Poll Res. 41 (1) : 70-77 (2022)

ISSN 0257–8050
DOI No.: http://doi.org/10.53350/PR.2022.v41i01.010

POTENTIALS OF GREEN OPEN SPACES IN AIR QUALITY CONTROL OF SEMARANG CITY, INDONESIA

DEWI LIESNOOR SETYOWATI[1*], PUJI HARDATI[2], EKO HANDOYO[3], MUHAMMAD AMIN[4], NASIR NAYAN[5] AND MOHMADISA HASHIM[6]

[1,2]Department of Geography, Universitas Negeri Semarang, Sekaran Gunungpati Semarang, Indonesia
[3]Departmentof Civic Education, Universitas Negeri Semarang, Sekaran Gunungpati Semarang, Indonesia
[4]Departmentof Agriculture Engineering, Lampung University, Bandar Lampung, Indonesia
[5,6]Department of Geography and Environment, Universiti Pendidikan Sultan Idris, Tanjong Malim, Perak, Malaysia

(Received 5 July, 2021; Accepted 13 August, 2021)

ABSTRACT

The development of Semarang City has an impact on reducing Green Open Space (GOS), decreasing air quality, only having 70 days which is categorized as quite good. The purpose of the study was to evaluate the distribution of GOS and determine the potential need for GOS for air quality control. The method applied is image interpretation to identify the area of GOS, measure air quality conditions at 5 locations in the city of Semarang, calculate the potential of GOS and analyze the need for green open space to reduce air pollution. The area GOS of Semarang City (covering 5 sub-districts) is only 21.6% or 1,109.8 hectares. Central Semarang District has the lowest carbon dioxide (CO_2) absorption capacity: only 12% GOS or 14,705 kg/day equivalent to CO2 emitted by 15,318 people (20.65% of the population). As a result, GOS in Central Semarang supplied the smallest amount of oxygen (O2), approximately 18,381.6 kg/day which could be inhaled as many as 14,705 people (19.83% of the population in Central Semarang District). Overall, the city of Semarang is only able to produce O2 of 375,067.2 kg/day. Increasing the plant area in the GOS to 30%, the amount of CO_2 absorbed will increase to 59.4% and O2 can be available for 57.02% of the total population in the coastal area of Semarang City.

KEY WORDS : Green open space, Air quality, Air absorption, Air pollution

INTRODUCTION

The city area is identical to the air condition that has been polluted by pollutants along with other environmental problems. Semarang City, as one of the metropolitan cities in Indonesia, has air pollution problems that are also experienced by many big cities in Indonesia. The air quality in cities varies, due to concentrations of particulate matter 10 micrometers (PM10), nitrogen dioxide (NO2), ozone (O3), carbon monoxide (CO), and sulfur dioxide (SO2) from emission sources including vehicle exhaust, manufacturing operations, and chemical facilities, among other sources (Alsaber *et al.*, 2021). The population of urban areas has increased over the last century and it is estimated that more than 60% of the world's population will live in cities by 2050 (Mexia *et al.,* 2018). The increase in population in the city of Semarang will directly impact the increasing number of motor vehicle users. In 2010 the city of Semarang had a population of 1,653,524. The number of motorbikes in that year amounted to 119,019 (BPS, 2010). The population increase occurred in 2016 so that the population of Semarang City reached 1,729,428 people. In that year, the number of motorbikes was recorded at 151,290 units (BPS, 2016). Motorized vehicles that use more and more fuel will potentially cause higher air pollution due to incomplete engine combustion due to lack of attention to engine maintenance (Masito, 2018). Air pollution may negatively impact cardiometabolic health through autonomic nervous system imbalance, pulmonary and systemic inflammation and oxidative stress (Araujo, 2011 and Bloemsma *et al.*, 2019). In Europe, more than 150 million citizens suffer from chronic allergic diseases, with an estimated cost between 55-151 billion euros/year to the National Health Services (Cariñanos *et al.*, 2019).

