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The analyze of green space need in Surabaya City using Gerarkis Method for 2010–2020

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Abstract*. Surabaya City is the second-largest city based on the population in Indonesia that is affected by the development of urban planning in the city. The development of the urban areas affected the increase of socio-economic development and peri-urban demographics but often took over land or green open spaces. It is an unavoidable possibility of air pollution due to the imbalance between oxygen producers and existing oxygen users. It is necessary to calculate the prediction of green open space requirements using the Gerarkis Method, which predicts green open spaces based on oxygen demand by using the number of residents, motor vehicles, livestock, industrial factories, and hotels. With the Gerarkis Method, the prediction of the need for green open space in Surabaya City for 2010–2020 is 22,088.89 hectares to 31,950.84 with the increased majority value in the area, except in 2015 and 2020, due to decreased users. This method proves that the need for oxygen produced from plants is increasing, making Surabaya City needs more green open space to make Surabaya City livable.*

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INTRODUCTION

The second-largest city in Indonesia, Surabaya City, has 3,095,026 populations (BPS 2019). As one of the most populous cities, Surabaya City is developing in urban planning to adapt to the rapid population growth, which had a population growth rate of 2.07% in 2019 and has increased more than 100% from 2018 with a figure of 0.64% (BPS 2019). According to Alfatikh (2014), development occurs because urban areas have high population density and become centers of community activity, so the area is more dominated by built-up land. The development of urban areas is increasing as socio-economic development and peri-urban demographics (Wahidah and Giyarsih 2013). However, infrastructure development to facilitate the need of urban residents often takes over previously existing land or green open spaces (Ratnasari et al. 2015).

This situation can affect the land surface cover material, which is one of the trends in land use in urban areas (Sobirin and Fatimah 2015). In other ways, development in urban areas can also impact the microclimate within the city, such as temperature, wind speed, radiation, and cloudiness, so that it can affect the distribution of air felt by urban communities (Alfatikh 2014). The consecutive impact of green open land reduction for development is the unavoidable possibility of air pollution due to the imbalance between oxygen producers and existing oxygen users. The increasing number of motorized vehicles and population can result in the density of existing activities so that the air quality in Surabaya City has decreased. The pollutant concentration

PM2.5 can measure on 7 May 2021 in Surabaya City, which has reached 90.5 g/m³, where the air pollution parameters at the national standard are 50 g/m3. The World Health Organization (WHO) is 20 g/m^3 (Syahadat et al. 2017).

As the data declared, Surabaya City has the worst air quality in Indonesia, caused mainly by motorized vehicles (Fahrisa and Syafei 2017). Air pollution can cause other health problems, such as respiratory disorders, irritation, and cancer (Syahadat et al. 2017). For this reason, it is necessary to predict the need for green open space as an oxygen producer using the Gerarkis Method. This method is used to improve the people's quality of life in Surabaya City by adapting to oxygen needs so that local governments can plan the demand for green open spaces in future urban planning.

METHODOLOGY

Research Location

The research was carried out in Surabaya City located at coordinates 07°11′00″–07°21′00″ South Latitude and 112°36′00″–112°54′00″ East Longitude. The area's boundaries are the Madura Strait in the north and east, the Gresik Regency in the south, and the Sidoarjo Regency in the west. Surabaya City has a total area of 33,206.30 hectares based on Surabaya City Government (Pemkot Surabaya 2021). The study was conducted using 11 years of data that occurred in Surabaya City. The area that used in this study mapped in Figure 1.

