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MORALITY BEFORE KNOWLEDGE

Spatial prioritization of urban green open space development using weighted overlay analysis

Dani Mauliyanti[1,*]
[1] *School of Environmental Science, Universitas Indonesia, Central Jakarta, DKI Jakarta 10430, Indonesia.*
*Correspondence: dani.mauliyanti@ui.ac.id

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ABSTRACT
Background: Urban areas are ecosystems where plants, animals, humans, and infrastructure interact. Green open spaces (GOS) like parks are vital in cities for facilitating this interaction. However, rapid urbanization and limited land often lead to the conversion of green spaces into built-up areas, which increases urban temperatures, disrupts ecosystems, and lowers the quality of life for city dwellers. The allocation of GOS development is often not aligned with the community's actual needs. This study aims to determine the priority locations for GOS development in Mataram City using the Weighted Overlay method in the ArcGIS application. **Method:** This study employs a qualitative approach using spatial analysis through the Weighted Overlay method in ArcGIS. Three key variables are considered: the comfort index (THI), vegetation density (NDVI), and population density. The data from these variables are combined to assess and prioritize areas in Mataram City for GOS development. **Findings:** The analysis shows that the sub-districts of Mataram and Cakranegara have the highest priority for GOS development, based on the combined analysis of comfort index, vegetation density, and population density. These areas require more green space to improve environmental quality and meet the community's needs. **Conclusion:** The study highlights the importance of prioritizing GOS development in Mataram and Cakranegara sub-districts. It suggests that urban planning policies in Mataram City should focus on these areas to enhance urban living conditions and mitigate environmental degradation caused by limited green spaces. **Novelty/Originality of this article:** This research is unique in applying the Weighted Overlay method in ArcGIS to evaluate and prioritize GOS locations based on multiple urban variables. It provides valuable insights for urban planners, offering a data-driven approach to address the challenges of green space distribution in urban environments.

KEYWORDS: green open space; weighted overlay analysis; NDVI; THI.

1. Introduction

The increase in the number of people living in urban areas has increased from around 751 million in 1950 to 4.2 billion in 2018 (Widyaningrum, 2018). The significant increase in the number of people in urban areas is due to the phenomenon of urbanisation where cities provide large employment opportunities and complete facilities and infrastructure compared to rural areas, thus attracting many people to live in cities. The substantial rise in urban area population is primarily attributed to the process of urbanization, which offers cities a wide range of job opportunities and comprehensive facilities and infrastructure in comparison to rural regions (Dadashpoor & Etemadi, 2024). Cities are always evolving and changing. The shape of the city, which is a product of changes in space and time, will always change to reflect the lives and characters of its inhabitants (Heryanto, 2001). Urban development is a process of change from one state to another in different times in the same

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space. The development and shape of the physical structure of a city can be known through changes in city elements as the shaper of urban space (Kurniawati, 2010). These elements are physical and non-physical elements. Physical elements include transportation facilities, markets, government centres, open spaces, worship centres, residential areas and so on, while non-physical elements are humans with all their activities. Few city governments in developing countries have the power, resources and trained personnel to provide the land, services and facilities that their rapidly growing populations need for a decent human life: clean water, sanitation, schools and transport. The result is the proliferation of illegal settlements with very modest facilities, increased overcrowding, and rampant diseases associated with unhealthy environments (Brundtland, 1987).

Cities will always develop with all the processes that surround them, be it physical, social and economic processes, the unpreparedness of the government in responding to the development of a rapidly growing city will have an impact on the city's inability to provide a decent life for its residents, especially providing green open spaces as a place for people to gather and interact with nature. Cities are centres of activity that have high levels of natural resource consumption, contributing greatly to global environmental issues (Mayona, 2021). Urbanization, deforestation, and the expansion of agricultural land, result in reduced or complete loss of wildlife habitats, poor connectivity for wildlife, loss of biodiversity, extinction of certain species, a multitude of environmental issues, and negative consequences for human well-being (Ma et al., 2024). The density of the city population causes the need for land for development to be higher and threatens the existence of urban animal and plant ecosystems that live in urban green open spaces. Investigations into urban development and land use modifications are often tied to ecological degradation and shifts in urban temperature levels (Patra et al., 2025; Duan et al., 2025).

According to global population rankings, Indonesia holds the fourth position. The Indonesian population has been expanding from 97.02 million in 1961 to 270.20 million in 2020 (Central Statistics Agency, 2020). By 2035, an estimated 66% of Indonesia's population will be living in cities, whereas a mere 34% will reside in the countryside (Central Statistics Agency, 2020). The increasing population density in urban areas leads to more development and land-use conversion, resulting in a decrease in the availability of green open spaces. The existence of green open spaces (GOS) in urban areas is a strategy for urban development to maintain the ecosystem of urban animals and plants, besides the existence of green open spaces such as urban parks has a relationship with human physical activity (Cohen, 2006). Green open space can improve physical and mental health (Bhor & Mayavel, 2024). Green open space is a major part of the urban ecosystem and has a significant impact on improving the ecology and sustainability of the urban environment (Jian & Hao, 2020). The ecological function of city parks is to guard the quality and stability of the urban environment, reduce noise, and regulate the microclimate. Ecologically comfortable parks will attract public interest as a means of recreation and education (Erdianto et al., 2019). Parks as green open spaces have an ecological function that is very beneficial for the survival of animals and plants as well as urban human life, the limited existence of land in urban areas often causes the ecological aspects of parks to not be optimally implemented. As park users, humans visit parks for many reasons, such as exercising or simply relaxing to enjoy nature.

The provision of urban green spaces not only plays a role for ecological quality but contributes to the identity of the city, beautifying the city, and increasing people's happiness (Nurfadhil & Zain, 2024). Cities increase development for urban purposes, when trees can sustain various ecosystems, urban residents enjoy several benefits with more trees, green open spaces help in addressing climate change, increase biodiversity and economy (Saha & Atiqul, 2024). Based on Law Number 26 of 2007 concerning spatial planning, GOS is an elongated area/path and/or grouping, which uses it more open in nature, where plants grow, either naturally growing or deliberately planted. Article 29 explains that the proportion of GOS in the city area is at least 30% of the city area. The distribution of GOS is adjusted to the distribution of population and service hierarchy by taking into account the structure plan and spatial pattern. Green open space, hereinafter abbreviated as GOS, is an elongated/lane and/or grouped area whose use is more open, where plants grow, both those that grow naturally and those that are deliberately planted, taking into account aspects of ecological, water catchment, economic, socio-cultural, and aesthetic functions (Regulation of the Minister of Agrarian Affairs and Spatial Planning/Head of the National Land Agency No. 14 of 2022).