The decrease in air quality due to pollution can still be minimized by building green open spaces. Green Open Space (RTH) is an area dominated by woody plants or trees that serve as a buffer urban areas, such as water management regulator and ability to absorb carbon in the air (Indriyani *et al.*, 2016). The presence of green open space can reduce the concentration of exhaust gases that are detrimental to humans. Green plants that act as land cover in green open space can absorb CO2 gas. Urban areas really need trees for water absorption facilities, as well as storage of backup water for dirty air filters due to industrial activity and vehicle pollution, as well as surrounding air conditioning. Increasing urban tree cover is an often proposed mitigation strategy against urban heat as cooled city trees would expect through evapotranspiration and provision of cover (Genc and Tuncel, 2010 and Meili *et al.*, 2020). Land use-land cover change (LULCC) as an environmental change driver plays an important role inmodulating the local microclimate including land surface temperature (LST), especially in urbanizing areas (Akinyemi, *et al*, 2019).

Green space has health benefits, such as increased physical activity and psychological well-being (Patterson and Harley, 2019). Healthy and well-managed urban green spaces contribute significantly to urban inhabitants' quality of life (Fongar *et al.*, 2019). The impact of this green open space is not only about improving air quality, but also on the psychological health conditions of people living in the vicinity. Utilization of urban green space contributes to the mental and physical health of the community (Li *et al*, 2020). Blue room and closed green space are preferred by parents and have many psychological restorative effects on parents (Qiu *et al*,, 2021). The possibility to perform physical activity in urban green spaces has been associated with decreases in the incidence of cardiovascular diseases, morbidity, and chronic diseases and also with the improvement of functional capacity and cognition among the senior population (Miralles *et al*,, 2019). This is why green open space needs to be considered, especially in terms of its area and distribution.

MATERIALS AND METHODS

This research was conducted in the city of downtown Semarang, called lower town. The city was divided into five zones namely, Sub District Central, East, South, West and North for comparative analysis. Semarang City is located in Central Java Province, Republic of Indonesia. Semarang City topography has a sloping texture, consisting of coastal areas, lowlands and hills. Based on the characteristics of its territory, it is divided into lower and upper city areas. The lower city is a beach and lowland area of 65.22%, has a height of 0.75 meters above sea level, and has a slope of 0% 25%. The upper city is a hilly area of 37.78%, has a height of 90-348 m with a slope varying between 15%-40% (Setyowati, 2008).

Research object is Green Open Space (GOS) and air quality in Semarang City. The activity in urban areas is one of the main sources of air pollution, due to potential city activity in changing urban air quality. The activities of urban residents include residential, transportation, commercial, industrial, solid waste management, and other supporting sectors.

GOS data were identified in 5 sub-districts (Table 1). Monitoring Air quality data is measured on 5 locations by installing air quality measurements. The basis for selecting the measurement site is land use aspect, as shopping area, settlement, hospital, airport, station. Criteria differences in traffic density in 5 locations were used to determine the location of ambient air quality monitoring, expected to be representative of the whole region.

The data used in this study are primary and secondary data. The method of collecting using purposive sampling technique. Primary data collected include spatial distribution of vegetation and land use cover, Green Open Spaces area, and air quality data (ambient). Secondary data include number of vehicles, amount of fuel consumed and regional climate data. In addition, spatial data is needed in the form of images and maps for land use identification. Analysis of land use data requires data from SPOT5 imagery, topographic map of scale 1: 25.000, land use map, and spatial plan of Semarang City (RDTRK).

The variables in this research are vegetation cover distribution, micro climate analysis, Leisure Index calculation, GOS requirement, and damping of air contaminant in GOS. Data analysis techniques performed, as follows.

