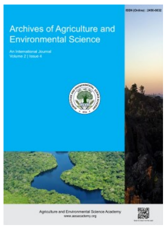

ORIGINAL RESEARCH ARTICLE

Biomass and carbon approximation model on burnt peatland in Eks- Milion Ha, Central Kalimantan Province of Indonesia

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ABSTRACT

Forest and land fires will lead to the loss of forest ecosystems, loss of forest biomass and the sustainability of forests. After the event of fire whether an ecosystem will improve the forest and its environment. The study is intended to calculate biomass and carbon stocks in secondary natural forests that burn after 10 years and determine the model of biomass estimation and carbon stocks in secondary forests that burn after 10 years. This research was conducted on burnt peatlands in the Ex Million ha of Central Kalimantan Province of Indonesia. The research method used is the analysis of vegetation and destructive sampling on forest biomass that grows on burning peatlands. The result showed that biomass content of secondary natural forest formed after peat burns > 10 years in 466.2 ton / ha of and carbon content of 264.4 ton / ha. The estimation of biomass in secondary natural forest formed after peat burn> 10 years log is B = - 0.127 + 1.83 log D ($B = 0.746\ D^{1.83}$) R^2: 87.5 % and carbon estimation is log K = - 0.506 + 1.92 log D ($K = 0.312\ D^{1.92}$) R^2: 85.7 %. In the location of the burnt peat swamp forest there has been a succession of secondary forest and the equation model obtained in the study can be used to estimate biomass and carbon content.

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INTRODUCTION

Indonesia's peat forests are on the island of Sumatra (7.2 million ha), Kalimantan Island (5.8 million ha), Papua Island (8 million ha), and slightly on the island of Sulawesi. The tree height in peat swamp forest is around 20-30 m. Peat forests have a high carbon content (Whitmore, 1990). Preservation of peat forests means preventing the release of carbon dioxide into the atmosphere, thereby reducing and preventing climate change (Soerianegara and Indrawan, 2005; IFCA, 2007; Wasis *et al.*, 2019). Peat forests store about 329-525 Gt of carbón or 15-35% of terrestrial carbon. About 86% (455 Gt) of carbon in the peatland is stored in temperate regions (Canada and Russia) while the remaining 14% (70Gt) is in the tropics. The clearance of peat forests for a million ha of agricultural land, which in 1997 burned (MacDicken, 1997; Murdiyarso *et al.*, 2004; Hoojier *et al.*, 2016). Peatland fires in 1997 have resulted in the release of carbon from peat forests into the air by about 0.81-2.57 Gt (Page *et al.*, 2002). Disruptions to the wetland ecosystem will affect the reserves and the carbon cycle in nature (Primack *et al.*, 1998). The disturbance can be land conversion after peat forest is deforested, fires and drainage are widespread (Barrow, 1991; Wasis, 2003; Murdiyarso *et al.*, 2004; Saharjo *et al.*, 2011; Wasis *et al.*, 2019).

Forest and land fires cause environmental damage, loss of forest biomass (50% of forest ecosystems), loss of flora and fauna and physical, chemical and biological damage to peat soil and loss of peatland life due to reduced thickness of peat / subsidized soils (Sorensen, 1992; Wasis, 2003; Debano *et al.*, 1998; Hooijer, 2008; Sutaryo. 2009; Wasis *et al.*, 2019). After 10 years of burning there is little known how the flora and fauna lives in the ex-PLG million ha, much more to the carbon content of the burning peatlands and how to restore them (Rahayu *et al.*, 2004). Of the many activities undertaken to date, very few have determined the model of carbon and biomass estimation based on live stands found on land 10 years ago burned, let alone using destructive sampling. The objective of the study was to determine the model of biomass estimation and carbon stock in secondary forest burned after 10 years.

MATERIALS AND METHODS

Place and time of research

Activities will be carried out in ex-PLG Million ha land, especially burnt land. Field research was carried out on March to August 2009. Improved data analysis and writing was carried out in October to November 2020.

Forest structure

Changes in the composition and structure of vegetation on burnt and unburned burnt peat land made 5 (five) sample plots measuring 20 m × 20 m (0.04 ha). In each sample plot is divided into sub plots of 10 m × 10 m (100 m^2), 5 m × 5 m (25 m^2) and 2 m × 2 m (4 m^2) (Figure 1) (Soerianegara and Indrawan, 2005). All vegetation from the seedling level to the tree and the lower plants are identified, and counted. For this purpose, there are several criteria that can be used (Kusmana and Istomo, 1995; Soerianegara and Indrawan, 2005). Vegetation analysis is a way of studying species composition and vegetation structure within an ecosystem (Soerianegara and Indrawan, 2005). In the vegetation analysis the calculation of the Importance Value Index (INP) is calculated. According to Odum (1971), INP is the sum of Relative Density (KR), Relative Frequency (FR) and Relative Dominance (DR).

