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Biomass Potential and Carbon Storage of Urban Forest of Government Office

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Abstract

One of the causes of global climate change is the increase of carbon dioxide content in the atmosphere. Trees have a role to absorb carbon dioxide (CO_2) in the atmosphere for photosynthesis. Trees absorb carbon dioxide (CO_2) through photosynthesis, which result is carbohydrate that is stored in form of biomass that contains carbon. City forest of government offices is one of areas to grow trees. Diameter of breast height was measured to find out the potential of biomass and carbon storage of trees in the city forest in the office of Governor of South Sulawesi. This measurement is conducted using census method that measured standing trees with minimum DBH of 5 cm. The results found that there are 193.71 trees per hecto are with Biomass potency is 1,436.84 tonnes which the average of biomass is 0.97 tonnes for each tree, and Carbon storage is 718.42 tonnes with the average of carbon storage is 0.49 tonnes for every tree.

Keywords: Urban forest; Biomass; Carbon storage; Diameter.

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1. Introduction

1.1. Background

In recent years, global warming and climate change have affected the whole world as an impact of the increasing of greenhouse gasses [1]. Between 1990 and 2010, global emissions from all major greenhouse gases had increased [2] Carbon dioxide gas (CO_2) is one of the major greenhouse gases [3] [4]. CO_2 at certain concentrations in the atmosphere becomes very useful, but it will have an impact on global warming if the concentration increases in the atmosphere. Urban trees provide many ecosystem services to citizens [5]. Carbon storage, in forms of trees biomass, and carbon sequestration by urban trees are the functions of urban forest [6]. Carbon is one of the constituents of carbon dioxide (CO_2). CO_2 has many functions for life on earth, one of them is the Compound which is needed for photosynthesis. During photosynthesis, CO_2 and H_2O aided by sunlight and chlorophyl from the leaves of green plants are processed to produce carbohydrates and oxygen. Urban forests with different types of constituent trees are CO_2 binders for photosynthesis and also a place to store carbon in form of trees biomass. Thus, the trees in the urban forests play a vital role in reducing the CO_2 concentration in the atmosphere. However, information of tree biomass and carbon stocks in urban forests is limited. Based on this problem, the questions in this study are how much the trees biomass and potential carbon storage in urban forest of government offices.

1.2. Objectives

The objectives of this research are to find out the potency of biomass in urban forest of government office and to calculate its carbon storage.

2. Methods

2.1. Time and Study Site

The research was conducted in the Governor's Office of South Sulawesi, Indonesia. The Office is located in Makassar City and the coordinate point 5 ° 8 '20.679 "LS and 119 ° 27' 8,701" BT. The Office, with an area of 6.2 ha, is designated as urban forest based on the Circular of Mayor of Makassar No. 522.4/19/S.Edar/BLHD/IV/2011. The study began in March 2017 until August 2017.

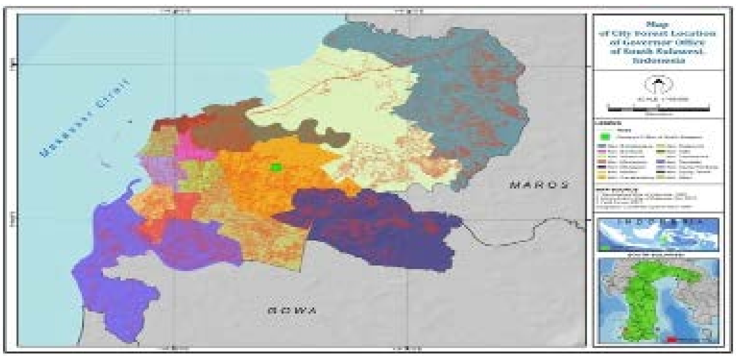

Figure 1: Location of urban forest at the office of Governor of South Sulawesi

2.2. Data Collection

Census of standing trees is the method used to observe and measure all the trees within the urban forest.A plot based on field conditions, with artificial boundaries like road or building borders, was made to facilitate the collection of data.

