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GREEN LAND MAPPING USING QGIS AND FUZZY LOGIC IN MAINTAINING AIR QUALITY IN CENTRAL JAKARTA

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ABSTRACT

The air quality in Central Jakarta in the past year has been the talk of the town. This is due to many things, including green spaces that are not maximized. In this research, in addition to using the QGIS geospatial application, fuzzy logic is also used in decision making. The research uses quantitative research with additional literacy studies. The data used in this research is image data from QGIS, which is then integrated with fuzzy logic. The parameters used in this research are Vegetation Density, Population Density, and Air Quality. The data obtained in this study is that the vegetation density obtained is included in the low category, the population density is included in the high category with a value of 22,062.98 people/km^2. Based on fuzzy logic, if vegetation is low and population density is high then air quality is low. This is in accordance with the data which states that during August-September 2024 the air quality in Jakarta was at 51.84 on the PM2.5 scale. Therefore, it is necessary to create more green open land than what currently exists if the air quality in central Jakarta is to be better than now.

Keywords: *Central Jakarta, Population Density, Fuzzy Logic, QGIS, Vegetation*

INTRODUCTION

In 2023, Central Jakarta was the talk of the town due to its high pollution levels. The pollution is obtained from several things, namely motor vehicle fumes, industrial areas, and the daily activities of the people of Jakarta. Based on the air quality index (AQI) states that the air quality in southern Jakarta is on average in the interval 150 to 200 which is an unhealthy air quality interval (Pratiwi et al., 2023). While Jakarta's IKU on July 29, 2024 was at a value of 139 which indicates unhealthy air quality for certain groups. Low air quality can cause many problems, both for health, and for environmental quality in the area. Based on research from Indonesia's National Risen and Innovation Agency (BRIN), there are five diseases caused by pollution, namely stroke, ischemic heart disease, diabetes mellitus, chronic obstructive pulmonary disease, and neonatal disorders (BRIN, 2024). So with low air quality, it is necessary to improve quality, one of which is by increasing green open space.

Green Open Space (GOS) is a public facility in which there is vegetation that refers to parks, open fields to other public facilities that have the aim of improving environmental quality in an area (Dollah et al., 2023). Then GOS can also be interpreted as public space in the form of parks, fields, waterside spaces found in urban environments (Wang et al., 2019). GOS is also a facility of urban communities, in the form of ecological services (Zhang et al., 2021). Based on some of these definitions, we can conclude that GOS is a public facility in the form of parks, open spaces (fields) that can be used for urban communities that have a function to improve the quality of the environment at that location. Therefore, it is necessary to map green open spaces in Central Jakarta, which can then be used as a reference in adding these green spaces or improving the quality of existing green spaces.

This research will discuss the mapping of green spaces in Central Jakarta which will then be resolved with Fuzzy logic. This research is empirical research by using Quantum GIS (QGIS) in retrieving Central Jakarta image data regarding the number of existing green spaces. This research aims to provide an overview and reference for the government regarding the mapping of existing green spaces in Central Jakarta using QGIS and Fuzzy logic. Then the relevant government can realize it by adding green spaces in certain locations or by improving the quality of existing green spaces. So that the air quality in Central Jakarta is in a normal state.

METHOD

Research Area

This research focuses on one area, namely Central Jakarta in Jakarta Province (figure 1). The selection of the research area is because Central Jakarta is the center of business in Jakarta so it needs good air quality.

Figure 1. Research Area

Data processing

In this study, integration between quantum GIS and fuzzy logic was carried out. Where the fuzzy logic used is with several variables. These variables include vegetation density, population density, and air quality in central Jakarta. Vegetation density was chosen to see how dense the vegetation is in Central Jakarta. Then population density was chosen, because people have an influence on the amount of pollutants produced. As for air quality, it is an important parameter in this study because it assesses the condition of the urban environment.

Vegetation Density

Vegetation density is information obtained from vegetation cover that affects peatland susceptibility to fire (Sari et al., 2022). In addition, vegetation density is also the proportion of plants in a certain area (Rhee et al., 2023). In this study, vegetation density refers to the NDVI (Normalized Difference Vegetation Index) which uses light reflected from the eaGOS's surface (Huang et al., 2021). In this study, NDVI image data was collected using the Quantum GIS application with image data from USGS earth Explore. Determine the amount of NDVI using the following formula 1:

NDVI = (NIR – RED)/(NIR + RED) ……..(1)

Where:

NIR : Near-Infrered (Near Infrared Light)

RED : Red Light (Visible wavelength)

NDVI values are in the interval -1 < NDVI < 1, with the explanation of the results being in table 1:

