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Changes in Land Requirements Analysis for Green Space Needed in Bogor City

Rasendriya Ramanda Darettamarlan [a], Hartanto Sanjaya [b], Agung Budi Cahyono [a], Nurwatik [a], Hepi Hapsari Handayani [a], Mohammad Rohmaneo Darminto [a,*]

[a] *Department of Geomatics Engineering, Faculty of Civil Planning and Geo-Engineering (CIVPLAN), Sepuluh Nopember Institute of Technology, Surabaya, East Java, 6011, Indonesia.*
[b] *Agency for The Assessment and Aplication of Technology, Center of Technology for Regional Resources Development, Serpong, South Tanggerang, Banten, 15314, Indonesia*
*Corresponding author: *rohmaneo@its.ac.id*

***Abstract*— Bogor City is one of the cities with declining air quality, which increases the risk of air pollution in the city. Improving the air quality requires the addition of vegetation as a green space that can be supported by remote sensing analysis using Google Earth Engine to know the availability of vegetation area in Bogor City. This process takes the median value of Landsat 8 Oli's satellite imagery data for 60 to 91 days of each year and classified by Random Forest Classification and supported by BPS-Statistic of Bogor Municipality data for the number of oxygen users of Bogor City that calculated by the Gerarkis Method to observe the needs of oxygen in Bogor City. The results contain a prediction of the addition of green spaces area needed in Bogor City based on the difference between the Gerarkis Method results and the availability of vegetation area in Bogor City each year. The results show an increased number from 2013 to 2019 because of the increased number of oxygen users each year. The highest number in 2019 shows that Bogor City needs 4,639 Hectares or 40.59% more green spaces area, while the lowest number happened in 2013 with 281.31 Hectares or 2.46% more green spaces area needed. This research could help the growth of development in Bogor City to be balanced between oxygen needs by the public user and urban planning plans.**

***Keywords*— Remote sensing; green spaces; gerarkis method; Google Earth engine; air pollution; air quality; sustainable cities.**

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I. INTRODUCTION

Bogor City is a city known as the 'Kota Seribu Angkot' due to the large number of city transportation operating in the center of Bogor City and its surroundings [1]. Based on data from the Department of Transportation of Bogor City (DISHUB), at the end of 2018, the number of city transportation in Bogor City was 2,400 units [2]. However, according to the statement of the Mayor of Bogor City, Bima Arya Sugiarto, 800 city transportation units were declared not roadworthy, leaving 1,600 units still operating on the highway [2]. In addition to public transportation, the number of cars, small trucks, and motorcycles also contribute to congestion in Bogor City due to the significant increase in numbers (Road Transport Traffic Office of Bogor City, 2015) [3]. The results of the lead examination conducted at several locations in Bogor City for 24 hours showed that there were locations that had the highest lead content, which scored 10µg/Nm3 at the Bogor Station, where the amount has passed the quality standard at the Ministerial Decree of Environment Number 12, 2010, which is 2 $\mu g/Nm^3$ [3]. Besides that, the increased world population will also lead to environmental problems in cities, one of them being increasing air pollution [4].

Adding green spaces is one of the best solutions to reduce air pollution and improve air quality in Bogor City [5]. Especially, having a large amount of small urban green spaces can help the urban inhabitants better and help the effect of climate change [6], [7]. Green spaces also can contribute to guarding the quality of urban life and public health by improving air quality [8], [9]. On the otherwise, green spaces can mitigate the increased temperature of land that could negatively affect urban heat islands in the city [10].

Bogor City, which has a higher rainfall rate than other cities, should have a high percentage of green covers [11]. However, it must be done by examining the availability of vegetation and the oxygen needs of the Bogor City

Community to validate the amount of green spaces and its need. Those are the number of populations, number of vehicles, and the number of livestock [12].

Therefore, the analysis should be easier by doing remote sensing survey techniques [13]. It can provide access to vertical data provision that is fast and relatively accurate based on satellite images for the use of land cover classification analysis to the detail of the earth's surface that can be obtained by sensors with the ability to highlight vegetation spectral as a vegetation index and eliminate non-vegetation spectral values [14]. Remote sensing also being an effective way to survey and cartographic analysis of urban green space with fast processing [15].

