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# Carbon stock estimation on some land cover: secondary forest, agroforestry, palm oil plantation and paddy fields

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**Abstract.** The diversity of plant in some land uses at East Luwu Regency has potential to absorb and store carbon, which varies due to the plant different constituent. The differences of carbon stored of each land cover need to calculate in order to find the amount of carbon stock available. This study aims to estimate carbon stocks in the land cover of secondary forest, agroforestry, oil palm plantation and rice fields. The research use sample plot size  $20 \times 50$  that taken 9 times for each land cover. Biomass data was collected using non-destructive sampling, since for undergrowth and necromass using destructive sampling by cutting and taking all the undergrowth and litter that are in a  $1 \times 1$  meter quadrant. There are two kinds of soil sampling that collected; disturbed soil and intact soil. The results showed that the highest estimated carbon stock is secondary forest with carbon stock value of 265.86 tons / ha, as for agroforestry the carbon stock value of 131.31 tons / ha, while oil palm with a carbon stock value of 100.89 tons / ha and the lowest is paddy fields with carbon stock value of 70.50 tons / ha.

## 1. Introduction

Global warming that happening lately caused by the disruption of the energy balance between the earth and the atmosphere. The balance is influenced by the enhancement of the acid gases or carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O), that also known as greenhouse gases (GHG). Current GHG concentrations have reached a level that endangers the Earth's climate and ecosystem balance. The GHG concentrations in the atmosphere increased as a result of improper land management, such as forest vegetation burning and the diversion of forest into farmland resulting in environmental destruction, changes in the number of carbon stocks and occurrence of climate change. [1], Stating, long-lived plants that growing in the woods and in the agroforestry are the place where more carbon stored than in annual crops. Therefore, natural forest with a variety of species of long-lived trees and litter is the highest storage warehouse both above and in the ground. The total of carbon that is stored in every use of land, litter and soil, also known as a reserve.

Natural forests are the highest carbon storage (C) when compared to agricultural land use systems. If the forest is converted into farmland or plantation, then the number of C stored will degenerate. The amount of C stored between the lands varies, depending on the diversity and density of existing plants,



the soil type and the way of land management [1]. On a global scale, more carbon stored in the soil than is stored in vegetation. Soil as the largest C depository in all regional ecosystems (biomes), while the largest C-storage vegetation is forest biome [2].

Indonesia has a wide variety of land use, ranging from the most extensive such as complex agroforestry that resembles the forest to the most intensive as a monoculture farming system. Diversity of plant species on a variety of land use in East Luwu district certainly have a range to absorb and store carbon that varies due to the different plant types and differences of land management by the community. This indicates the difference in the value of carbon stocks in each land cover. The amount of C stored in each land are varies and needs to be measured to determine the number of available carbon deposits, thereby measuring the amount of carbon stored in the living plants can spread the amount of CO<sub>2</sub> in the atmosphere that is absorbed by plants, while the measurement of carbon stocks that are still stored in the part of dead plants indirectly describe the CO<sub>2</sub> that is not released into the air through combustion. The numbers of each land carbon stocks are varies depend on plant diversity, plant density, soil type and land management. This research aims to estimate carbon stocks on some land cover in secondary forest, agroforestry, palm oil plantation and paddy fields.

Several studies have conducted about the potential of carbon stocks, those research includes research on aboveground and belowground carbon stocks based on various types of forests [3,4], carbon analysis on various types of agroforestry land uses [5–7], monoculture land use [8,9] and the relevance between carbon stocks and some soil properties in land use [10]. From these various studies, the results obtained differ according to the type of each land cover. This study focuses on carbon stock estimation on some land uses that compare to the other land uses.

The results of the research on the calculation of carbon stocks in East Luwu District can be a reference in the management and properly land use. This research is expected to be a source of information and material considerations in utilizing and managing land cover. In addition, it can be additional to the understanding of the potential knowledge of carbon stocks on various land cover; secondary forest, agroforestry, palm oil plantation and paddy fields, also as a valuation material and calculation basis for the community and local governments in future carbon sales.