1. Analysis of vegetation cover, including species and extent of green plants, species composition, tree density and vegetation index distribution.
2. Analysis of GOS potential has been calculated with the help of analysis from SPOT5 image, processed using Geographic Information System (GIS) technique. The criterion of human oxygen demand value and motor vehicle is taken from Geravkis method (Aprianto *et al.,* 2010).
3. GOS analysis to reduce air pollution; The source of air pollution and noise in metropolitan cities is 75% of transport activities and 25% is generated by land use activities, especially the components of CO (carbon monoxide) and HC (hydrocarbon) pollution.

An Interventionary studies involving animals or humans, and other studies that require ethical approval, must list the authority that provided approval and the corresponding ethical approval code.

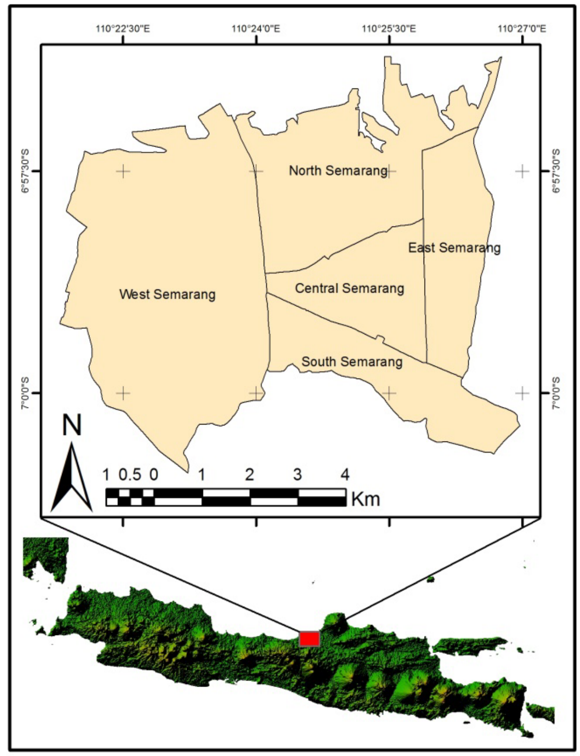

Fig. 1. Research Location in Urban Area of Semarang City, Central Java Province.

RESULTS AND DISCUSSION

Study Site

The study was conducted in Semarang City, Central Java Province. Semarang city is growing with widespread settlements and density of buildings. The lower Semarang City area covers five sub-districts, namely North Semarang, Central Semarang, East Semarang, West Semarang, and South Semarang. UTM Coordinates of Semarang City locations are: 444000mT and 422000mT-9226000mU-9236000mU. Research object is the condition of micro climate, GOS, and air quality in Semarang City. Map of the location of the administration of the study area is presented in Fig. 1.

Broad Green Open Space Area in Semarang City

GOS covers forest plantation area, sports areas, public cemetery, landscaping area, a green lane road, green belt for garbage, yard and garden. The GOS area in Central Semarang District is 76.59 ha (12.64%), East Semarang 98.06 ha (13.24%), South Semarang 179.27 ha (21.14%), North Semarang is 266.04 ha (23.32%), and West Semarang covering an area of 486.84 ha (26.14%), as shown in Table 1.

As the 30% GOS standard was not fulfilled, it is necessary to increase the green area in each Sub District. In Central Semarang the GOS shortage area was 105.14 ha (17.36%), 124.15 ha (16.76%) in East Semarang, 75.15 ha (8.86%) in South Semarang, 76.22 ha (6.68%) in South Semarang and 72.32 ha (3.86%) in West Semarang. That means the least GOS shortage was in West Semarang (3.86%), which nearly met the specified standards. Meanwhile, Sub Central Semarang has the lowest level of GOS standard (12.64%).

Air Quality Conditions

Generally, there are eight parameters including Carbon Monoxide (CO), Nitrogen Oxide (NO2), Sulfur Oxides (SO2), Oxidants (O3), Lead (Pb), hydrogen sulfide (H2S), ammonia (NH3), particulate matter (TSP) and noise are used to determine the pollutants (Deniz el al., 2010). In Semarang city, there is substantial increase in air pollution which are mainly contributed by growing number of industries and gradual multiplication of vehicles. In this regard, during field survey found that in Semarang city the average level of all the eight parameters are far below the national environmental quality standard (Table 2).