Urban green open space is part of the open spaces of an urban area filled with vegetation to support ecological, socio-cultural and architectural benefits that can provide economic benefits (welfare) for the community. Sobol & Skubala (2022) states that green open spaces provide several benefits to urban life, having the potential to improve environmental conditions, biodiversity, outdoor activities, active community life, social interaction and people's physical and emotional health. Green spaces are where people improve their happiness, economic situation and mental and physical health. Saha & Atiqul (2024) states that one of the important functions of green open spaces is to improve environmental quality, providing living space for plants and animals. Plants can absorb CO_2 and other elements in the air so that the presence of green spaces can reduce pollution, provide sound protection, reduce urban water flow and reduce the impact of urban heat island (Kim et al., 2020).

To find out the urban heat island of a city can use remote sensing methods with landsat satellite imagery, one of the calculations used is the land surface temperature (LST). LST is one of the fundamental aspects of climate change, which impacts organisms and ecosystems from small to large scales. Land surface temperature is a state controlled by the energy balance of the surface, atmosphere, thermal properties of the surface, and subsurface media (Becker & Li, 1990 in Utomo et al., 2017). As the content of greenhouse gases in the atmosphere increases, the land surface temperature will also increase (Rajeshwari & Mani, 2014 in Guntara, 2016). Several studies on the urban heat island phenomenon have been conducted in Indonesia using the LST and NDVI approaches. Research in Bogor City found an urban heat island phenomenon, which occurs due to the increase in built-up areas and the decreasing green open spaces, resulting in an increase in temperature of more than 27°C in the city center (Deviro et al., 2025). Research in Padang City also shows that the LST shows a significant temperature difference in Padang City between the highlands and lowlands, and temperatures in the lowlands, which are dominated by built-up areas, show a high temperature increase (Antomi et al., 2025).

Land surface temperature can be known through remote sensing technology that produces land surface temperature data from an area based on landsat satellite images that have thermal sensors. In addition, there is a vegetation density analysis or Normalised difference vegetation index (NDVI) which is important in understanding urban land dynamics. According to Jiang et al. (2008), NDVI is a sensitive indicator in determining vegetation density and condition. This NDVI analysis provides a clear picture of vegetation distribution in urban areas (Weng, 2012). The NDVI parameter enables effective monitoring of land changes, such as increasing urbanisation and decreasing green open land (Zhou & Wang, 2011). According to Shahtahmassebi et al. (2021), in evaluating urban land cover change, high NDVI values indicate good vegetation, while low values indicate a lack of vegetation or low density. This analysis can identify rapid urbanisation and changes in land use patterns (Seto et al., 2012).

Mataram City is one of the developing cities in Indonesia, apart from being the provincial capital, in the National Spatial Structure and Spatial Pattern Plan of Mataram City is designated as a National Activity Centre and in the spatial plan of Nusa Tenggara Barat Province is designated as a Provincial Strategic Area, the location of Mataram City which is on the island of Lombok and adjacent to the island of Bali which is one of Indonesia's tourism centres provides its own attraction for tourists to vacation on the island of Lombok, this condition is especially beneficial for Mataram City, which causes the development of the city to increase both in terms of physical and economic. The development of Mataram City is characterised by the increasing number of residents, so that city development is increasingly massive (Mataram City, 2019).

The limitation of urban land causes land conversion to occur, urban green land such as agriculture and plantations turn into built-up land. This condition will cause the green open space cover area to decrease and increase the surface temperature in Mataram City, the increasing temperature will cause damage to urban ecology and also affect the activities of urban residents. Determining the location of additional green open space in urban areas in Indonesia has experienced problems including the human population that tends to accumulate in the city centre making it difficult to add public green open space optimally in cooling urban air temperatures, as well as the basis for planning green open space in urban areas in Indonesia so far only paying attention to the quantity or amount of green open space (Humaida, 2016). Increased development in Mataram City causes the existence of green spaces to be important. The purpose of this study is to analyse the determination of areas that must have green spaces so that there is an increase in the number and area of green spaces, so as to meet the 30% green space requirement in the city and improve the quality of the environment and life of urban communities, especially in Mataram City.

2. Methods

2.1 Research location

The research location is in Mataram City, West Nusa Tenggara Province. The area of Mataram City consists of a land area of 61.30 km^2. Geographically, Mataram City is located at the western end of Lombok Island and is in the position of 116º04'-116º10' East Longitude and 08º33'-08º38' South Latitude with the following boundaries: Gunungsari Sub-district and Lingsar Village, West Lombok Regency to the north. Narmada Sub-district and Lingsar Village of West Lombok Regency to the east. Labuapi sub-district, West Lombok district to the south. Lombok Strait to the west. Administratively, Mataram City consists of: 6 sub-districts, 50 urban villages, 325 neighbourhoods and 1,673 neighborhood association.

