PLANT POTENTIAL OF GREEN AND OPEN SPACE PREPARATION (RTH) TO MITIGATE CO₂ GAS EMISSION IN AMBON**POTENSI TUMBUHAN PENYUSUNAN RUANG TERBUKA HIJAU (RTH) KOTA AMBON DALAM MITIGASI EMISI GAS CO₂**Frenly Marvi Selanno^{1)*}, Ris Hadi Purwanto¹⁾, Probo Santoso²⁾

Received : June, 1 2021

Accepted : July, 14 2021

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How to cite:Selano, FM, RH Purwanto, P Santoso. 2021. Plant potential of green and open space preparation (RTH) to mitigate CO₂ gas emission in Ambon. *Journal of Tropical Biology* 9 (3): 178-184.**ABSTRACT**

The urbanization rate may give an adverse effect on a city. For example, it accrues the number of urban dwellers and induces the exploitation of land resources with a quick conversion rate, which leads to the degradation of the quality of the environment. This condition is exacerbated by deescalated green and open spaces (RTH) as a CO₂ absorber. CO₂ emissions in urban regions can be mitigated by exerting trees, which have a pivotal role in carbon uptake. This research imparts an analysis of plant species that are potential for absorbing carbon and storing biomass in green and open spaces in Ambon. The research method is quantitative by estimating biomass and carbon uptake of trees. Results indicate that trembesi (*Samanea saman*), linggua (*Pterocarpus indicus*), mahoni (*Swietenia macrophylla*), bintanggaur (*Calophyllum inophyllum*), and kerai payung (*Filicium decipiens*) are typical trees planted in Ambon. The highest CO₂ uptake capacity ($B = 110.95 \text{ tons/ha}$, $\text{CO}_2 = 191.38 \text{ tons/ha}$) is identified in Trembesi (*Samanea saman*), linggua (*Pterocarpus indicus*), the second-highest with a $B = 61.66 \text{ tons/ha}$ and $\text{CO}_2 = 106.36 \text{ tons/ha}$, and Akasia (*Acacia mangium*), the third-highest with a $B = 25.24 \text{ tons/ha}$ and $\text{CO}_2 = 41.69 \text{ tons/ha}$.

Keywords: CO₂ gas mitigation, gas emission, open and green space**ABSTRAK**

Laju urbanisasi dapat memberikan dampak yang negatif pada suatu kota, dampak tersebut adalah meningkatnya jumlah penduduk perkotaan yang menyebabkan semakin banyaknya pemanfaatan sumber daya lahan dengan laju konversi yang sangat cepat, sehingga berimplikasi pada penurunan kualitas lingkungan. Kondisi ini diperparah dengan berkurangnya Ruang Terbuka Hijau (RTH) yang berfungsi sebagai penyerap gas CO₂. Mitigasi emisi gas CO₂ dapat dilakukan dengan memanfaatkan keberadaan pepohonan di perkotaan yang memiliki peran penting sebagai penyerap karbon. Penelitian ini bertujuan untuk mengetahui potensi jenis-jenis tumbuhan dalam menyerap karbon dan simpanan biomassa di RTH Kota Ambon. Metode penelitian menggunakan metode kuantitatif dengan menghitung biomassa dan serapan karbon pada pohon. Hasil penelitian menunjukkan pohon trembesi (*Samanea saman*), linggua (*Pterocarpus indicus*), mahoni (*Swietenia macrophylla*), bintanggaur (*Calophyllum inophyllum*), dan kerai payung (*Filicium decipiens*) merupakan jenis pohon penyusun RTH yang umum ditanam di Kota Ambon. Kemampuan penyerapan CO₂ tertinggi tercatat pada jenis trembesi (*Samanea saman*) sebesar ($B=110,95 \text{ ton/ha}$; $\text{CO}_2 \text{ } 191,38 \text{ ton/ha}$), diikuti linggua (*Pterocarpus indicus*) sebesar ($B=61,66 \text{ ton/ha}$; $106,36 \text{ ton/ha}$), dan akasia (*Acacia mangium*) sebesar ($B=25,24 \text{ ton/ha}$, $\text{CO}_2 = 41,69 \text{ ton/ha}$).