Calculation of biomass

The biomass of each plant part within the site to be measured can be predicted by allometric equations. Construct a square plot inside a stand that grows on a burnt-out field of size (10-30 m × 10-30 m). The length of the shortest side distance from the plot to be built should be longer than the average height of the tree contained in the plot. To avoid over estimate in guessing its biomass, two or three lines from the edge of the plot of the stand to be calculated must be removed from the calculation.

The baseline data of the tree especially the diameter > 2 cm in each tree in the plot should be recorded. The location of dead and missing trees should also be noted so that field notes really describe actual field conditions. In order to compile the allometric equations in the estimation of tree biomass then a number of trees will be felled based on the distribution of the diameter class. Trees that have been ascertained the amount and distribution are then cut down, separated in parts and then weighed, examples of each part of a 200 g plant are taken and separated for further analysis and to avoid placement errors it is necessary to be written and labeled clearly.

Counting bush biomass (underneath), tree stumps and litter

Calculating biomass is done by plotting a 2 m × 2 m plot, then taking samples of each 200 gram biomass section taken for determination of carbon content.

Carbon content = 100% - hard content of ash- charcoal content

Biomass assumption model

The model relationship between tree biomass and tree dimension (diameter and tree height) was made using allometric regression equations that describe biomass as a function of tree diameter and height. The equations were compiled using mathematical models based on previous research, allometric regression and taper function used to estimate tree biomass (Y) with x1 as diameter and x^2 as tree height with the following equations (Mac Dicken, 1977 Brown, 1997: Ludwig and Reynolds, 1988 ; Brown, 1997; Mattjik and Sumertajaya, 2013; Stell and Torries, 1991; Wibisono, 2009):

Y	$= b_o + b_1x_1$	Y	$= b_o + b_1x_1 + b_2x_2$
Y	$= b_o + b_1x_1 + b_2x_2^{\,2}$	Y	$= b_o + b_1x_1^{\,2}$
Y	$= b_o + b_1x_1^{\,2}\,x_2$	Y	$= bo + b_1 (\log x_1)x_2$
Y	$= b_1 \log x_1$	Y	$= bo\, e^{x_1}$
$\log Y$	$= b_o + b_1 \log x_1$	Y	$= b_1x_1^{\,bo}$
Y	$= a D^{b} H$	$\log Y$	$= b_o + b_1 (\log x_1)\, x_2$
Y	$= b_o + b_1x_1 + b_2x_1^{\,2}$		

Model relationship carbon content and biomass

The model of the relationship between carbon content and biomass is made for stands. The relationship model made is based on the function that carbon = ƒ (biomass). This relationship function is built through a simple regression equation. From the relationship model built will be known level of closeness between carbon content with biomass (Mattjik and Sumertajaya, 2013; Stell and Torries 1991; Wibisono, 2009). The model chosen based on several criteria, namely: compatibility with the phenomenon and the nature of model reliability based on: coefficient of determination (R^2), variant (S^2) and corrected coefficient of determination.