## 2. Methods

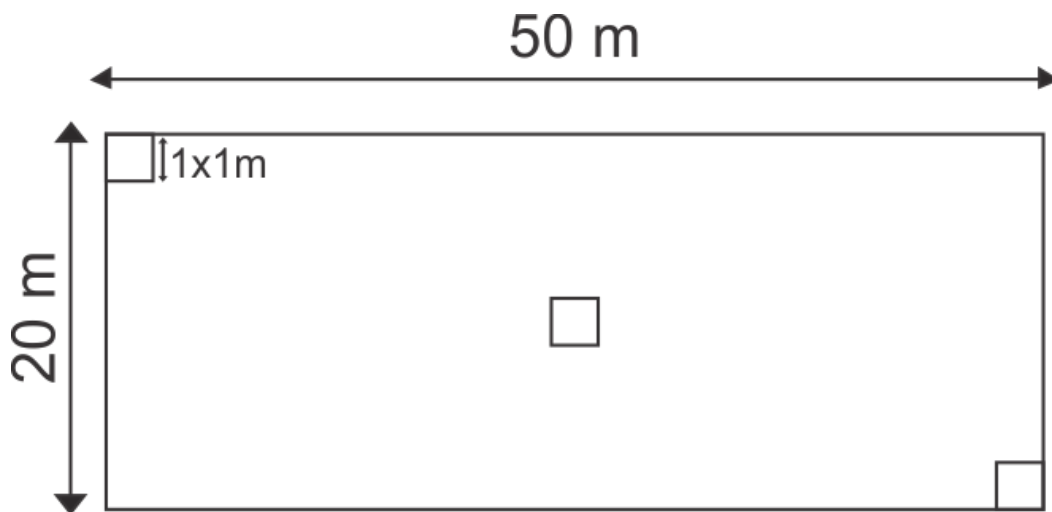
The field research was conducted in October 2019 at East Luwu, South Sulawesi. There are four type of land use that analyzed those are secondary forest, agroforestry, palm oil plantation and paddy fields. After collecting the samples, then analyzed in chemistry laboratory and soil fertility of Soil Sciences Department, Faculty of Agriculture, Makassar, Hasanuddin University. The tools that is used in this research are GPS (Geographical Positioning System), meter roll 50 m, coloring strap, measuring tape, hag meter, peg, aluminium quadrant frame size 1 m<sup>2</sup>, sample envelope, iron box with volume 4000 cm<sup>3</sup>, shovel, sample pouch and rubber band, analytical scales 0.01 g, oven, and digital pH meter.

The data that was collected in this research are necromass, disturbed soil samples, intact soil samples, under storey and litter. Primary data was collected using destructive sampling methods then analyzed in laboratory. Secondary data relating to the general conditions of research location; rainfall, land cover type, land cover area, and scientific publications from various government agencies.

### 2.1. Data collection method

The determination of the sampling point carried out on each land cover unit with a fairly similar vegetation representing that land cover. The measuring of tree diameter (DBH  $\geq$  3 cm) to suspect biomass above the surface of the soil is collected without damaging the sample (non-destructive sampling). As for the lower plant (DBH < 3 cm), and the litter was conducted by damaging the sample (destructive sampling).

Plot creation is carried out at a location that is considered to represent each land cover and the point of specified sample location. The sampling is conducted by making a plot measuring 50 m x 20 m which is repeated 9 times on each land cover of secondary forest, agroforestry and palm oil plantation.



**Figure 1.** Plot observation and sampling on land.

Description: = Sub Plot of plant sampling below and felt

Collecting the data of biomass tree is required diameter of the rod that measured as high as the chest (Diameter at Breast Height, DBH) or as high as about 1.3 m from the ground surface. In order to collect the biomass of the under storey sampling, the researcher used destructive method (damaging the plant parts). The litter is the remnants of plants derived from the fallen leaves and twigs but have not been decomposed. The measurements were carried out on the dead tree, the circumference measured at the position of 1.3 m above ground level. For the tree that dies in some parts like the branches, twigs, and stumps, the measuring circumference is conducted at both ends. The untapped part of the necromass was; 100% for the intact necromass and 50% for the half rotten necromass.

Soil sampling is carried out at 3 depth levels of 0–10 cm, 10–20 cm, and 20–30 cm. Soil samples that were taken consist of disturbed soil samples and intact soil samples that analyzed for texture analysis, bulk density, pH KCl, pH H<sub>2</sub>O and C-organic.