Observation was conducted on trees with the following criteria:

a. Small trees with growth rate of sapling, 5 cm to <10 cm of DBH and 15.7 cm to 31 cm of stem circumference.
b. Small trees with growth rate of pole, 10 cm to 29 cm of DBH and 32 cm to 91 cm of stem circumference.
c. Large trees, DBH $\geq$30cm or stem circumference $\geq$94 cm.

The collected data consists of rod circumference that was measured at DBH in cm, species of trees and the amount of trees of each species. Primary data from observation and measurement were recorded on tally sheet as shown in Table 1.

Table 1: Tally Sheet of trees observation

Plot number : ....
Date of observation : ....
Name of urban forest : ....
Location/address : ....
Sub-district/village : ....
Plot size: (20x20) m = 400 m^2 = 0.04 ha

No.	Species	Branching/Not	Circumference (cm)	Pattern and spacing	Branch – free bole length (m)	Total height (m)	Information

2.3. Data Analysis

2.3.1. Analysis of Biomass Potential

Field mensuration was established by measuring rod circumference, whilst parameter for trees biomass calculation is DBH. Data convertion from rod circumference to stem diameter was conducted to obtain DBH data. Determination of trees biomass of urban forest was using allometric equations based on the plant species [7]. Allometric equation is a function or a mathematical equation that demonstrates the relationship among particular partsor certain functions of organisms.This equation is used to predict specific parameters by using other easily measured parameters such as diameter and height [8]. No-logging nor trees destruction and more saving on time and money are the advantages of allometric equation. Allometric model that were used to estimate the aboveground biomass of urban forest in The government office of the Governor of South Sulawesi is listed in Table 2.

Table 2: Allometric model used for Aboveground Biomass Assessment of the urban forest in the Governor's Office of South Sulawesi.

No.	Equations	References
Eq. 1	$W = 0{,}118\ D^{2{,}53}$	[9]
Eq. 2	$W = 0{,}11\ \rho\ D^{2+c}$	[7]

Information:

W = biomass per tree (kg),
D = DBH (cm), ρ = wood density (g / cm3 or t / m3);
c = coefficient that describes the relationship between diameter and tree height (c = 0.62 based on

[7] on jungle in Jambi).

ρ = density of tree species. The ρvalue refers to [10,11,12,7,13]

2.3.2. Analysis of Potency of Forest Carbon Stock

Potency analysis of forest carbon stock of trees urban forest was using approach of biomass content which developed by IPCC [14]. The used general formulation is:

$$C = 0.5 \times W \qquad (1)$$

Information:

C : Carbon stocks (tC)

W : Biomass (tons)

0.5 : Coefficient of carbon content in plants

3. Results and Discussion

3.1. Composition of Tree Species in Urban Forest

The source of biomass and carbon source in urban forest are the trees that grow in it. The trees consist of various species and families. The amount of carbon contained in their trunks depend on the number of individu. Table 3 below presents the composition of tree species grown in the urban forest in the Governor's Office of South Sulawesi.

Table 3: Composition, population and tree density of urban forest of government office

No.	Species	Family	Amount of Trees	Density of tree (Individu/ha)
1	*Pterocarpus indicus*	Leguminoceae	841	135.65
2	*Mimusop elengi L.*	Sapotaceae	220	35.48
3	*Filicium decipiens* Thw.	Sapotaceae	23	3.71
4	*Manikara kauki* Dup	Sapindaceae	12	1.94
5	*Mangifera indica* L	Anacardiaceae	53	8.55
6	*Anacardium occidentale*	Anacardiaceae	1	0.16
7	*Artocarpus heterophyllus*	Anacardiaceae	3	0.48
8	*Dracontomelon dao*	Anacardiaceae	1	0.16
9	*Polyalthia longifolia* Bent & Hook. F.	Annonaceae	2	0.32

Continued Table 3.

