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# Carbon Potentials in Biomass of Fruit Trees in Home Gardens in the Bogor Regency, West Java

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## ABSTRACT

A study using the point centered quarter method for trees and quadrats for saplings in homegardens of 41 hamlets within 40 districts in the Bogor Regency, West Java, revealed a rich diversity of fruit trees. *Artocarpus heterophyllus*, *Nephelium lappaceum*, *Mangifera indica*, and *Durio zibethinus* were the dominant and widely distributed fruit tree species. Above ground biomass of trees and saplings were calculated using allometric equations and the C (carbon) stocks were estimated by assuming that C constitutes 50% of biomass. The total biomass of trees with diameter at breast height ≥ 10 cm amounted to 1,081.7 tons, varied between hamlets from 10.1 to 66.7 tons/ha and the mean per hamlet of 26.4 ± 9.9 ton/ha, while that of saplings with diameter of 2 to 9.9 cm recorded to be 390.4 tons with a range between hamlets of 3.9 to 12.9 tons/ha and the mean per hamlet of 9.5 ± 3.7 tons/ha. The total aboveground C stocks was 540.9 tons for trees with a range between hamlets of 5.1 to 33.4 tons/ha and the mean per hamlet of 13.2 ± 4.9 tons/ha, while that of saplings was 195.2 tons with a range between hamlets of 0.7 to 9.4 tons/ha and the mean per hamlet of 4.9 ± 1.8 tons/ha. The main fruit trees with highest carbon sequestration capacity were *Artocarpus heterophyllus*, *Mangifera indica*, *Mangifera foetida*, and *Sandoricum koetjape*.

Keywords: Above ground biomass, carbon stocks, home gardens, species diversity, Bogor

## INTRODUCTION

Tree biomass is the total amount of aboveground living matter of the tree expressed in tons dry weight per unit area (Brown, 1997; Ketterings *et al.*, 2001). It is the product of conversion of carbon dioxide ($CO_2$) absorbed from the atmosphere into organic carbon through photosynthesis and is stored as woody biomass (Rahayu *et al.,* 2004; Hairiah *et al.,* 2011). One of the sources of aboveground tree biomass is homegardens. A homegarden is an agroecosystem where plant diversity is contained therein. The diversity plays an important role in storing the biomass, contributing to maintainance of carbon stability in the long term (Kumar and Nair, 2004; Henry *et al.*, 2009; Sujarwo, 2016). Homegarden conservation, therefore, requires serious attention, given the role that homegardens together with natural forests can play in maintaining carbon stocks and the presence of a homegarden in an area can reduce the pressure on utilization and destruction of natural forests (Kumar, 2010).

Conversion of home gardens into residential areas and other land uses results in the loss of tree biomass, which in turn causes the opening of carbon pockets, leading to the release of carbon to atmosphere (Brown, 1997; Manuri *et al.*, 2018). Such a condition has become a serious concern in the calculation of carbon stocks (UNFCCC, 2007). Johnsen *et al.* (2001)

stated that the measurement of biomass as the sources and carbon sinks may be used to estimate the potentials of carbon stocks in an ecosystem.

Carbon stocks in soils may be improved by planting and maintaining trees (Rahayu *et al.,* 2004). Trees with diameters at breast height ≥ 30 cm constitute 30% of the total carbon stocks in the entire garden system aged 0-10 years dominated by fruit trees (Lusiana *et al.*, 2008). The above carbon stocks are comparable to the trees of similar diameters in the forest that have 30 - 40% carbon stocks in the total tree biomass (Brown and Gaston, 1996; Brown, 1997). To date, only few studies have been carried out with regard to the potential of the homegardens as an alternative carbon storage (Kumar, 2010). The present study aims at determining the biomass of fruit and non fruit trees to estimate the carbon stocks in the homegardens in the Bogor Regency, West Java.

## METHODS

The study was conducted from May 2012 to August 2012 in the Bogor Regency (*Kabupaten* Bogor) West Java, which is geographically located at 6º18′ – 6º47’10 South and 106º23’45 – 107º13’30 East. Purposive random sampling was adopted in all sub-districts (*kecamatan*) in the Bogor Regency (Figure 1). In each district, one village (*desa*) was selected at random, and in each village a hamlet (*kampung*) was selected. In Tajurhalang sub-district, however, two villages and two hamlets were selected, in order to meet the sampling requirements stipulating that the number of samples should be 10% of 410 hamlets in 40 villages in the Bogor Regency, in line with the sampling requirements of 10% of the total area of the study (Mueller-Dombois and Ellenberg, 1974, 2016).

