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Estimating Carbon Storage on Teak (*Tectona Grandis* Linn. F)

Mochamad Chanan[1*] Aniek Iriany[2]

1. The Department of Forestry, Faculty of Agriculture and Animal Husbandry, University of Muhammadiyah Malang, Indonesia
2. The Department of Agrotechnology, Faculty of Agriculture and Animal Husbandry, University of Muhammadiyah Malang, Indonesia

* E-mail of the corresponding author: chanan_m2@yahoo.co.id

Abstract

Most of the areas of production forest management in Java island spread among East Java, Central Java and West Java. On the other hand, the management of production forests is consequential to the changes in vegetation due to the process of planting and harvesting the plantation. Plantation potential changes will cause changes in carbon storage which is stored in the areas of production forest. Information about patterns of changes in carbon storage, in particular on teak forest, is vital and urgent so that it can be used to help governments to predict and identify deposit patterns or carbon storage and their changes as early as possible. Next, steps to taken based on the information and the demands of Clean Development Mechanism (CDM) program can be determined. The results showed that there is a correlation between plantation age on biomass content and carbon of teak plantations; the higher the age of the plantation will be followed by an increase in the diameter of the tree, higher biomass storage and carbon content of teak plantations. The biggest biomass and carbon storage stored in research areas are at the tree level in class age IV, whose biomass average is 406.67 ton/ha and carbon average is 101.67 ton/ha.

Keywords: teak, sequestration, carbon

1. Introduction

On the island of Java, production forests are managed by the state owned forestry institution whose areas spread among East Java, Central Java and West Java.Besides the production forests on the island of Java, there are also large protected areas.It has a potential role in reducing carbon emissions. On the other hand, the management of production forests is consequential to the changes in vegetation due to the process of planting and harvesting the plantation.Plantation potential changes will cause changes in carbon storage which is stored in the areas of production forest.

The ability of teak in sequestrating carbon is determined by age class or growth level. Khanduri, Lalnundanga, and Vanlalremkimi (2008) showed that in the oldest teak which is represented by larger trunk diameter, the stored carbon is also higher, around 699.01m^3 $ha^{-1,}$, while according to Grant (2008) a 21-year-old teak will store 1,037 kg of carbon.

Information about patterns of changes in carbon storage, in particular on teak forests is vital and urgent so that it can be used to help as a determinant of forest management and environmental policies in order to predict and identify deposit patterns or carbon storage and changes as early as possible, and to determine the next steps based on the information and the demands of *Clean Development Mechanism* (CDM).

Demographic transition and economic growth in Java have led to expansion of cultivated area and a decrease in forest area which always occurs from time to time.This will affect, among others, the increase of CO2 content in the air.The important role of the production forestsinJava, especially teak forests, on the problem of carbon emissions, encourages the role of good forest management, given the island of Java, which covers only 6.6% of Indonesia while its population is more than 60% of Indonesia's population will bear heavier burden, such as shortage of clean water, floods, landslides, and declining agricultural productivity.In East Java, the areas of production forests especially teak forests occupy a vast area that has a big role on carbon sequestration in the vicinity, so it is relevant to study to which extent the ability of teak plantations in sequestrating carbon.

The spread of teak age class which is not balanced has made teak forest function in tackling emission not optimum.Data of teak forest distribution in Java based on ageclasses, especially in East Java indicate that age class I (1) is located in an area of 700,000 ha.The higher teak age class, the smaller the total planting area which ranges from 5000 ha (VII-up).This suggests that the distribution of age classes in teak is imbalanced, so it will have an impact on the potential of carbon storages stored in teak plantations as a whole, further the role of carbon sequestration will not be optimal.

This study is in line with the government program to improve the reduction of global carbon emission that will impact on global warming.Therefore, we need the support of science and technology, in particular in the environmental area to produce a prediction model of carbon storage that can be used as a foundation of environment amelioration technology in East Java and in Indonesia in general.The goal is to obtain an overview of potential carbon storage in teak plantations with various age and to determine the pattern of carbon storagechanges in teak plantations with various ages.