No.	Species	Family	Amount of Trees	Density of tree (Individu/ha)
10	*Olyalthea longfolia pendula*	Annonaceae	98	14.52
11	*Ceiba pentandra*	Annonaceae	1	0.16
12	*Alstonia scholaris* (L)	Apocynaceae	2	0.32
13	*Roystonea regia*	Arecaceae	126	20.32
14	*Areca catechu*	Arecaceae	15	2.42
15	*Elaeis guineensis*	Arecaceae	21	3.39
16	*Casuaria cunninghami*	Araucariaceae	68	10.97
17	*Terminalia catappa* L.	Combretaceae	12	1.94
18	*Tamarindus indica*	Leguminoceae	1	0.16
19	*Delonix regia* Raf.	Leguminoceae	83	13.39
20	*Cassia siamea* Lamk	Leguminoceae	17	2.74
21	*Aleurites moluccana*	Euphorbiaceae	1	0.16
22	*Bambusa sp.*	Foaceae	21	3.39
23	*Vitex cofassus* Reinw	Lamiaceae	4	0.65
24	*Muntingia calabura*	Malvaceae	3	0.48
25	*Hibiscus tiliaceus*	Malvaceae	2	0.32
26	*Klenhovia hospita*	Malvaceae	6	0.97
27	*Paraserianthes falcataria*	Leguminoceae	4	0.65
28	*Acacia auriculiformis*	Leguminoceae	28	4.52
29	*Leucaena glauca*	Leguminoceae	17	2.74
30	*Samanea saman*	Leguminoceae	171	27.58
31	*Swietenia mahagoni Jacq.*	Meliaceae	31	5.00
32	*Ficus religiosa L*	Moraceae	19	3.06
33	*Artocarpus altilis*	Moraceae	12	1.94
34	*Ficus benyamin L.*	Moraceae	19	3.06
35	*Averrhoa bilimbi* L.	Oxalidaceae	4	0.65
36	*Pinus merkusii*	Pinaceae	5	0.81
37	*Morinda citrifolia*	Rubiaceae	2	0.32
38	*Citrus maxima Merr*	Rutaceae	1	0.16
39	*Gmelina arborea*	Verbenaceae	3	0.48
	Jumlah		**1,953**	**313.71**

Table 3 shows there are 39 species out of 20 families of trees growing inthe urban forest of government offices. The population is 1,953 trees with a density of 313.71 or 314 trees per hectare. There are seven species of trees that have the largest population as shown in Figure 2 below.

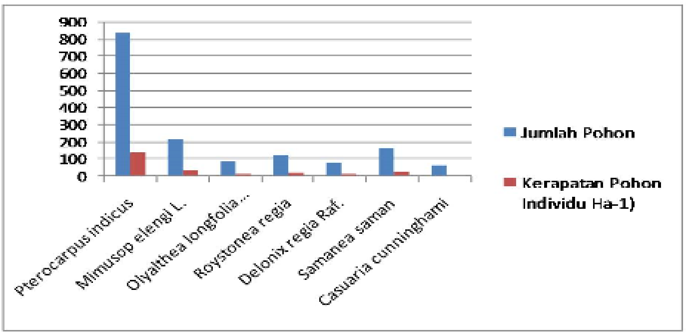

Figure 2: Seven species of trees with the highest population and density

The highest number of tree species is Pterocarpus indicus with total population of 841 trees, followed by *Mimusop elengi* L. and the third is *Samanea saman* with total population of 220 trees and 171 trees respectively. These tree species are the ones that produce biomass in urban forest of government offices.

Figure 3: Situation map of urban forest of office of Governor of South Sulawesi

Here is a histogram that illustrates tree species in each diameter class.