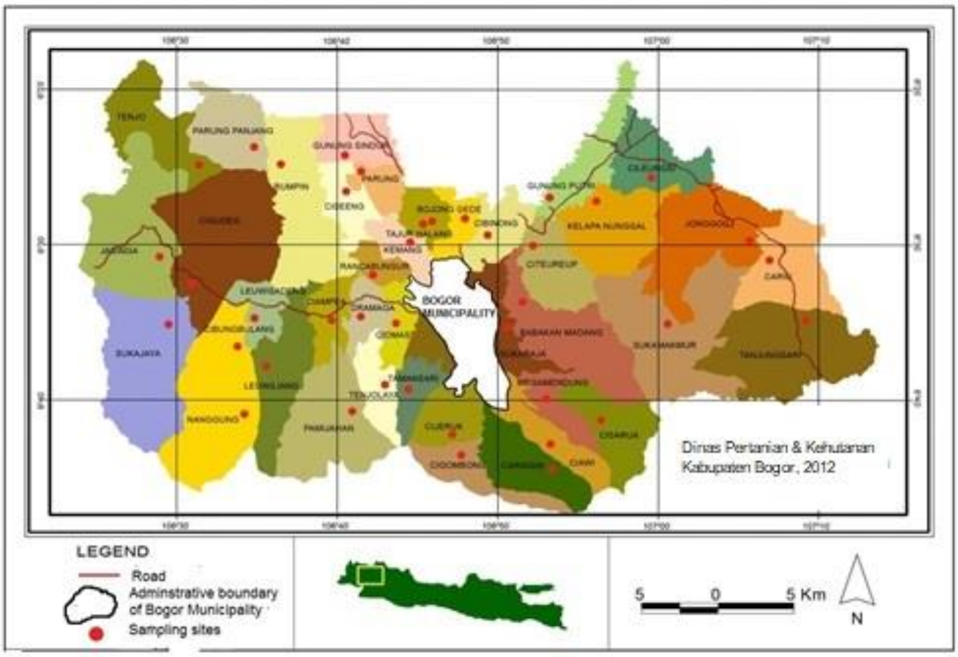


Figure 1. Sampling sites at 41 hamlets in 40 districts within the Bogor Regency

Trees were sampled with the point-centered quarter method (Cox, 1967; Mueller-Dombois and Ellenberg, 1974, 2016). In each selected hamlet sampling was made in a transect line following the hamlet main street. In each hamlet, 10 sampling points were placed alternately at a distance of 5 m to the left and 5 m to the right side of the transect line. The distance between sampling points was 50 m (Figure 2) making the length of the transect line of 500 m. At each sampling point 4 quadrants were established (Q1 - 4) by drawing a line parallel to transect line and another line crossed and perpendicular to the first line. In each quadrant, the distance from the sampling point to the nearest tree with a diameter at breast height (DBH) ≥ 10 cm was measured as d1, d2, d3, and d4. At the Q2 sampling point, a quadrat of 5 m x 5 m was constructed to sample tree saplings, with DBH of 2.0 – 9.9 cm. The total number of sampling points in 41 hamlets was 410.