Table 1. NDVI Scale Interval and Descriptions

No	NDVI value	Description
1	Approaching -1	Water, Snow, Land without Vegetation
2	Approaching 0	Areas with very sparse vegetation
3	Approaching 1	Dense and healthy vegetation

Then in this study, the vegetation density variable is divided into three scales, namely low, medium and high. Where the scale can be seen from image data and NDVI calculations, then adjusted to the following table 2:

Table 2. The Scale used in this Research

No	Scale	NDVI values	Symbol	Description
1	Low	< 0.2	Red	Very sparse vegetation (arid land, hard surfaces, open ground, buildings)
2	Medium	0.2 < NDVI < 0.5	Yellow	Vegetation Sparse to moderate (grassland, shrubs)
3	High	>0.5	Green	Dense vegetation (tropical forest, dense forest)

Futhermore, this vegetation density will be mapped using quantum GIS using data from Landsat 8.

Population Density

Population density is the number of people living in an area, usually expressed as the number of people per square kilometer (Bhadra et al., 2021). In this study, data was obtained from BPS data in the form of population and area in km^2. Based on this understanding, the population density has the following formula 2:

PD = Total Population/Area ……(2)

Where:

PD = Population Density

Then from that data, we use a scale in determining population density. The scale used in this research is (table 3):

Table 3. PD Scale Used

No	Scale	PD Value (soul/km^2)	Description
1	Low	< 1000	More vacant land
2	Medium	1000 < PD < 5000	Has green land, but is densely populated
3	High	>5000	Densely populated

Air Quality

Air quality is a scale of how clean the air in an area is from various types of pollutants (Shihab, 2023). Usually the geographical location determines the quality of the air in an area. For example, for areas with a geographical location in the mountains, the air quality is in the good category, while in metropolitan cities the air quality is poor. In this study, the main component that affects air quality that will be discussed is particular matter 2.5 (PM2.5). The scale used in this study, especially in PM2.5, is as follows in table 4:

Table 4. PM2.5 Scale Used

No	Scale	PM2.5 value $\left(\mu g/m^3\right)$	Description
1	Low	0-12	Clean, good air
2	Medium	12.1-55.4	Quality is acceptable but for sensitive individuals there is a mild risk
3	High	55.5-150.4	Unhealthy and health impacts are starting to be felt

Source: (Chen & Copes, 2013)

Fuzzy Logic

Fuzzy logic can be used to model the relationship between the three variables. The result of fuzzy logic is a formulation that produces flexible and realistic decisions (Li & Gao, 2015; Maddeh et al., 2023; Ren et al., 2022). The fuzzy logic in this study is to determine the relationship between vegetation density and population density in determining air quality in Central Jakarta. The following are the fuzzy rules in this study (table 5:

Table 5. Fuzzy Logic in this Research

If		So
Vegetation Density	**Population Density**	**Air Quality**
High	Low	Good
Medium	Medium	Medium
Low	High	Bad
High	Medium	Medium
Low	Low	Medium
Medium	High	Bad
High	High	Medium

Source: (Laécio Carvalho de Barros, Rodney Carlos Bassanezi, & Weldon Alexander Lodwick, 2017)

RESULTS AND DISCUSSION

Vegetation Density

Jakarta is a metropolitan city with a dense population, and is the economic center of Indonesia. This causes a lot of land to be used for settlements, which means that land use for green open space is lacking. We can see this from data processing using image data obtained on Landsat 8 images with processing using Quantum GIS. The data used is data for output in the form of vegetation density, namely Bands 4 and 5 on Landsat 8. The following is the resulting data (figure 2).

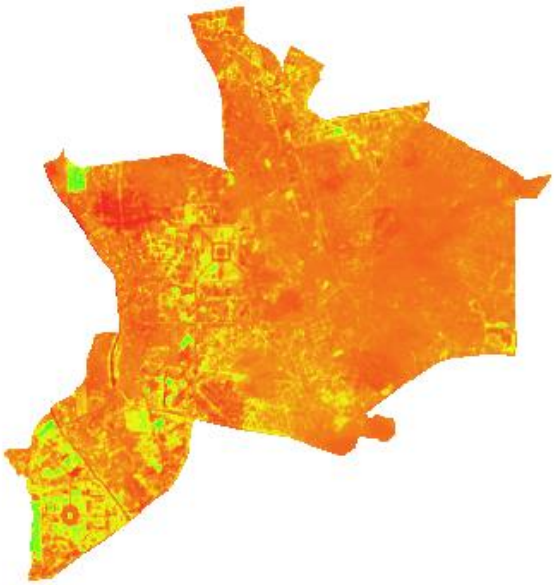

Figure 2. Result of NDVI Data Processing with QGIS

From the image, we see that the resulting color is more dominantly yellow to red (orange) although there are some areas that are green. From the image, we can also see that most of the colors are orange, which means that the vegetation in the central Jakarta area is in the low category.