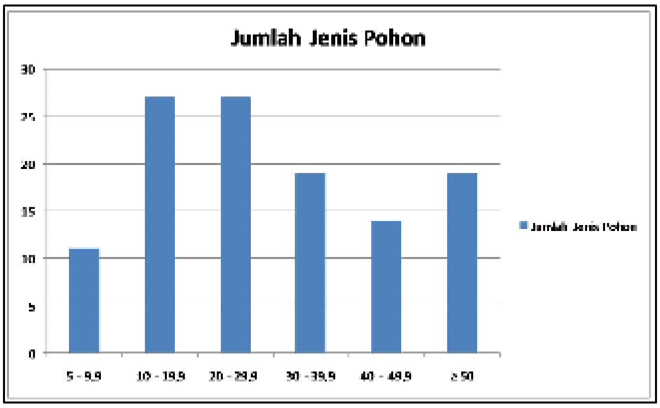

Figure 4: Number of tree species based on class of diameter

Figure 4 displays that the diameter class that has the largest number of tree species is the diameter class of 10 cm - 19.9 cm and 20 cm - 29.9 cm with 27 tree species. The diameter class that has the lowest number of tree species is the diameter class 5 cm - 9.9 cm with as many as 11 tree species. It also shows that there are 28 species of trees that do not have trees in the diameter class of 5 cm - 9.9 cm.

In addition to the presence of tree species in the diameter class above, then it is also important to notice the number of population of tree species in each diameter class. Figure 5 below presents data on the population of tree species in each diameter class.

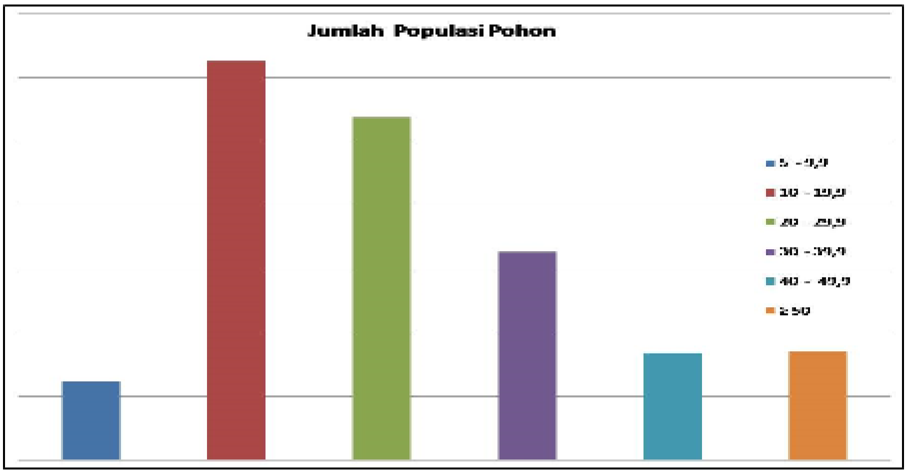

Figure 5: Number of tree populations based on class of diameter

Similar to the number of tree species in each diameter class, the largest number of tree populations is in the diameter class of 10 cm - 19.9 cm. But, the smallest is in the class of diameter 5 cm - 9.9 cm. Hence, , it is necessary to plant enrichment crops to maintain the composition and structure of trees in the urban forest, so that the population and number of tree species in the lowest diameter class can increase. A good tree structure is when a tree species can be found in all diameter classes. A goodcompotition of tree species when in one class of diameter there are all tree species.

3.2. Potential of Tree Biomass

Tree biomass is calculated based on the DBH and density of each species. Different species will have different amount of biomass. Table 4 presents the biomass potential of trees grown in urban forest of government offices.

Table 4 shows the total potential of tree biomass in urban forest of government offices is 1,436,838,9401 kg or 1,436,8389 tons of biomass. This biomass derives from 39 tree species and 1,953 individual trees. The average biomass is 0.7357 tons per tree. The histogram of the six tree species that have the largest biomass in the Urban Forest of Government Office is illustrated in Figure 6.