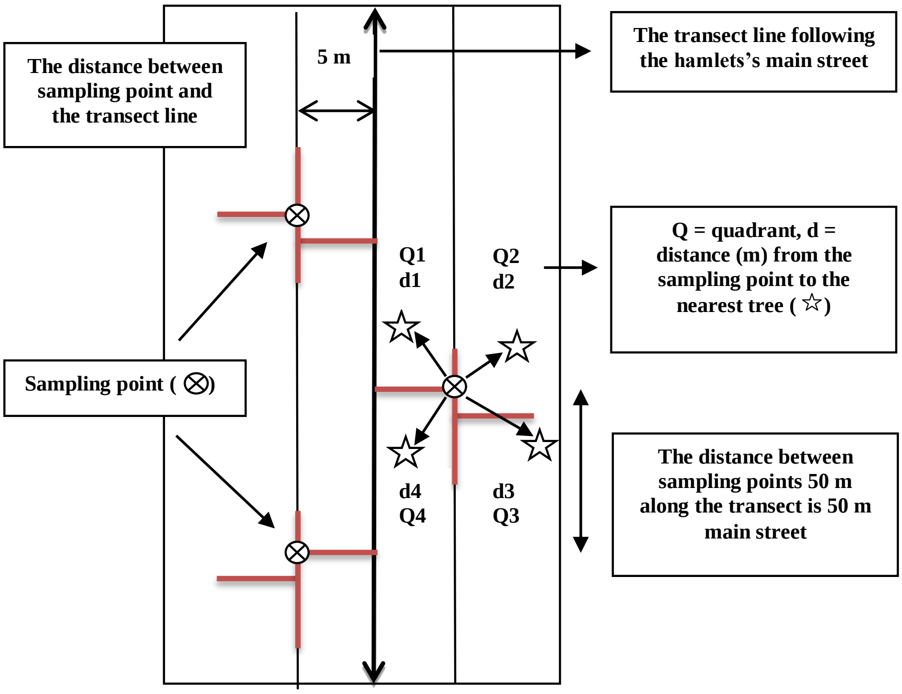


Figure 2. Design of sampling using the the point-centered quarter method with 10 sampling points laid out at 50 m interval along a transect in a sampled hamlet

Data analysis included community structure in terms of tree and species classification according to the following diameter classes, i.e. 2 – 9.9 cm, 10 – 19.9 cm, 20 – 34.5 cm, and ≥ 35 cm, to reflect population structure and regeneration. Tree diameter was also used as the basis for calculating biomass using allometric multispecies and mixed species equation in tropical forests of Indonesia by Brown (1997). Basuki *et al.* (2009) stated that Brown Allometric equations were quite accurate for predicting aboveground total species biomass. The allometric equation was:

$$B = \exp\,[-2.134 + 2.53 \ln (D)]$$

where B = total aboveground biomass (kg/tree), and D = diameter at breast height (cm)

For bananas and coffee, we used the following allometric equations developed by van Noordwijk *et al.* (2002):

$$W = 0.03D^{2,13} \text{ (banana), and } W = 0.281\, D^{2,06} \text{ (coffee)}$$

where W = total biomass (kg/tree)

The amount of biomass per hectare was calculated using the following equation:

$$\mathrm{W} = \sum_{i=1}^{n} \mathrm{pi} \ \text{x} \ 10{,}000 \ (\text{m2}) \ /\text{A}$$

Where W = Total biomass (ton/ha), W*P*i = Biomass of tree (ton), A = Plot width ($m^2$), and N = Number of tree

The total amount of biomass was used to estimate carbon stocks. Carbon stocks that were stored in a tree is 50% of the total tree biomass (Brown, 1997; Heriansyah *et al*., 2003; IPCC, 2003). Based on this assumption, the potential carbon stock in the home garden was calculated by using the formula Y = W x 50 %. Y represented the value of aboveground standing tree carbon content (ton/ha). Uptake of carbon dioxide ($CO_2$) was also calculated based on carbon stocks potential using relative molecular mass ratio of $CO_2$ (44) and the relative atomic mass of C (12), which was the uptake of $CO_2$ = 3.67 x Y (IPCC, 2006).

## RESULTS AND DISCUSSION

### Composition of Tree Species

The complete results of the analysis of the composition of plant species in the home gardens in 41 hamlets belonging to 41 villages in 40 sub-districts in Bogor will be reported elsewhere. We recorded 74 species of 31 families. A total of 71 species and 30 families were woody trees (Table 1). It was reported that the dominant tree species with the mean Importance Value of 35 - 60% and distributed evenly in all the villages with the frequency range of 75 - 100% were *Artocarpus heterophyllus*, *Durio zibethinus*, *Mangifera indica*, and *Nephelium lappaceum*. Tree species that could be categorized as very rare with frequency range 1 - 5% were *Annona squamosa*, *Cassia siamea*, *Cerbera manghas*, *Diospyros philippensis*, *Filicium decipiens*, *Glochidion borneense*, *Mangifera foetida*, *Michelia champaca*, *Phyllanthus acidus*, *Samanea saman*, *Syzygium polyanthum*, *Tectona grandis*, and *Terminalia catappa*.

It was further noted that some woody fruit trees that were getting to be rarely found in the market were present at the sites, including *Antidesma bunius*, *Bouea macrophylla*, *Diospyros philippensis*, *Lansium domesticum* var. *aqueum*, *Mangifera caesia*, and *Syzygium polycephalum*. A total of 29 species of woody trees were producers of timber, spices, medicinal material, aromatic oils, and beverages. Some species of woody trees have specific gravity of less than 0.5 (Oey, 1990) such as *Annona muricata*, *Cananga odorata*, *Cerbera manghas*, *Ficus callosa*, *Maesopsis eminii*, *Mangifera caesia*, *Parkia speciosa*, *Sandoricum koetjape*, and *Spondias dulcis*. The species with such low specific gravity generally have a fast growth rate, which could indicate a high rate of carbon absorption.