II. Material and Method

A. Research Sites

The location of the study area is Bogor City, which has 6 sub-districts and 68 urban villages.

Fig. 1 Bogor City On Google Maps

B. Data

The datasets used are tabular and spatial data. On tabular data, we used the BPS - Statistic of Bogor Municipality's data, such as the number of populations, the number of livestock, and the number of vehicles in Bogor City in order from 2013 until 2019 that downloaded on the official website of BPS - Statistic of Bogor Municipality: [16]–19].

Besides those data, we also used each user's oxygen consumption [20], [21]. Tabular data were processed in Microsoft Office Excel software. On the spatial data, the datasets used are the median image of Landsat 8 Oli satellite imagery data from 2013 to 2019, with each taking a time range of 60 to 91 days due to the image conditions with the least clouds and the clearest imagery. Moreover, we also used the vector data of the Bogor City Administration Boundary [22]. Spatial data is processed using Google Earth Engine.

TABLE I
NUMBER OF POPULATIONS IN BOGOR CITY BASED ON BPS – STATISTIC OF BOGOR MUNICIPALITY

Year	The Number Of Populations
2013	1,013,019
2014	1,030,720
2015	1,047,922
2016	1,064,687
2017	1,081,009
2018	1,096,828
2019	1,048,610

TABLE II
NUMBER OF VEHICLES IN BOGOR CITY BASED ON BPS - STATISTIC OF BOGOR MUNICIPALITY

Year	The Number Of Vehicles			
	Car	Bus	Truck	Motorcycle
2013	35,377	369	5,162	131,492
2014	57,838	516	7,388	202,113
2015	75,64	721	9,857	267,735
2016	95,765	915	12,102	335,682
2017	116,443	1,116	14,266	404,053
2018	137,688	1,323	16,353	472,85
2019	159,518	1,538	18,366	542,075

TABLE III
NUMBER OF LIVESTOCKS IN BOGOR CITY BASED ON BPS – STATISTIC OF BOGOR MUNICIPALITY

Year	The Number Of Livestocks			
	Cow and Buffaloe	Horse	Goat and Sheep	Poultry
2013	1,267	55	13,392	344,683
2014	1,205	56	14,543	316,387
2015	1,173	60	13,774	333,525
2016	1,216	67	13,877	316,809
2017	1,228	83	15,481	264,9
2018	1,481	101	15,885	267,318
2019	1,494	102	15,981	266,975

C. Method

The first stage of this analysis is preparing the tabular and spatial data required in the data processing process. After all, data is ready, process the spatial data using Google Earth Engine. The steps taken on the Google Earth Engine include clipping the image with existing vector data to make the imagery satellite only focuses on the region of interest. After that, do the calculation of vegetation indexes in the form of Normalized Difference Vegetation Index (NDVI), Normalized Difference Built-Up Index (NDBI), and Normalized Difference Water Index (NDWI) to see the visual appearance as well as the resulting land cover [23] that make it easier to collect the training data and define objects more clearly. After that, processing the imagery satellite uses the pixel-based classification feature that is processed by machine learning: Random Forest [24].

The classification process is divided into two classes: vegetation and non-vegetation, which are defined by taking data training as much as needed in feature collection at Google Earth Engine. To see how accurate is the image classification process, calculate the confusion matrix and the accuracy [25], where the highest scale at the best accuracy is 100% [26]. Furthermore, calculate the availability of the pixel on the screen to see how large the vegetation area and non-vegetation classes are from the classification process. After that, convert it into hectares and percentages for easier understanding and

could be compared with another calculation that Microsoft excel does. After all data processing on the Google Earth Engine is complete, make the map layout at Earth Engine Apps and add some widgets containing legend so that the display of classification results is more attractive, clear, and easy to understand.