Population Density

Jakarta is one of the provinces with a large population. Based on data released by the Central Bureau of Statistics (BPS), the total population in Jakarta in 2023 was 10,672,100 people, with an administrative area of 660.98 km^2. Based on this number, the population density in the province of Jakarta is 16,145,874 people / km^2 and is included in the densely populated category, with the distribution of population density for each region as follows in table 6:

Table 6. Population Density in Jakarta Province

No	Region Section	Total Population (People)	Area (km^2)	Population Density (People/km^2)	Description
1	Kepulauan Seribu	28.523	10,73	2.658,25	Medium
2	Jakarta Selatan	2.235.606	144,94	15.424,36	Densely populated
3	Jakarta Timur	3.079.618	185,54	16.598,14	Densely populated
4	Jakarta Pusat	1.049.314	47,56	22.062,95	Densely populated
5	Jakarta Barat	2.470.054	125,00	19.760,43	Densely populated
6	Jakarta Utara	1.808.985	147,21	12.288,47	Densely populated

(Source: BPS, 2024)

Based on this table, most of the cities in Jakarta are densely populated areas, especially Central Jakarta City with a very high population density where the KP value obtained is 22,062.95 people / km^2.

Air Quality

In addition to the dense population, Jakarta province also has poor air quality, where on September 16 the air quality in Jakarta was 47.3 µg⁄m^3 on the PM2.5 scale or unhealthy and hazardous to health or moderate category. While in the last one month, August 17, 2024 to September 16, 2024, the air quality in Jakarta is as follows in figure 3:

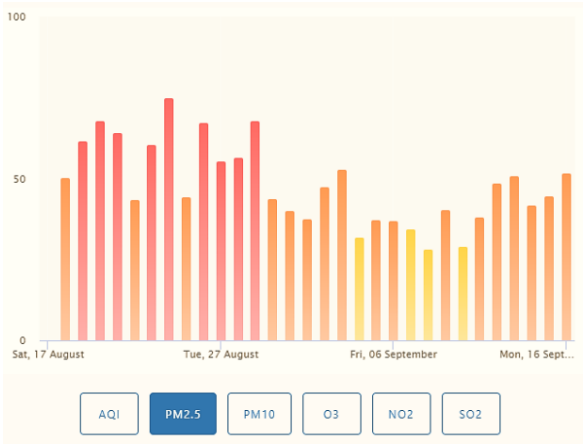

Figure 3. Graph of Air Quality in Jakarta with PM2.5 Scale in the last Month (Source: IQ Air, 2024)

Based on this data, the vertical line describes the air quality index using the PM2.5 scale, while the horizontal line describes the time of data collection. The graph explains that the average air quality index in Jakarta with the PM2.5 scale is at ± 51.84 $\mu g/m^3$ which means that the air quality is in the moderate category.

Fuzzy Logic

Based on the data processing of vegetation density, population density, and air quality in Central Jakarta, then the next step is to process and analyze with fuzzy logic. Where based on the data obtained we get the results in the following table 7:

Table 7. Fuzzy Logic Processing and Analysis

Vegetation Density	Population Density	Air Quality	Fuzzy logic	Conclusion
Low	High	Medium	Based on the fuzzy logic table displayed above. If the vegetation density is low and the population density is high, then the air quality in the area is low.	Air quality is low, so there is a need to reopen green spaces.

CONCLUSIONS

Conclusion

From the data processing and analysis using fuzzy logic above, it can be concluded that the condition of vegetation in Central Jakarta is included in the low category so it needs to be a concern for the local government in improving this. Then in terms of population density, Central Jakarta is the city with the highest population density in Jakarta province. Based on the calculation, the population density obtained is 22,062.95 people/km2. This indicates that the population in Central Jakarta is very dense, so it can be used as a reference in making population transmigration policies to other cities or districts. Based on this data, when vegetation is low and population density is high, the air quality in the area is poor. This is in accordance with data released by Index Quality Air (IQ Air) which states that in the last month, Jakarta has a scale of 51.84 on the PM2.5 scale which means that the value is quite high and is included in the moderate category. Therefore, from the data obtained, it is necessary to increase the amount of green open space in Jakarta, especially in Central Jakarta, as well as the transmigration of residents from Jakarta to other cities or districts that are still sparsely populated.

Suggestions

Suggestions given for futher research are:

1. For air quality, it can be seen from various types of scales, for example PM10, NO_2, NO_2, which are then integrated between several scales
2. Mapping pollution sources such as roads, factories, and pollution from households.

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