

## ABOVE GROUND TREES BIOMASS OF LORE LINDU NATIONAL PARK-CENTRAL SULAWESI : A STUDY COMBINING FIELD MEASUREMENT AND REMOTE SENSING

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Penyerahan Naskah: 18 Januari 2010  
Diterima untuk diterbitkan: 26 Mei 2010

### ABSTRACT

Forests play an important role in global carbon cycling, since they hold a large pool of carbon as well as potential carbon sinks and sources to the atmosphere. Accurate estimation of forest biomass is required for greenhouse gas inventories and terrestrial carbon accounting. The information on biomass is essential to assess the total and the annual capacity of forest vigor. Estimation of aboveground biomass is necessary for studying productivity, carbon cycles, nutrient allocation, and fuel accumulation in terrestrial ecosystem. The possibility that above ground forest biomass might be determined from space is a promising alternative to ground-based methods. Remote sensing has opened an effective way to estimate forest biomass and carbon. By the combination of data field measurement and allometric equation, the above ground trees biomass possible to be estimated over the large area. The objectives of this research are: (1) To estimate the above ground tree biomass and carbon stock of forest cover in Lore Lindu National Park by combination of field data observation, allometric equation and multispectral satellite image; (2) to find the equation model between parameter that determines the biomass estimation. The analysis showed that field data observation and satellite image classification influencing much on the accuracy of trees biomass and carbon stock estimation. The forest cover type A and B (natural forest with the minor timber extraction) has the higher biomass than C and D (natural forest with the major timber extraction and agro forestry), it is about 607 ton/ha and 603 ton/ha. Forest cover type C is 457 ton/ha. Forest cover type D has the lowest biomass is about 203 ton/ha. Natural forest has high biomass, because of the tropical vegetation trees heterogeneity. Forest cover D has the lowest trees biomass because its vegetation component as secondary forest with the homogeneity of cacao plantation. The forest biomass and carbon estimation for each cover type will be useful for the further equation analysis when using the remote sensing technology for estimating the total biomass and for the economic carbon analysis.

**Keyword:** biomass, carbon stock, allometric equation, remote sensing.

### INTRODUCTION

#### Background

Forests play an important role in global carbon cycling, since they hold a large pool of carbon as well as potential carbon sinks and sources to the atmosphere. Accurate estimation of forest biomass is required for greenhouse gas inventories and terrestrial carbon accounting (Muukkonen and Heiskanen, 2006).

Lore Lindu National Park, Central Sulawesi, Indonesia is one of the most important protected

areas in Indonesia and was declared a "Biosphere Reserve" in 1977. Biosphere reserves were conceived as "experimental sites for sustainable development, research and monitoring on ecosystems and conservation of biodiversity", and are at the same time meant to "promote well being of local people who live in and around the reserve" (UNESCO, 1995). The forest properties will become an important thing to be explored when dealing with the protection effort of the area, and to know the function of the forest for reserving biomass and the carbon pool to the environment.

Biomass was the name given to any recent organic matter that had been derived from plants as a result of the photosynthetic conversion process. The biomass of forest provides estimates of the carbon pools in forest vegetation because about 50% of it is carbon. The carbon stock indicates the contribution of forest to carbon cycles related to mitigation of climate change. Direct measurement of biomass on the ground is time consuming (expensive), and repeated measurements, if they occur at all, are generally limited to 10 year interval. Remote sensing has opened an effective way to estimate forest biomass and carbon absorption (Rosenqvist *et al.*, 2003; June *et al.* 2006). By combining remote sensing technology and empirical model of allometric equation biomass and carbon stock of forest cover area can be estimated with ease.

### Objectives

1. To estimate the above ground tree biomass and carbon stock of forest cover in Lore Lindu National Park by combination of field data observation, allometric equation and multispectral satellite image.
2. To find the equation model between parameter that determines the biomass estimation.

### Output

1. Correlation and Regression equation model of biomass and vegetation indexes, remote sensing biomass and field biomass.
2. Normalized Difference Vegetation Index (NDVI) value using QuickBird satellite image.
3. Per hectare trees biomass derived from different forest cover type and multispectral satellite

image classification as the reference to estimate the total biomass and carbon stock in sample plot and whole area.