After the spatial data processing is complete, then processing the tabular data in Microsoft Office Excel by using the exponential model calculation for prediction [27] of the incomplete data from the BPS - Statistic of Bogor Municipality and using the Gerarkis Method calculation for each data of each year.

The Gerarkis method is a method for determining the amount of vegetation area in the city by approaching the important issues that arise in the study area in meeting the amount of oxygen demand of a city area calculated by the equation [12]. The determining parameters are the number of populations, the number of livestock, and the number of vehicles [28]. The formula [13] is as follows:

$$Lt = \frac{Pt+Kt+Tt}{54 \times 0.46} \quad (1)$$

Information:
Lt = Vegetation area that calculates by each year (m^2).
Pt = The amount of oxygen demand of the population per day by each year (g/day).
Kt = The amount of oxygen demanded by vehicles per day per year (g/day).
Tt = The amount of oxygen demand of livestock each year (g / day).
54 = Constant, 1 m^2 land area produces 54 grams of dry plant weight per day (g/day/m^2)
0.46 = The percentage of carbon concentration is 46% of each kilogram of dry weight [13].
With assumption:

- Oxygen users are only humans, vehicles, and livestock [20].
- The number of entering and leaving vehicles in the research area is considered the same every day [20].
- The need for oxygen per day for each human being is the same, which is scored 600 liters/day or 0.864 kg/day [20].
- The need for oxygen by vehicles is scored 11.63 kg/day for cars; 45.76 kg/day for buses; 22.88 kg/day for trucks; 0.58 kg/day for motorbikes [20].
- The need for oxygen by livestock is scored 1.70 kg/day for cows and buffaloes; 1,854 kg/day for horses; 0.314 kg/day for goats and sheep; and 0.17 kg/day for poultries [21].
- Oxygen supply outside the area is ignored and only supplied by plants [20].

After knowing the result from the calculation of the required vegetation area based on the Gerarkis Method, subtract the vegetation needs results based on the Gerarkis Method and the area of existing vegetation in Bogor City according to the classification results at Google Earth Engine. The difference between the two results of these calculations is the addition of green spaces requirement needed to fulfill the oxygen demand needed in Bogor City every year, from 2013 to 2019.