2. Methods

The research object is areas that represent teak forest areas in the city of Malang, East Java, which are managed for the purpose of producing timber, otherwise known as plantations. Those areas were selected as a test site with the consideration that the distribution of teak plantation is relatively extensive on various classes of age.

Research locations were selected based on the criteria of the total area of teak forest and age diversity of teak plantations from the data obtained from Perhutani Unit II of East Java, so it will be able to determine how many locations which will be used as a test site.

2.1. Data inventory in the test site

Systematic and random sampling design are two types of sampling design used to assess the potential of forest carbon (Paciomik and Rypdal, 2003). Systematic sampling design used a regular grid to identify the locations of plots spread throughout the area.Random sampling design is applied to select the locations of the plot. Potential forest carbon can be estimated statistically using a field-survey-data based sampling.Allometric relations are applied to measurements of forest with field-survey based (the basis for estimating the average carbon storage in each forest strata (C/ha).

To determine the potential of tree carbon in a forest area, inventory data of wood that has been done in the area is used.The method is by estimating the volume of wood for each tree that has been inventoried using a volume equation, then convert the volume of wood into wood biomass using wood density.The next stage is converting wood biomass value into total tree biomass using a constant value of *biomass expansion factors* (BEF).

2.2. Collecting data of biomass production

The largest carbon component in vegetation comes from tree biomass, so determining the amount of tree biomass that occupies an expanse of plantations is the most important part in calculating the potential of forest carbon.Biomass is expressed in unit of dry weight.Tree biomass is generally estimated indirectly by using tree biomass allometric equation, which states the relationship between specific dimensions of the tree (e.g. tree diameter or height) with the total value of tree biomass.Another important component of biomass as a part of carbon component is under-growing plants and litter.The determination of the carbon component of the under-growing plants and litter refers to the method suggested by Hairiah et al (1999).

2.3. Measurement of carbon storage of plantations and total carbon of upperpart

The potential of carbon supply is derived from upper part carbon and below ground.Upper part carbon covers the top of the tree biomass carbon (woody vegetation), litter and under-growing plants, while lower part carbon is mainly from root biomass carbon and soil carbon.In this study, total carbon plantations are restricted to the carbon in the upper part of the soil.

For every unit of land selected for the research location, measurement plot was made by stretching a plastic rope.Measurement plot to measure trees is an elongated line with a width of 10 m and length for multiple distance of 10 m.Square plots of 10 m x 10 m is considered as the smallest recorded unit.Measurement plot for under-growing plants is 1 m x 1 m and for litter, the size is 0.5 x 0.5 m plot which was made in the measurement plot for trees (10 m x 10 m).

Under-growing plants and litter measurements were made on plot for under-growing plants/ litter.The entire under-growing plants and rough litter contained in the plot were collected and the wet weight was subsequently weighed. The sample test of under-growing plants and litter was taken and brought to the laboratory to determine the water content and then it was used to estimate the dry weight of under-growing plants/litter in the plot.

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Tree biomass in the plot was determined using tree biomass allometric equations.The total number of trees in the plot states the amount of biomass per unit of plot width.The potential total carbon in above-ground consists of tree biomass carbon, carbon derived from litter, and under-growing plants carbon or it is expressed in the following relationship: $C_{tot} = C_{biost} + C + C_{litt\ herb}$ where C_{tot} = total upperpart carbon, C_{biost} = biomass carbon of trees/plantations, C_{herb} = carbon derived from the under-growing plants and C_{litt} = carbon derived from litter.