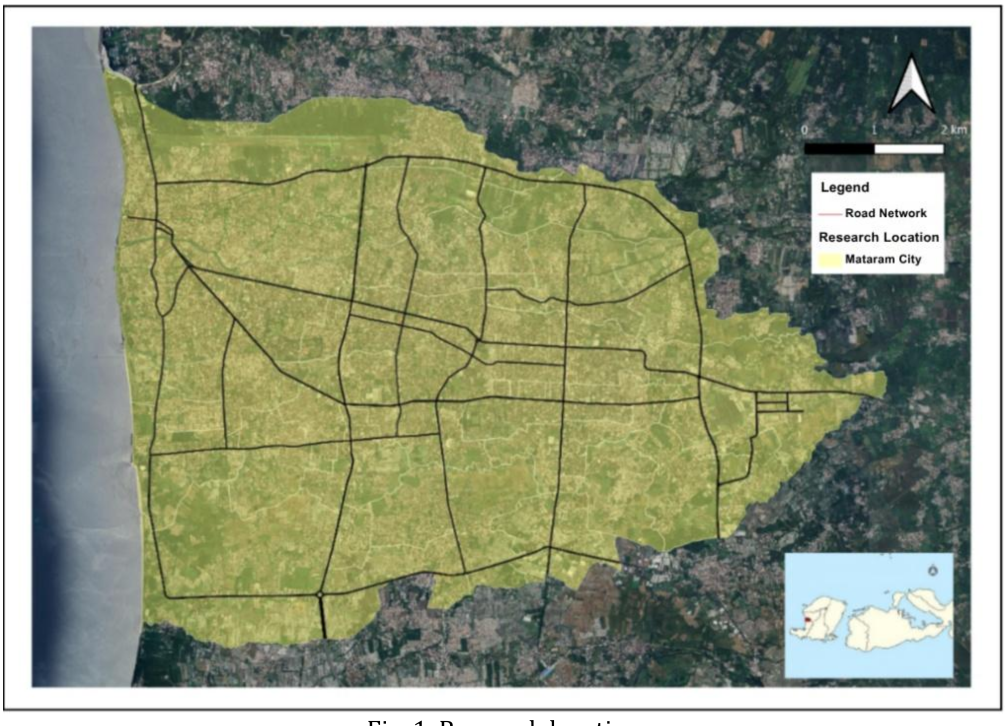

Fig. 1. Research location

2.2 Research method

The method used is remote sensing method, using landsat multi spectra satellite data obtained from the United States Geological Survey (USGS) processed using Arc Gis 10.8.2.

The 2023 image uses landsat 8 ORI/TIRS satellite image dated 14 October 2023. Landsat 8 imagery was selected with the criteria that the research location in the image was free of cloud cover. In determining the priority location of GOS, 3 aspects are used, namely the biological aspect measured using the vegetation index (NDVI) which describes the density value and the level of green biomass, areas with low NDVI values in the form of vacant land, built-up land, grass and shrubs will become priority areas of GOS. The comfort index (THI) is used as a physical aspect to describe the effect of air temperature and humidity on human comfort. The social aspect uses population density as the measuring value because population density has a relationship with the lower presence of green open space and tends to have hot temperatures.

2.3 Analysis data method

The data analysis used is an overlay analysis technique using the Weighted Overlay tool in ArcGIS 10.8.2 application by overlaying the three variables analysed (THI, NDVI and population density) based on the scoring given to each variable (Table 1), The total score of each variable consisting of comfort index (THI), vegetation density (NDVI), and population density is then sorted from highest to lowest. Those with the highest scores will be prioritised first, namely locations with high humidity and temperature, low vegetation density and high population density. Determination of priority areas for green open space uses several variables, namely vegetation density index, temperature humidity index and population density (Umar et al., 2022). The criteria for determining the GOS area are as follows:

Table 1. Determination of green open space priority criteria

Variable	Indicator	Criteria	Score
Comfort index (THI)	Humidity and temperature	21-24, 25-27 >27	1 3 5
(NDVI)	Vegetation density and condition	Not Dense (0-0.1), Moderately Dense (0.1-0.2), Dense (0.2-0.3), & Very Dense (0.3-0.5)	4 3 2 1
Populatin density (Jiwa/km^2)	Popultion density	Dense (5000-6000), Moderately Dense (6001-7000), Very Dense (>7000)	1 2 3

(Umar et al., 2022)

2.3.1 Temperature heat index

The Temperature Heat Index (Comfort Index) is one method that can be used to assess the level of comfort in an area. This method produces an index to determine the effect of heat conditions on human comfort that combines the elements of temperature and humidity. The Comfort Index is calculated using the Thermal Humidity Index (THI) formula. The THI formula is as follows:

$$THI = 0.8\ T + (RH \times T)/500 \quad \text{(Eq. 1)}$$

THI (Thermal Humidity Index) is an index used to assess the level of comfort or heat stress experienced by humans or animals due to the combined effect of air temperature and humidity. This index takes into account temperature (T), measured in degrees Celsius (°C), and relative humidity (RH), expressed as a percentage (%).

2.3.2 Land surface temperature

One of the data used to measure THI is air temperature. The air temperature data used is obtained from land surface temperature data. Land surface temperature can be known through remote sensing technology that produces land surface temperature data from an area based on landsat satellite images that have thermal sensors. If there is a change in surface temperature, it will potentially change the cycles that work on earth. Indirectly, the cause of the increase in surface temperature is due to human activity. The increase in population has resulted in the conversion of land that was previously green open land into residential areas. The less vegetation in a city causes the surface temperature to increase, because there is no vegetation to absorb heat. In addition, with the number of factories built and the use of motorised vehicles, CO_2 levels are increasing in the atmosphere and surface temperatures are also increasing. LST processing is done with the mono windows algorithm (MWA) method, where thermal band 10 data and emissivity values are used to obtain LST values (Wachid & Tyas, 2022). The following equation 9is used:

$$LST = Tb / 1 + (\lambda \times Tb/\alpha) \ln\varepsilon \quad \text{(Eq. 2)}$$

LST (Land Surface Temperature) is the land surface temperature (K). Tb is the TOA brightness temperature (K). λ is the emitted radiance equal (11.5×10^{-6}). α is 1.438×10^{-2} m·K. ε is the land surface emissivity.

2.3.3 Normalized diference vegetation index

The NDVI calculation follows the principle that green plants grow very effectively by absorbing radiation in the visible light spectrum (PAR or Photosynthetically Actif Radiation), and then green plants reflect radiation from the near infrared region.The calculation of NDVI is as follows (Darlina et al., 2018; Muzaky & Jaelani, 2019; Putra et al., 2018; Zhang et al., 2017 in Wachid & Tyas, 2022):

$$NDVI = (NIR - RED) / (NIR+RED) \quad \text{(Eq. 3)}$$

NIR is near infrared radiation from pixels. RED is red light radiation from pixels. The general range for green vegetation is in the value range of 0.2 - 0.8. According to Sobrino et al. in Wachid & Tyas (2022) the classification of NDVI is divided into 3, namely NDVI < 0.2 pixels are considered as bare land, both NDVI > 0.5 pixels are considered as moderately vegetated land, namely pixels with NDVI values higher than 0.5 are considered fully vegetated.