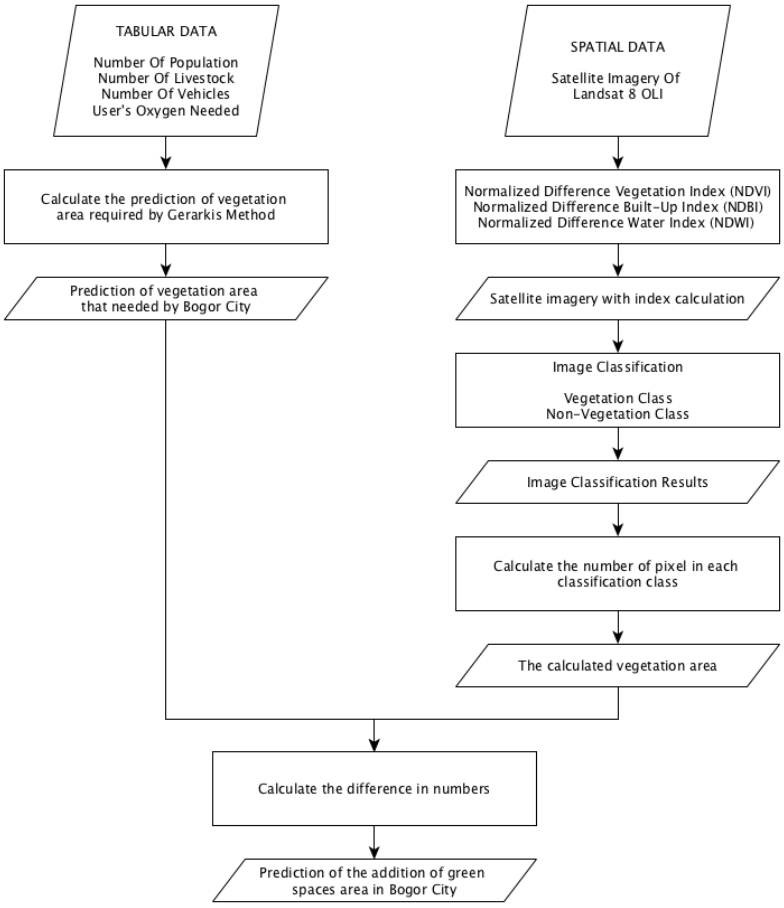

Fig. 2 Flowchart Of The Process

III. Result and Discussion

A. *Results of Spatial Data Processing*

The results of spatial data processing are in the form of classification results, the calculation of the area of the vegetation and non-vegetation class, and the accuracy of each year.