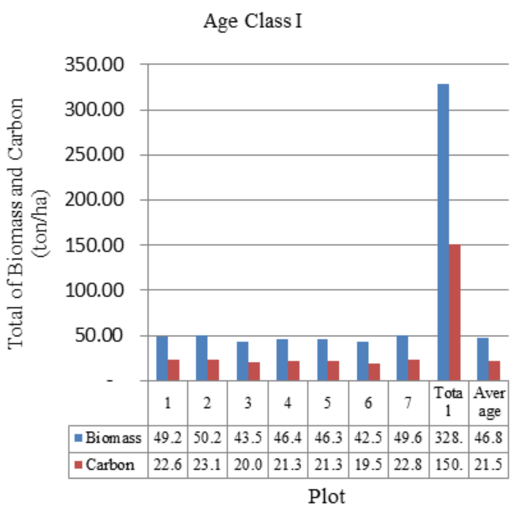
3. Results and Discussion

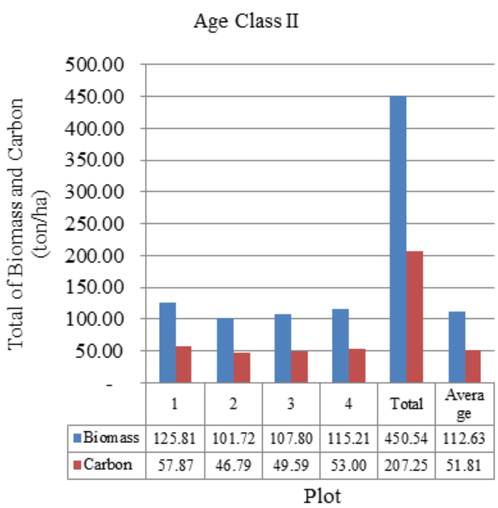
3.1. Biomass and Carbon in Teak Plantation

The measurement of biomass and carbon in teak is performed infourage classes, i.e. age class I, II, III, and IV. The results of measurements of biomass and carbon in teak plantations are presented in Table 1 and 2 and Figure 1, 2 and 3.

Table 1. Biomass and Carbon in teak Plantations in age classes I - IV

Plot No.	Age Class I		Age Class II		Age Class III		Age Class IV	
	Biomass (tons/ha)	Carbon (tons/ha)	Biomass (tons/ha)	Carbon (tons/ha)	Biomass (tons/ha)	Carbon (tons/ha)	Biomass (tons/ha)	Carbon (tons/ha)
1	49.24	22.65	125.81	57.87	144.12	66.30	198.09	91.12
2	50.29	23.13	101.72	46.79	148.03	68.09	190.83	87.78
3	43.54	20.03	107.80	49.59	130.94	60.23	259.98	119.59
4	46.47	21.38	115.21	53.00	146.90	67.57	235.17	108.18
5	46.32	21.31						
6	42.58	19.59						
7	49.67	22.85						
Total	328.10	150.93	450.54	207.25	569.99	262.20	884.07	406.67
Average	46.87	21.56	112.63	51.81	142.50	65.55	221.02	101.67