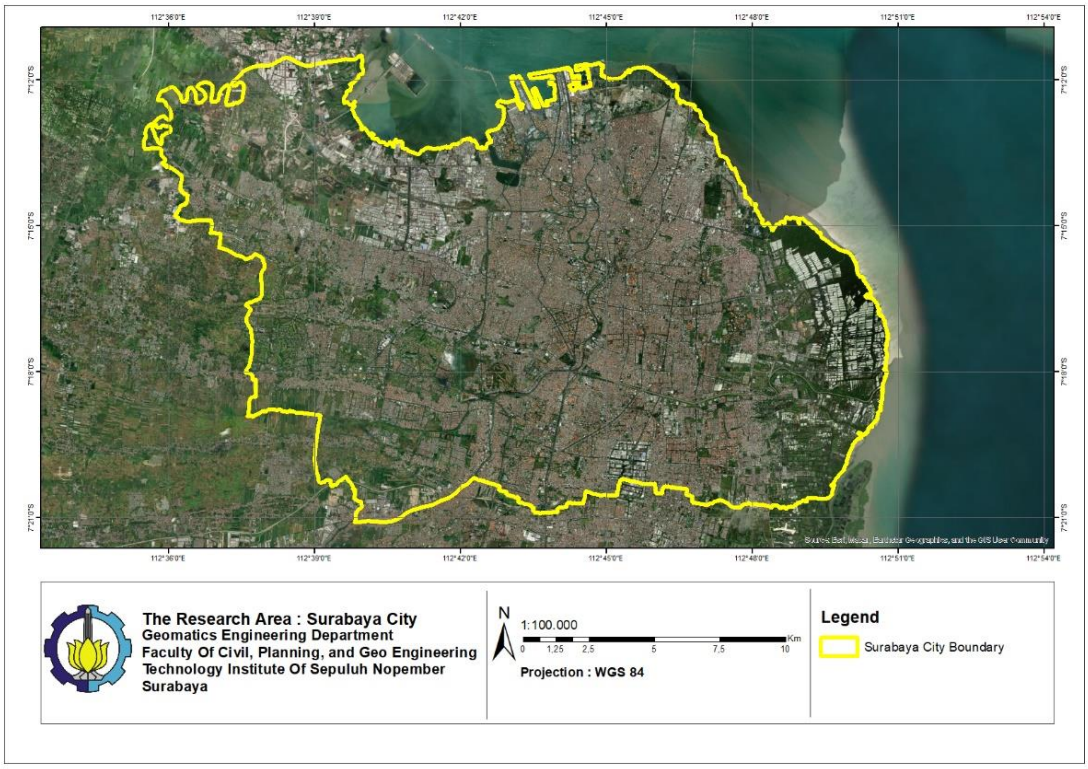


Figure 1 Research sites

Data Collecting Method

The data used in this research contains tabular data that shown in Table 1. The necessary data are the population in Surabaya City for 2010–2020, the number of livestock in Surabaya City for 2010–2020, the number of vehicles in Surabaya City for 2010–2020 from the official government institutions of Surabaya City, the number of factories and hotels in Surabaya City for 2010–2020, and the amount of oxygen consumption for each user according to Wisesa (1988) and Putra (2012).

Table 1 Number of oxygen users in Surabaya City for 11 years

Year	Total population	Number of vehicles	Number of livestock	Number of factories	Number of hotels
2010	2,929,528	1,584,382	50,871	838	111
2011	3,024,321	1,645,132	49,087	803	126
2012	3,125,576	1,800,265	51.785	836	151
2013	3,200,454	2,076,743	43,272	838	169
2014	2,853,661	2,285,201	26.578	816	177
2015	2,943,528	2,125,991	43,811	836	189
2016	3,016.653	2,628,175	38.352	873	209
2017	3,074,883	2,781,731	24.018	957	209
2018	3,094,732	2,959,554	26,184	878	227
2019	3,159,481	3,166,603	22009	595	251
2020	2,977,300	3,259,465	20,921	589	256

Data Analysis Method

The Gerarkis method is a method for deciding the sum of green open space in a city with an approach to critical issues that emerge within the considered area in assembly the sum of oxygen requests in a city that's calculated by the condition in equation (Wisesa 1988):

$$\mathrm{Lt} = \frac{\mathrm{At} + \mathrm{Bt} + \mathrm{Ct} + \mathrm{Dt}}{54 \times 0.9375}$$

The deciding parameters are the number of populaces, the number of livestock, the number of vehicles, and the number of factories and hotels. The details of data analysis is shown in Figure 2.

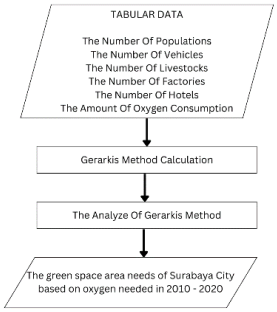


Figure 2 Flow chart of the research

Information:

Lt = Area of green open space in year t (m^2).
At = Total oxygen demand of the population per day in year t (g/day).
Bt = Total oxygen demand of motorized vehicles per day in year t (g/day).
Ct = Total oxygen demand of livestock in year t (g/day).
Dt = Total oxygen demand for factories and hotels in year t (g/day).
54 = Constant, 1 m^2 of the land area produces 54 grams of dry weight of plants per day (g/day/m^2).
0.9375 = The constant indicating that 1 gram of dry weight of the plant is equivalent to 0.9375 grams of oxygen.

With assumption :

• Oxygen users are humans, vehicles, livestock, factories, and hotels.