Table 1. Families and species of fruit trees and non-fruit trees (*) with local names in brackets recorded at the sampling sites in the Bogor Regency

WOODY TREE

**Anacardiaceae**: *Anacardium occidentale* L. [Jambu mete]; *Bouea macrophylla* Griff. [Gandaria]; *Mangifera caesia* Jack. [Kemang]; *Mangifera foetida* Lour. [Mangga limus]; *Mangifera indica* L. [Mangga]; *Mangifera odorata* Griffith. [Mangga kuweni]; *Spondias dulcis* Parkinson [Kedondong]

**Annonaceae**: *Annona muricata* L. [Sirsak]; *Annona squamosa* L. [Srikaya]; *Cananga odorata* (Lam.) Hook.F. & Thomson [Kenanga]*
**Apocynaceae**: *Cerbera manghas* L. [Bintaro]*
**Bombacaceae:** *Durio zibethinus* Murray. [Duren]; *Ceiba pentandra* L. Gaertn. [Randu]*
**Combretaceae**: *Terminalia catappa* L. [Ketapang]
**Clusiaceae:** *Garcinia mangostana* L. [Manggis]
**Ebenaceae:** *Diospyros philippensis* (Desr.) Gurke. [Bisbul]
**Elaeocarpaceae:** *Muntingia calabura* L. [Kersen]
**Euphorbiaceae:** *Antidesma bunius* (L.) Spreng. [Buni]; *Baccaurea racemosa* (Reinw. ex Blume) Müll.Arg. [Menteng]; *Glochidion borneense* (Müll.Arg.) Boerl. [Mareme]*; *Phyllanthus acidus* (L.) Skeels. [Ceremai]
**Fabaceae:** *Adenanthera pavonina* L. [Saga]*; *Cassia siamea* Lmk. [Johar]*; *Leucaena leucocephala* (Lam.) de Wit. [Petai Cina]*; *Parkia speciosa* Hassk. [Petai; *Samanea saman* (Jacq.) Merr. [Trembesi]*; *Tamarindus indica* L. [Asam]; *Archidendron pauciflorum* (Benth.) I.C.Nielsen. [Jengkol]*; *Paraserianthes falcataria* (L.) Nielsen. [Sengon].*
**Flacourtiaceae:** *Pangium edule* Reinw. [Picung]*
**Gnetaceae:** *Gnetum gnemon* L. [Melinjo]*
**Lauraceae:** *Persea americana* Mill. [Alpukat]
**Lythraceae:** *Punica granatum* L. [Delima]
**Magnoliaceae:** *Michelia champaca* L. [Kayu kembang]*
**Malvaceae:** *Theobroma cacao* L. [Kakao]*
**Meliaceae:** *Lansium domesticum* Corrêa. [Duku]; *Lansium domesticum* var. *aqueum* Jack. [Kokosan]; *Sandoricum koetjape* (Burm. f.) Merr. [Kecapi]; *Swietenia mahagoni* (L.) Jacq. [Mahoni]*
**Moraceae:** *Artocarpus champeden* (Lour.) Spreng [Chempedak]; *Artocarpus altilis* (Parkinson) Fosberg. [Sukun]; *Artocarpus heterophyllus* Lam. [Nangka]; *Ficus benjamina* L. [Beringin]*; *Ficus callosa* Willd. [Pangsor]*
**Myristicaceae:** *Myristica fragrans* Houtt. [Pala]
**Myrtaceae:** *Syzygium aqueum* (Burm.f.) Alston [Jambu air]; *Syzygium polycephalum* (Miq.) Merr. & L.M.Perry [Gowok]; *Psidium guajava* L. [Jambu batu]; *Syzygium aromaticum* (L.) Merr. & L.M.Perry [Cengkih]*; *Syzygium cumini* (L.) Skeels [Jamblang]; *Syzygium malaccense* (L.) Merr. & L.M.Perry [Jambu bol]; *Syzygium* sp. [Pucuk merah]*; *Syzygium polyanthum* (Wight) Walp. [Salam]*
**Oxalidaceae:** *Averrhoa bilimbi* L. [Belimbing wuluh]; *Averrhoa carambola* L. [Belimbing]
**Rhamnaceae:** *Maesopsis eminii* Engl. [Kayu Afrika]*
**Rubiaceae:** *Coffea* spp. [Kopi]; *Morinda citrifolia* L. [Mengkudu]
**Rutaceae:** *Citrus hystrix* DC. [Jeruk purut]; *Citrus maxima* (Burm. f.) Merr. [Jeruk Bali]; *Citrus nobilis* Lour. [Jeruk siem]
**Sapindaceae:** *Dimocarpus longan* Lour. [Lengkeng]; *Filicium decipiens* (Wight & Arn.) Thw. [Kirai payung]; *Nephelium lappaceum* L. [Rambutan];
*Pometia pinnata* J.R. & G.Forst. [Matoa]
**Sapotaceae:** *Chrysophyllum cainito* L. [Sawo duren]*; *Manilkara kauki* (L.) Dubard [Sawo kecik]*; *Manilkara zapota* (L.) P.Royen [Sawo manila]; *Pouteria campechiana* (Kunth) Baehni. [Sawo mentega]
**Thymelaeaceae:** *Phaleria macrocarpa* (Scheff) Boerl. [Mahkota dewa]*
**Verbenaceae:** *Tectona grandis* L.f. [Jati]*