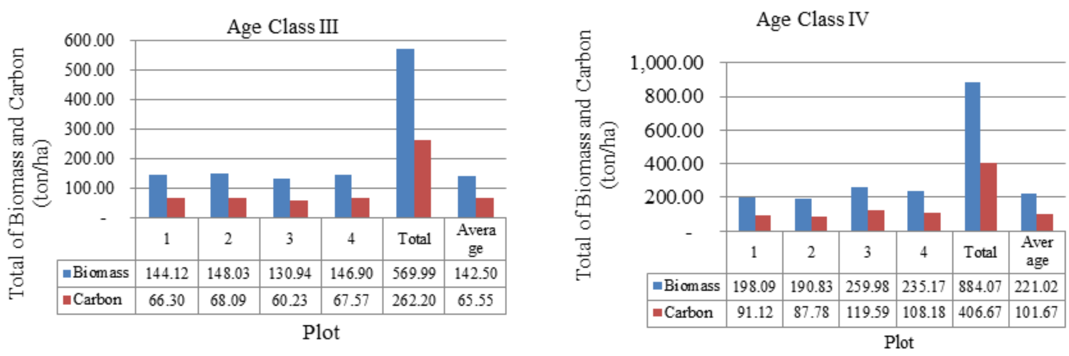


Figure 1. Biomass and Carbon of Teak Plantation in Age Class I – IV

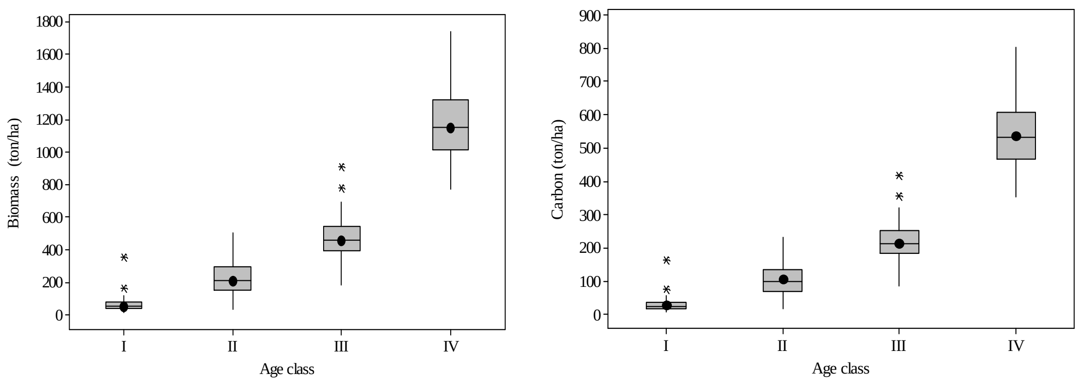


Figure 2. Total of Biomass and Carbon of Teak Plantations in Age Class I – IV

Table 2. Total Average of Biomass and Carbon of Teak Plantations in Age Class I – IV

Age Class	Biomass (ton/ha)	Carbon(ton/ha)
I	46,87	21,56
II	112,63	51,81
III	142,50	65,55
IV	221,02	101,67

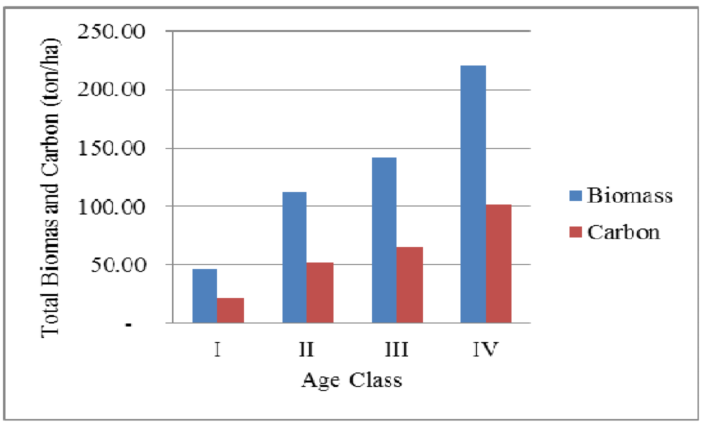


Figure 3. Graph of the total average of Biomass and Carbon of Teak Plantations from age class I to IV

The content of Biomass and carbon of teak plantations increase in every increased plant age and the quality of plantation's growing site. This is due to the increased plant age resulting from bigger plants as well as better growing areas which provide a better nutrient element.

Table 1 shows that every increase of biomass contents/ storage will be followed by the increased content of carbon, which indicates that both carbon and biomass have a positive correlation, resulting in any decrease or any increase of biomass that also causes a decrease and an increase of carbon content. Table1 depicts that biomass and carbon contents have a different plot. That difference is more likely to be affected by the density of plantations, plantation age ande the quality of plantation's growing area.

The Total of Teak plantation's biomass (*T, grandis* Linn, F) in Age class I is 328,10 ton/ha, averaging46,87 ton/ha, while the total carbon amount is 150,93 ton/ha, averaging 21,56 ton/ha. In age class II total biomass is 450,54ton/ha, averaging112,63ton/ha, and carbon total amount is 207,25 ton/ha, averaging 51,81 ton/ha. In age class III, the total biomass is 569,99ton/ha, averaging142,50ton/ha, and carbon total amount is 262,20 ton/ha, averaging 65,55 ton/ha. In age class IV the total biomass is 884,07ton/ha, averaging221,02ton/ha, and the total carbon amount is 406,67 ton/ha, averaging 101,67 ton/ha.

