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# The dynamics of variations in carbon biomass in community forest and agroforestry in South Sulawesi

S A Paembonan<sup>1</sup>, B Putranto<sup>2</sup>, S Millang<sup>1</sup>, B Nurkin<sup>1</sup>

<sup>1</sup>Silviculture Laboratory, Forestry Faculty, Hasanuddin University

<sup>2</sup>Forest Product Laboratory, Forestry Faculty, Hasanuddin University

E-mail: samuelap@unhas.ac.id

**Abstract** Knowledge of the variation of potential carbon stocks in different types of forests provides information about the capabilities of each forest type in dealing with climate change mitigation. This research was conducted to determine the dynamics of carbon stocks in gofasa plantation community forests and compared to other land use systems in South Sulawesi. The research used sample plots 20 m x 50 m to measure tree biomass and 1 m x 1 m sub plots for undergrowth and litter. The results of the study indicated that there were variations of potential carbon stocks in plantation community forests and agroforestry. Carbon stocks in plantation community forest were varied according to the condition and age of forest stand. The total aboveground carbon stocks in homogenous gofasa stand ranged from 22.34 to 52.65 ton/ha by the difference in stand ages, while in mixed community forest was 77.60 ton/ha. As for agroforestry system, the carbon stocks ranged from 46.40 to 65.89 ton/ha. The dynamics of variations in carbon stocks in plantation community forest and agroforestry were determined by several variables such as species composition, stand age, and stand density. Therefore, a good management of community forests and agroforestry systems will ensure the mitigation of climate changes and environmental preservation through effective carbon storage.

## 1. Introduction

Global warming is a condition that has actually happened in the present decade. Various environmental variables that are affected by global warming are: the occurrence of climate change, the temperature that rises gradually, and the seasons are uncertain.

The occurrence of climate changes directly have significant impact on the physiological activity of plants and then it affects the overall forest productivity. In the agroforestry pattern, sustainable products can be obtained due to different harvest times for each type of plant, and this will make a significant contribution to farmers' income, while in homogenous forest is mostly occupied by longterm age of trees. In addition to providing direct production, the forest also functions as a carbon store. The type of forest community has different constituent components so that they have different capabilities in carbon stocks capacity.

Several studies have conducted about the potential of biomass and carbon stocks. Such studies include research on the carbon stock of aboveground and soil organic carbon in natural forests [1], forest plantations [2, 3], and carbon sinks on various types of land use, especially agroforestry in Indonesia [4]. Furthermore, few studies have been reported concerning the ability of various types of tropical tree mixture to absorb CO<sub>2</sub> from the air to reduce global warming both in landscape and in site scale [5].



One of the most effective land-use systems for absorbing and storing carbon is the agroforestry system [6].

From these various studies, the results differed according to the characteristics of each forest type and species. However, so far there has been no special discussion of carbon stocks to compare the different location and different land use in south Sulawesi. This study focuses on several research locations for gofasa stands of the community forest by comparing carbon stocks capacity with other types of land use.

Therefore, as the representative of a landscape-scale study of the Sulawesi island, Indonesia, this study was conducted to identify the most appropriate way to maintain the potential carbon pool and to preserve and increase the carbon reserves within the framework of global climate change mitigation. This study aimed to investigate the dynamics of variations of carbon biomass potential of different landuse system in south Sulawesi, Indonesia.

## 2. Research Methods

### 2.1. Site Description

The research was carried out for two years from 2016 to 2018 in South Sulawesi Province, in four regencys, namely Gowa, Makassar City, Bulukumba and Toraja regency. There are 2 types of landuse compared, those are agroforestry systems and plantation community forests (mixed and homogeneous).

### 2.2. Techniques of Data Collection

The focus of this study was to determine the potential for carbon stocks in gofasa plantation community forest stands in South Sulawesi, namely in Bulukumba, Gowa and Makassar City, and then compared with carbon stocks capacity in mixed community forests and agroforestry in Toraja Regencies.

A total of 40 plots of 20 m × 50 m (0.1 ha) in size, were chosen purposively according to the type of landuse systems in 4 regencys in South Sulawesi Province which representing community plantation forest and agroforestry systems. Within each main plot, 5 subplots of 1m × 1m, each in a rectangular corner and in the middle, were used to measure the biomass of undergrowth and litter.

The primary data collected included tree diameter and height, the fresh and dry weights of the undergrowth, and the necromass (dead plants and litter). The measurement of the plots that were categorised as 'trees' was conducted non destructively, while the measurement of the undergrowth was conducted destructively. Measurements of diameter and height of trees were conducted in the plots of 20 m × 50 m, while fresh weights of the undergrowth and necromass were measured in subplots. Dry weights of the undergrowth and litter samples were measured in the laboratory after kiln-drying for 48 hours at a temperature of 80 °C.