**NON-WOODY TREE**
**Arecaceae:** *Areca catechu* L. [Pinang]*
**Caricaceae:** *Carica papaya* L. [Pepaya]
**Musaseae:** *Musa paradisiaca* L. [Pisang]

**Aboveground Biomass of Tree**

The total aboveground biomass of 1,640 trees with DBH ≥ 10 cm recorded in the study sites was 1,081.7 tons and that of the 462 saplings with diameters of 2.0 - 9.9 cm was 390.4 tons (Figure 3). Between hamlets the biomass of trees ranged from 10.1 to 66.7 tons/ha with the mean for hamlet of 26.4 ± 9.9 tons/ha. Meanwhile, the biomass of saplings ranged from 3.9 to 12.9 tons/ha the mean for hamlet of 9.5 ± 3.7 tons/ha.

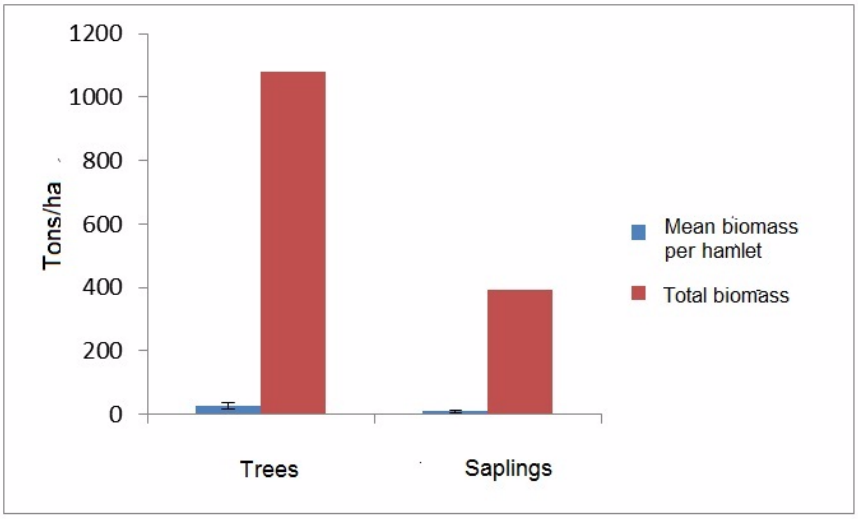


Figure 3. Total biomass of trees with DBH ≥ 10 cm, saplings with DBH of 2.0 – 9.9 cm and the mean biomass per hamlet

The amount of biomass of trees with DBH ≥ 10 cm varied between hamlets (Table 2). A total of 7 hamlets had biomass of trees of 10 – 19 tons/ha, 25 hamlets of 20 – 29 tons/ha, 7 hamlets of 30 – 40 tons/ha, and 2 hamlets of 50 – 70 tons/ha). The variations of biomass of trees were strongly influenced by the presence, distribution and the number of trees with DBH ≥ 20 cm (Figure 4). To some extent this is comparable to the finding of Laumonier *et al.* (2010), who pointed out that 60% of the total tree biomass in a hill dipterocarp forest in Sumatra is concentrated in trees with DBH of 20 – 70 cm. Twenty five hamlets with the number of biomass of 20 – 29 tons/ha and a total of 1,000 individuals had about 55% of trees with DBH of 20 – 34.5 cm, with 10 – 15 species. Species having such diameter ranges were *Nephelium lappaceum*, *Artocarpus heterophyllus*, and *Mangifera indica*. These three species were widely planted in most home gardens because they did not require intensive management and care. Meanwhile, the biomass of saplings varied little between hamlets. Table 2 shows that there were 19 hamlets with biomass of 10 – 15 tons/ha, 18 hamlets with biomass of 5 – 9 tons/ha, and 4 hamlets with biomass of 1 – 4 tons/ha. Species that dominated the saplings were *Annona muricata*, *Psidium guajava*, and *Syzygium aqueum*. The three species are widely cultivated in homegardens because they produced fruits throughout the year and had economic value as a source of household income.

