Carbon sequestration by above-ground biomass in urban green spaces in Singaraja city

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Abstract. This study aims to determine the biomass, C-organic content, carbon stock, and CO₂ sink in above-ground biomass on Urban green space (UGS) in Singaraja city. Vegetation sampling was conducted according to the SNI 7724:2011. Vegetation carbon stock in trees was estimated using allometric equations, litter and herbaceous were estimated using biomass expansion factor (BEF) equation. The organic carbon content in vegetation samples was measured by Walkley and Black method. The result showed that average biomass in the trees is 23.645 tons per ha and 44.768 tons per ha, 0.211 tons per ha and 0.194 tons per ha for the herbaceous, while the litter is 0.347 tons per ha and 0.268 tons per ha respectively for boulevard and roadside. The average C-organic content in the tree is 1.30% and 2.03%, 6.26% and 4.79% for the herbaceous, while the litter is 4.86% and 4.29% respectively for boulevard and roadside. The average carbon stock in the tree is 30.750 tons per ha and 90.880 tons per ha, 1.321 tons per ha and 0.930 tons per ha for the herbaceous, while a litter is 1.686 tons per ha and 1.182 tons per ha respectively for boulevard and roadside. The sequestration of CO₂ by the tree is 112.751 tons per ha and 333.226 tons per ha, 4.845 tons per ha and 3.408 tons per ha for the herbaceous, while the litter is 6.184 tons per ha and 4.334 tons per ha respectively for boulevard and roadside.

1. Introduction

During the twentieth century, the number of the global urban population grew tenfold and is currently estimated at more than half the world's population live in cities or urban areas. In Indonesia, this proportion had reached 57% by 2010 and is expected to reach 68% by 2025[1]. It is also reported that in some provinces, especially Java and Bali provinces, the level of urbanization are much higher than the total Indonesian population living in urban areas. In Bali, the level of urbanization in 2025 is estimated to over 79% [1]. As a result, some environmental issues emerge in terms of land, use and greenhouse gas emissions, especially about CO₂ release into the atmosphere. This has prompted the government to provide land-use policy, especially in urban centers with Law of the Republic of Indonesia No. 26 of 2007 that concerning Spatial Planning. This requires each municipality to provide and utilize urban green space of at least 30% of the total area.

Urban green space is part of aregional urban open spaces, filled with plants and plant systems to support urban ecosystem services. Therefore, the urban green space can contribute to reducing the atmospheric concentration of CO₂. Like plants in the forest, trees and vegetation in parks of urban
green space also have the capacity to store carbon. According to Nowak and Crane [2], Nowak et al. [3] and Nowak et al. [4], although the density of vegetation in urban green space is relatively smaller than forest, urban green space can be a substantial carbon storage capacity. Another authors Jo and McPherson [5], Davies et al. [6], Roshetko et al. [7], Krisdianto et al. [8], Velasco et al. [9], Yue et al. [10], and Davies et al. [11] were also estimate that the urban green space is the carbon storage capacity in various city and state. These studies were conducted in different methods and size of the urban green space and vegetation cover, to provide carbon sequestration and storage capacity are different. Therefore, estimated carbon storage of an urban area cannot be extrapolated to other urban areas due to the pattern of urbanization, spatial planning, and the type of vegetation as cover in fundamentally different conditions.

This study aims to estimate the carbon storage potential of urban green space in Singaraja city, Buleleng district, Bali Province. The city was chosen because it has a relatively larger urban green space than other towns in the Bali Province.

2. Research methods

This research was conducted in the area of Singaraja city, located in the northern part of Bali island. Samples biomass were obtained from 17 zone of urban green spaces with three replication each site, including 7 places in the boulevard and 10 places in roadside. The chemical analysis was conducted at the Laboratory of Chemical Analyst, Department of Chemistry, Faculty of Mathematics and Natural Sciences, University of Pendidikan Ganesha (Undiksha).

The biomass of the tree was measured by nondestructive sampling method. The local name and scientific name of the measured tree were recorded. DBH (Diameter at Breast Height) was measured with a caliper. Two allometric equations (Table 1) Hairiah and Rahayu [12] were used to calculate the above-ground of tree’s biomass.

| No | Kind of Tree              | Allometric Equitation       |
|----|---------------------------|-----------------------------|
| 1  | Tree with branch          | $ABG = 0.11 \rho (D)^{2.62}$ |
| 2  | Tree without branch       | $ABG = \pi \rho D^2 H / 40$ |

Table 1. Allometric equations

ABG: tree biomass (kg)
P: the specific density of trees (g cm$^{-3}$)
D: the diameter at breast height (cm)