4. Total trees biomass and carbon stock of whole study area.

## METHODOLOGY

### Time and Location

This research was conducted from February-August 2007. The study area is located Toro-Kulawi district of Lore Lindu, Central Sulawesi, Indonesia. Lore Lindu is one of the National Parks in Central Sulawesi, administratively it is belong to Donggala and Posos regency, Central Sulawesi. Geographically lays on  $119^{\circ}58' - 120^{\circ} 16' E$  and  $1^{\circ}8' - 1^{\circ}3' N$ .

This research was funded by BMZ and STORMA program. STORMA stand for Stability of Rainforest Margin in Indonesia, is an Indonesian-German collaborative Research Centre funded by the German Research Foundation (FDG).

### Data Source

There are two main kinds of data using in this research are remote sensing data and field measurement data. The multispectral satellite image data that will be used in this research is QuickBird satellite image with the acquisition date of April, 15<sup>th</sup> 2004. The main measurement data derived from field are LAI (Leaf Area Index), plant height, diameter breast height, and plant density.

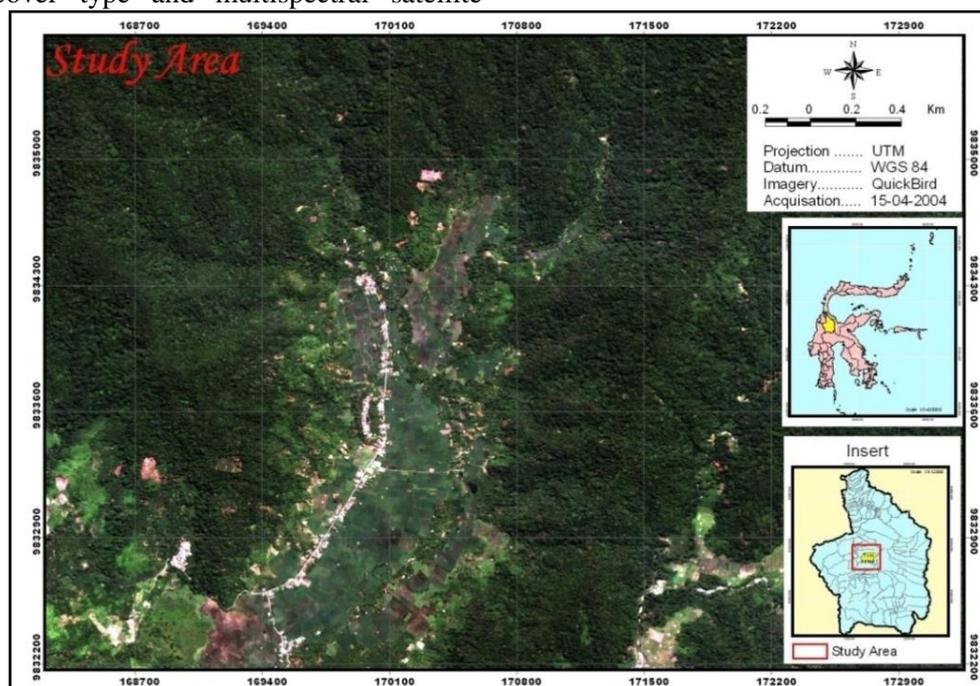


Figure 1 Study Area Location.

**Method**

This research conducted by using the fourth approach as mentioned in literature of estimating the biomass that combines field studies (forest inventory data), analysis of multispectral satellite imagery, allometric equation and statistical analysis. The general procedure is described in Figure 3.

**Field Data Measurement**

The selected trees must come from the population of interest, represent the major species in the forest and represent all size classes. The method of field sampling applied for collecting field data is quadrature sampling, with 30m x 30m plot size. The scheme for distributing sample over the area of interest, use stratified systematic random sampling. Stratification done for the forest cover becomes A, B, C, D type (D, E and F plot grouped into D). Systematic way was chosen to spread the plant in row evenly, and then the trees were measured for each row randomly.

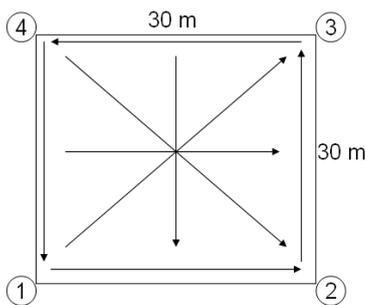


Figure 2 The sampling scheme for field measurement data.