Table 2. The total biomass (ton/ha) of trees and saplings according to the tree diameter classes in transects within 41 hamlets in the Bogor Regency

| **Trees with DBH ≥ 10 cm** | **Locality with the total biomass in ton/ha** |
|---|---|
| 10–19 | Cimanggu (19.0), Waringin (10.1), Lemahduhur (19.8), Citapen (17.6), Tugu Utara (19.1), Kadumanggu (19.6), Ciapus (14.7) |
| 20–29 | Jasinga (22.6), Dago (27.9), Tapos (22.6), Bangunjaya (21.0), Kiarapandak (21.2), Parakanmuncang (21.9), Karacak (22.8), Kalong (21.1), Ciampea (29.4), Pasarean (21.0), Cinangneng (21.2), Jabonmekar (24.9), Tegal (21.7), Rancabungur (24.4), Sasakpanjang (27.1), Citayam (28.0), Pabuaran (28.2), Neglasari (23.9), Megamendung (25.1), Gandoang (26.5), Sirnagalih (21.3), Sukamulya (24.5), Mekarwangi (27.3), Cibadak (25.1) |
| 30–40 | Rabak (34.2), Pedurenan (34.8), Cihoe (33.3), Cilebut Barat (35.0), Ciburuyut (30.2), Sukajadi (35.3), Klapanunggal (30.7) |
| 50–70 | Cipicung (58.3), Bojongnangka (66.7) |
| **Saplings with DBH of 2.0–9.9 cm** | |
| 1–4 | Waringin (3.9), Sasakpanjang (4.9), Citayam (4.3), Gandoang (4.4) |
| 5–9 | Jasinga (6.9), Bangunjaya (5.4), Kiarapandak (7.2), Kalong (9.3), Cimanggu (7.3), Ciampea (7.2), Pasarean (9.5), Rabak (6.8), Cinangneng (8.5), Pabuaran (9.7), Ciburuyut (9.1), Lemahduhur (9.5), Sukajadi (9.6), Klapanunggal (6.6), Sirnagalih (6.7), Sukamulya (8.4), Mekarwangi (9.2), Cibadak (5.6) |
| 10–15 | Dago (11.2), Tapos (12.2), Parakanmuncang (11.9), Karacak (11.6), Pedurenan (12.9), Jabonmekar (12.7), Cihoe (10.8), Tegal (11.5), Rancabungur (11.1), Cilebut Barat (11.4), Neglasari (12.4), Cipicung (11.3), Citapen (10.4), Megamendung (12.1), Tugu Utara (14.1), Pasirmukti (12.6), Kadumanggu (11.1), Ciapus (10.1), Bojongnangka (12.9) |

The presence of trees of DBH ≥ 35 cm with the highest biomass between 50–70 tons/ha contributed to a large biomass in two hamlets, namely Kampung Cipicung and Kampung Bojongnangka (Table 2). The tree species included *Nephelium lappaceum*, *Durio zibethinus*, *Mangifera caesia*, and *Mangifera foetida*. Those woody fruit plants were reaching the age of 1 – 15 years and were the home garden plants which were passed from generation to generation. Although fruit productivity started to decline, the plants were retained because they served as the shading. The results also showed that the high diversity among the species did not always make a major contribution to the biomass storage if the tree diameters classes ranged from 10 to 20 cm. Jabon mekar hamlet which had the highest species diversity (23 species) had the number of biomass of 24.9 tons/ha, while the Bojong nangka sub-village which had 14 species had biomass of 66.7 tons/ha which was contributed by the presence of *Archidendron pauciflorum*, *Mangifera caesia*, and *Mangifera foetida* that had DBH ≥ 50 cm.