The data obtained processed and classified and then analyzed with qualitative and quantitative descriptive methods.

### 2.3. Analysis method

#### 1. The basal area of the tree

For the calculation of the basal area of a tree using the formula:

$$A = 0.25 \pi D^2 \dots\dots\dots (1)$$

#### 2. Calculation of Tree Biomass

Estimation of branched tree biomass and necromass using allometric models developed by [4] with the equation:

$$W = 0,0509 \times \rho \times D^2 \times H \dots\dots\dots (2)$$

Whereas for estimating *Areaceae* biomass and unbranched necromass, the equation is used as follows [7]:

$$W = 0,25\pi \times \rho \times H (D^2) \dots\dots\dots (3)$$

To estimate the biomass in the undergrowth and litter, the following equation is used [6]:

$$W = \left( \frac{DW \text{ sampel}}{FW \text{ sampel}} \right) \times \text{Total FW} \dots\dots\dots (4)$$

where :

- W = Biomass (kg);
- ρ = Wood density (Mg / m<sup>3</sup>, kg / dm<sup>3</sup>, g / cm<sup>3</sup>);
- D = Tree diameter at breast height (cm);
- H = Tree Height (m);
- DW = Dry Weight (g);
- FW = Fresh Weight (g);

3. *Estimation of Carbon Trees, undergrowth, and Litter*

According to [7], Carbon content in biomass using conversion factors as follows:

$$C = W \times 0,46 \dots\dots\dots (5)$$

Where,

- C = Total carbon stock (kg / ha)
- W = Dry Biomass (Kg / ha)
- 0.46 = Conversion factor for carbon estimators

**3 Results**

3.1. *Basal Area (BA)*

The basal area is a measure of the level of land occupied by a stand illustrated in the comparison of the tree basal area with the total area. Mixed community forests in Toraja Regency, consisting of several local superior species, have a total basal area of 6.6 - 37.5 m<sup>2</sup> / ha, while homogenous seed stands in Gowa Regency are 9.44 m<sup>2</sup> / ha at the age of 11 years and Bulukumba District of 15.04 m<sup>2</sup> /ha at the age of 23 years.

The area of tree basal area in agroforestry systems is lower and ranges from 0.61 to 2.09 m<sup>2</sup>/ha, because tree density is around 60-100 trees/ha compared to community forests of 500-800 trees/ha. The total Basal Area is mostly determined by tree diameter, stand density, and tree age.

3.2. *Carbon Stocks in Homogeneous and Mixed Community Forests*

Carbon stocks for homogeneous community forests in gofasa stands is shown in Table 1.

**Table 1.** Carbon stock in homogeneous gofasa plantation of community forest

Component	Bulukumba		Gowa		Makassar		Average	
	C (ton/ha)	%	C (ton/ha)	%	C (ton/ha)	%	C (ton/ha)	Proportion (%)
Trees	51.50	97.82	23.46	94.15	20.90	93.53	31.95	95.95
Undergrowth	0.54	1.03	0.64	2.58	0.97	4.34	0.71	2.13
Litter	0.61	1.15	0.82	3.27	0.48	2.13	0.64	1.92
Total of Aboveground parts	52.65	100	24.92	100	22.34	100	33.30	100

As depicted in Table 1, real contributions were obtained from tree components in storing carbon if compared to undergrowth and litter. The carbon stocks in different sites was quite varied. Bulukumba has the highest carbon stocks referred to the order stand age compared to other two regencies. The average proportion of aboveground carbon stocks consist of 95.95% for trees, 2.13% for undergrowth, and 1.92 % for litter.

The carbon stock of mixed community forests in Toraja regency is quite higher, but the same tendency shows the potential for carbon deposits between trees, undergrowth and litter (Table 2).

**Table 2.** Carbon stock in mixed community plantation forests in Toraja Regency

Components	Carbon Stocks (ton/ha)	Proportion (%)
Trees	72.38	93.27
Litter	3.17	4.09
Under growth	2.05	2.64
Total of above ground parts	77.60	100

### 3.3. Carbon Stocks in agroforestry systems

Agroforestry practices in Toraja Regency occupy a large area of around 80% in community farming systems and the rest are mixed community forests. The carbon stocks in agroforest systems in Toraja regency are in moderate capacity, but the tendency for the proportion of carbon stocks between trees, undergrowth and litter is also the same as plantations and mixed forest (Table 3).