The parameters of NO_2, SO_2, H_2S and NH_3 were still far below the ambient quality standard (Table 2).

The analysis reveals that areas having the CO values greater than 10,000 µgr/m^3 were recorded at Kalibanteng round about (West Semarang), Kariadi Bus Stop (South Semarang), in front Poncol Station (North Semarang) and Bubakan (East Semarang). In addition to this, the value of dust/TSP acceding 300 µgr/m^3 were found at Bubakan, Kariadi Street, Gadjah Mada Street, and street around Poncol Station and Kalibanteng.

Locations prone to air pollution were mostly in the crowded area such as intersection of Kalibanteng roundabout, Kariadi Bus Stop, in front of BRI, and in front of Poncol Station. At that moment, the parameters of CO and dust were close to the quality standards but their escalation needs to be observed in the next few years, in line a rise in private vehicle ownerships. The impacts of increased CO and dust are immensely harmful for human health particularly highway users. Therefore, GOS improvement shall be prioritized in order to absorb poisonous gases and dust as plants can cut down the levels of CO and dust.

Regarding the data of ambient air quality (CO, NO_2, O_3, SO_2 and dust particles), the predictive value of air pollutant standard index was measured in some locations in Semarang City viz. Kuhl's (East Semarang), Gadjah Mada Street (Central Semarang), Bubakan (East Semarang), Kariadi Bus Stop (South Semarang), Kalibanteng (West Semarang), and Poncol Station (North Semarang). Spatial data on measurement of ambient air quality in the city of Semarang is presented in Figure 2.

Table 1. Determination of Air Quality, Data Monitoring, and Location

No	Sub District	Location of Air Quality Monitoring	consideration of monitoring location
1	East Semarang	Bangkong- East Semarang	the traffic area around the shops
2	Central Semarang	Gadjah Mada Street- Central Semarang	Traffic area around the setlement
3	South Semarang	Kariadi hospital-South Semarang	Traffic area near the hospital
4	West Semarang	Kalibanteng- West Semarang	Traffic area around the airport
5	North Semarang	Poncol Station -North Semarang	Traffic area near Poncol station