Litter and herbaceous biomass were measured by destructive sampling method. The samples were collected in a subplot with size 3 meters x width according to the width of the garden at UGS on plot determined. Litter and herbaceous were cut into small pieces using scissors. Furthermore, according to SNI 7724: 2011, litter and herbaceous were dried in an oven at a temperature of 85°C for 24 hours or until the weight of the plant is constant. Litter and herbaceous biomass were calculated using the following Biomass Expansion Factor (BEF) formula (eq. 3).

$$\text{Biomassa} = \frac{\text{dried weight sample}}{\text{wet weight sample}} \times \frac{\text{total weight sample}}{\text{sample weight}}$$ (3)

Total carbon storage was calculated using equation 4.

$$C_{\text{stored}} = \text{Biomassa total} \times \%C$$ (4)

Where stock C is carbon storage in total biomass and \%C is carbon organic content in biomass. Carbon organic content was determined by the Walkley-Black method. Furthermore, the carbon sequestration was calculated using equation 5.

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\[
\text{CO}_2 = \frac{\text{MrCO}_2}{\text{ArC}} \times \text{Stok C}
\]  

(5)

Note:
Mr: Massa molecule relatives
Ar: Massa atom relative
Stok C: carbon storage in total biomass

3. Results and discussion

3.1. Results
The results of this study indicate that trees have a much higher biomass value compared to herbaceous and litter. In contrast, herbaceous C-organic content is much higher than C-organic trees. Because of its large size, the value of carbon stocks and CO\(_2\) sink capacity of trees is much greater than that of herbaceous and litter. In more detail, the results of this study are presented in Table 2.

Table 2. Biomassa, C-organic content, carbon stock and CO\(_2\) sestration.

| No. | Location | Vegetation | Average Biomass (ton 10\(^{-1}\)) | Average C-Organic (%) | C Stock (ton per ha) | Sink CO\(_2\) (ton per ha) |
|-----|----------|------------|----------------------------------|-----------------------|---------------------|---------------------------|
| 1   | Boulevard| Trees      | 23.654                           | 1.30                  | 30.750              | 112.751                   |
|     |          | Herbaceous | 0.211                            | 6.26                  | 1.321               | 4.845                     |
|     |          | Litter     | 0.347                            | 4.86                  | 1.686               | 6.184                     |
|     |          | Trees      | 44.768                           | 2.03                  | 90.880              | 333.226                   |
| 2   | Roadside | Herbaceous | 0.194                            | 4.79                  | 0.930               | 3.408                     |
|     |          | Litter     | 0.268                            | 4.41                  | 1.182               | 4.334                     |

3.2. Discussion
Average biomass in tree vegetation is 23.654 tons per ha and 44.768 tons per ha, 0.211 tons per ha and 0.194 tons per ha for herbaceous, and for the litter is 0.347 tons per ha and 0.268 ton/ha respectively for boulevard and roadside. The higher biomass roadside is dominated by large trees, while the boulevard consists mostly of herbaceous and litter. As Usyadi et al. [13] reported that the average biomass in Balikpapan Botanical Gardens was 203.42 tons per ha and dominated by tree biomass of 137.31 tons per ha while herbaceous biomass was 4.5 tons per ha. Other research Hardjana [14] showed that the potential of biomass in *A. mangium* stands is 159.75 tons per ha with the type of mangium which has a different potential distribution of biomass based on each tree organ. Litter in the basal area of the *Shorea macrophylla* stand has an average biomass value of 11.599 tons per ha [15].

The results of the research with similar studies have similarities in obtaining results, namely, the highest biomass is found in tree biomass. According to Chanan[16], vegetation in the form of trees with a diameter of>30 cm was the most storing biomass than herbaceous and litter. The lowest biomass is in herbaceous it occurred due to the intensity of sunlight that reaches the ground is very low due to very tight canopy closure. The low intensity of the sun's light resulted in the number of herbaceous which can grow relatively little so that the production of understory biomass at that location is low [13]. Factors that cause litter biomass have various values and tend to be higher than herbaceous biomass because of the competition to get sunlight. The denser a stand or canopy will produce more litter because trees that grow rather tightly will release branches and leaves from below so that light is not enough for photosynthesis [15].

Average C-organic content in tree vegetation is 1.30% and 2.03%, herbaceous is 6.26% and 4.79%, and litter is 4.86% and 4.41% respectively for boulevard and roadside. The value of biomass and C-organic content is stored differently in various ecosystems because it depends on the diversity and
density of existing plants, types of soil, and how to manage them [17]. The carbon content in a litter is influenced by its constituent components, namely rotten wood, leaves and twigs [18].