The diameter breast height was measured from the girth of the trees and converted to the trees diameter. Trees total height was measured by using vertex that has the function of measuring heights,

distance, angle inclination and air temperature. The x and y trees canopy was also measured by using vertex.

Plots observation were based on the forest cover type as defined by STORMA in the second phase (by workshops of 1-9 September 2003) consist of 6 type, these are: Habitat type A, B, C, D, E and F.

- Habitat type A : Natural forest with traditional use (rattan extraction) but without timber extraction; closed canopy.
- Habitat type B : Natural with minor extraction of small trees (used to build small *pondoks*) not affecting the closure of the upper canopy layer.
- Habitat type C : Natural forest with major timber extraction indicated by large, artificial gaps in and pronounced decrease of the canopy cover to only 40-60%.
- Habitat type D : Agro-forestry system (dominated by cacao) with remaining natural forest trees as shade trees. Canopy closure: 20-50%. Low intensity management.
- Habitat type E : Agro-forestry system (dominated by cacao) shaded by diverse spectrum of planted trees and trees naturally grown after clear cutting.
- Habitat type F : Agro-forestry system with a shade tree layer dominated by one tree species (*Erythrina*) >90% of all shade trees belong to one tree species. Canopy closure: 20-50%

[Note: the intensity of the agro forestry management not really differs between habitat types D, E and F in all types crops are more or less planted in rows, so that D, E, and F grouped into D type]

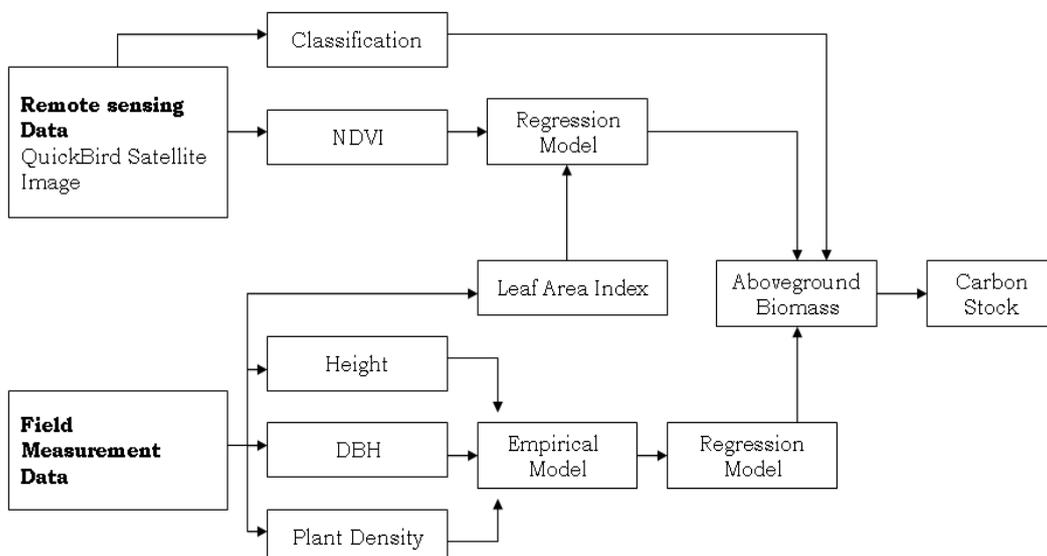


Figure 3 General procedure of biomass and carbon stock estimation.

### Forest covers type classification of QuickBird satellite image

The classifications for each cover type by using region (training sample set of plot observation) based the different spectral value in each observation plot refer to QuickBird Image.