The difference of biomass amount in every plot is caused by the number of trees and the tree's diameter in every age class which is varying. Despite having the same age class, it has different content of biomass and carbon. This results from different tree numbers and growing areas. Teak tree is grouped into C3 plant, meaning that its sunlight need is relatively lower than that of plants grouped into C4 (Knowlosky, 1977).

The level of growth is signed by the increased length and size of plant organs (Simon, 1999). The age of a tree can be estimated by noticing the trunk circle (Salisbury dan Ross, 1992). The level of tree growth depends of varieties and environment as well as the plant management. In an early year, space between plantations is still opened but when population reaches an optimal limit, there is a relatively reduced space availability.

Sequestrastion of carbon is commonly defined as semipermanent capture of CO_2 by plants via photosynthesis from atmosphere to the inner part of organic components, or is also called carbon fixation (Hairiah et al., 2000). In the context of forestry growth, sequestration of carbon is an increase of carbon storage which forest contains (Murdiyarso & Herawati, 2005).

The result of measuring biomass and carbon in either class age I, II, III or IV, indicates the higher plantation age that will also be balanced with the higher content of biomass and plantation carbon in a unit area. This conforms to Hairiyah, Kand Rahayu (2007) who concluded that the biggest proportion of reserving carbon in land is in big trees. The capacity of teak plants to absorp carbon is highly determined by their age or their level of growth. Khanduri, Lalnundanga and Vanlalremkimi (2008) showed that the already old teak trees were represented by the higher trunk diameter, carbon storaged which is also higher, averaging 669.01 m^3 ha^{-1}. Also, Grant (2008)argued that a 21-year-old teak tree will storage 1.037 kg of carbon.

Woody plants having a longer age store carbon in woods and other tissues until they are dead and decomposized which are then released to atmosphere as CO_2, carbonmonoxideor methane, or even remain united with soil as organic materials (Anderson & Spencer, 1991).

3.2. Biomass and Under-growing plant's Carbon

Result of biomass and under-growing plant's carbon in age class I, II, III and IV is presented in Table 3 and 4 as well as Figures 4, 5 and 6.

Table 3. Biomass and Carbon of Under-Growing Plants in Class Age 1 to IV

Plot Number	Age class I		Age Class II		Age Class III		Age Class IV	
	Biomass (tons/ha)	Carbon (tons/ha)	Biomass (tons/ha)	Carbon (tons/ha)	Biomass (tons/ha)	Carbon (tons/ha)	Biomass (tons/ha)	Carbon (tons/ha)
1	3,06	1,41	2,28	1,05	1,71	0,79	3.46	1.59
2	2,07	0,95	3,10	1,42	1,84	0,84	2.47	1.14
3	2,66	1,22	2,86	1,32	3,31	1,52	3.54	1.63
4	2,57	1,18	3,36	1,54	3,02	1,39	3.21	1.48
5	2,88	1,33						
6	2,50	1,15						
7	2,99	1,38						
Total	10,36	4,77	11,60	5,34	9,89	4,55	12.68	5.83
Average	1,48	0,68	2,90	1,33	2,47	1,14	3.17	1.46