Base on its biomass and C-organic content, the carbon stock of trees is 30.750 tons per ha and 90.880 tons per ha, herbaceous amounted to 1.321 tons per ha and 0.930 tons per ha, and for the litter is 1.686 tons per ha and 1.182 tons per ha respectively for boulevard and roadside. The largest carbon stock is tree vegetation. Therefore, carbon stocks are strongly influenced by biomass so that anything that causes increased or reduced biomass potential will also affect carbon uptake [16]. Biomass and carbon stocks in an ecosystem are determined by the diversity and density of vegetation, soil fertility and how to manage it [19].

Sujarwo and Darma [20] studied the vegetation and estimated carbon stored in trees in the area of Mount and Lake Batur, Kintamani, Bali. In this study carbon stored in trees in the Mountain Area and Lake Batur Kintamani was 26.07 tons per 0.24 ha. Hardjana [14] showed that A. mangium stands have stored 54.70 tons per ha of carbon content or carbon stock. Carbon stock in Balikpapan Botanical Gardens on the range from 105.64 to 228.01 tons per ha, with an average carbon stock of 141.55 tons per ha [13]. This shows that carbon stocks in urban areas are lower than in forest areas because of the level of diversity, the density of vegetation, and soil fertility better than urban areas. Many factors that cause an increase in carbon potential are thinning or reducing the number of plants to give the remaining space for plants because thinning will reduce competition between trees so that the quality of growth in tree vegetation will increase the amount of carbon uptake [21]. The more stands contained in a plot, the more herbaceous or litter produced will allow greater carbon to be produced [22].

CO₂ sequestration generated on tree vegetation is 112.751 tons per ha and 333.226 tons per ha, herbaceous by 4.845 tons per ha and 3.408 tons per ha, and for the litter is 6.184 tons per ha and 4.334 tons per ha respectively for boulevard and roadside. CO₂ sequestration in the roadside was more potential than in the boulevard. CO₂ sequestration in the roadside was more potential than in the boulevard. This is inseparable from the type of vegetation in the place with the high and low carbon stocks available. Dharmawan [23] reported Rhizophora mucronata stands in Ciasem, Purwakarta has a potential above-ground biomass content of 77.2 tons per ha and above-ground carbon content of 38.6 tons per ha. Regarding above-ground biomass, the absorption value CO₂ of R. mucronata stands at 141.5 tons per ha is with an average CO₂ uptake of 0.251 tons per ha. Hardjana [14] showed that the potential of biomass in A. mangium stands is 159.75 tons per ha, with the stored carbon content of 54.70 tons per ha, while the ability of A. mangium to sequestrate CO₂ gas ranges from 40.72 to 60.08 tons per ha per year. The average CO₂ absorption potential per year shows the average annual rate of standability in absorbing CO₂ to be distributed to plant organs stored as biomass.

In line with the results of previous studies, in this study also found that, besides the tree, herbaceous also has a high CO₂ uptake which is found in the type of trumpet and areaea flower vegetation. This is because the type of vegetation is a plant which was easy to grow in environmental conditions with full sunlight intensity. Absorption of CO₂ also cannot be separated from the photosynthesis process of a plant. With photosynthesis ability, leaves from trees around UGS are able to convert CO₂ into oxygen (O₂) which is beneficial for all life around it. The absorption capacity of CO₂ in the air is certainly different for each plant, knowing that this CO₂ absorption can reduce air pollution and global warming. In addition, the ability of plants to absorb CO₂ is influenced by several factors such as temperature, sunlight, water availability, plant area, plant age, and growth phase [23]. Increased CO₂ concentrations coupled with high sunlight intensity can increase the rate of CO₂ fixation in several types of plants.

4. Conclusion
The results of this study have shown that, although the carbon content in trees is much lower than its presence in herbaceous and litter, because of the amount of biomass it has, making its potential to sink CO₂ is much higher. Therefore, the presence of trees in the UGS is very important in providing ecosystem services especially in reducing greenhouse gas emissions.
References

[1] Word Bank 2012 *Indonesia The Rise of Metropolitan Regions Toward Inclusive and Sustainable Regional Development* (Washington, DC: Word Bank) URL: http://documents.worldbank.org/curated/en/520931468269430645/pdf/717400WP00PUBL020FINAL0to0PRINTING0.pdf

[2] Nowak D J and Crane D E 2002 Carbon storage and sequestration by urban trees in the USA *Environ. Pollut.* **116** 381–9

[3] Nowak D J, Crane D E, Stevens J C, Hoehn R E, Walton J T and Bond J 2008 A ground-based method of assessing urban forest structure and ecosystem services *Arboric. Urban For.* **34** 347–58

[4] Nowak D J, Greenfield E J, Hoehn R E and Lapoint E 2013 Carbon storage and sequestration by trees in urban and community areas of the United States *Environmental Pollution* **178** 229-36

[5] Jo H-K and McPherson G E 1995 Carbon storage and flux in urban residential greenspace *Journal of Environmental Management* **45** 109–33