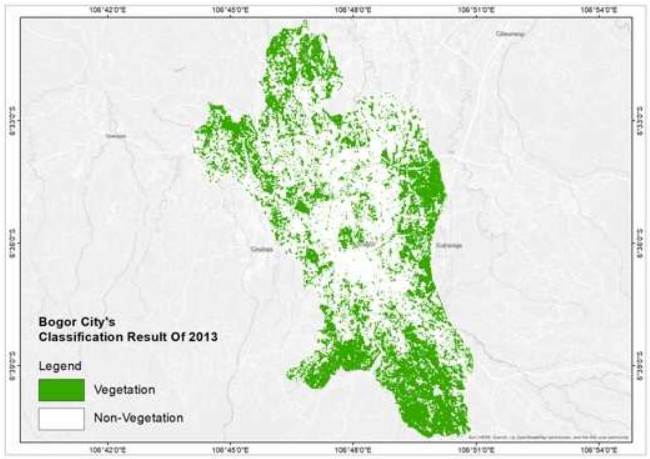

Fig. 3 The classification results of 2013

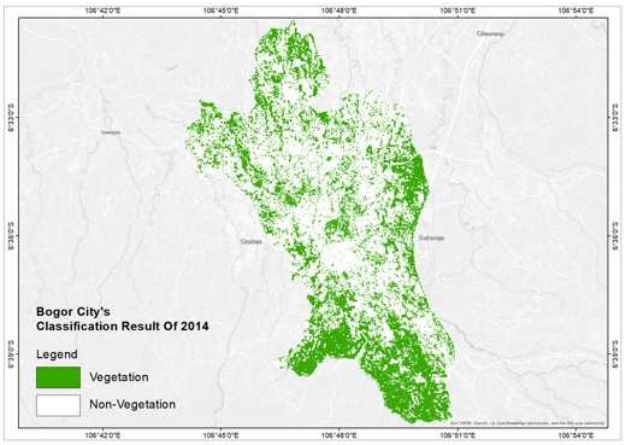

Fig. 4 The classification results of 2014

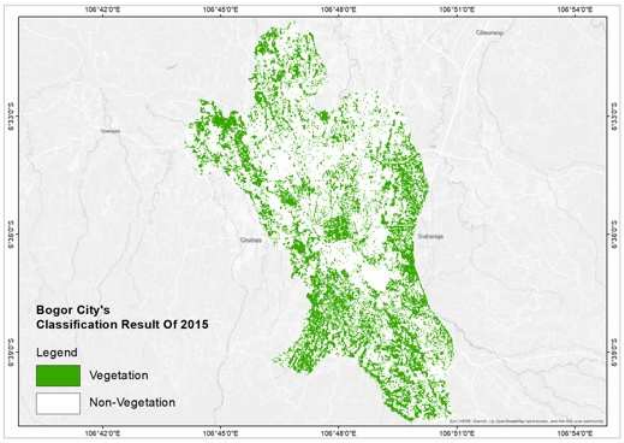

Fig. 5 The classification results of 2015

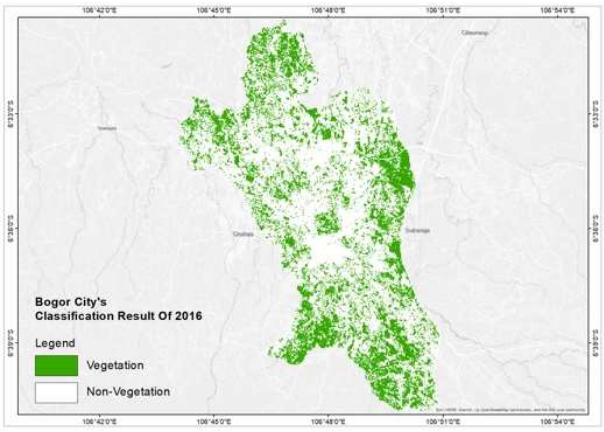

Fig. 6 The classification results of 2016

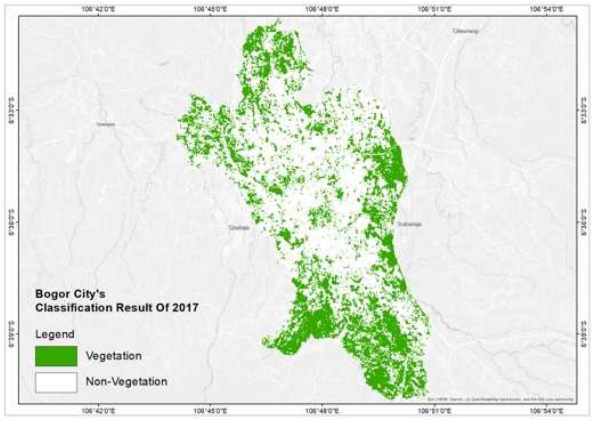

Fig. 7 The classification results of 2017

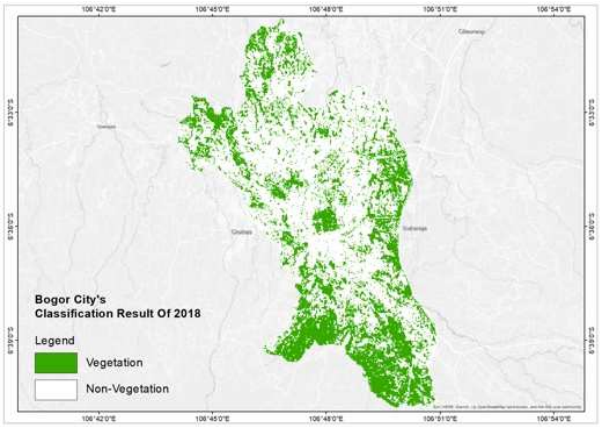

Fig. 8 The classification results of 2018

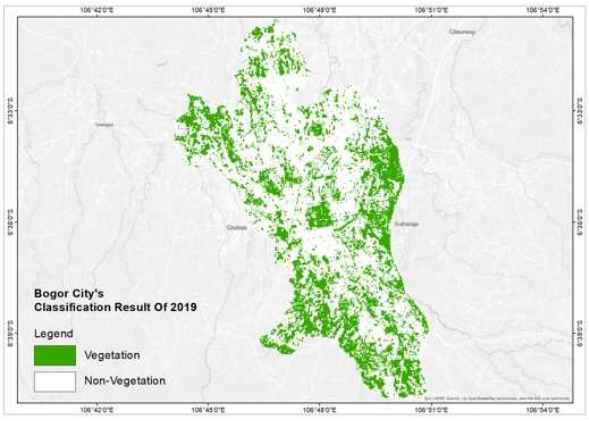

Fig. 9 The classification results of 2019

TABLE IV
THE CLASSIFICATION RESULTS

Year	Date / Month	The Classification Results	
		Non-Vegetation	Vegetation
2013	Sept 1st – Oct 30th	6,808.05	4,619.52
2014	Sept 1st – Oct 30th	7,138.89	4,288.68
2015	Sept 1st – Oct 30th	7,641.00	3,786.57
2016	June 1st – August 30th	7,570.17	3,857.40
2017	March 1st – May 30th	7,345.89	4,081.68
2018	Sept 1st – Oct 30th	7,404.21	4,023.36
2019	Sept 1st – Oct 30th	7,513.02	3,914.55