3. Result and Discussion

3.1 Green open space condition in Mataram City

Mataram City is the capital of West Nusa Tenggara province, as a capital city with all the facilities and infrastructure, Mataram City is the main choice for people to work and live, so that the development of Mataram City is growing rapidly every year. One of the impacts of the rapid development of the city is the change in land use due to the increasing demand for housing and other city infrastructure facilities. Table 2 shows land use in Mataram City in 2016, 2020 and 2023. From the table it is known that in addition to housing development, land is also used to build office facilities, other economic facilities and government facilities as well as public facilities for city residents such as school facilities, recreation facilities, health, sports facilities, worship facilities, and entertainment facilities. Land use in Mataram City in more detail can be seen in the following table and figure:

Table 2. Land use in Mataram City in 2016, 2020 and 2023

No	Land use	Land area (Ha) (2016)	Land area (Ha) (2020)	Land area (Ha) (2023)
1.	Residential	2,432.00	2,492.00	2,508.48
2.	Sport Field	46.1	46.1	46.1
3.	Cemetery	51.64	51.64	51.64
4.	Office Buildings	116.13	116.94	121.83
5.	Educational Facilities	152.47	153.03	153.96
6.	Healthcare Facilities	23.9	23.9	23.9
7.	Places of Worship	63.33	63.33	63.53
8.	Services	-	0.38	0.41
9.	Markets/Terminals	68.35	68.35	68.35
10.	Shops/Gas Stations	106.17	108.7	110.21
11.	Food Stalls/Restaurants	1.56	1.56	3.07
12.	Hotels/Motels	19.23	20.47	21.96
13.	Warehousing	52.4	54.8	56
14.	Industry	51.75	51.75	51.82
15.	City Parks	6.07	6.07	6.07
16.	Designated Land	129.88	129.88	130.97
17.	Agricultural Land	2,726.78	2,659.30	2,629.68
18.	Unused Land	81.89	81.89	82.02
19.	Total	6,130	6,130	6,130

(Central Statistics Agency of Mataram City, 2024)

Based on the table above, it can be seen that during the period 2016-2023 Mataram City experienced an increase in land use in most sectors. However, with the area of Mataram City remaining at 6,130 Ha, the increase in some sectors caused a decrease in other sectors, in this case there was an increase in the construction of housing, offices, education, worship, services, shops, stalls.

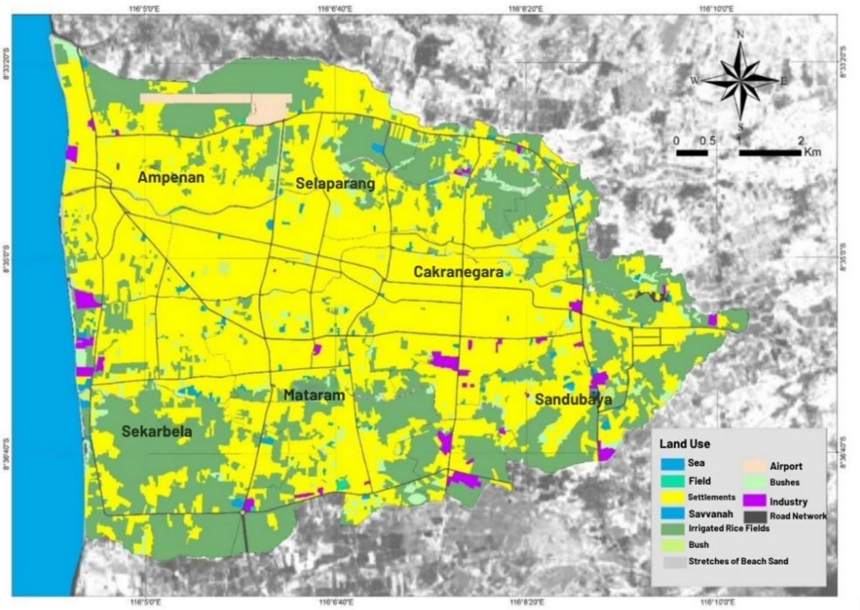

Fig. 2. Land use in Mataram City

Hotel, warehousing, industry, and land allotted, the development of these sectors indicates the increasing amount of built-up land in the city of Mataram. In contrast, the agricultural sector experienced a reduction in area of 97.1 Ha from 2016 to 2023 and the city park did not experience an increase in area of 6.07 Ha. This condition indicates that the existence of green open lands is decreasing in the city of Mataram. In analysing the priority of green spaces, a land use map is also needed, which will provide an overview of the actual land use conditions in the research location. In this study, ten land cover classes were determined, namely housing, shrubs, irrigated rice fields, fields, savanna, shrubs, beach sand, airports, industry and road networks.

3.2 Comfort index (temperature humidity indeks)

To find out the comfort index, a search for surface temperature data using land surface temperature and humidity data obtained from BMKG stations located in West Lombok Regency, namely Zainuddin Abdul Madjid Meteorological Station with a data range in October 2023.

3.2.1 Land temperature

Analysis of surface temperature in Mataram City using landsat 8 OLI TRIS imagery acquired in October 2023 shows that Mataram City has a variable surface temperature with a minimum temperature of <23°C and a maximum temperature of >32°C Areas with high temperature levels are in the middle of the city which has a high built-up area and for the suburban area relatively has a low temperature because there is still a lot of open space and vegetation in the area, the more vegetation/green open space is able to reduce land surface temperature in urban areas. Surface temperature in Mataram City is classified into 4 categories, namely:

Table 3. Classifications

Color	LST value (Temperature °C)	Classification
Red	>32	High temperature
Orange	28-31	Moderately high temperature
Yellow	24-27	Moderate temperature
Green	<23	Low temperature

In the northern part of Mataram City there is one part that produces a very red colour, the location is the former Selaparang airport which is currently not functioning again, the temperature increase is due to the aircraft runway which is made of asphalt so that it emits high heat. The following is a map of LST in Mataram City:

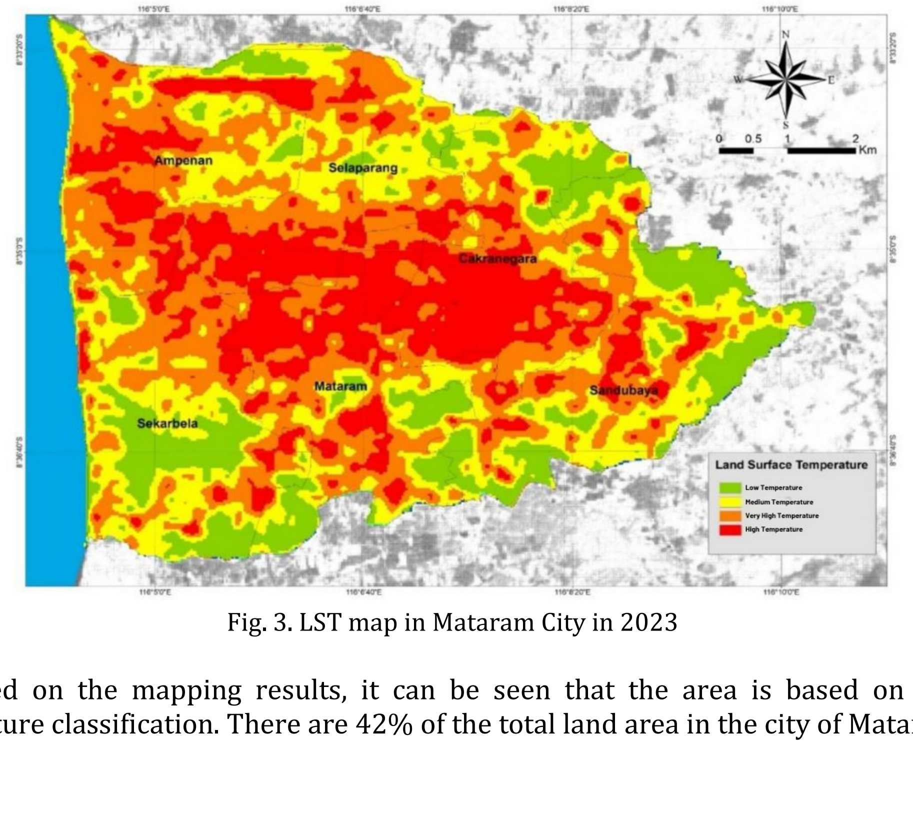

Fig. 3. LST map in Mataram City in 2023

Based on the mapping results, it can be seen that the area is based on the LST temperature classification. There are 42% of the total land area in the city of Mataram is at a fairly high temperature which is between 28-31 ° C, and 36% is at a low temperature <23%, the rest is at a medium temperature of 20% and 0.8% is at a very high temperature which is more than> 32 ° C. The following is a table of LST values and areas in Mataram City in 2023:

Table 4. LST value and area of Mataram City in 2023

NDVI value	Classification	Area (km^2)
>32	High temperature	0.74
28-31	Moderately high temperature	41.59
24-27	Moderature temperature	19.55
<23	Low temperature	36.1

3.2.2 Relative humidity level

Relative humidity data obtained from the Meteorological, Climatological and Geophysical Agency (BMKG) station data located in West Lombok Regency, namely the Zainuddin Abdul Madjid Meteorological Station with a data range in October 2023, data collection in October is adjusted to the retrieval of satellite imagery data used in the study, namely in October. The following is the average humidity data in Mataram City in October 2023.

Table 5. Mataram City average humidity data in October

Date	Average humidity (RH_avg)
01-10-2023	80
02-10-2023	82
03-10-2023	82
04-10-2023	86
05-10-2023	81
06-10-2023	81
07-10-2023	78
08-10-2023	78
09-10-2023	74
10-10-2023	81
11-10-2023	82
12-10-2023	80
13-10-2023	77
14-10-2023	76
15-10-2023	78
16-10-2023	82
17-10-2023	79
18-10-2023	79
19-10-2023	-
20-10-2023	72
21-10-2023	79
22-10-2023	80
23-10-2023	-
24-10-2023	78
25-10-2023	79
26-10-2023	78
27-10-2023	78
28-10-2023	82
29-10-2023	75
30-10-2023	74
31-10-2023	74
01-11-2023	77
Average	76.2

(Meteorology Climatology and Geophysics Agency of Mataram City, 2024)

The humidity data used is the result of the calculation of the average daily relative humidity in 2023 obtained from the BMKG online data page. The relative humidity value in Mataram City is 76.2%. The relative humidity (RH) value of 76.2% is included as the RH value in the THI formula.

3.2.3 Comfort index

Based on the results of the calculation of land surface temperature and average humidity in Mataram City, the comfort index is then calculated. The Comfort Index is calculated using the Thermal Humidity Index (THI) formula. The following is a map of the comfort index in Mataram City in 2023:

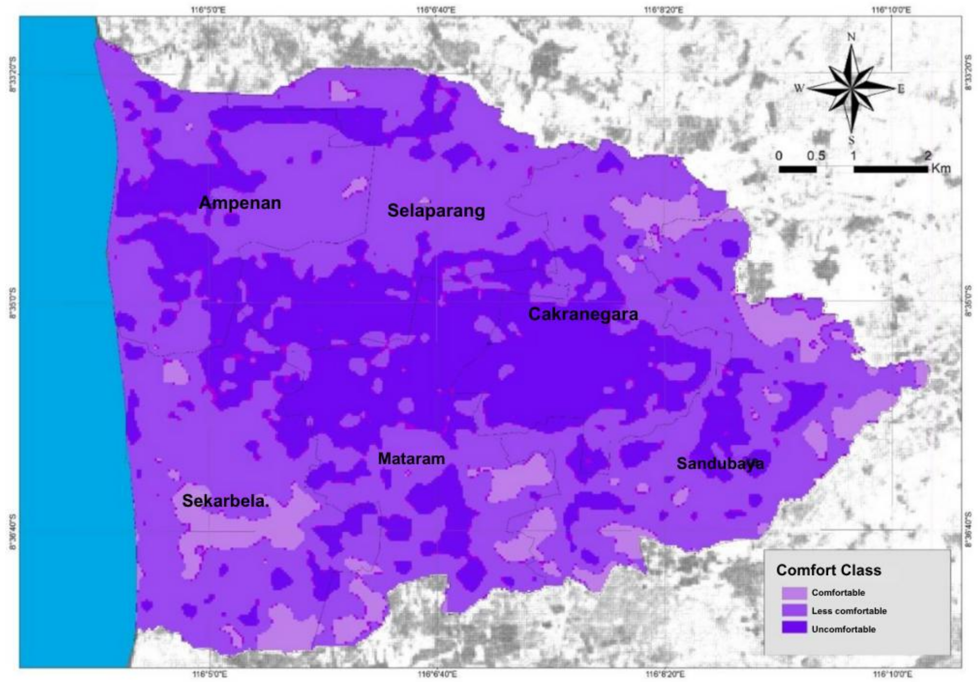

Fig. 4. THI map in Mataram City in 2023

Based on the results of the THI calculation, it is known that the central part of the city is dominated by less comfortable comfort level in the temperature range of 25-27 ° C and in the suburbs has an uncomfortable comfort level of >28 ° C and some are at a comfortable level in the temperature range of 21-24.9 ° C. One of the factors that causes the tendency to increase areas with uncomfortable categories is due to high urbanisation rates which causes the reduction of green open areas and the increase in built-up areas (Wati & Fatkhuroyan in Umar et al., 2022).