## 2.2. Analysis method

**2.2.1. Tree biomass calculation.** The calculation of tree biomass is formulated with previously developed allometric equations. Models of allometric equations using formula:

$$\text{Tree} \quad W = r^* \exp \left( -1.499 + 2.148 \ln(D) + 0.207 \left( \ln(D) \right)^2 - 0.0281 \left( \ln(D) \right)^3 \right) [11]..(1)$$

$$\text{Palm oil} \quad W = 0.002382 D^{2.3385} \times H^{0.9411} [12].....(2)$$

$$\text{Cocoa} \quad W = 0.1208 D^{1.98} [13].....(3)$$

$$\text{Banana} \quad W = 0.030 D^{2.13} [14].....(4)$$

Where, W = biomass tree, kg/tree  
D = DBH, diameter of rod-height, cm  
H = height of tree, m  
ρ = BJ wood, g/cm<sup>3</sup>.

2.2.2. *Calculation of tree necromass.* Estimation of carbon stocks on tree necromass, calculate by measuring the diameter or circumference of the trunk and length or height of the tree with the equation [15]:

$$D = (\text{averagetrunkcircumference} / \rho) \dots\dots\dots (5)$$

Where,  $\rho = 3.14$

$$BK \left( Kg / nekromasa \right) = \rho r H D^2 / 40 \cdot \% \text{weathering} \dots\dots\dots (6)$$

Where, BK is the dry weight of necromass,  
H is long/high necromass (M),  
D is the diameter of necromass (cm),  
 $\rho$  is the weight of wood type (g/cm).

2.3. *Lower plant and litter data collecting.*

Sub-samples of under plant are put into envelopes, labelled, and heated up at 80 °c for about 48 hours. The dried sub-samples are weighed and calculated with the formula developed by [15] :

$$\text{TotalBK} (g) = BKsc (g) / BBsc \cdot BBtot (g) \dots\dots\dots (7)$$

Where, BK is a dry-weight biomass plant,  
BKsc and BBsc respectively are heavy dry and heavy wet sub-sample biomes  
BBtot is a total wet weight of biomass.

The lower plant sampling was calculated on the quadrant, so the total dry weight of the lower plant on the observed plot is the average value of the three quadrants.

2.4. *Root biomass assessment*

The biomass assessment of roots is measured using the default value, which is based on the value of the header and root ratio. The general ratio between a biomass of a heading and a root section for a wet tropical forest in a dry land is 4:1 [16]

2.5. *Assessment of soil carbon stocks*

Underground carbon deposits are calculated based on the data of the content density and C-organic content of each layer of soil. The soil weight in each layer per unit area is calculated by the formula [15] :

$$Mt - n = Vt - n \cdot BI - N \dots\dots\dots (8)$$

Where, Mt-n is the weight of soil on the ground layer,  
Vt-n is the volume of soil on Layer N  
BI-n is the weight of the soil on the coating

The estimation of the Per hectare carbon stock on each layer of soil is calculated by the formula of [15] :

$$MCn = Mtn \cdot MCn \dots\dots\dots (9)$$

Where, MCn is the weight of carbon (ton) on the layer as thick as n,  
MTN is the weight of dry soil (tons) on the layers as thick as N  
MCn is the weight of carbon (ton/ton) on the layer as thick as n

### 2.6. Estimation of carbon stocks at land level.

All total data of tree biomass, root biomass, necromass and litter are the result of final estimates of carbon deposits[1]. The Carbon Stocks are estimated by following the 46% biomass rule being carbon. So that estimated carbon stocks per component can be calculated by formula [15] :

$$C = Mb_{ione}k \times 0.46 \dots \dots \dots (10)$$

Where, C is the C stocked

Mbione is a dry weight of biomass or necromass,

0.46 is a constant factor.

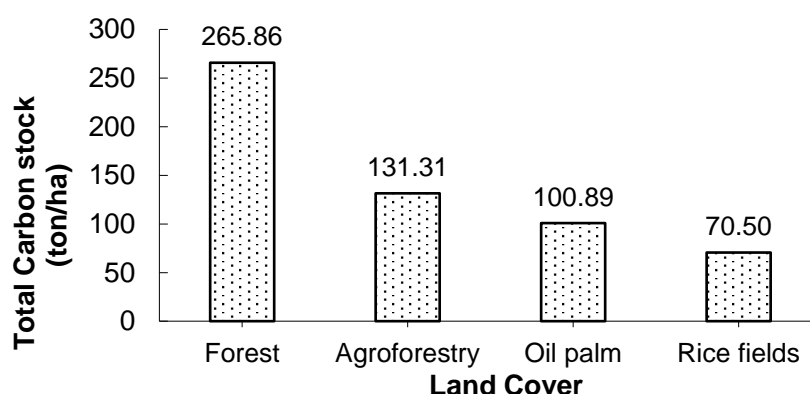
### 3. Results and discussion

The total carbon stock value from the results of this study is presented in Table 1.