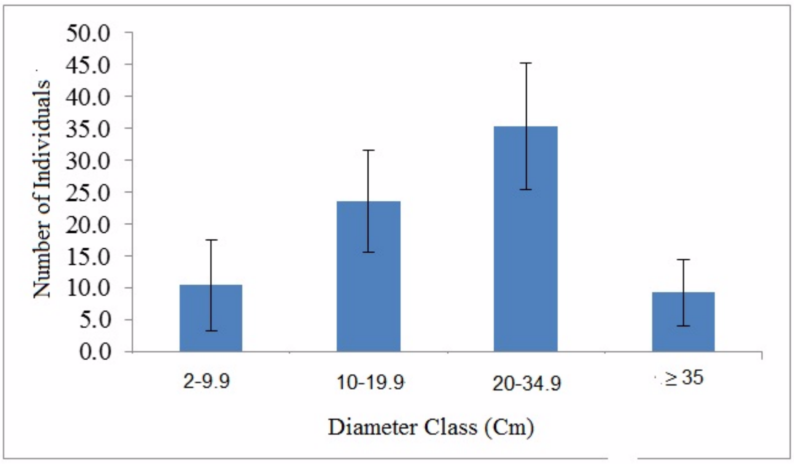


Figure 4. Mean number of individuals per hectare of saplings (DBH of 2 – 9.9 cm) and trees (DBH ≥ 50 cm) and standard deviations according to diameter classes

## Carbon Reserves in the Home gardens

Based on total plant biomass obtained, calculation of the total stored carbon stocks gave the value of 50% of the total biomass. It follows that the total carbon stocks for trees was 540.9 tons and saplings 195.2 tons. The total uptake of $CO_2$ calculated by multiplying the total amount of carbon stocks with a factor of 3.67 gave the value of 1,985.1 tons for trees with the range of 5.1 to 33.4 tons/ha and the mean of 13.2 ± 4.9 ton /ha. For saplings the value obtained was 716.4 tons with the range of 0.7 – 9.4 tons/ha and the mean of 4.9 ± 1.8 tons/ha (Figure 5). This is in line with the finding of Lusiana *et al.* (2008), who reported that trees with DBH ≥ 30 cm held 30% of the total carbon stocks in the entire garden system, aged 0 – 10 years dominated by fruit trees. They are comparable to those of the forest trees with similar diameters which accounted for 30–40% of the carbon stocks of the total tree biomass (Brown and Gaston, 1996; Brown, 1997).

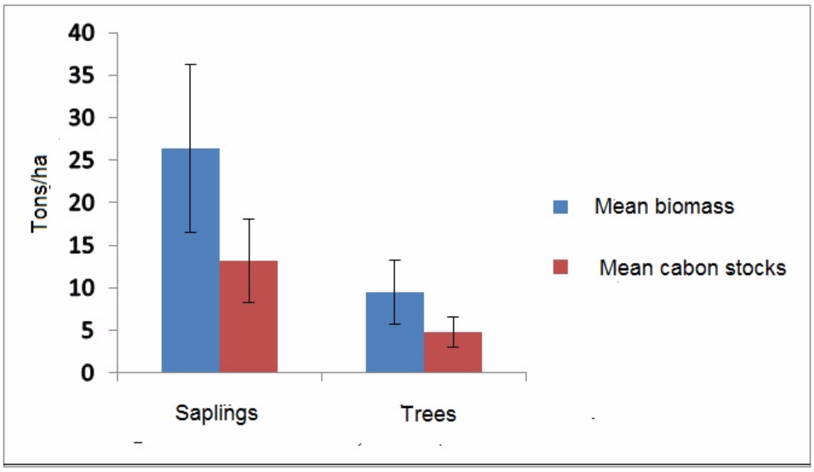


Figure 5. The comparison of total biomass with total carbon stocks in trees with DBH ≥ 10 cm and saplings with DBH of 2.0 – 9.9 cm

The home gardens having a large amounts of woody fruit trees will have bigger carbon stocks compared to gardens planted with comparable amounts of food crop plants. This may be due to the fact that woody fruit trees, such as *rambutan*, rose-apple (*jambu air*), guava, jackfruit, and mango that produce fruits throughout the year will not be arbitrarily cut down by the owner as long as they productively produce fruits. A home garden owner will only cut down old fruit trees, which are marked by hollow tree trunks and lots of broken branches and twigs.