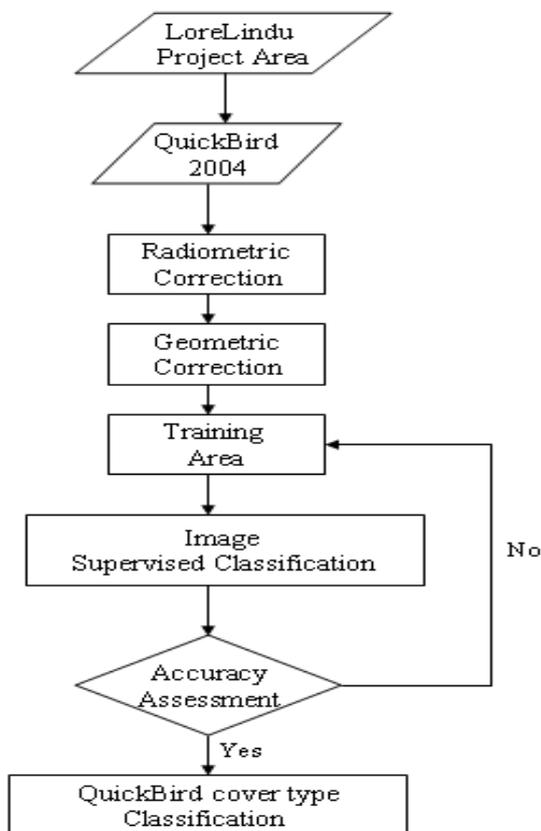


Figure 4 Forest covers type classification procedure.

### Calculating Biomass using Allometric Equation (ton/ha)

The empirical model was chosen to estimate biomass and carbon content by using field data. Empirical model were based on statistical analysis of observed data, and these were usually applicable (derived from previous research). Therefore, the biomass of the tree is estimated with allometric relationship of total height and DBH. Allometric relationship of total height and DBH will be used to measure quantity of biomass (FAO 1997). To calculate biomass ton per hectare the following allometric equation use Brown, 1997):

$$W_{dry} = \exp[-3.1141 + 0.9719 \ln(D^2 H)] * P / 1000$$

Where:  $W_{dry}$  = Total biomass (ton/ha)  
 $D$  = Diameter Breast height (cm)  
 $H$  = height of plant between blocks (m)  
 $P$  = planting density within the blocks

### Calculating Carbon-Stock (ton/ha)

An estimate of carbon stock in plantation is generally based on allometric equations relating as carbon or biomass to plant height. Equation to calculate carbon stock (Winrock 1997):

$$C - Stock = 0.55 * Biomass(total)$$

## RESULT AND DISCUSSION

### Field Data Measurement

The observation sites of each forest cover type is shown in Figure 5. Forest covers A, B, C is natural or primary forest, and forest cover type D, E and F are agro forestry system. Forest cover A has more closed canopy than the other, because there is no timber extraction. Forest cover B still has closed canopy, even with minor extraction of small tress (diameter < 5 cm) it has no significant influences on canopy layer. Forest cover C has less trees and canopy layer than A and B due to the timber extraction that reduce trees density inside the plot observation. Forest cover D, E and F are agroforestry system that dominated with cacao, because most of the plot observation is cacao plantation that combined with shaded trees.

### Forest Cover Type Classification

The study area of Toro-Kulawi District was chosen for the biomass analysis, because of the consideration about the image data availability that covered this area (Figure 6). Forest cover type classification was conducted by using Supervised Classification of QuickBird satellite image based on region training that utilizes the spectral value of field plot observation. The image was classified into forest and non-forest area. Forest cover type was classified into A, B, C, D and non-forest area (Bare land, shrubs, cloud and paddy field) as depicted in Figure 7.

Table 1. Plot distribution of field data observation covering NDVI value

Plot No.	Cover Type	Plot Name	NDVI Value	NDVI Rate
1	A	South Kalabui	0.812	0.81
2	A	North Kalabui	0.821	
3	A	Lonca	0.829	
4	A	Kolewuri	0.782	
5	B	Lonca	0.836	0.81
6	B	Kalabui	0.827	
7	B	Kolewuri	0.779	
8	C	Komanua	0.812	0.79
9	C	Kuku	0.780	
10	C	Lonca	0.819	
11	D	Penga	0.768	0.76
12	D	Ambi	0.766	
13	D	Abia	0.772	
14	E	Iskandar	0.769	0.74
15	E	Ace	0.685	
16	E	Abdullah	0.731	
17	F	Dada	0.762	0.73
18	F	Theodoris	0.770	
19	F	Andreas	0.646	