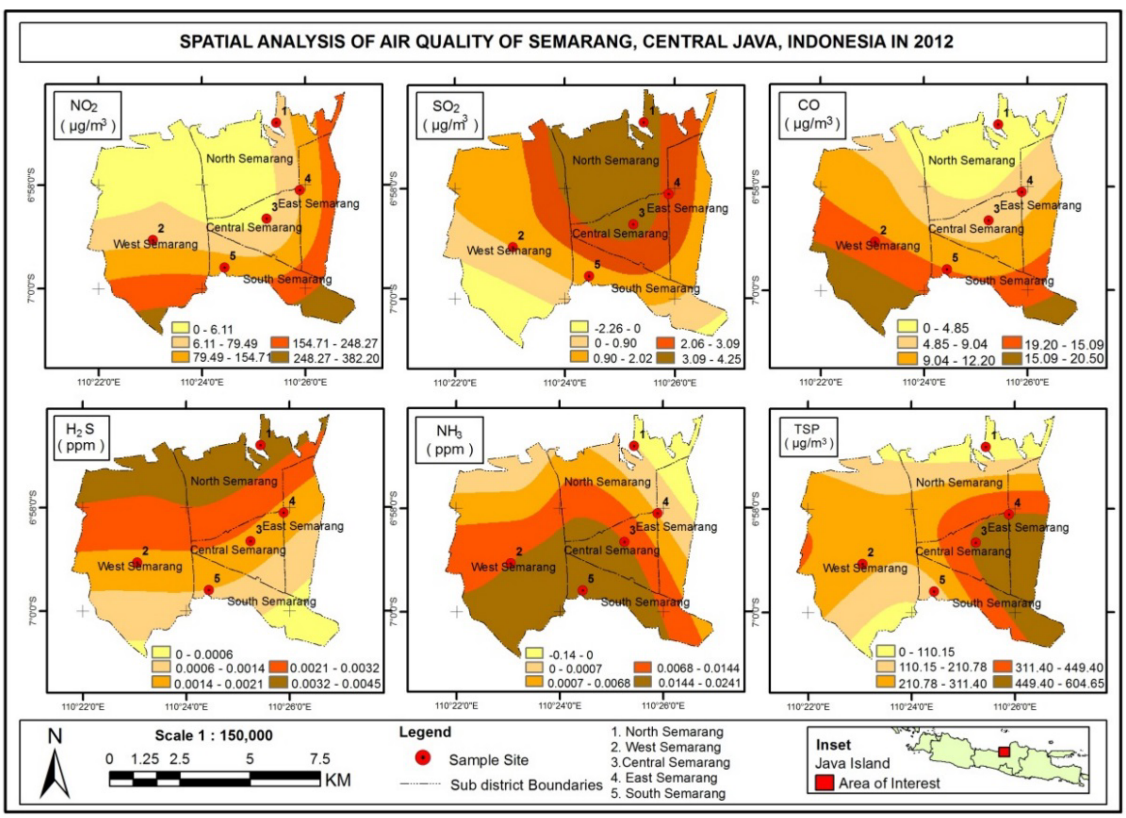

Fig. 2. Spatial distribution of ambient air quality data in Semarang City (NO_2, SO_2, CO, H_2S, NH_3, dan dust particles)

Table 1. Size, Requirement, and Deficiency GOS in Semarang City

Sub District	Sub Area (Ha)	Size GOS (Ha)	Size GOS %	Area Requirement GOS 30% (Ha)	Deficiency GOS (Ha)	Deficiency GOS %/
Central Semarang	605.78	76.59	12.64	181.73	105.14	17.36
South Semarang	740.70	98.06	13.24	222.21	124.15	16.76
North Semarang	848.05	179.27	21.14	254.42	75.15	8.86
East Semarang	1,140.88	266.04	23.32	342.26	76.22	6.68
West Semarang	1,873.86	489.84	26.14	562.16	72.32	3.86

Source: Results of interpretation and analysis of SPOT 5 imagery

Table 2. Results Ambient Air Quality Measurement Semarang

No	The location of Measurement	The Results of Ambient Air Quality Analysis					
		NO_2 (μgr/m³)	SO_2 (μgr/m³)	CO (μgr/m³)	H_2S (ppm)	NH_3 (ppm)	Debu/ TSP (μgr/m³)
1	Bangkong- East Semarang	0.789	2.844	8.016.0	0.0010	0.015	464.67
2	Gadjah Mada Street- Central Semarang	0.033	3.433	8.016.0	0.0010	0.004	481.84
3	Kariadi-South Semarang	1.222	1.422	13.743.0	0.0003	0.0005	207.12
4	Kalibanteng- West Semarang	0.611	0.922	14.887.0	0.0010	0.0004	273.20
5	Poncol Station -North Semarang	0.911	0.000	12.597.0	0.0004	0.0000	371.37
	Quality standard	316.000	632.000	15.000.0	0.0200	2.000	230.00

Source: Ambient air quality standards (Decree of Central Java Governor No.8/2001) and (Decree of the State Minister of the Environment Number 48/1996)

Table 3. Size GOS and its Ability to Absorb CO2 in Semarang City

Sub District	Area of GOS (Ha)	Absorption of CO_2 (kg/day)	Absorption of CO_2 (person)	CO2 is absorbed by GOS (%)
Central Semarang	76.59	14,705.28	15.318	20.65
South Semarang	98.06	18,827.52	19.612	23.87
North Semarang	179.27	34,419.84	35.854	41.88
East Semarang	266.04	51,079.68	53.208	42.31
West Semarang	489.84	94,049.28	97.968	61.80
	Total =	1,109.80	213.081.60	221.960