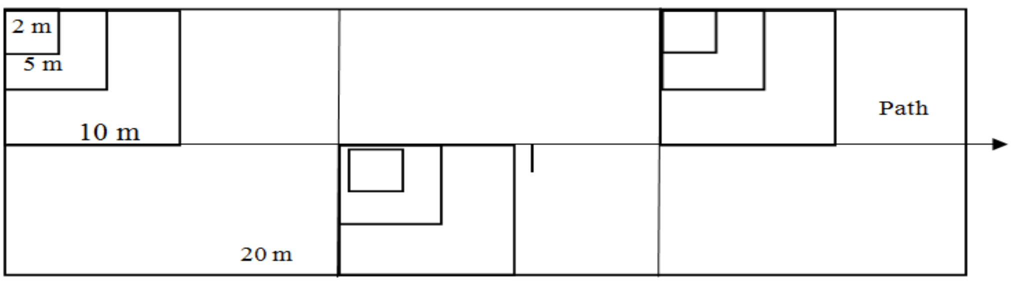

Figure 1. *Observation plot of natural forest structure.*

RESULTS AND DISCUSSION

Vegetation structure

Based on the analysis of tree-level vegetation on secondary forest there are 17 species of trees. The types of plants at the tree level are: Geronggang (*Cratoxylon arborescens* (Vahl) Blume), Tumih (*Combretocarpus rotundatus* (Miq.) Danser), Hangkang (*Palaquium leiocarpum*), Nyatoh (*Palaquium rostratum* (Miq.) Burck), Jelutung (*Dyera costulata* Hook. F), Meranti (*Shorea* sp.) etc. The result of tree-level vegetation analysis obtained density equal to 490 Individual / ha. Based on result of vegetation analysis for pole level in secondary forest there are 24 species with density equal to 790 Individual / ha. Based on the analysis of vegetation for the level of sapling in secondary forest there are 33 species with a density of 20-70 Individuals / ha. Based on result of vegetation analysis for seedling level in secondary forest there are 31 species with density equal to 30 - 60 Individual / ha. Based on the analysis of vegetation for undergrowth in secondary forest there are 16 species with density of 60 - 100 Individuals / ha.

Biomass estimation

The results showed that biomass in natural forest secondary after burning> 10 years was 466.2 ton / ha with biomass growth rate 33.3 ton / ha / year. Based on the result of biomass observation, the distribution of biomass of secondary forest vegetation part is done. The result of calculation of biomass distribution of plant part can be seen in Table 1. The proportion of vegetation biomass in secondary natural forests from the highest plant part to the lowest was stem 363.1 tons / ha (77.9%), branches 27.2 tons / ha (5.9%), twigs 23.0 tons / ha (4.9%), leaves of 22.1 tons / ha (4.75%), necromass 14.2 tons / ha (3.0%), fresh litter of 11.2 tons / ha (2.4%) and old litter of 5.4 ton / ha (1.2%). In this burning peatland forest has been formed secondary forest because there is still natural forest around it. The existence of this natural forest causes forest renovation on burning peatland (Kusmana and Istomo, 1995, Soerianegara and Indrawan, 2005). The results of this study indicate that the largest biomass is in the tree stem. So that the largest biomass type of secondary forest vegetation is stored on tree stem. Timber harvesting activities in secondary forests will result in the loss of forest biomass that will ultimately lead to ecosystem impoverishment and loss of vegetation capability to absorb carbon (Saharjo and Wasis, 2006; Saharjo *et al.*, 2011; Siregar *et al.*, 2018; Wasis *et al.*, 2018; Wasis *et al.*, 2019b). Secondary forest succession in burnt forest will slowly improve peat subsidence lost due to burning (Wasis *et al.*, 2019a). This study also shows that the burnt peat soil has caused a subsidence of 20-30 cm.

The result of determining the model of vegetation biomass estimation on secondary forest can be seen in Table 2. Based on the model of biomass equation which then can be selected the best model using the highest and lowest R^2 criterion then log model B = - 0.127 + 1.83 log D or B = 0.746D1.83 (number 5) selected to model biomass estimator based on tree diameter.

Biomass estimation model is very important to determine the forest biomass quickly because there is no need to cut trees (Sutaryo, 2009; Brown, 1997). Information on forest biomass estimation models is relevant to addressing forest management in addressing climate change and sustainable forest management issues.

Table 1. The distribution of biomass in secondary forest burns > 10 years.

Spread of biomass	Biomass (ton/ha)	Percentage (%)
Stem	363.1	77.9
Branches	27.2	5.9
Twigs	23.0	4.9
Fresh leave	22.1	4.7
Necromass	14.2	3.0
Fresh litter	11.2	2.4
Old litter	5.4	1.2
Total biomass	466.2	100

Table 2. Biomass equation model based on tree diameter and total height in secondary forest burned> 10 years.

Number	Model	R^2 (%)	S^2	Count F
1	$B = -31.9 + 10.2D$	70.9	37.4607	39.94**
2	$B = -20.3 + 11.1D - 0.228H^2$	73.2	35.9368	22.85**
3	$B = 36.3 + 0.0256D^2H$	36.7	55.2282	10.27**
4	$B = -86.5 + 172 \log D$	59.2	44.3588	24.18**
5	$\log B = -0.127 + 1.83 \log D$ or $B = 0.746D^{1.83}$	87.5	0.2179	112.91
6	$\log B = 0.143 + 1.90 \log D - 0.364 \log H$ or $B = 1.39D^{1.90}H^{-0.364}$	87.5	0.2182	56.76
7	$B = -1.6 + 11.2D - 4.47H$	72.9	36.1580	22.48**
8	$B = 15.1 + 0.419D^2$	61.6	43.0104	26.67**
9	$B = 1.7 + 8.09(\log D)H$	27.0	59.3188	6.91*
10	$\ln B = 1.33 + 0.221D$ atau $B = 3.78e^{0.221D}$	80.8	0.6215	68.35
11	$\log B = 0.793 + 0.0877(\log D)H$	43.5	0.4631	13.31**

Remarks: ** very significant model means, * significant model, K : Carbon, D : Diameter H : height.