Table 4: Potential biomass in urban forest of government offices

No.	Species	Family
1	*Pterocarpus indicus*	841
2	*Mimusop elengi L.*	220
3	*Mangifera indica* L	53
4	*Olyalthea longfolia pendula*	90
5	*Roystonea regia*	126
6	*Delonix regia* Raf.	83
7	*Samanea saman*	171
8	*Pterocarpus indicus*	841
9	*Mimusop elengi L.*	220
10	*Mangifera indica* L	53

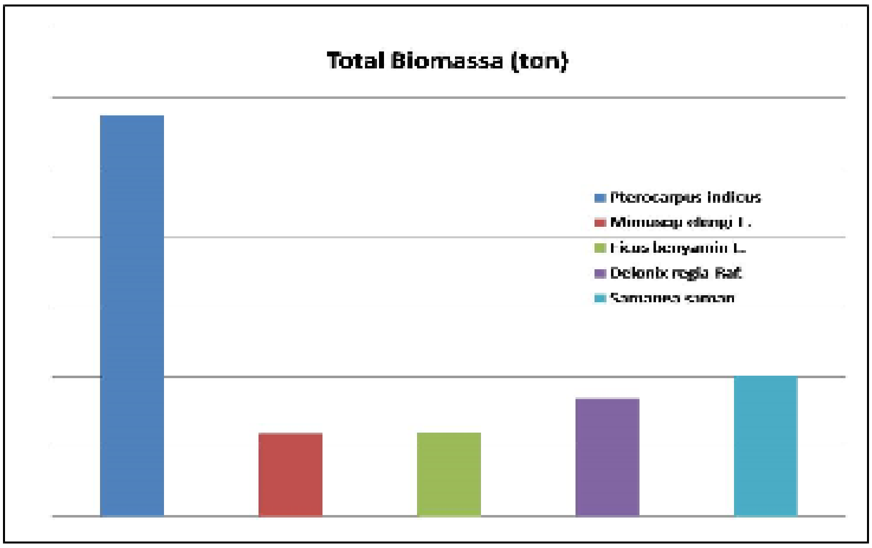

Figure 6: Six species that have the largest biomass

Figure 6 demonstrates that *Pterocarpus indicus* has the highest biomass potential, which is 574,4303 tons followed by *Samanea saman* with biomass potential as much as 201,5016 tons and the third is *Delonix regia* Raf. with biomass potential of 168.6139 tons.

The size of the biomass potential of a tree species is determined by the number of individuals and the dbh of the species.

Table 5 below shows the average dbh that become the base of biomass calculation.

Table 5: Mean of Biomass Potential and Mean of Tree diameter at Urban Forest of Government Office

No.	Species	Average of Diameter (cm)	Average of biomass potential per tree (ton)
1	*Pterocarpus indicus*	27,26	0,68
2	*Mimusop elengi L.*	22,63	0,54
3	*Filicium decipiens* Thw.	19,98	0,27
4	*Manikara kauki* Dup	21,92	0,30
5	*Mangifera indica* L	22,17	0,61
6	*Anacardium occidentale*	26,11	0,04
7	*Artocarpus heterophyllus*	22,08	0,36
8	*Dracontomelon dao*	15,29	0,08
9	*Polyalthia longifolia* Bent & Hook. F.	22,93	0,33
10	*Olyalthea longfolia pendula*	12,46	0,10
11	*Ceiba pentandra*	84,08	8,74
12	*Alstonia scholaris* (L)	37,10	0,56
13	*Roystonea regia*	29,47	0,21
14	*Areca catechu*	14,93	0,10
15	*Elaeis guineensis*	58,60	0,15
16	*Casuaria cunninghami*	11,61	0,07
17	*Terminalia catappa* L.	41,75	1,58

Continued Table 5.

No.	Species	Average of Diameter (cm)	Average of biomass potential per tree (ton)
18	*Tamarindus indica*	17,83	0,17
19	*Delonix regia* Raf.	42,16	2,03
20	*Cassia siamea* Lamk	36,44	1,63
21	*Aleurites moluccana*	15,61	0,12
22	*Bambusa sp.*	12,14	0,39
23	*Vitex cofassus* Reinw	31,53	0,96
24	*Muntingia calabura*	15,92	0,17
25	*Hibiscus tiliaceus*	54,30	2,89
26	*Klenhovia hospita*	23,89	0,30
27	*Paraserianthes falcataria*	45,06	1,04
28	*Acacia auriculiformis*	29,16	0,81
29	*Leucaena glauca*	22,52	0,66
30	*Samanea saman*	37,75	1,18
31	*Swietenia mahagoni Jacq.*	29,00	0,74
32	*Ficus religiosa L*	18,82	0,23
33	*Artocarpus altilis*	40,21	0,79
34	*Ficus benyamin L.*	46,88	6,32
35	*Averrhoa bilimbi* L.	34,79	1,31
36	*Pinus merkusii*	31,91	0,84
37	*Morinda citrifolia*	25,00	0,41
38	*Citrus maxima Merr*	8,28	0,02
39	*Gmelina arborea*	25,48	0,25
	Average	**29,10**	**0,97**