3.3 Vegetation density index (NDVI)

Mataram City, with its rapid development, has caused many vegetation land cover to decrease, especially agricultural land. NDVI analysis can produce an overview of the vegetation cover covering Mataram City. According to Jia et al. in Lasaiba & Tetelepta (2023) the range of NDVI values from -1 to 0 indicates non-vegetated areas such as water, rocks, or snow. In contrast, a range of values from 0 to 1 indicates the presence of vegetation, where higher values indicate a higher density of vegetation. In use, high NDVI values indicate a high density of vegetation present in an area. According to Zhou & Wang in Lasaiba & Tetelepta (2023) high NDVI values indicate the presence of good, dense and lush vegetation. NDVI values close to 1 indicate the presence of areas covered by very dense and good vegetation. The following is a classification of vegetation density levels in Mataram City:

Table 6. Classification of vegetation density levels in Mataram City

Color	NDVI value	Classification
Red	0.3-0.5	Very dense vegetation such as rice fields, plantations and shrubs
Yellow	0.2–0.3	Dense vegetation such as rice fields, plantations and shrubs
Blue	0.1-0.2	Moderately dense vegetation such as vacant land, settlements, buildings and industries
Dark Blue	0-0.1	Non-dense vegetation such as vacant land, settlements, buildings and industries
Black	-0.1-0	No vegetation such as water and roads

From the analysis results, it is found that the NDVI value in Mataram City shows a fairly high value. The lowest NDVI value is -0.04, a minus NDVI value indicates non-vegetated areas such as water, rocks, roads or open areas not covered by plants. The highest NDVI value is 0.4, the value range of 0-1 indicates the presence of vegetation where high values indicate a higher density of vegetation.

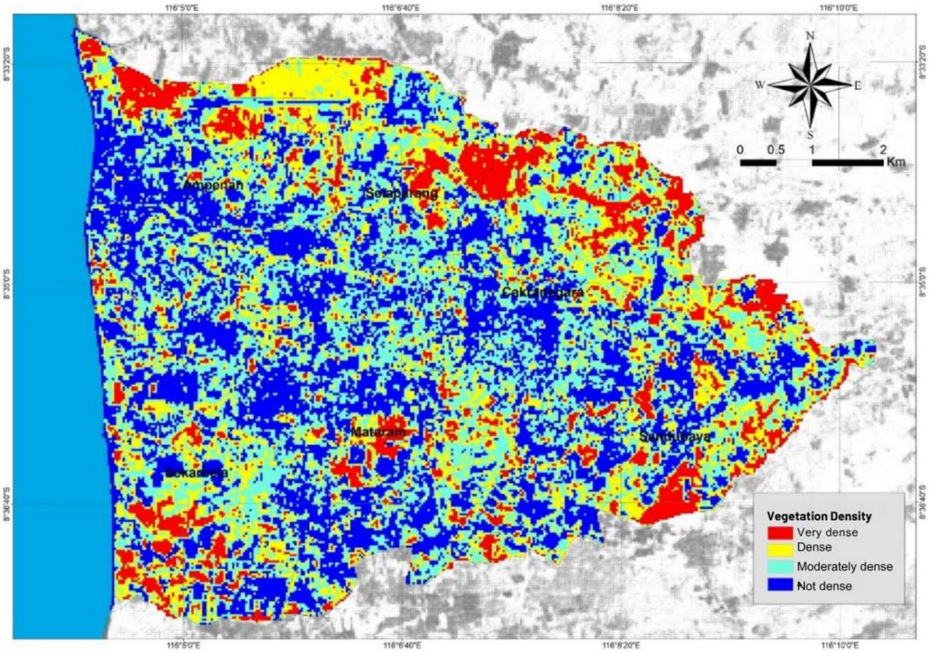

Fig. 5. NDVI map of Mataram City in 2023

Based on the mapping results, it can be seen that the area is based on the NDVI classification. There are 31.07 km^2 of the total land area in the city of Mataram has a level of vegetation density that is not dense and 18.96 km^2 has a fairly dense vegetation condition. Only 0.83 km^2 has dense vegetation and 7.45 km^2 is in very dense condition. The low vegetation density indicates that the built-up land is quite dense in the area.

Table 7. NDVI value of Mataram City in 2023

NDVI Value	Classification	Area (km^2)
0.4-0.6	Very dense	7.45
0.3 -0.4	Dense	0.83
0.2-0.3	Moderately dense	18.96
0-0.1	Sparse	31.07
-0.1-0	Non-begetated	1.79

3.4 Population density index

The number of residents in Mataram City increases every year, in 2023 the population of Mataram City is 441,147 people, an increase of 11,496 people from the 2020 population of 429,651 people. The population of Mataram City has not spread evenly throughout the Mataram City area. Many people live and settle in Ampenan sub-district. On average, the population density of Mataram City in 2023 was recorded at 7,197 people per square kilometre, and the most populous area is Ampenan sub-district with a density of 9,652 people per square kilometre. The table below shows that the population density in the 2020-2023 period has increased from 7,009 people/km^2 in 2020 to 7,197 people/km^2 in 2023. Then for the population growth rate indicator, based on population census data, it has increased from 0.635% per year to 1.34% per year, sandubaya sub-district is the sub-district with the highest growth rate in 2024 at 2.10% per year and selaparang sub-district with the lowest growth rate of 0.22% per year.

Table 8. Number and population density per sub-district in Mataram City

District	Population (2020)	Density per km^2 (2020)	Growth Rate (%) (2020)	Population (2023)	Density per km^2 (2023)	Growth Rate (%) (2023)
Ampenan	88,022	9,305	1.08	91,311	9,652	1.87
Sekarbela	58,786	5,696	0.99	60,816	5,893	1.73
Mataram	77,465	7,199	0.56	79,132	7,354	1.08
Selaparang	68,657	6,375	-0.55	68,965	6,403	0.22
Cakranegara	67,826	7,014	0.55	69,261	7,162	1.06
Sandubaya	68,895	6,676	1.17	71,662	6,944	2.10
Mataram City	429,651	7,009	0.63	7,789	7,197	1.34

(Central Statistics Agency of Mataram City, 2024)

Based on the population composition per sub-district, the densest population distribution in Mataram City is in Ampenan Sub-district. Apart from the fact that the area is not that large, this sub-district is one of the oldest settlements in Mataram City which continues to experience population growth.