**Table 3.** Value of agroforestry carbon stocks in Toraja Regency

Components	Distric-1		District-2		Average (ton/ha)	Proportion (%)
	C (ton/ha)	%	C (ton/ha)	%		
Trees	44.01	94.85	63.53	96.42	52.77	95.76
Litter	1.75	3.77	1.87	2.84	1.81	3.22
Undergrowth	0.64	1.38	0.49	0.74	0.57	1.02
Total of Aboveground parts	46.40	100	65.89	100	56.15	100

Table 3 shows that the potential for carbon stocks in agroforestry systems is moderately higher compared to homogeneous forests but is below the capacity of mixed forests.

## 4. Discussion

The proportion of above the ground carbon stocks varied based on different types of land use. Gofasa homogeneous plantation forest have total carbon stocks ranges from 22.34 to 52.65 ton/ha referred to tree ages. While for mixed community forest was 77.60 ton/ha and agroforestry systems ranged from 46.40 to 65.89 ton/ha. The proportion of carbon deposits between trees, undergrowth and litter tends to be similar among land uses, where tree carbon proportions are very dominant above 90%, while undergrowth and litter below 5%. Basal area has a linear relationship with carbon deposits where areas overgrown with trees have the ability to store carbon higher than understorey and litter.

The biomass of trees represented the greatest proportion of the aboveground plant biomass, while the biomass of the undergrowth and leaf litter represented the lowest proportion. The proportion represented by trees increases with age, whereas the proportion represented by the undergrowth and leaf litter remains small over the same time frame. This proportion is greater in line with the increasing age of trees because trees grow bigger while undergrowth plants and litter only increase slightly [8].

Through the rapid growth of the diameter and height of trees in stands, it is linearly proportional to the increase in carbon stocks [9]. The amount of C stored between these land use varies depending on

the diversity and density of the plants, the type of soil and the way it is managed [7]. In order to adapt and mitigate climate change, the development of plant species that can absorb carbon quickly and can store carbon for a long time can be the right solution [10].

The results of carbon measurements in this study was in the ranged value with that obtained by [1], who reported that the C density in the above- and below-ground biomass of productive forests in Turkey and Europe was 41.66 Mg C/ha and 43.90 Mg C/ha, respectively and also by [11] of 71.5 Mg C ha<sup>-1</sup>. [12] also found in a dry deciduous forest in western Himalaya from 37.34 tons C/ha to 65.98 tons C/ha. However, our study was smaller than that reported by [2] for tall, evergreen forests in Bolivia (with 208.6 tons/ha C). [10] also found a higher carbon stocks for plantation forest in Nepal of about 140.32 tons C/ha.

The results of this study concur with those of [13], who studied the land use system in 25-year old monocultural rubber plantations with C stores of 97 tons/ha and 74 tons/ha. [9] conducted a study for carbon content on *Acacia mangium* stands at different ages in Sarawak Malaysia and found that 5-year-old *A. mangium* stands store a total carbon of about 138.9 t C ha<sup>-1</sup>, and also [1] reported that aboveground carbon stocks of *Populus deltoides* in central Himalaya was 90.1 Mg C ha<sup>-1</sup> at 11 year old. Carbon stocks in the undergrowth and litter of this research is almost equivalent to those reported by [12] for various forests types in Bolivia (with 2.4 tons/ha C), but smaller than the C storage in the home gardens of North Lampung (of 0.3 tons/ha) [5]. This results are slightly lower compared to the results of the study reported by [15] on mangium (*Acacia mangium*) plants in Sumatra which amounted to 76.7 tons / ha and the results of the trial of carbon monitoring methods in North Lampung by [16] which amounted to 60.8 tons / ha. The value of carbon stocks of the mixed community forest stands and agroforestry patterns in Toraja Regency is smaller compared to the results of [15] study in Bolivia in forests with high canopy and always green (tall, evergreen forest) of 173 tons ha<sup>-1</sup> and in various forest types amounting to 155 tons ha<sup>-1</sup> or in secondary forest (secondary forest) in North Lampung and Jambi of 177 tons ha<sup>-1</sup> and 176 tons ha<sup>-1</sup>.

There is a significant difference in the dynamics of carbon stocks between landuse systems and forest types. This difference is very much determined by several things, namely: forest type, composition of the type of constituent of each type of forest, stand density, age of stand, and vertical and horizontal structure of the type of compiler. Type of vegetation and differences in wood density also has an influence on carbon stocks capacity in land-use [18, 19].

The enhancement of plant diversity in agroforestry programs could help towards absorbing C quickly while storing C for extended time periods could contribute towards mitigating climate change [20]. Thus, the sustainable management of community forest and agroforest systems could be adapted to play a role in C storage, which could help towards mitigating climate change, as well as securing and preserving the ecological functions.

## 5. Conclusion

There are significant variations in carbon stocks between homogeneous community forests, mixed community forests with agroforestry in South Sulawesi.

The dynamics of variations in carbon stocks in various types of land cover are influenced by forest type, the composition of the types of constituents of each type of forest, stand density, the age of stands, and vertical and horizontal structures of forest types.