**Table 1.** Total carbon stock on land cover

Land cover	Carbon Stock (Ton/ha)						Total
	Tree	Plant under	Necromass	Litter	Root	Land	
Forest	165.17	0.20	2.41	2.14	41.34	54.60	265.86
Agroforestry	57.13	0.18	-	1.56	14.33	58.13	131.31
Oil palm	32.16	0.21	-	1.04	8.09	59.38	100.89
Rice fields	-	-	-	-	-	70.50	70.50

The table above shows that land cover that has the highest total carbon stock is secondary forest which is 265.86 tons / ha, and the lowest is rice fields with a total carbon stock value of 70.50 tons / ha. The high carbon stored in secondary forest land cover is due to the diversity of plant populations, the composition of the tree diameter, the age of the tree, and the specific gravity of the vegetation. The results of this study also showed that the total carbon stock is stored on the surface of the land; trees, undergrowth, necromass and litter, then underground surface carbon stocks; roots and soil have the results of a total carbon value that varies in each land cover. Land cover that has the highest total carbon stock value in a row is secondary forest land cover with carbon reserve value of 265.86 tons / ha, as agroforestry with carbon stock value of 131.31 tons / ha, while oil palm with carbon stock value of 100, 89 tons / ha and the lowest carbon stock is rice fields with a value of 70.50 tons / ha.



**Figure 2.** Total land cover carbon stock chart

Table 1 and figure 2 above show that land cover that has the highest carbon storage capacity is secondary forest while the rice fields as the lowest carbon store. The amount of carbon stored in these

land covers varies due to the diversity of plant species, plant diameter, plant density, plant height, plant spacing, soil type, and land management.

When compared to the previous studies, the data obtained that the value of total carbon stock in the secondary forest land cover of this study is almost equivalent to the results of research conducted by [9][3] in the Yaspi District of Jayapura which produced a total carbon value of 269.63 tons / ha in moderate mountains, but in medium hills the value is much greater that is at 419.74 tons / ha. Meanwhile, in agroforestry land cover the total carbon stock is greater when compared to the results of research conducted by [10] regarding carbon stocks in the cocoa plantations of simple agroforestry patterns in Polewali, Mandar district with a value of total carbon at 86.11 tons / ha, however if compared with the results of research conducted by [5] on the analysis of the potential of carbon stocks in several agroforestry patterns carried out in Gowa district, the total carbon values ranged from 79 to 243.24 tons / ha, this study is among the results obtained get it.

In the oil palm plantation land cover, the value of carbon stocks in this study is greater when compared to the study of [3] with a value of 80.09 tons / ha, but the results of this study are smaller than what [9] did regarding estimating reserves carbon stored in oil palm which is carried out in Bengkulu which gets carbon content above ground level ranges from 6.98 - 69.32 tons / ha. Meanwhile, the results of carbon stocks in paddy land cover in this study are greater when compared to the study of [17] regarding the estimation of soil organic carbon stock in various agricultural land uses carried out in Bali Regency, on land used for stored rice plants carbon of 23.1 - 38.7 tons / ha, in maize land by 25.9 tons / ha and horticultural crops successively planted broccoli by 35 tons / ha, mustard greens 45.5 tons / ha, cabbage 53 , 2 tons / ha and tomatoes 41.8 tons / ha.

#### 4. Conclusion

The value of total carbon stock is the sum up of the carbon stock value that stored on the surface of the soil i.e. tree, lower plant, necromass, litter and soil carbon stocks of the roots and soil. The results of this research show that the value of total carbon stocks on various land cover in East Luwu district varies for each land cover. Land cover that has been storing the largest carbon kneel down as follows; secondary forest, agroforestry, palm oil plantation and rice field.

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