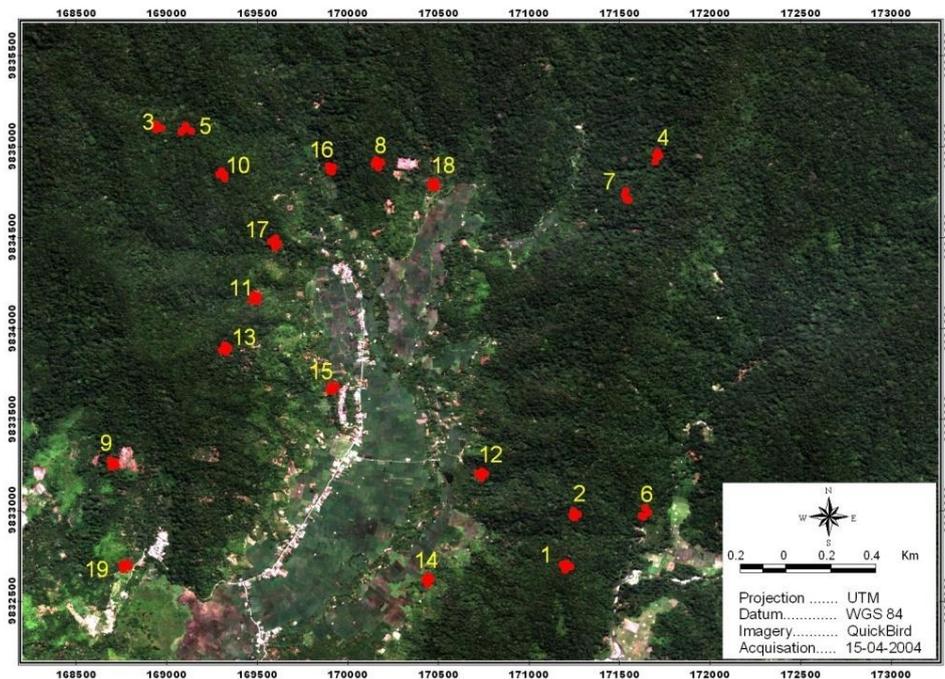


Figure 5 Plot distribution of field data observation.

Table 2. Percentage of forest and non-forest area in the study site

Area	Type	Total Area (ha)	%
Forested	A	699.04	40
	B	525.02	30
	C	94.53	5
	D	119.54	7
Non-forested	Bareland	28.26	2
	Shrubs	94.41	5
	Paddy field	193.23	11
Total		1754.03	100

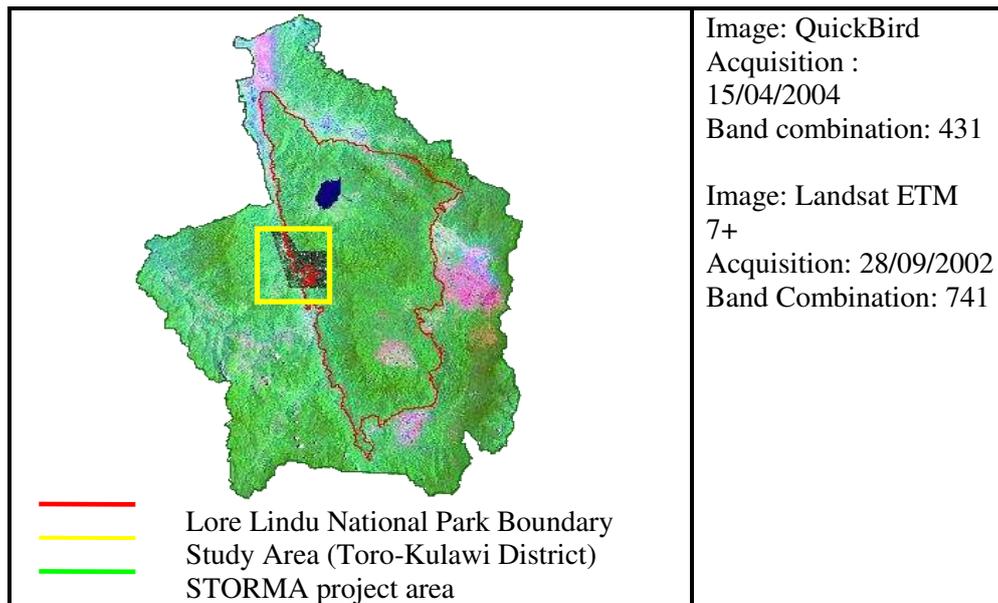


Figure 6 Image of STORMA project area and study area of Toro-Kulawi District.