Table 5 shows the average variation of DBH of trees in urban forest of government offices. *Citrus maxima* Merr has the smallest diameter of 8.28 cm, while the largest diameter is *Ceiba pentandra* with 84.08 cm of diameter. Similarly, the average potential for biomass is also vary. *Ceiba pentandra* has the largest average biomass potential per tree by 8.74 tons per individual while *Citrus maxima* Merr has the smallest potential biomass by

0.02 tons per tree.

3.3. Trees Carbon Stock

Trees absorb carbon from the atmosphere as they grow, store it in leaves, wood tissue, roots and organic matter in the soil [15]. Carbon absorbed by trees from the atmosphere in the form of CO_2 gas along with water becomes the raw material in the process of photosynthesis. Photosynthesis results in the form of carbohydrates, which make up the biomass, where the carbon stored in the tree. Quantification of carbon absorbed in urban trees provides an estimated offset of carbon emissions [5]. The following Table 6 presents the carbon stored in each tree species in the urban forest.

Table 6: Carbon stock of each tree species in urban Forest of Government Offices

No.	Species	C stock of tree (kg)	C stock of tree (ton)
1	*Pterocarpus indicus*	287.215,17	287,22
2	*Mimusop elengi L.*	59.550,10	59,55
3	*Filicium decipiens* Thw.	3.139,75	3,14
4	*Manikara kauki* Dup	1.829,88	1,83
5	*Mangifera indica* L	16.251,75	16,25
6	*Anacardium occidentale*	19,99	0,02
7	*Artocarpus heterophyllus*	547,30	0,55
8	*Dracontomelon dao*	40,43	0,04
9	*Polyalthia longifolia* Bent & Hook. F.	334,73	0,33
10	*Olyalthea longfolia pendula*	5.025,19	5,03
11	*Ceiba pentandra*	4.367,95	4,37
12	*Alstonia scholaris* (L)	563,76	0,56
13	*Roystonea regia*	13.227,32	13,23
14	*Areca catechu*	759,06	0,76
15	*Elaeis guineensis*	1.611,70	1,61
16	*Casuaria cunninghami*	2.347,57	2,35
17	*Terminalia catappa* L.	9.486,02	9,49
18	*Tamarindus indica*	86,40	0,09
19	*Delonix regia* Raf.	84.306,94	84,31
20	*Cassia siamea* Lamk	13.835,83	13,84
21	*Aleurites moluccana*	61,63	0,06
22	*Bambusa sp.*	4.049,39	4,05
23	*Vitex cofassus* Reinw	1.916,53	1,92
24	*Muntingia calabura*	252,95	0,25
25	*Hibiscus tiliaceus*	2.892,46	2,89
26	*Klenhovia hospita*	913,23	0,91
27	*Paraserianthes falcataria*	2.074,86	2,07
28	*Acacia auriculiformis*	11.379,71	11,38
29	*Leucaena glauca*	5.636,28	5,64
30	*Samanea saman*	100.750,82	100,75
31	*Swietenia mahagoni Jacq.*	11.502,27	11,50
32	*Ficus religiosa L*	2.194,85	2,19
33	*Artocarpus altilis*	4.737,02	4,74
34	*Ficus benyamin L.*	60.010,58	60,01
35	*Averrhoa bilimbi* L.	2.612,09	2,61
36	*Pinus merkusii*	2.092,13	2,09
37	*Morinda citrifolia*	408,72	0,41
38	*Citrus maxima Merr*	12,40	0,01
39	*Gmelina arborea*	374,73	0,37
	Total	**718.419,47**	**718,42**

Estimation of carbon stocks are strongly correlated with biomass estimation, but carbon content is relatively varied across species [16]. Table 6 shows that there are 39 tree species with a population of 1,953 individual trees, containing 718,419.47 kg or 718.42 tons of carbon. The largest carbon stocksfound in *Pterocarpus indicus*, which amounted to 287.22 tons. The lowest carbon stocksfoundin the *Citrus maxima* Merr with 0.01 tons per individual.