Kata kunci: emisi gas, mitigasi gas CO₂, RTH**INTRODUCTION**

Cities come with specific characteristics and are regarded as a center of different activities, e.g., governance, trading, education, residential, and others. Additionally, cities are known for their exceptionally high intensity for activities, and their inhabitants' livelihood, built on trading and service sectors instead of agricultural ones [1]. Administrative borders of city areas are governed by regulations [2]. Cities are established to cater to the need of the citizenry. Hence, cities are always demanded burgeon.

City development is commonly boosted by the process of urbanization. Many factors affect this process, one of which is providing facilities with adequate numbers and quality. It drives more people to come to cities. They may live in cities permanently (inhabitants), but some may prefer a temporary one; this brings on an increase in the urban population.

That increase will undoubtedly cause a higher use of land resources at a faster conversion rate, engendering environmental quality degradation. It conforms with the statement [3], arguing that

environmental quality degradation is generated by human activities (anthropogenic) in changing land uses. Also, that degradation may be generated by environmental pollutants, such as motor vehicles and ever-growing industries [4]. Consequently, urban environmental conditions grow adversely, turning the environment into an unhealthy residence.

In an unhealthy or polluted environment, there are most likely greenhouse gas emissions, namely carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and three industrial gases containing fluorine (HFC, PFC, and SF₆). Increased greenhouse gas emissions may lead to climate changes [5]. However, climate changes, albeit relatively small and slow, induce varied harmful impacts, e.g., global warming, loss of biodiversity, erosion, floods, sea-level rise, depletion of the ozone layer, and air and water pollution.

The impacts of climate change, among which are sea level rises, hurricanes, coastal erosion, and increased land subsidence, are prevalent in coastal areas and small islands in Indonesia [6]. Ambon is an island in Maluku and belongs to the most imperiled areas by climate changes, located between the Eurasian and Pacific Plates. The capital city of Maluku, Ambon, comes with high proneness and sensitivity to the effects of climate change. Considering those diverse negative impacts, the Ambon Government, in its spatial planning, invariably pays attention to climate change and environmental aspects. In addition, the Ambon Government is persistent in optimizing green and open space arrangement programs in urban areas.

The attempts are considered effective given that green and open spaces in urban areas can produce oxygen (O₂) and absorb carbon dioxide (CO₂) and other greenhouse gases through photosynthesis. The green and open space capability in absorbing or storing carbons (carbon sinks) are elucidated in research [7], which contends that leaves from the urban forest plant species in Kupang can absorb CO₂ by 1.31 tons/year. Another research by [8] figures out that the CO₂ uptake of the leaves from the urban plant species by the roadsides in Vadodara, India is 73.59 tons/year. Besides the two research, another one explains the ability of green and open spaces in minimizing climate change impacts. For instance, research by [9] posits that green and open spaces can reduce rising temperatures in urban areas, whereas research by [10] clarifies that green and open spaces can mitigate the risk of floods. Thus, the research exhibits the significance of green and open spaces, thereby reminding us to maintain and sustain their quality and quantity.

Supposedly maintained, green and open spaces in Ambon are now in jeopardy due to minimum supervision, continuous facility and infrastructure construction, and an elevated number of pollutant sources in Ambon. The Maluku Greenhouse Gas (GRK) Inventory report in 2016 manifests that of the total greenhouse gas emissions in Maluku, i.e., 6,667,740-ton CO₂ equivalent, Ambon is ranked first to contribute to the emissions. This condition detracts the quality of the environment in Ambon. If it continues, the urban society's sustainability there will be seriously threatened. Accordingly, an examination of CO₂ gas uptake and plant species sustaining green and open spaces in Ambon is seminal and foreseeable to be a recommendation and evaluation for the Ambon Government in spatial planning, fostering the government to be more concerned about green and open spaces. The examination result is also expected to induce community awareness of the cruciality of the trees in CO₂ gas emission uptake.

METHODS

This research uses a descriptive-quantitative method, finding answers to the problem examined by defining a condition of the object investigated based on empirical facts quantitatively. The research areas are green and open urban spaces in Ambon. Data were collected in four months, starting from December 2018-March 2019. The research instruments are a map of the distribution of green and open urban spaces in Ambon, Garmin GPSMAP 78s, phiband, and hagameter. Data are collected using an inventory method in green and open spaces in Ambon.