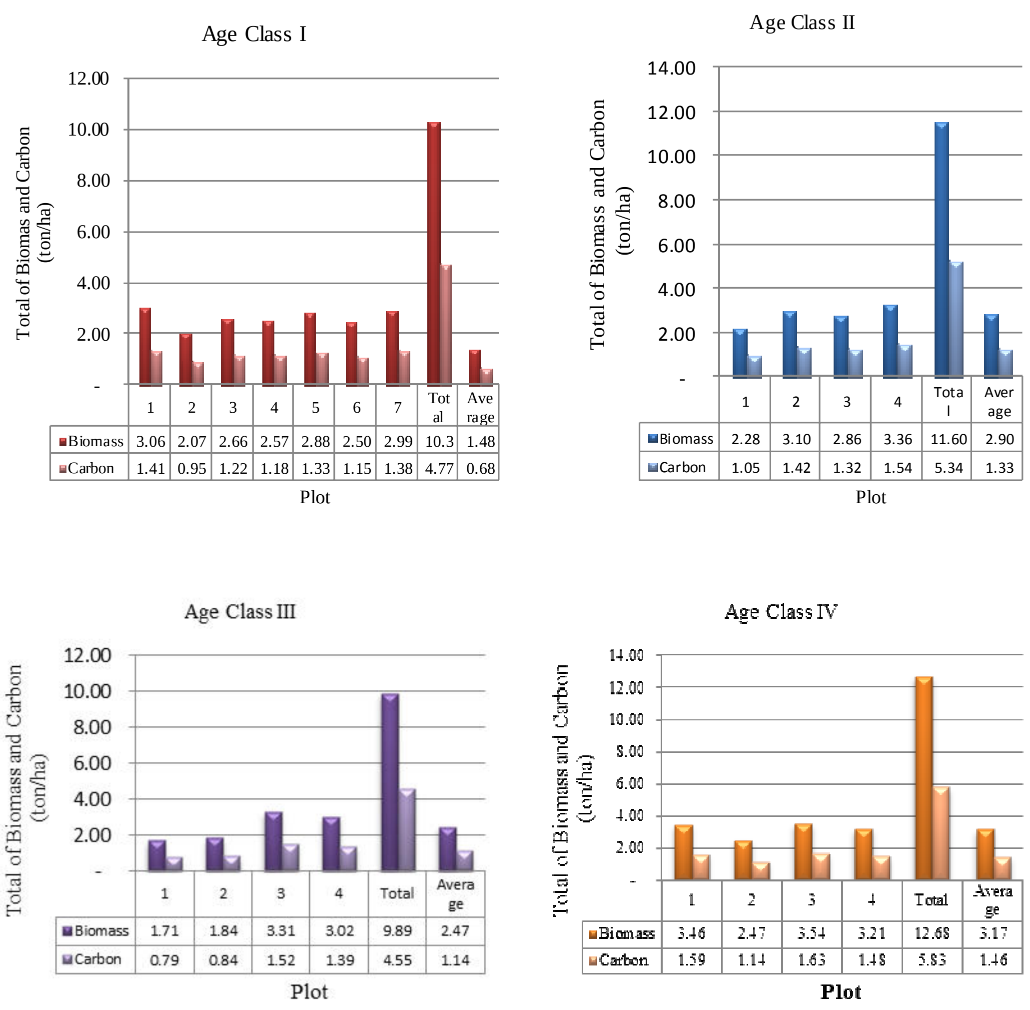


Figure 4. Biomass and Carbon of Under-growing plants from age class I to IV

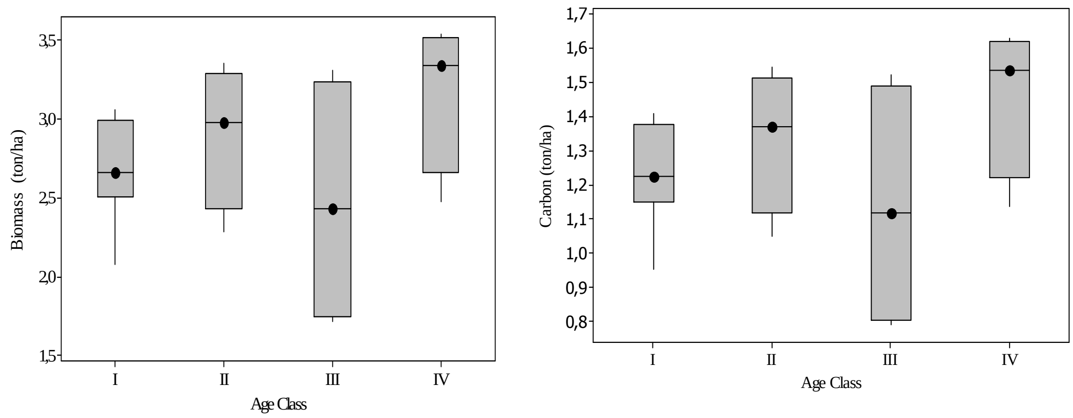


Figure 5. Total of Biomass and Carbon of under-growing plants from age class 1 to IV

Table 3. The average biomass and Carbon Total and under-growing plant's carbon in age class I to IV.