Below is the data on average tree diameter and average carbon stocks of the trees. The data are presented in Table 7.

Table 7: Average Diameter of Trees and Mean of Carbon Trees at Urban Forest of Government Offices

No.	Species	Average of diameter (cm)	Average of C stock per tree (ton)
1	*Pterocarpus indicus*	27,26	0,34
2	*Mimusop elengi L.*	22,63	0,27
3	*Filicium decipiens* Thw.	19,98	0,14
4	*Manikara kauki* Dup	21,92	0,15
5	*Mangifera indica* L	22,17	0,31
6	*Anacardium occidentale*	26,11	0,02
7	*Artocarpus heterophyllus*	22,08	0,18
8	*Dracontomelon dao*	15,29	0,04
9	*Polyalthia longifolia* Bent & Hook. F.	22,93	0,17
10	*Olyalthea longfolia pendula*	12,46	0,05
11	*Ceiba pentandra*	84,08	4,37
12	*Alstonia scholaris* (L)	37,10	0,28
13	*Roystonea regia*	29,47	0,10
14	*Areca catechu*	14,93	0,05
15	*Elaeis guineensis*	58,60	0,08
16	*Casuaria cunninghami*	11,61	0,03
17	*Terminalia catappa* L.	41,75	0,79
18	*Tamarindus indica*	17,83	0,09
19	*Delonix regia* Raf.	42,16	1,02
20	*Cassia siamea* Lamk	36,44	0,81
21	*Aleurites moluccana*	15,61	0,06
22	*Bambusa sp.*	12,14	0,19
23	*Vitex cofassus* Reinw	31,53	0,48
24	*Muntingia calabura*	15,92	0,08
25	*Hibiscus tiliaceus*	54,30	1,45
26	*Klenhovia hospita*	23,89	0,15
27	*Paraserianthes falcataria*	45,06	0,52
28	*Acacia auriculiformis*	29,16	0,41
29	*Leucaena glauca*	22,52	0,33
30	*Samanea saman*	37,75	0,59
31	*Swietenia mahagoni Jacq.*	29,00	0,37
32	*Ficus religiosa L*	18,82	0,12
33	*Artocarpus altilis*	40,21	0,39
34	*Ficus benyamin L.*	46,88	3,16
35	*Averrhoa bilimbi* L.	34,79	0,65
36	*Pinus merkusii*	31,91	0,42
37	*Morinda citrifolia*	25,00	0,20
38	*Citrus maxima Merr*	8,28	0,01
39	*Gmelina arborea*	25,48	0,12
	Average	**29,10**	**0,49**

Carbon per unit of tree varies in urban forest based on variation in tree density, tree size distribution, and species composition [6]. Table 7 displays that the average diameter of all tree species is 29.10 cm and the average stock of carbon is 0.49 tons. The largest average diameter is*Ceiba pentandra* with 84.08 cm diameter that has 4.37 tons of carbon stocks, while the smallest average diameter is *Citrus maxima* Merr with diameter 8.28 cm andhas an average carbon stock of 0, 01 tons.

The biomass potential and carbon stock of a tree stand in the urban forest is determined by the tree population and the DBH. It can be seen in Table 8 and Table 9.