Data collection method. Data deployed here are both primary and secondary. Primary data are collected using the vegetation census approach and purposive sampling. A vegetation analysis by census or 100% sampling intensity is carried out for green and open spaces in the form of lanes. Meanwhile, for green and open spaces in the form of clusters, we conduct a vegetation analysis using purposive sampling by placing several measuring plots in the size of 20 × 20 m systematically. Data collected are vegetation data, namely the species, diameter, and height of trees, which are then analyzed using allometric equations. Tree physical measurement is also executed to collect data and information as follows:

a. Trunk diameter

The Diameter at Breast High (DBH) measurement is executed at the height of 130 cm from the ground using a phi band.

b. Tree height

Tree height is measured using a hagameter.

Figure 1. Map of open space area (RTH) in Ambon City

c. Tree identification

This activity is performed to identify the tree species and their Latin names.

Moreover, secondary data are collected from literature studies of the number of inhabitants and the distribution of green and open spaces in Ambon.

Data analysis

Estimating above-ground biomass

Above-ground biomass is estimated using a non-destructive sampling method based on plant inventory data with a criterion of the diameter at breast height (DBH) of ≥ 10 cm. The plant inventory data are analyzed using the formula of $Biomass_{stands} = BV \times BEF_{stands}$ [11]. BV is the product of multiplying the trunk volume (m^3/ha) to wood density (ton/m^3). If BV is higher than 190 tons/ha, a BEF of 1.74 can be applied [12] (Brown, 1997). However, if BV is smaller than 190 tons/ha, BEF can be acquired using this equation, developed by Brown dan Lugo (1984), i.e., $BEF_{stands} = \exp \{3.213 - |0.506 \times \ln (BV)\}$.

Estimating carbon

Carbon content was estimated using equation [13]:

$$Wtc = Wt \times \%C$$

Wtc is carbon weight in ton/ha. Meanwhile, %C is a plant carbon fraction at a value of 0.47 (a default value from IPCC Guidelines) for the plant species unavailable on the list of the carbon fraction of

plant species in Indonesia. Several plant species, e.g., rainbow eucalyptus (*Eucalyptus deglupta*) and acacia (*Acacia mangium*), come with a carbon fraction of 0.45 [14].

Estimating CO_2 uptake

CO_2 uptake is estimated using the following equation.

$$WCO_2 = Wtc \times 3.67$$

WCO_2 is the amount of CO_2 uptake in ton/ha. Moreover, 3.67, acquired from the ratio of the relative atomic mass of C (12) to the relative molecular mass of CO_2 (44), is the conversion constant of the element carbon to CO_2 .

RESULTS AND DISCUSSION

The ever-increasingly rapid development of Ambon was influenced by varying factors, one of which was its status as the capital city of Maluku and as the National Activity Center (PKN) in Maluku. A thriving city was attractive, hence boosting the population growth rate and urbanization rate [15]. Predicated on the 2018 data from Statistics Indonesia in Ambon, in 2017, Ambon was inhabited by 444,956 people, which was higher than that in 2016.

A growing population affected an increasing number of activities, inducing environmental quality degradation [16]. As a result, our healthy environment turned into an unhealthy one because of overburdened nature, which now had to bear environmental issues beyond its capacities, such as

surplus accumulated heavy metals in soil and unduly high greenhouse gas concentration in the air [17].

A standardized need for green and open spaces predicated on the population size and following Regulation of the Minister of Public Works Number 05/PRT/M/2008 was 20m²/capita. In the 2018 data from Statistics Indonesia in Ambon, 444,956 people were registered as Ambon inhabitants in 2017, and therefore, Ambon called for green and open spaces of 889.9 Ha in that year. The need of Ambon for green and open spaces, based on Regulation of the Minister of Public Works Number 5/PRT/M/2008, was manifested in Table 1.

The need for green and open spaces in Ambon, based on the population size in 2017, was 889.91 Ha. If we investigated the ratio of the need for green and open spaces based on the population size (889.91 Ha) to the existed green and open spaces in Ambon (554.81 Ha), it was easy to conclude that the existed green and open spaces in Ambon did not cater to the estimated need per capita. Accordingly, we should enhance the spaces to fulfill the need. Minimum spaces allocated to green and open space development in Ambon due to its increasing population and rapid infrastructure development drive the Ambon government to find the best solutions, one of which was green open space planning for sustainable development [19]. Green open space planning was expected to maximize the function of green open space, which contributes to improving air quality conditions through photosynthesis by absorbing air pollutants [20]. Reduction of CO₂ content in the air was made by absorbing CO₂ and storing it as carbon in plant tissues. The process of carbon hoarding in the body of living plants (biomass) on land could describe the amount of CO₂ in the atmosphere absorbed by plants [21].