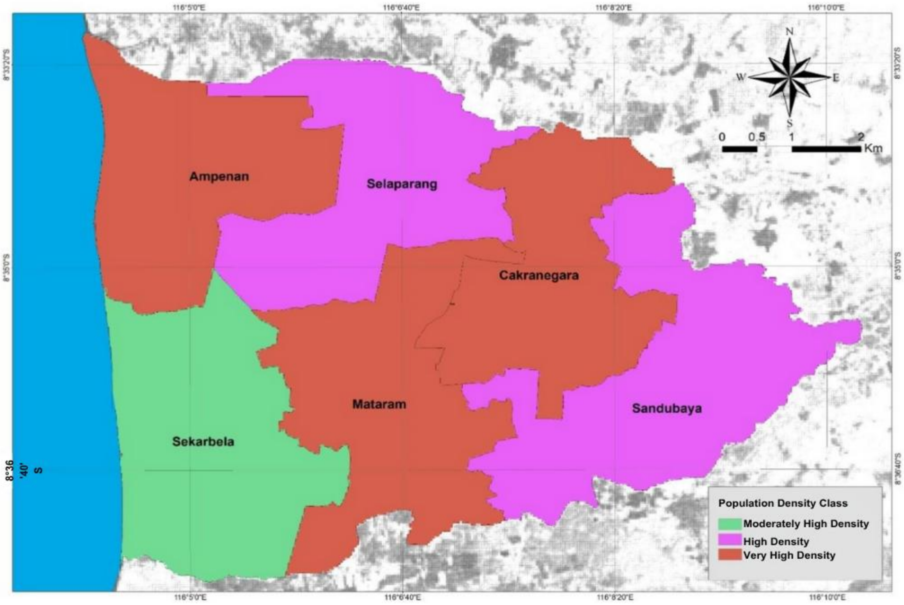

Fig. 6. Population density of Mataram City in 2023

Meanwhile, Selaparang Sub-district with the third largest area has the lowest population density. Most of the land in the sub-district was previously agricultural land, but has now been converted into housing and hotels to provide housing for its residents and to support trade and services as sectors that drive the economy of Mataram City. The population density analysis of Mataram City uses data from the Central Statistics Agency of

Mataram City in 2024. From this data, it is then visualized into spatial data in the form of a population density map and assessed based on density class.

Based on the population density data of Mataram City in 2023, it is known that all sub-districts in Mataram City are classified as having a dense population density. So that the classification is divided into quite high density from 5000 – 6000 people/km^2, high density from 6001 – 7000 people/km^2 and very high density >7001 people/km^2. From the results of a spatial analysis through population density maps, it is known that Ampenan District, Mataram District and Cakranegara District have very high population density, Sandubaya District and Selaparang District have a high population density and Sekarbela District is the only sub-district that has a fairly high density.

3.5 Determination of green open space priority areas

The determination of green open space priority areas in Mataram City was carried out through a spatial overlay analysis integrating three essential variables—thermal humidity index, normalized difference vegetation index, and population density. Each variable represents a key aspect of urban environmental quality: THI indicates the level of thermal comfort, NDVI represents vegetation cover and greenness, and population density reflects social pressure on land and the community's need for open space. The integration of these variables through the Weighted Overlay Analysis in ArcGIS allows for a comprehensive assessment that identifies the most critical areas requiring green infrastructure intervention. The following is a map of priority areas for green open space in Mataram City:

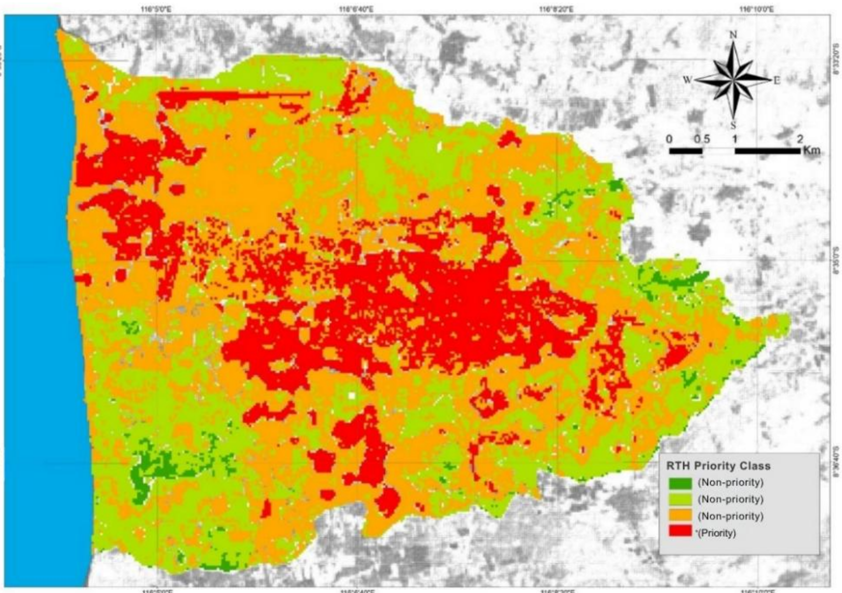

Fig. 7. Map of green open space priority areas

The analysis reveals a clear spatial pattern of priority zones across Mataram City. Areas classified as priority class 4—the highest level of urgency—are predominantly located in the central and eastern parts of the city, particularly in Cakranegara and Mataram sub-districts. These zones are characterized by a combination of low vegetation density (NDVI values between 0.0 – 0.2), low comfort levels (THI >27°C), and very high population densities exceeding 7,000 people/km^2. The limited vegetation cover in these zones results in higher surface temperatures and lower comfort level. Consequently, these areas demand immediate attention for the development of new green open spaces to restore environmental balance and enhance urban liveability.

The overlay results of population density maps, vegetation density (NDVI) and comfort index (THI) can describe the community's need for green open space to reduce urban temperatures by determining priority locations to be added/changed into green open space locations (Humaida, 2016). The priority class of GOS is divided into 4 classes, where classes

1-3 are non-priority locations and class 4 is a location that is prioritized to become GOS with the highest score. The large priority area is in the center of Mataram City. The following is a table of land area per priority class of GOS:

Table 9. land area per green space priority class

Priority class	Area (km^2)
1	0.95
2	17.32
3	27.3
4	12.05

Based on the table and map above, it is known that non-priority classes (1–3) are distributed mostly in peripheral regions such as Sekarbela and parts of Sandubaya, where vegetation density remains moderate to high and population pressure is relatively lower. These regions still maintain agricultural lands and natural vegetation that contribute to the cooling and ecological functioning of the urban environment. Therefore, although green infrastructure remains important, these areas are considered secondary in terms of development urgency.