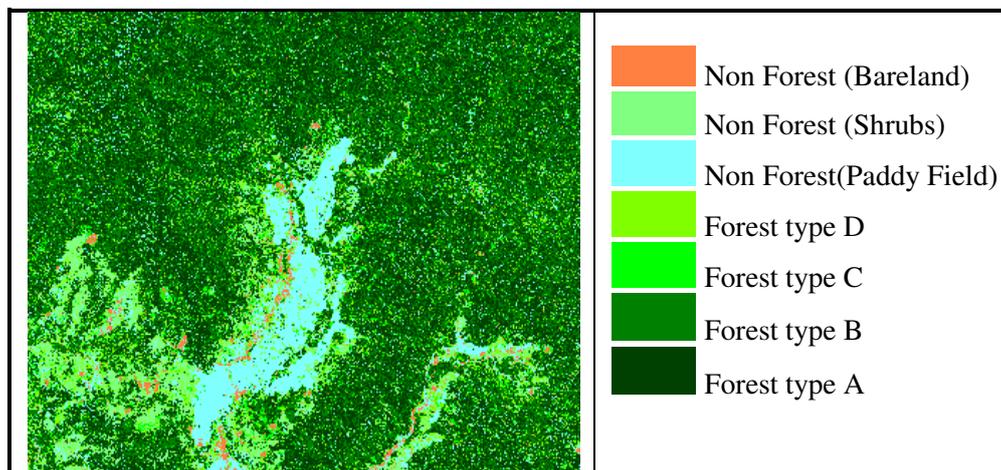


Figure 7 Forest cover classification derived from Quick Bird image.

### Regression Model of Forest Cover Type

The equation models of trees biomass, DBH and height derived from each cover type are summarized in the Table 3. The A, B, C and D forest cover type have different model to estimate the trees biomass. It based on the specific condition of each cover type. The statistical analysis was done by using many sample data (50-70 trees for each cover type) within

field plot observation. Each model has different regression coefficient that shows the correlation strength of parameters in the model. The highest regression coefficient has the highest correlation; it means that the model is highly recommended. These models can be applied for estimating biomass in the tropical rain forest with the same condition as mentioned in Table 4.

### Biomass and Carbon Stock Estimation

Table 3 shows that the trees biomass of each forest cover type is different. The forest cover type A and B has the higher biomass than C and D, it is about 607 ton/ha and 603 ton/ha. Forest cover type C has 457 ton/ha trees biomass. Forest cover type D has the lowest biomass is about 203 ton/ha. The three high biomass per hectare is belongs to natural forest A, B and C cover type. Natural forest has heterogeneity of tropical vegetation trees that lead to the high biomass. Forest cover D has the lowest biomass because its vegetation component as secondary forest with the homogeneity of cacao plantation.

The total biomass of study area was calculated by multiplying the area in hectare

resulted from Quick Bird image classification with biomass per hectare of each forest cover type. The total trees biomass estimation in the study area is 808932 ton, and carbon stock 444912 ton (Table 5).

Table 3. Field trees biomass and C-stock estimation of every plot in each cover type

Forest Cover Type	Biomass (ton/ha)	C-Stock (ton/ha)
A	607	334
B	603	331
C	457	251
D	203	112