Age class	Biomass (ton/ha)	Carbon (ton/ha)
I	1,48	0,68
II	2,90	1,33
III	2,47	1,14
IV	3,17	1,46

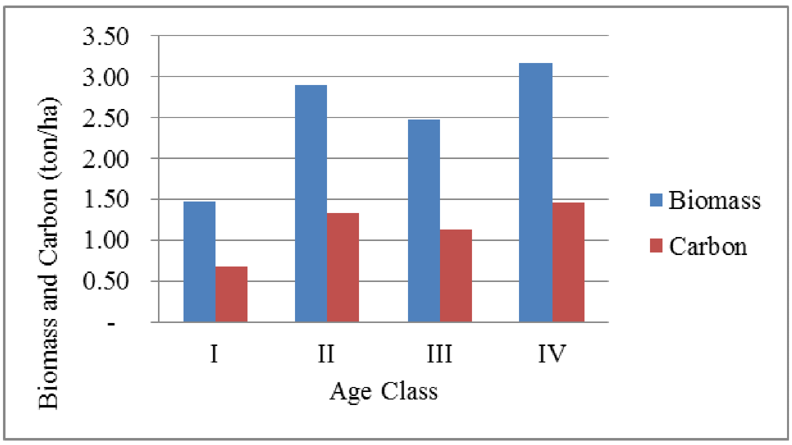


Figure 6. The average total of under-gowing plant's carbon from age class I to IV

General description of under-growing plants existing in teak plantation forest (*T. grandis* Linn, f)in the researched sites makes up grasses and herbs. Biomass and carbon contents in under-growing plants are various and depend on the quality of plantation growing areas. The higher the age class, the more compressed the growth of under-growing plants due to the limited sunlight as a result of teak plantation canopy which have covered each other.

Biomass and under-growing plant's carbon calculation result as depicted in table 3 show that the content of biomass and carbon have a difference in every plot which is affected by the density of tree plantations, plantation age and the quality of growing sites.

Table 3 indicates that the average biomass of under-growing plants at age class I is 1,48 ton/ha, and the average of carbon is 0,68 ton/ha. In age class II, the average of biomass is 2,90 ton/ha, and the average of carbonamounts 1,33 ton/ha. In age class III the average of biomass is 2,47 ton/ha, and carbon average is 1,14 ton/ha. In age class IV biomass average is 3,17 ton/ha, and carbon average is 1,46 ton/ha.

Contribution of biomass storage and under-growing plant's carbon is extremely low compared to that of biomass and tree's carbon in either class age I, II, III orIV as the under-growing plants are in the lowest level and are protected by trees. As stated by Hairiah (2007) that the denser the tree's canopy is, the more decreased under-growing plant's biomass as there is the decreased rate of sunlight that reaches the forest floor.

Carbon pool is heavily affected by biomass. Therefore, factors affecting the increased or the decreased biomass potency will also affect carbon intake. A factor affecting the increased carbon potency is thinning. This thinning will result in the decreased competition among trees, allowing the higher quality of tree growth and plantation dimension. Tree age will increase the amount of carbon intake because the older the tree is, the bigger dimension the plantation is and thehigher the potency of carbon is.

The biggest part of carbon storage in forest is living biomass, soil and timber products. The living biomass included upper part and lower part of roots, trees, herb plants, bushesand ferns. The dead biomass comprises litter and rough timber remains. Soil makes up mineral, organic layers and turf. Hamburg (2000) stated that carbon calculation which aims to know carbon pool is calculated from the upper part of biomass over land surface, lower part of biomass of land surface, dead wood and soil carbon.

4. Conclusion

The increase of plantation age has an impact on the content of biomass and teak plantation carbon, as the higher the plantation age, the more increased tree's diameter and the higher content of biomass and teak plantation's carbon.

The highest content of biomass and carbon supply is retained in the researched site, in a 4 age class tree level, averaging 406,67 ton/ha of biomass content and 101,67 ton/ha carbon.

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