Community forests and agroforestry can guarantee carbon stocks in order to mitigate climate change if managed properly through sustainable forest management.

## References

- [1] Tolunay D 2011 Total carbon stocks and carbon accumulation in living tree biomass in forest ecosystems of Turkey. *Turkish J. Agric. For.* **35**, 265–279.
- [2] Brown S 1999 Guidelines for Inventorying and Monitoring Carbon offsets in Forest-Based Projects. Winrock International. Arlington, VA 22209.

- [3] Cacho O, Wise R and MacDicken K 2002 Carbon Monitoring Cost and their Effect on Incentives to Sequester Carbon through Forestry. *International Symposium on Forest Carbon Sequestration and Monitoring*, Taiwan Forestry Research Institute.
- [4] Chave J, Condit R, Aguilar S, Hernandez A, Lao S and Perez R 2004 Error propagation and scaling for tropical forest biomass estimates. *Phil. Trans. R. Soc. B* **359** 409–420.
- [4] Hairiah K and Rahayu S 2007 Pengukuran ‘karbon tersimpan’ di berbagai macam penggunaan lahan. Bogor. World Agroforestry Centre - ICRAF, SEA Regional Office, University of Brawijaya, Unibraw, Indonesia. p 77
- [5] Stas S M, Rutishauser E, Chave J, Anten N P R and Laumonier Y 2017 Estimating the Aboveground Biomass in an Old Secondary Forest on Limestone in the Molluccas, Indonesia: Comparing Locally Developed Versus Existing Allometric Models. *Forest Ecol Manag* **389** 27-34
- [6] Mattsson E, Ostwald M, Nissanka S P and Pushpakumara D 2015 Quantification of carbon stock and tree diversity of home gardens in a dry zone area of Moneragala district, Sri Lanka. *Agrofor. Syst.* **89** 435–445.
- [8] Anonim 2012 Hutan Tanaman dan Serapan Karbon, *Masagena Press*. Makassar. Pp.188.
- [9] Paembonan S A 1997 Analysis of the Relationship Between Tree Growth Dimension and Dry Organic Matter of Hinoki Stand. *Journal Ilmiah Flora dan Fauna* **5** 46-55.
- [10] Lal R 2007 Carbon Sequestration. *Journal of Philosophical Transactions of the Royal Society B.* **363** 815-830.
- [11] Marklund L G and Schoene D 2006 Global assessment of growing stock, biomass and carbon stock. (*Glob. Assess. Grow. Stock. Biomass carbon Stock*) p 7-8
- [12] Mandal G and Joshi S P 2015 Biomass accumulation and carbon sequestration potential of dry deciduous forests. *International Journal of Ecology and Development* **30** 64 - 82
- [13] Mandal S A, Dutta I C, Jha P K and Haque S M 2013 Potential carbon offset in public plantation: offering opportunity for REDD+ and soil fertility. *International Journal of Ecology and Development* **25** 21 - 31.
- [14] Arora G, Chaturvedi S, Kaushal R, Nain A., Tewari S, Alam N M and Chaturvedi O P 2014 Growth, biomass, carbon stocks, and sequestration in an age series of *Populus deltoids* plantations in Tarai region of central Himalaya. *Turkish J. Agric. For.* **38** 550–560
- [15] Lee K L, Ong K H, King, P J H, Chubo J K and Su D S A 2015 Stand productivity, carbon content, and soil nutrients in different stand ages of *Acacia mangium* in Sarawak, Malaysia. *Turkish J. Agric. For.* **39** 154–161.
- [16] Delaney M and Roshetko J M 1999 Field test of carbon monitoring methods for homegardens in Indonesia. In: *Field Tests of Carbon Monitoring Methods in Forestry Projects*. Winrock International, Arlington, Virginia, USA. p 231-245.
- [17] Hutchinson J J, Campbell C A and Desjardins R L 2007 Some Perspectives on Carbon Sequestration in Agriculture. *Journal of Agricultural and Forest Meteorology.* **142** 288-302.
- [18] Thomson A M, Izaurralde R C, Smith S J and Clarke L E 2008 Integrated estimates of global terrestrial carbon sequestration. *Glob. Environ. Chang.* **18** 192–203.
- [19] Topaloglu E, A Y N, Altun L and Serdar B 2016 Effect of altitude and aspect on various wood properties of oriental beech (*Fagus orientalis* Lipsky) wood. *Turkish J. Agric. For.* **40** 397–406.
- [20] Widiyanto, Hairiah K, Suharjito D dan Sardjono M A 2003 Fungsi dan Peran Agroforestry. *World Agroforestry Centre (ICRAF)*( Bogor, Indonesia) p 78-80