- The range number of vehicles passing over is considered the same in every day.
- The need for oxygen per day for humans is 600 liters/day or 0.864 kg/day (Wisesa 1988).
- The need for oxygen by vehicles is 11.63 kg/day for cars; 45.76 kg/day for buses; 22.88 kg/day for trucks; 0.58 kg/day for motorcycles (Wisesa 1988).
- The need for oxygen by livestock is 1.70 kg/day for cattle and buffalo; 1.854 kg/day for horses; 0.314 kg/day for goats and sheep; and 0.17 kg/day for poultry (Putra 2012).
- Oxygen demand for industrial factories and hotels is 529.41 kg/day with an active time of 5 hours/day (Wisesa 1988)
- Oxygen supply from outside the area is produced only by plants.

RESULTS AND DISCUSSION

Processing the need for green open space according to oxygen demand in Surabaya City is carried out using Microsoft Office Excel software by calculating the Gerarkis Method. In this method, the main elements that affect the value of the calculation results are the total population, the total number of motorized vehicles, the total number of livestock, the total number of medium-scale industrial factories, and the total number of hotels in the city of Surabaya from 2010–2020. The data was obtained from the official agencies of the Government of East Java Province and the City of Surabaya. By entering all elements into the equation of the Gerarkis Method, the final result is the need for the green open space area based on the users' oxygen requirements that have been defined.

In data processing calculation using Gerarkis Method's, the predicted value of the required Green Open Space area tends to increase from 2010 to 2020 but decreases in 2015 and 2020. This result occurs due to the increasing number of oxygen users each year, except for the number population and the number of vehicles in 2015. Also, decreasing the population, the number of livestock, and the number of industrial factories in 2020. The condition of the variable number in the calculation turns out to be very influential in the calculation of the Gerarkis Method. As the calculation of the Pearson correlation between the total number of oxygen users and the results of the green open space area that needed using Gerarkis Method turns out to be 0.9916, that makes the correlation between the two data strong and correlated to each other.

From the percentage of green open space needed in Surabaya City based on the area of Surabaya City, already required more than half of Surabaya City area in 2010. It continues to increase up to 96.22% (Table 2), or almost equivalent to the size of Surabaya City's area. The result of the calculation that shown in Figure 3 and Figure 4 proves that the need for oxygen produced from plants is increasing it requires more green open space to make Surabaya City a livable city for people's lives.

Table 2 The prediction of required green open space is based on the calculation of the Gerarkis Method

Year	Total green spaces predicted (hectares)	Percentage of Surabaya City area (%)
2010	22,088.89	66.52
2011	22,631.03	68.15
2012	24,005.57	72.29
2013	26,105.24	78.62
2014	26,115.54	78.65
2015	25,671.68	77.31
2016	28,564.97	86.02
2017	29,735.02	89.55
2018	30,852.56	92.91
2019	32,113.58	96.71
2020	31,950.84	96.22