TABLE V
THE PERCENTAGE AND ACCURATION OF CLASSIFICATION RESULTS

Year	Date/Month	Percentage		Accuracy
		Non Vegetation	Vegetation	
2013	Sept 1st – Oct 30th	59.58%	40.42%	95.11%
2014	Sept 1st – Oct 30th	62.47%	37.53%	91.45%
2015	Sept 1st – Oct 30th	66.86%	33.14%	92.93%
2016	June 1st – August 30th	66.24%	33.76%	94.79%
2017	March 1st – May 30th	64.28%	35.72%	96.49%
2018	Sept 1st – Oct 30th	64.79%	35.21%	96.88%
2019	Sept 1st – Oct 30th	65.74%	34.26%	95.24%

The results of the 2 classes classification from 2013 to 2019 show a graph of vegetation classes that tend to be unstable where there is an increased value in 2016 and 2017 and a decreased value in 2014, 2015, 2018, and 2019. Meanwhile, the non-vegetation class graph has the same condition as the vegetation class, but the increase and decrease at the non-vegetation value show a greater difference in the range of the existing year. In the non-vegetation class, there was an increased value in 2014, 2015, 2018, and 2019 and a decrease in 2016 and 2017. The results of the classification of these 2 classes are contradictory because the increase or decrease in value that occurs in these two classes must fulfill the total area of Bogor City. The 2 classification classes processed from 2013 to 2019 produce an average accuracy of 94.70%.

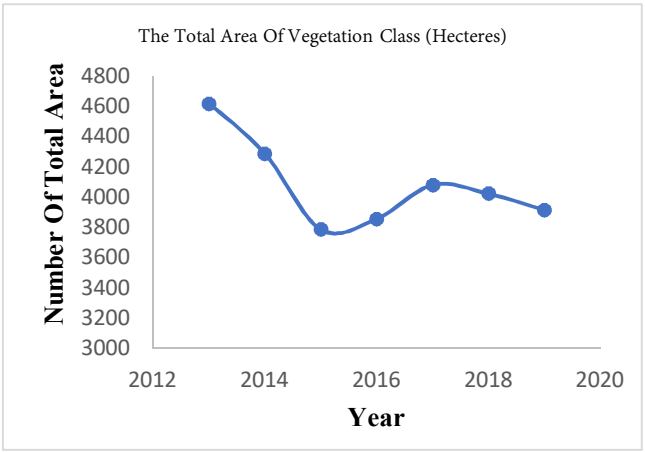

Fig. 10 Graph of the vegetation area of the classification result.

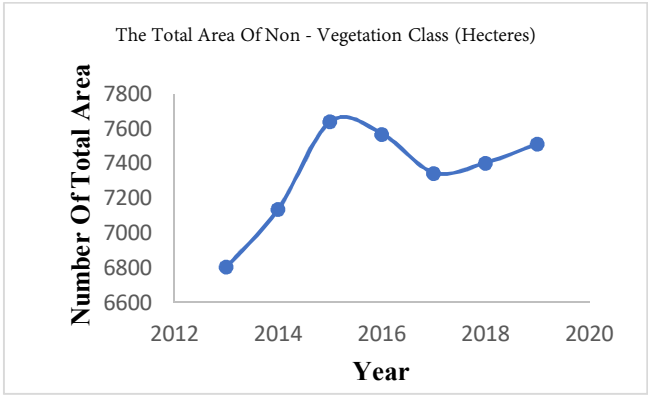

Fig. 11 Graph of the non-vegetation area of the classification result.

The classification results can be accessed in https://rasendriyaramanda.users.earthengine.app/view/vegetation-and-non-vegetation-classification-of-bogor-city

B. Results of Tabular Data Processing

The processing results from the Gerarkis Method Calculation have increased every year. The highest value was in 2019, which scored 8553.55 hectares, and the lowest value was in 2013, which scored 4900.83 hectares.