[6] Davies Z G, Edmondson J L, Heinemeyer A, Leake J R and Gaston K J 2011 Mapping an urban ecosystem service: quantifying above-ground carbon storage at a citywide scale *Journal of Applied Ecology* **48** 1125-34

[7] Roshetko J M, Dalaney M, Hairiah K and Purnomosidhi P 2002 Carbon stocks in Indonesian home gardens: Can smallholder system be targeted for increased carbon storage? *American Journal of Alternative Agriculture* **17** 138-48

[8] Krisdianto, Soemarno, Udiansyah and Januwiai B 2012 Standing carbon in an urban green space and its contribution to the reduction of the thermal discomfort index: a case study in the City of Banjarbaru, Indonesia *International Journal of Scientific and Research Publications* **2** 1-6

[9] Velasco E, Roth M, Tan S H, Quak M, Nabarro S D A and Norford L 2013 The role of vegetation in the CO₂ flux from a tropical urban Neighbourhood *Atmos. Chem. Phys.* **13** 10185–202

[10] Yue D, Shaobo G and Yonghong W 2013 Study on carbon storage of urban garden vegetation – A case study of Jiangnan University *Proceedings of the 2013 International Academic Workshop on Social Science* (IAW-SC 2013) 1030-4

[11] Davies Z G, Dallimer M, Edmondson J L, Leake J R and Gaston K J 2013 Identifying potential sources of variability between vegetation carbon storage estimates for urban areas *Environmental Pollution* **183** 133-42

[12] Hairiah K and Rahayu S 2007. Pengukuran karbon tersimpan di berbagai macam penggunaan lahan (Bogor: World Agroforestry Centre) pp. 77

[13] Usmadi D, Hidayat S, Yuzammi and Asikin D 2015 Potensi biomassa dan cadangan karbon kebun raya Balikpapan, Kalimantan Timur *Buletin Kebun Raya* **18** 1–14

[14] Hardjana A K 2010 Potensi biomassa dan karbon pada hutan tanaman *Acacia mangium* di HTI PT. Surya Hutani, Kalimantan Timur *Jurnal Penelitian Sosial Dan Ekonomi Kehutanan* **7** 237–49

[15] Budiman M, Hardiansyah G and Darwati H 2015 Estimasi biomassa karbon serasah dan tanah pada basal area tegakan meranti merah (*Shorea macrophylla*) di Areal Arboretum Universitas Tanjungpura Pontianak *Jurnal Hutan Lestari* **3** 98–107

[16] Chanan M 2011 Potensi karbon di atas permukaan tanah di blok perlindungan Taman Wisata Alam Gunung Baung Pasuruan – Jawa Timur *Jurnal Gambar* **6** 101-12

[17] Mandari D Z, Gunawan H and Isda M N 2016 Penaksiran biomassa dan karbon tersimpan pada ekosistem hutan mangrove di kawasan Bandar Bakau Dumai *Jurnal Riau Biologia* **1** 17–23

[18] Asril 2009 Pendugaan cadangan karbon di atas permukaan tanah rawa gambut di stasiun penelitian Suaq Balimbing Kabupaten Aceh Selatan Propinsi Nanggroe Aceh DarussalamThesis (Medan: Universitas Sumatera Utara)
[19] Widyatmoko D, Astutik S, Sulistyawati E, Rozak A H dan Mutaqien Z 2013 Stok karbon dan biomassa di Cagar Alam Biosfer Cibodas, Indonesia *Konservasi biokarbon, lanskap dan kearifan lokal untuk masa depan: integrasi pemikiran multidimensi menuju keberlanjutan* Ed. E Sukara, D Widyatmoko, S Astutik (Cianjur: UPT Balai Konservasi Tumbuhan Kebun Raya Cibodas–LIPI) pp. 98-133

[20] Sujarwo W dan Darma I D P 2011 Analisis vegetasi dan pendugaan karbon tersimpan pada pohon di kawasan sekitar Gunung dan Danau Batur Kintamani Bali *Bumi Lestari* 11 85–92

[21] Chanan M 2012 Pendugaan cadangan karbon (C) tersimpan di atas permukaan tanah pada vegetasi hutan tanaman jati (*Tectona Grandis* Linn.F) (Di RPH Sengguruh BKPH Sengguruh KPH Malang Perum Perhutani II Jawa Timur) Jurnal Gamma 7 61–73

[22] Rusdiana O dan Lubis R S 2012 Pendugaan korelasi antara karakteristik tanah terhadap cadangan karbon (carbon stock) pada hutan sekunder*Silvikultur Tropika* 3 14–21

[23] Dharmawan I W S 2010 Pendugaan biomasa karbon di atas tanah pada tegakan *Rhizophora mucronata* di Ciasem, Purwakarta *Jurnal Ilmu Pertanian Indonesia* 15 50–6