Table 8: Five species of Trees that have the largest Total Biomass and C stocks in Urban Forest of Government Offices

No.	Species	Total Biomass (ton)	C stock (ton)	Number of tree (individu)
1	*Pterocarpus indicus*	574,43	287,22	841
2	*Mimusop elengi L.*	119,10	59,55	220
3	*Delonix regia* Raf.	168,61	84,31	83
4	*Samanea saman*	201,50	100,75	171
5	*Ficus benyamin L.*	120,02	60,01	19

Five species that have the greatest biomass potential and carbon stocks in the Urban Forest of Government Office in Table 8 have large populations. *Pterocarpus indicus* has the largest tree population of 841 individuals, which has the largest biomass and carbon stocks of 574.43 tons and 287.22 tons respectively. Similarly, *Mimusop elengi* L., *Samanea saman*, *Delonix regia* Raf. and *Ficus benyamin* L., indicate that the higher the population, the greater the potential biomass it has.

Table 9: Five species with Average C stocks and Average Largest Diameter in Urban Forest of Government Offices

No.	Species	Average of C stock per tree (ton/individu)	Average of diameter (cm)
1	*Ficus benyamin L.*	3,1585	46,8823
2	*Ceiba pentandra*	4,3680	84,0764
3	*Delonix regia* Raf.	1,0157	42,1648
4	*Hibiscus tiliaceus*	1,4462	54,2994
5	*Terminalia catappa* L.	0,7905	41,7463

C stock of each tree is determined by the dbh of the tree. Table 10 shows that trees with large diameter will have large carbon stores, and vice versa. If the diameter is small, then the C stock is also small.

Ceiba pentandra has a large diameter of 84.0764 cm, so it has a large carbon store which is 4.3680 tons perindividu. On the contrary, *Terminalia catappa* L., has the smallest diameter that is 41.7463 cm and carbon storage of 0.7905 tons perindividu. Hence, It can be said that the larger the DBH, the greater the C stock. Furthermore, a Histogram showing five species of trees with the largest Biomass, carbon stores and number of trees can be seen in Figure 7.

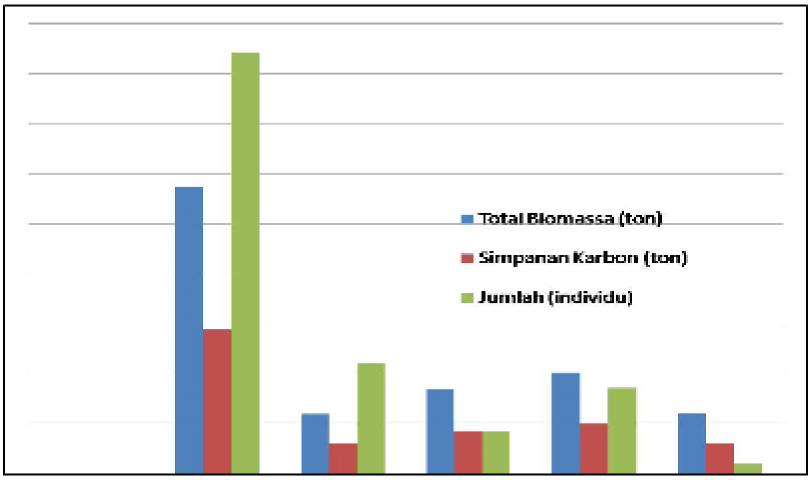

Figure 7: Histogram of Five species of Trees with the largest Biomass, C stock and trees Number.

4. Conclusions and Recommendations

4.1. Conclusions

Based on the results of research and discussions, it can be concluded that:

1. There are 39 species and 20 families of tree species in the Urban forest, with a population of 1,953 individuals and a density of 313.71 trees per hectare.

2. Biomass potential in urban forest is 1,436.84 tons, with average potential for biomass of each tree species is 0.97 tons.

3. Carbon stocks in urban forests is 718.42 tons, with an average of 0.49 tons per species.

4.2. Recommendations

Based on the description on the discussions and conclusions, it is recommended:

1. To enhance plants to maintain and increase the amount of biomass potential and carbon stocks.

2. Planting of crops is conducted by increasing variation of tree species to enhance the variety of species.

by addition of various types of trees, thus the greater variety of tree species.

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