Table 4. Equation model between the parameters

Type	Vegetation Type Description	Model	R <sup>2</sup>
A	Natural forest with traditional use (rattan extraction) but without timber extraction; closed canopy	$Y = \log \text{DBH} - 1597$	0.83
		$Y = 1.2888\text{DBH}^2 - 16.508\text{DBH} + 60.506$	0.96
		$Y = 0.0829 \text{DBH}^{2.629}$	0.98
		$Y = 0.0354 \text{TH}^{3.151}$	0.88
		$Y = - 1192 + 125 \text{DBH} - 46.4 \text{TH}$	0.84
B	Natural with minor extraction of small trees not affecting the closure of the upper canopy layer.	$Y = 117.37\text{DBH} - 1857.1$	0.79
		$Y = 1.194\text{DBH}^2 - 11.926\text{DBH} + 9.4608$	0.99
		$Y = 0.0886\text{DBH}^{2.5909}$	0.97
		$Y = 0.0401\text{TH}^{3.1412}$	0.85
		$Y = 5.1393e^{0.2038\text{TH}}$	0.81
C	Natural forest with major timber extraction indicated by large, artificial gaps in and pronounced decrease of the canopy cover to only 40-60%.	$Y = - 863 + 158 \text{DBH} - 120 \text{TH}$	0.85
		$Y = 0.1021\text{DBH}^{2.5478}$	0.96
		$Y = 104.26\text{TH} - 1048.4$	0.86
		$Y = 0.3184\text{TH}^2 + 53.034\text{TH} - 393.45$	0.90
D	Agroforestry system (dominated by cacao) with remaining natural forest trees as shade trees.	$Y = - 1223 + 13.4 \text{DBH} + 97.9 \text{TH}$	0.86
		$Y = 104.26\text{DBH} - 1048.4$	0.86
		$Y = 0.3184\text{DBH}^2 + 53.034\text{DBH} - 393.45$	0.90
		$Y = 0.9688\text{TH}^2 + 46.49\text{TH} - 222.83$	0.70
		$Y = - 416 + 24.7 \text{DBH} + 40.0 \text{TH}$	0.76
Tropical Forest containing ABCD cover type		$Y = 0.1475\text{TH}^{2.8426}$	0.75
		$Y = 6E-05\text{DBH}^{2.6705}$	0.96
		$Y = 0.0013\text{DBH}^2 - 0.0159\text{DBH} + 0.0347$	0.86
		$Y = 0.0002\text{TH}^{2.6783}$	0.82
		$Y = - 1.13 + 0.0701 \text{DBH} + 0.0364 \text{TH}$	0.67
		$Y = 33.584 e^{0.4073 \text{LAI}}$	0.59
		$Y = 0.0065 e^{13.615 \text{NDVI}}$	0.54
$\text{LAI} = 17.955 \text{NDVI}^{5.3265}$	0.67		

Note:

Prerequisite model under moist climate (1500<rainfall<4000mm/year) and DBH>5 cm

Y = Biomass (kg/plant)

DBH = Diameter Breast Height (cm)

TH = Total height (m)

LAI = Leaf Area Index

NDVI = Normalized Difference Vegetation Index

To derive biomass in ton/ha= by multiplying biomass with Population in Ha/1000

Table 5. Total trees biomass estimation of study area

Type	Total Area (Ha)	Biomass/ha (ton)	Total Biomass (ton)	C-Stock (ton)
A	699.035	607	424690	233579
B	525.021	603	316620	174141
C	94.533	457	43255	23790
D	119.541	203	24365	13401
Total			808932	444912

### Comparison between research result with other published data

The estimated above ground trees biomass resulted from the research, especially from cover type A and B is comparable with reported biomass for tropical forest cover before human incursion and with the condition of evergreen high yield in another tropical Asian countries. The above ground trees biomass of forest cover type C 457 ton/ha trees biomass. This estimation biomass value is relatively high if compared with forest cover type C condition (major timber extraction). This condition equal with the disturbed close, logged hill and evergreen logged forest of another tropical Asian countries that range about 180-255 ton/ha. Forest cover type D has the lowest biomass range about 193 – 214 ton/ha.

### CONCLUSION

This research has analyzed the combination of the field data observation, allometric equation, multispectral satellite images classification in estimating the total biomass and carbon stock of the study area. The field data observation influencing much on the accuracy of trees biomass and carbon stock estimation.

The result of the estimation of biomass and carbon from different cover type in Lore Lindu National Park, provide the basic data and information of the losing carbon (carbon stock reduction) as the result of forest cover change into different forest cover type, summarized in this following table.

Forest Cover Type	Biomass (ton/ha)	C-Stock (ton/ha)
A	607	334
B	603	331
C	457	251
D	203	112

Landcover Changing	C-Stock Reduction (ton/ha)
A-B	2
A-C	82
A-D	222
B-C	80
B-D	219
C-D	139

Land cover change could give a significant reduction of terrestrial C-Stock. These significant C-Stock loss occurred in land cover change from A type become D type (natural forest become cacao plantation) and land cover changing form B type become D type (natural forest with minor extraction become cacao plantation). Furthermore, this estimation could be worthy information to be brought to the economical and environmental analysis, especially for carbon trading and green house gas inventories due to the recent global warming phenomenon.

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