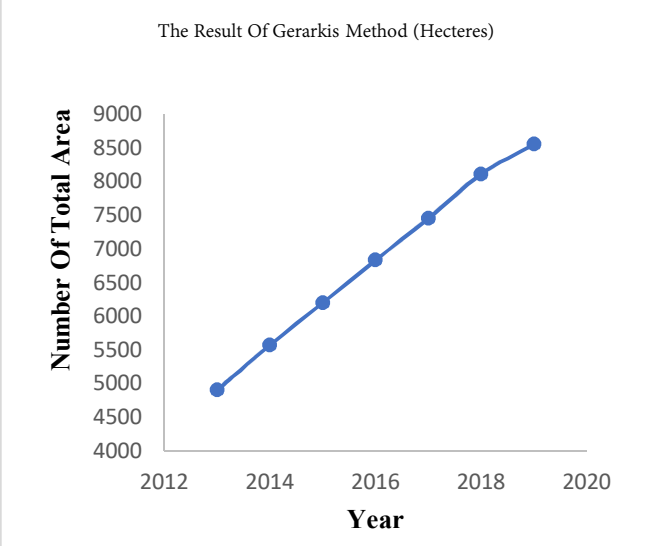

Fig. 12 Graph of the vegetation area based on the Gerarkis Method

TABLE VI
THE RESULTS OF GERARKIS METHOD

Year	The Results of The Gerarkis Method (Hectares)	Percentage of The Total Area
2013	4,900.83	42.89%
2014	5,571.39	48.75%
2015	6,198.93	54.25%
2016	6,834.53	59.81%
2017	7,452.99	65.22%
2018	8,113.04	71.00%
2019	8,553.55	74.85%

This result appeared that the number of users is majority increasing from 2013 to 2018 (users: populations, vehicles, livestocks). Meanwhile, the number of populations and livestock has decreased in 2019, but the increased number of vehicles still followed it.

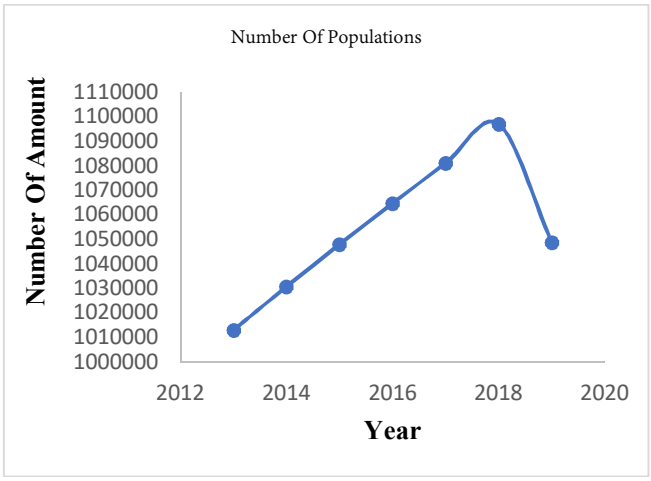

Fig. 13 Graph of the number of populations.

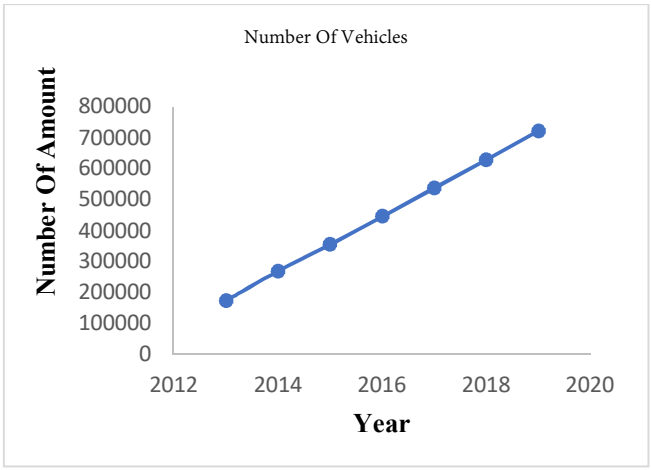

Fig. 14 Graph of the number of vehicles.