Quantitatively, the total area designated as priority class 4 covers approximately 12.05 km^2, representing around 19.6% of the total urban area of Mataram City. The majority of this land is composed of built-up and semi-built areas, including residential zones, commercial districts, and vacant lands that can potentially be converted into green parks, community gardens, and linear green corridors. Such conversion would not only help mitigate the urban heat island (UHI) effect but also support social interaction and urban aesthetics.

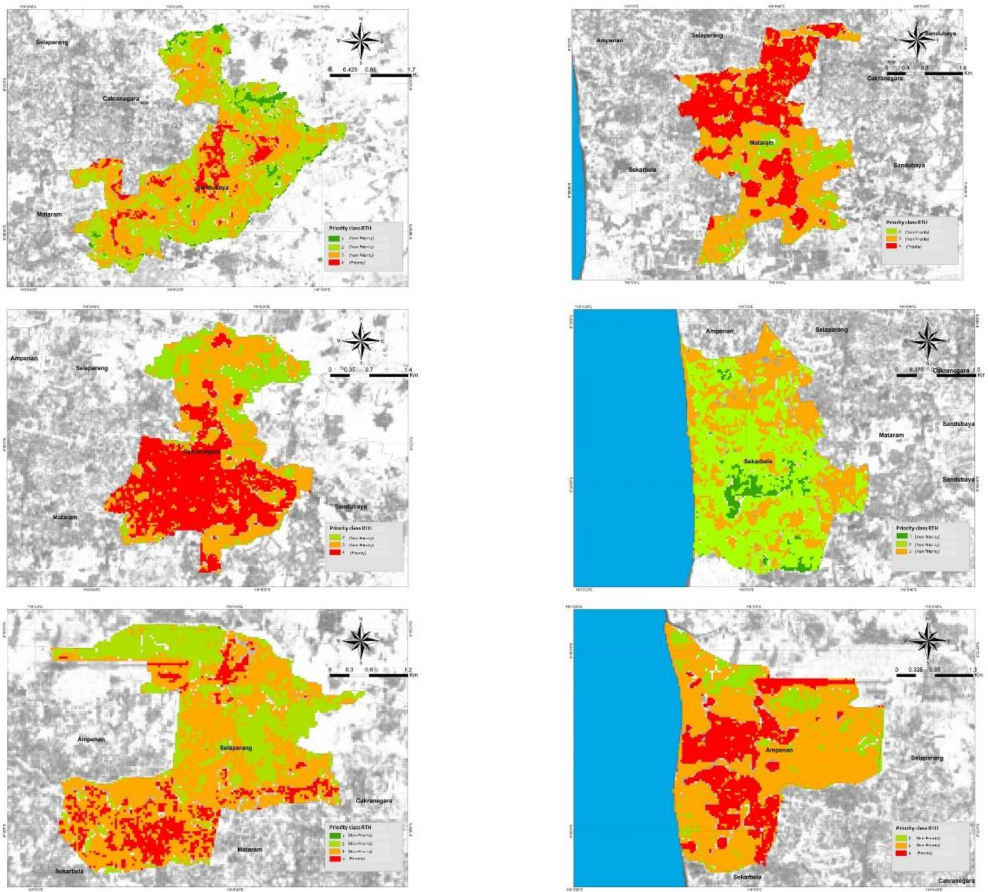

Fig. 8. Map of green open space priority areas in each sub district

The spatial distribution pattern demonstrates that the densest and least vegetated areas correspond closely with the city's commercial and administrative cores. This finding underscores the uneven distribution of green spaces within Mataram City, where accessibility and availability of GOS are concentrated in certain neighborhoods while others remain underprovided. Integrating this spatial prioritization into municipal planning policies will help achieve the national mandate of 30% green open space coverage, while also supporting environmental sustainability and urban resilience goals. The Weighted Overlay Analysis effectively highlights that Cakranegara and Mataram sub-districts should become the main targets for green open space development, followed by Ampenan, Sandubaya, and Selaparang. Strategic urban planning interventions in these areas can promote ecological restoration, reduce thermal discomfort, and enhance public well-being. The results also provide valuable input for future urban design policies, emphasizing the need for data-driven decision-making to ensure equitable and sustainable green space distribution across Mataram City.

4. Conclusions

This study demonstrates the effectiveness of the Weighted Overlay Analysis method in identifying priority locations for urban green open space development in Mataram City. By integrating three spatial variables—Thermal Humidity Index (THI), Normalized Difference Vegetation Index (NDVI), and population density—the research provides a comprehensive assessment of urban areas most in need of ecological restoration and green infrastructure. The findings reveal that the sub-districts of Cakranegara, Ampenan, Sandubaya, Mataram, and Selaparang possess the areas requiring immediate prioritization for GOS development. These areas exhibit a combination of low vegetation density, low thermal comfort, and high population density, reflecting the imbalance between rapid urbanization and environmental sustainability.

The spatial prioritization process offers a valuable framework for data-driven decision-making in urban planning. Establishing new or improved green open spaces in high-priority zones can significantly enhance thermal comfort, mitigate urban heat island effects, and improve the overall ecological balance of Mataram City. Furthermore, this approach aligns with Indonesia's national spatial planning policies that mandate a minimum of 30% green open space in urban areas. In conclusion, sustainable urban development in Mataram requires strategic integration of green infrastructure into city planning. The Weighted Overlay approach not only supports environmental management but also contributes to improving public health, social well-being, and urban resilience. Future studies are encouraged to incorporate additional environmental variables such as air quality and land surface moisture to strengthen the accuracy and applicability of spatial prioritization for urban green space planning.

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Author Contribution
The author solely designed the study, collected and analyzed spatial data, interpreted results, and prepared the manuscript for publication on urban green space prioritization.

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Biographies of Author

Dani Mauliyanti, School of Environmental Science, Universitas Indonesia, Central Jakarta, DKI Jakarta 10430, Indonesia.

- Email: dani.mauliyanti@ui.ac.id
- ORCID: N/A
- Web of Science ResearcherID: N/A
- Scopus Author ID: N/A
- Homepage: N/A