Green and open spaces in urban areas functioned as both city space infills and city ecosystem balance controllers, manifesting proper ecological function continuity. In addition to ecological functions, green and open spaces had other functions, such as social, economic, and aesthetic [22]. Those different functions should be

wisely taken care of to realize sustainable green and open space management.

Based on their use, green and open spaces were classified into two, namely passive and active green and open spaces [23,24]. Passive green and open spaces, i.e., green enclaves, reservoirs, cemeteries, artificial forests, riverside forestation, and airports, were open spaces built to sustain the local ecosystem with relatively small activities of humans. In contrast, active green and open spaces were commonly used by people to do activities, and therefore were more efficient. Among active green and open spaces were city parks, camping grounds, floral city parks, recreational parks, sports fields, zoos, and others.

Our inventory activities were carried out in active green and open spaces in urban areas of Ambon, observing the growth characteristics of plants supporting the spaces. The characteristics studies were the diameter at breast height, height, tree density, and basal areas. Data from these activities were analyzed using some assumptions commonly applied to estimate biomass storage, carbon content, and carbon uptake of each of the plant species supporting a green and open space.

Recapitulation of the data of inventory, estimated biomass storage, and carbon uptake of each plant species supporting active green and open spaces in urban areas was pointed out in Table 2.

As pointed in Table 2, the total biomass in green and open spaces in Ambon was 347.91 tons/ha, which was considered lower than the total biomass and carbon uptake in green and open spaces in Sleman and those in Polewali, with 540.20 tons/ha and 571.83 tons/ha [25,26]. The various biomass was largely influenced by types/characteristics of green and open spaces in each region, e.g., types and dimensions of trees, the composition of stands, and areas of green and open spaces. It was also affected by vegetation density and weight distribution of the vegetation, wherein the use of the land comprising trees belonging to species with a high wood density, the biomass would be higher than that on the land where species with low wood density grow [27].

Table 1. Need for green and open spaces by regulation of the Minister of Public Works number 5/PRT/M/2008

No.	Subdistrict	Number of inhabitants (person)		Need for Green and Open Space (Ha)	
		2016	2017	2016	2017
1	Nusaniwe	112.510	113.355	225.02	226.71
2	Sirimau	178.611	183.297	357.22	366.59
3	T.A. Baguala	73.644	81.627	147.29	163.25
4	Teluk Ambon	51.307	55.098	102.61	110.20
5	Leitimur Selatan	11.862	12.101	23.72	24.20
	Ambon	427.934	444.956	855.87	889.91

Source: Processed data from Statistics Indonesia, 2018

Table 2. Recapitulation of inventory data, biomass storage, and carbon uptake of each plant species supporting active green and open spaces in urban areas of Ambon

No.	Species	Mean per Ha			
		BV (tons)	TB (tons)	CO ₂ (tons)	N (%)
1	<i>Samanea saman</i>	20.668	110.956	191.387	74.33
2	<i>Pterocarpus indicus</i>	6.293	61.662	106.361	12.05
3	<i>Mimusops elengi</i>	0.156	9.938	17.142	0.75
4	<i>Delonix regia</i>	0.311	13.950	24.063	1.32
5	<i>Swietenia macrophylla</i>	0.549	18.484	31.883	3.39
6	<i>Filicium decipiens</i>	0.812	22.419	38.671	1.69
7	<i>Lagerstroemia speciosa</i>	0.151	9.779	16.867	1.19
8	<i>Ficus benyamina</i>	0.052	5.768	9.949	0.50
9	<i>Eucalyptus deglupta</i>	0.581	19.009	31.394	1.00
10	<i>Tamarindus indica</i>	0.010	2.568	4.430	0.06
11	<i>Mangifera indica</i>	0.027	4.206	7.256	0.19
12	<i>Ceiba pentandra</i>	0.008	2.295	3.959	0.06
13	<i>Canarium indicum</i>	0.013	2.869	4.949	0.13
14	<i>Pometia pinnata</i>	0.009	2.393	4.127	0.06
15	<i>Artocarpus heterophyllus</i>	0.006	1.913	3.300	0.06
16	<i>Acacia mangium</i>	1.032	25.246	41.694	0.69
17	<i>Syzygium cordatum</i>	0.290	13.477	23.247	0.19
18	<i>Calophyllum inophyllum</i>	0.555	18.586	32.058	2.26
19	<i>Intsia bijuga</i>	0.009	2.398	4.136	0.06
Total		2.799	347.91	596.87	100