Table 4. The Size of GOS and The Ability of GOS to Produce O2 in Semarang City

Sub District	Area of GOS (Ha)	Produced Oxygen (O2) (kg/day)	Produced Oxygen (O2) (People)	Percentage of O2 produced
Central Semarang	76.59	18.381,60	9.191	19.83
South Semarang	98.06	23.534,40	11.767	22.92
North Semarang	179.27	43.024,80	21.512	40.21
East Semarang	266.04	63.849,60	31.925	40.62
West Semarang	489.84	117.561,60	58.781	59.32
Total =	1,109.80	266,352.00	532,704.00	

In the case of ambient air quality measurement in Semarang, the air has no effect on human or animal health, but on plants and aesthetic values. ISPU basically describes ambient air quality condition at a particular location and time and its subsequent impacts on aesthetic values, human health and other living creatures. According to (Fauziah et al., 2017) the annual mean of ISPU in 2017 was 56,73. The data of Semarang ISPU were obtained from the radar monitoring station in Mangkang, Penggaron, and Terboyo.

DISCUSSION

In line with the increasing population of the city, the

Table 5. Design of Standard GOS 30% to Produce O2 and Absorb CO2 Semarang City

Sub District	Area of GOS 30% (Ha)	CO_2 Absorption		O_2 Production	
		(kg)	(People)	(kg)	(People)
Central Semarang	181.73	34,892.16	36,346	43,615.2	21,808
East Semarang	222.21	42,664.32	44,442	53,330.4	26,665
South Semarang	254.42	48,848.64	50,884	61,060.8	30,530
North Semarang	342.26	65,713.92	68,452	82,142.4	41,071
West Semarang	562.16	107,934.72	112,432	134,918.4	67,459
Total =	1,562.78	300,053.76	312,556	375,067.2	187,533

natural and environmental resources in the city are increasingly being utilized. This has resulted in a decrease in forest and green open space resources as well as an increase in the activities of urban communities using fossil fuels which have resulted in high air pollution. The high level of CO2 in the atmosphere is one of the impacts of reduced green land in cities, because the existing plants are unable to absorb the amount of CO2 in the atmosphere (Lukmanniah and Fatimah, 2016 and Setyowati *et al.*, 2020).

Environmental factors that impact the concentration of pollutants in the air depend on the distance from the source of pollution, topography, altitude, rainfall, solar radiation, wind speed and red. The polluted air as a consequence of smoke and gases of fossil fuel combustion by industry and motor vehicles will increase the chemical elements for instance NO, NO2, CO, SO2, and of course, the amount of CO2. One of the formations being introduced to improve the quality of urban air is vegetative barriers, which are deployed as a kind of passive space organization (Podhajska *et al.*, 2020). The effectiveness of vegetative barriers is determined by the spatial conditions of not so many individual elementsbut primarily all the communities (Podhajska *et al.*, 2020).

Agency of Central Java conducted a study in 1997 and suggested the mechanism to reduce air pollutants by extending greening plants due their ability to clean the aforementioned gases. Photosynthesis of plants would absorb CO2 from the air, and supply pure oxygen as a byproduct to its surrounding air. Here, because the amount of CO and CO2 decrease, the air was fresh air containing oxygen will be abundant. The referred plants according to that research are croton shrubs, sablo, soka (a kind of flowering tree), hibiscus, and beautiful homeland trees.