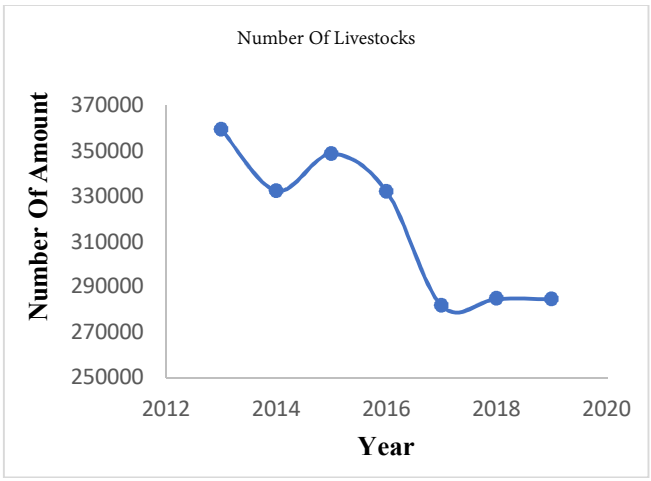

Fig. 15 Graph of the number of livestocks.

After knowing the value from the Gerarkis Method's calculation and also known the value of the number of vegetation class from the classification process, which assumes the condition of the existing vegetation in Bogor City, then calculates the difference between the two values to see the prediction of the required addition of green spaces area based on the oxygen demand of users in Bogor City. The results of the difference are as follows:

TABLE VII
PREDICTION RESULTS OF THE ADDITION OF GREEN SPACES AREA

Year	Prediction Of the addition Of Green Space Area	Percentage Of The Total Area
2013	281.31	2.46%
2014	1,282.71	11.22%
2015	2,412.36	21.11%
2016	2,977.13	26.05%
2017	3,371.31	29.50%
2018	4,089.68	35.79%
2019	4,639.00	40.59%

It can be seen that the prediction condition of the addition of green spaces area in Bogor City continues to increase every year. This is due to the increasing value of the Gerarkis Method calculation. As a result, adding green areas is important to improve the quality of life of city's residents [29], especially with the high growth of oxygen users. Besides that, the development must be considered as the area's proportion, distribution, configuration, and types of existing green spaces in Bogor City [30].

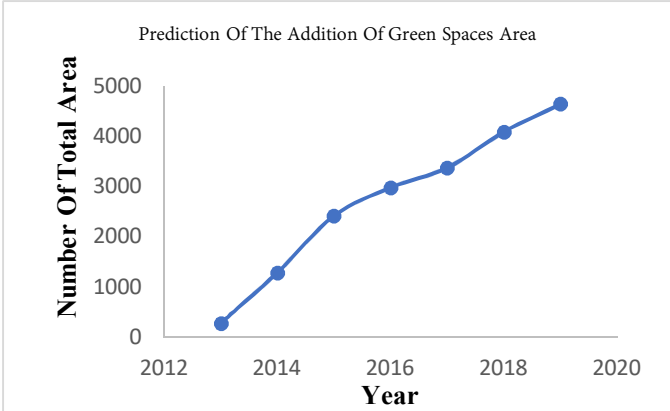

Fig. 16 Graph of the addition of green spaces area prediction.

IV. CONCLUSION

In this study case of the Bogor City area, it can be seen that 2019 became the year of the highest score of the prediction for the needs of the addition of green spaces area compared to previous years where the needs area in 2019 reaches 4,639.00 Hectares, or around 40.59% of the total area of Bogor City. Meanwhile, the lowest score occurred in 2013, with the needs area being 281.31 Hectares or around 2.46% of the total area of Bogor City. These two things are caused by the majority of the number of users who are the objects of calculation in the Gerarkis Method has increased every year. So in 2019 becomes the highest number of the majority of users and in 2013 is the lowest number of all users. Also, the average accuracy from the results of the classification process on Google Earth Engine from 2013 to 2019 occurred as 94.70%, and the total area of Bogor City detected on Google Earth Engine is 11,427.57 hectares with a total number of pixels are 126,973 pixels.

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