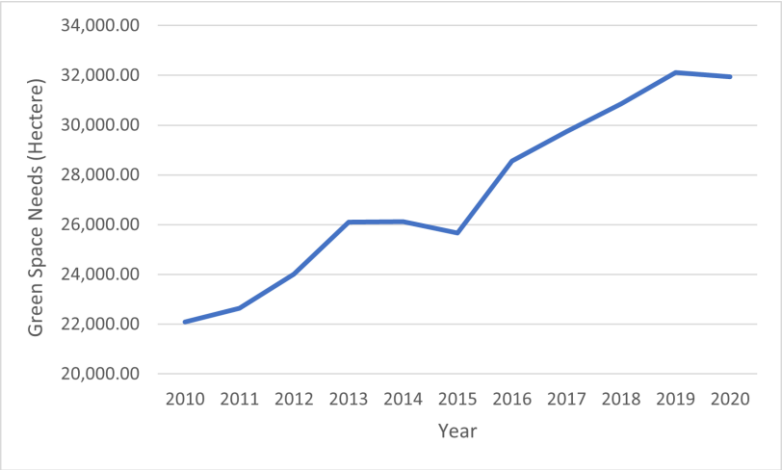
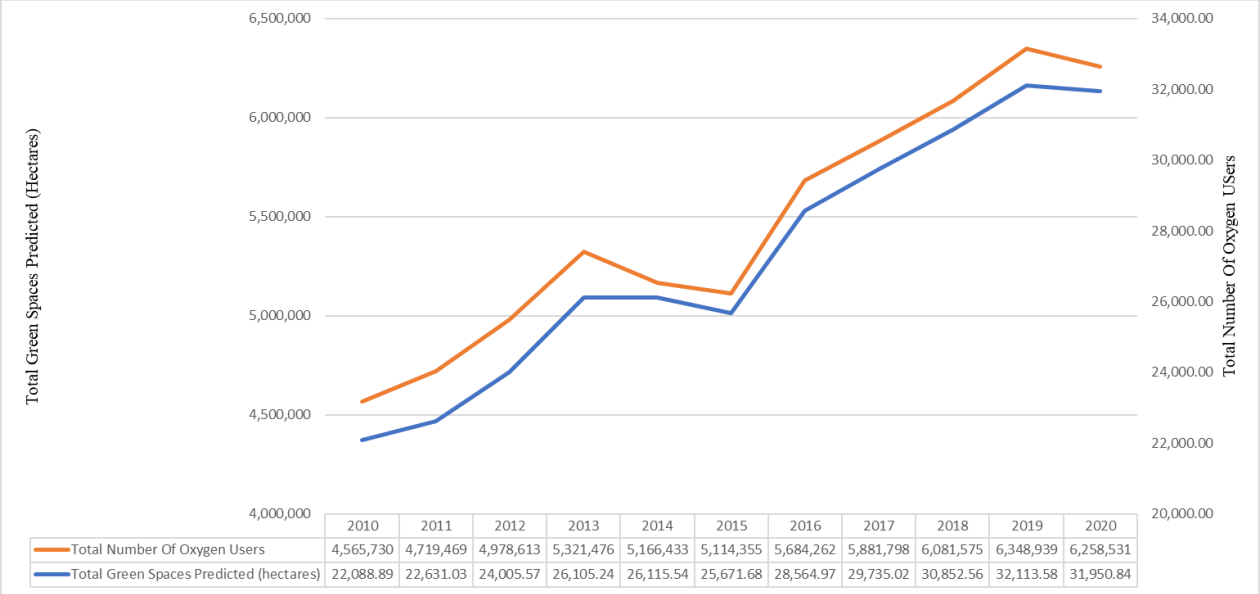


Figure 3 Graph prediction of the required green open space based on the calculation of the Gerarkis Method



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total Number Of Oxygen Users	4,565,730	4,719,469	4,978,613	5,321,476	5,166,433	5,114,355	5,684,262	5,881,798	6,081,575	6,348,939	6,258,531
Total Green Spaces Predicted (hectares)	22,088.89	22,631.03	24,005.57	26,105.24	26,115.54	25,671.68	28,564.97	29,735.02	30,852.56	32,113.58	31,950.84

Figure 4 Correlation between total number of oxygen users and total green spaces area predicted

The following analysis is also supported by the results of the Gerarkis Method calculation in Serengan District, Surakarta City, which concludes that the population (as oxygen users) and the need for green open space in an area must be correlated and fulfill the government regulations from Minister of Public Works Regulation no. 5 PRTM/2008 regarding guidelines and utilization of green open space in urban areas, that the area of each regional administration unit must have a balanced area between population and green space area (Utami 2020). Similar to the results of research conducted by Riadi (2022) for Palangkaraya City, the need for public green open space is also considered by the number and density of the population because of the radial movement of the land use development followed by population density and facilities. This data is supported by Government Regulation No. 26/2007 Chapter 30 about spatial that the distribution of public green open space is adjusted to the distribution of the population and the hierarchy of services by considering the structural plans and spatial patterns (Riadi 2022).

CONCLUSION

In the case study, the Surabaya City area, with an area of 33,206.30 hectares, requires an area of green open space in 2010 22,088.89 hectares; in 2011, was 22,631.03 Hectares; in 2012 was 24,005.57 hectares; in 2013 was 26,105.24 hectares; in 2014 was 26,115.54 hectares; in 2015 was 25,671.68 hectares; in 2016 was

28,564.97 hectares; in 2017 was 29,735.02 hectares; in 2018 was 30,852.56 hectares; in 2019 is 32,113.58 hectares; and in the year 2020 is 32,113.58 hectares to fulfill the need for oxygen use in Surabaya City through the equation of the Gerarkis Method. In the range of 11 years, the need for green open space in Surabaya City has mainly increased except in 2015 and 2020 due to a decrease in the number of users. To improve air quality in Surabaya City in the following years, it is necessary to add green open spaces adjusted to the number of existing users. Therefore, Surabaya City will fulfill the oxygen need of users and improve air quality in the city.

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