Here are the calculations of GOS role in absorbing carbon dioxide and producing oxygen. The standard form is used to examine the oxygen requirements of ecological standards, through an analysis of photosynthesis process, described as follows:

1. Trees can reduce CO2 (569.07 tons/ha/year) more than grass (12 tons/ha/year) (Aly & Kondorura, 2020).
2. Through Photosynthesis, oxygen (O2) produced by plants is released into the air and inhaled by humans. Every one person needs about 0.5 to 2 kg of oxygen per day, while each ha of trees can produce approximately 240 kg of oxygen per day (Kushnir, *et al.*, 2006).
3. The absorption value of CO2 in tree vegetation is 58.26 tonnes/ha for forest plant types, while 3.30 tonnes/ha for shrubs. (Iverson et al., 1993; Tinambunan RS, 2006; and Lukmanniah & Fatimah, 2016).
4. A tree can eliminate 26 pounds of carbon dioxide (Kasim and Shafri, 2019).

According to the data, GOS in Semarang city was not fulfil the proportion of 30% as stipulated in Law No. 26/2007, but only around 21.3%. The worst case occurred in Sub District Central Semarang in which only 12% GOS area was available. Size GOS can be utilized as a reference for calculating its ability in air pollution control parameters in terms of carbon dioxide (CO2) and oxygen (O2). The amount of carbon dioxide absorbed by the GOS was 1109.08 ha area (Table 3).

GOS in West Semarang was wider than the four other Sub Districts, so that its value of CO2 absorption was the greatest. In contrast, Sub District Central Semarang CO2 absorption value was definitely the smallest of all (14,705 kg/day equivalent to the CO2 released by 15,318 people. Only 20.65% of CO2 from the population living in Central Semarang were absorbed. The largest CO2 absorption value was from West Semarang, followed by North, South, East and Central Semarang (Table 3).

Urban GOS with a dense canopy of trees has a maximum cooling effect and produce O2 (Wang *et al.*, 2019; Setyowati *et al.*, 2020; Sillar *et al.*, 2020). GOS will produce O2 in accordance with its coverage. O2 produced in West Semarang was 117,561.6 kg/day or could be inhaled by 58,781 residents in the vicinity. Nevertheless, the poorest GOS in Central Semarang, 76.59 ha area, produced less O2 that was about 18,381.6 kg/day equivalent to 9191 people. In regards to Central Semarang population total (74,167 inhabitants), if one hectare GOS produces 240 kg of O2 (one person requires 0.5-2 kg/day) thus only 19.83% of its population can respire O2 from GOS in the vicinity (Table 4).

The total size of GOS in Semarang City (five Sub Districts) only covered 21.3%, which still needs to be expanded or intensified by vegetation. If, for example, its GOS expands to 30% of the total area, the amount of CO2 absorbed will approximately be 300,053.76 kg/day equivalent to 312,556 residents in that region (Table 5). At that time, GOS in Semarang can merely produce O2 of 375,067.2 kg/day equivalent to 1562.78. If the space is vastly improved to 30% then the amount of absorbed CO2 will rise up to 59.4% and the O2 can be available for 57.02% of the total population residing in coastal area of Semarang (covering five Sub Districts).

CONCLUSION

GOS in the urban area of Semarang is still below the standard of 30% (according to the provisions of Law No. 26/2007). The total GOS in five sub-districts in Semarang City is only 21.6%. The results of air quality measurements in the center of Semarang City exceed the quality standards, especially CO levels. Semarang City is only able to produce O2 of 375,067.2 kg/day. By optimizing the GOS plant area up to 30%, the amount of CO2 absorbed by plants will increase to 59.4% and O2 can be available for 57.02% of the total population in the coastal area of Semarang City. Research findings related to the area and potential needs for GOS, CO2 absorption, and oxygen availability. Furthermore, it can be implemented by increasing the area of the park, planting trees along the road, as well as mobilizing the community to plant trees around the house and the surrounding environment.

ACKNOWLEDGMENTS

The authors would like to thank the Indonesian Ministry of Education and Culture, for Semarang State University through the Institute for Research and Community Service (LP2M), at the Applied Research Scheme.

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