Table 3. Carbon distribution in secondary forest burns> 10 years.

Spread of Carbon	Carbon (ton/ha)	Percentage (%)
Stem	212.8	80.5
Branches	15.9	6.0
Twigs	13.5	5.1
Fresh leaves	8.0	3.0
Necromass	8.3	3.1
Fresh litter	4.0	1.5
Old litter	1.9	0.8
Total carbon	264.4	100

Table 4. Model of carbon equation based on diameter and total tree height in secondary forest burned> 10 years.

Number	Model	R^2 (%)	S^2	Count F
1	K = -24.4 + 6.4 D	72.6	22.6249	43.43**
2	K = -19.5 + 6.79D – 0.0951H^2	72.6	22.6206	22.23**
3	K = 16.8 + 0.0174 D^2H	44.9	32.1017	14.02**
4	K = - 55.8 + 105 log D	56.7	28.4519	21.95**
5	log K = - 0.506 + 1.92log D or K = 0.312$D^{1,92}$	85.7	0.2472	97.06**
6	log K = - 0.233 + 2.00 log D – 0.366 log H or K = 1.39$D^{1,90}H^{-0,364}$	85.5	0.2493	48.07**
7	K = - 12.0 + 6.82D – 1.82H	72.4	22.7133	21.99**
8	K = 4.27 + 0.271D^2	66.9	24.8930	33.27**
9	K = - 6.5 + 5.47(log D)H	33.0	35.4008	8.87**
10	In K = 0.472 + 0.239D or K = 1.60 $e^{0.239D}$	84.2	0.5982	86.45**
11	Log K = 0.449 + 0.0938 (log D)H	44.2	0.4887	13.67**

Remarks: ** very significant model means, * significant model, K : Carbon, D : Diameter H : height.

Carbon estimation

The carbon content of secondary forests is burnt> 264.4 tons / ha and carbon uptake rate of 18.9 tons / ha / year. Based on the results of carbon observations, then the distribution of carbon distribution of secondary forest vegetation part. The results of the calculation of biomass distribution of secondary forest vegetation type can be seen in Table 3. The proportion of vegetation carbon in the secondary forest from the highest part of the plant to the lowest is stem 212.8 tons / ha (80.5%), branches 15.9 tons / ha (6.0%), twigs 13, 5 tons / ha (5.1%), leaves of 8.0 ton / ha (3.0%), necromass of 8.3 ton / ha (3.1%), fresh litter of 4.0 ton / ha (1.5%) and old litter 1.9 tons / ha (0.8%). The results of this study indicate that the largest carbon is in the tree stem. So the carbon type of secondary forest vegetation is stored on tree stem. Timber harvesting activities in secondary forest will lead to forest carbon and the ability to absorb carbon (Murdiyarso *et al.*, 2004; Wasis, 2006; Siregar, 2018). Loss of forest biomass due to illegal logging and forest fires. Forest fires can cause forest destruction, loss of flora and fauna and cause air pollution. Forest fires can be prevented if all interests such as government, companies, communities and others do it together (Putra *et al.*, 2019).

The result of modeling of carbon prediction in secondary forest burning> 10 years can be seen in Table 4. Based on the model of carbon equation then the best model can be selected using the highest and lowest R^2 criteria then the log model K = - 0.506 + 1.92log D or K = 0.312$D^{1,92}$ (number 5) selected to model the biomass estimator based on diameter and height total trees.

Equation models, measurement methods and monitoring techniques for absorptive capacity and carbon stocks and their dynamics are essential for achieving sustainable forest management and carbon trading (Rusolono, 2006; Saharjo *et al.*, 2011; Siregar *et al.*, 2018)

Conclusion

This investigation concluded that the biomass content of secondary natural forest formed after peat burns> 10 years in 466.2 ton / ha of and carbon content of 264.4 ton / ha. The estimation of biomass in secondary natural forest formed after peat burn> 10 years is log B = - 0.127 + 1.83 log D (B = 0.746 $D^{1.83}$) R^2 : 87.5 % and carbon estimation is log K = - 0.506 + 1.92 log D (K = 0.312 $D^{1.92}$) R^2: 85.7 %. This research shows that in the burned forest there has been a succession of secondary forests. The model from this research can be used to estimate biomass and carbon.

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