Figure 2. Biomass storage and carbon uptake of each plant species supporting active green and open spaces in urban areas of Ambon

The result of the biomass and carbon (CO₂) uptake estimation was the total accumulation of biomass and carbon uptake of each plant species supporting green and open spaces in Ambon. Biomass and carbon uptake of each plant species supporting green and open spaces in Ambon are presented in Figure 2.

Figure 2 showed the biomass storage and carbon uptake of each plant species supporting green and open spaces in urban areas of Ambon. The predominating plant species, by the number of individuals, are trembesi (*S. Saman*), lingua (*P.*

indicus), mahoni (*S. macrophylla*), bintanggur (*C. inophyllum*), and kerai payung (*F. decipiens*). Meanwhile, three plant species which contributed to biomass storage and carbon uptake were trembesi (*S. saman*) (B = 110.956 tons/ha, C = 191.387 tons/ha), lingua (*P. indicus*) (B = 61.662 tons/ha, C = 106.361 tons/ha), and akasia (*A. mangium*) (B = 25.246 tons/ha, C = 41.694 tons/ha). The three plant species were also found many in the green and open space of Universitas Tanjungpura and that in Pontianak [29,30], because they were known for being prohibitively

beneficial. Trembesi and linggua served as a road shade tree for they can stand for decades, resist pests and diseases, grow tall owing to a strong wooden structure, grow straight up with a high canopy above the height of vehicles [30].

Biomass storage and carbon uptake of the three plant species (trembesi, linggua, and akasia) supporting green and open spaces in Ambon came with a high score since they were mainly planted as green spaces infill in city parks. Biomass storage and carbon uptake were also affected by the number, dominating species, climate, and vegetation habitat [27,31,32]. Another study clarified that the age factor impacts estimated biomass and carbon uptake [32]. Biomass and carbon content stored in a tree would elevate when trunk dimensions (diameter and height) grew. This showcased a linear relationship between trunk diameter and height [33]. Trees with a large diameter might store more carbons because of the cardinal contribution of biomass to its trunk [34].

Results showed off that trembesi (*S. saman*) had the highest total biomass and carbon uptake. Their fast growth and ability to optimize carbon dioxide (CO₂) uptake provided the trees to have the highest carbon uptake [26,35,36]. In a year, a trembesi (*S. saman*) was capable of absorbing 28,488.39 kg of carbon dioxide [37]. Moreover, another researcher concluded that linggua (*P. indicus*) had a considerably high CO₂ uptake capability, i.e., 426 tons/ha [38].

Green and open space development planning by studying plant species with a high carbon uptake capability and an aesthetic value might optimize efforts to mitigate CO₂ gas in Ambon. For our green and open spaces, it was better to have local plant species, preserving germplasms. The roles of green and open spaces in greenhouse gas absorption should be routinely maintained and enhanced for the maintenance quality, considering their urgent contribution to the government's effort in mitigating greenhouse gas emissions at the national level.

CONCLUSION

Biomass and CO₂ uptake of green and open spaces in Ambon is 347.91 tons/ha and 596.87 tons/ha, respectively. Plant species dominating green and open spaces in Ambon, by the highest biomass storage and CO₂ uptake, are trembesi (*S. saman*) (B = 110.95 tons/ha, CO₂ = 191.38 tons/ha), linggua (*P. indicus*) (B = 61.66 tons/ha, CO₂ = 106.36 tons/ha), and akasia (*A. mangium*) (B = 25.24 tons/ha, CO₂ = 41.69 tons/ha).

ACKNOWLEDGMENT

We would like to express the highest gratitude to the Ambon government and offices concerned which have helped this research completion.

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