As a whole tree species grown in the home gardens in the Bogor Regency had $CO_2$ absorbing capacity that varied from very low to very high (Table 3). The species of fruit trees that had high to very high absorbing capacity were *Artocarpus heterophyllus*, *Baccaurea racemosa*, *Bouea macrophylla*, *Lansium domesticum*, *Mangifera foetida*, *Mangifera indica*, *Pometia pinnata*, and *Sandoricum koetjape*. Therefore, these fruit species along with non-fruit woody tree species, having high $CO_2$ absorbing capacity should be maintained as home garden plants. Beside having high, $CO_2$ absorbing capacity, the species of woody fruit trees constitute a source of income for home garden owners, as their fruits have high selling values as fresh fruit. The fruit species beginning to be rarely found in the market, such as *gandaria* and *menteng*, could be sold up to 2 – 3 times higher than ordinary fruits.

Table 3. The classification of species of trees with high $CO_2$ absorbing capacity occurring in the research sites

| **Classification of $CO_2$ absorbing capacity (kg/tree/year)**[4] | **Species** |
|---|---|
| Extremely High (> 1,000) | *Artocarpus heterophyllus*[6], *Ceiba pentandra*[6], *Samanea saman*[4] |
| Very High (500 – 1,000) | *Bouea macrophylla*[5], *Baccaurea racemosa*[5], *Ficus benjamina*[4], *Mangifera foetida*[6], *Myristica fragrans*[1], *Sandoricum koetjape*[1], *Terminalia catappa* [6] |
| High (150 – 499) | *Adenanthera pavonina*[4], *Filicium decipiens*[4], *Lansium domesticum*[1], *Mangifera indica*[2], *Pometia pinnata*[2], *Swietenia mahagoni*[4], *Tectona grandis*[4] |
| Moderate (50 – 149.9) | *Anona muricata*[4], *Cananga odorata*[3], *Syzygium malaccense*[2] |
| Low (10 – 49.9) | *Manilkara kauki*[4] |
| Very Low (< 9.9) | *Garcinia mangostana*[3], *Nephelium lappaceum*[4], *Tamarindus indica*[4] |

Notes: [1] = Sharrow and Ismail (2004); [2] = Karyadi (2005); [3] = Purwaningsih (2007); [4] = Dahlan (2008); [5] = Hariyadi (2008); [6] = Lailati (2008)

All species of fruit and non-fruit trees with various diameters, especially trees with DBH > 30 cm in the home gardens will contribute a great deal to the storage of carbon stocks. In terms of structure, a tree community in the home gardens is equivalent to a selectively logged forest. In a selectively logged forest, the carbon stocks in trees with DBH > 30 cm increase with age of the forests, i.e. 75%, 78%, and 83% at age 0 – 10, 11 – 30, and 31 – 50 years, respectively (Hairiah, 2011). For these reasons, the maintenance and care of fruit and non-fruit trees in home gardens becomes important. The presence of trees at seedling and sapling stages should be maintained in order to smoothen the regeneration and stimulate the growth rate by providing canopy opening to allow sunlight to reach the home garden floor, comparable to the gaps in natural forests and selectively logged forests.

Coffee plants that were found in the research site were also worth maintaining for the same reason. Rahayu *et al.* (2004) stated that coffee plantations aged 20 – 30 years with tree diameter range of 5 – 30 cm could contribute to carbon stocks by 41%. A homegarden could be classified as an agroforest, which, according to Sharrow and Ismail (2004), could accumulate carbon more efficiently than plantations.

## CONCLUSIONS

The home gardens in the Bogor Regency contained a high diversity of fruit and non-fruit tree species with varied population structures. Home gardens with fruit and non-fruit tree species, producing high biomass and carbon content as well as having high $CO_2$ absorbing capacity, are comparable to forest plantations and selectively logged forests. The home garden, as an important carbon storage, should be taken into consideration in the program of mitigation and adaptation to climate change, including the Reducing Emissions from Deforestation and Forest Degradation (REDD) program. The home garden can be one of the important components that support forest conservation and carbon storage. The conservation of trees in the home gardens should, therefore, be maintained, and even the quality, quantity, and species diversity should be enhanced, not only by planting fruit tree species, but also such species as other food crops, medicinal plants, and plants with cultural values as well as other useful plants. A home garden can also be a site for *ex-situ* conservation of the rare species of fruits, food crops, and medicinal plants and also for the conservation of genetic variability for a range of useful plants. It would be relatively easy through the home garden to make the local community as part of the ecosystem to manage the agro-ecosystem and involve them in various activities related to climate change and biodiversity conservation, leading to a better understanding of the issues.

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