Green Open Space Development Based On Urban Heat Island Phenomenon in Malang City

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Abstract. The development of facilities and infrastructure in Malang is triggering green open space (GOS) into built-up land. However, the development causes an urban heat island phenomenon (UHI). Therefore, to overcome the increase in environmental temperature, it is necessary to develop green open space. This study aims to identify existing green open spaces in Malang City, identify areas with UHI in Malang City, and determine green open spaces in Malang City. The identification of existing GOS based on land cover data generated through on-screen digitizing Google Earth while identifying UHI generated from the analysis of land surface temperature. The analysis shows that the total green open space in Malang City is 4.214 hectares, consisting of private GOS covering 3.635 hectares (34%) and public GOS covering 579 hectares (5%). Meanwhile, the UHI phenomenon in Malang City already covers 59% of the area of Malang City. Therefore, based on some criteria, 30 urban villages can be developed with green open space and arranged into three priority groups to become priority one covering four villages, priority two covering 14 villages and priority three covering 12 villages.

1. Introduction

Malang City is the second-most populous city in East Java [1]. Development has become the government’s primary concern in every region [1]. Malang has experienced an expansion of its urban areas because of industrial activities [2]. This expansion will indirectly affect the increasing need for open space in the city [3]. The increasing area of this built-up area will then sacrifice green open spaces [4].

According to the law of the Republic of Indonesia Number 26 of 2007 about Spatial Planning, the proportion of green open space (GOS) in the city area is at least 30% of the city area with the proportion of public GOS of 20% and private GOS of 10%. However, the GOS for Malang City continued to decline from 2000 to 2015 [5].

Urban heat island phenomena can occur if the surface that should absorb heat from the sun reflects more heat due to land conversion from vegetation to asphalt, concrete, tall buildings, and other infrastructure, resulting in high surface temperatures [6]. Therefore, to overcome the increase in environmental temperature, it is necessary to develop green open space. This research aims to spatially analyze green open space and urban heat island distribution in Malang City. This study also analyzes priority areas in developing green open spaces that can be carried out based on the urban heat island phenomenon.
2. Methodology
The data needed in this study is a Google Earth 2020. This image data used to obtain land cover and green open space distribution. In addition, Landsat 8 OLI/TIRS imagery data path/row 118/66 with month of acquisition November 2019 used to obtain land surface temperature and urban heat island distribution. The selection of month for the image retrieval in this study is based on the latest availability of images that are clean from interference so as not to interfere with the calculation results.

Land covers obtain from a manual interpretation of satellite image data (on-screen digitization). The existing conditions of green open space in Malang City identified by land cover analysis. There are seven types of land cover classification in this study: rivers, built-in land, urban forests/parks, forests, plantations, rice fields, and shrubs. To differentiate some certain vegetation land cover by the appearance of several types of GOS when viewed from the image. Verification is done by checking the existing GOS on Google Earth and accuracy test are conducted to know the overall accuracy and the kappa accuracy. Based on land cover classification results, public GOS obtained in the form of urban forests/parks and private GOS in forests, rice fields, plantations, and shrubs.

Landsat 8 data used in this study are TIR band 10 to estimate the brightness temperature and band 4 and 5 to calculate NDVI. Land surface temperature by converting the DN value to spectral radians using the following formula where \(M_L\) represents the band-specific multiplicative rescaling factor, \(Q_{cal}\) is the Band 10 image, \(A_L\) is the band-specific additive rescaling factor [7]:

\[
L\lambda = M_L \times Q_{cal} + A_L
\] (1)

After the digital numbers (DN) converted to reflection, the TIRS band data should be converted from spectral radiance to brightness temperature (BT) using the thermal constants provided in the metadata file. The following equation is:

\[
BT = \frac{K_2}{\ln\left(\frac{K_1}{L\lambda} + 1\right)} - 273.15
\] (2)

\(K_1\) and \(K_2\) stand for the band-specific thermal conversion constants from the metadata.

Furthermore, the NDVI value is needed to obtain the value of the proportion of vegetation used later in finding the value of land surface emissivity (LSE). The formula for NDVI, proportion of vegetation and emissivity as stated below [8]:

\[
\text{NDVI} = \frac{\text{NIR (band 5)} - \text{R (band 4)}}{\text{NIR (band 5)} + \text{R (band 4)}}
\] (3)

This model adapted from Valor and Caselles, who proposed a theoretical model linking emissivity with NDVI as follows [8]:

\[
\varepsilon_\lambda = \varepsilon_v P_v + \varepsilon_s (1 - P_v) + 4(d_\varepsilon P_v (1 - P_v)
\] (4)

\[
P_v = \left(\frac{\text{NDVI} - \text{NDVI}_{\text{min}}}{\text{NDVI}_{\text{max}} - \text{NDVI}_{\text{min}}}\right)^2
\] (5)

Where \(\varepsilon_\lambda\) is emissivity, \(\varepsilon_v\) and \(\varepsilon_s\) are vegetation and soil emissivities, and \(P_v\) is the proportion of vegetation. Thus, the last step of retrieving the LST is computed as follows [9]:

\[
\text{LST} = \frac{BT}{\left[1 + \left(\frac{\varepsilon_v}{\rho} \ln \varepsilon_\lambda\right)\right]}
\] (6)

\[
\rho = h \frac{\varepsilon_v}{\sigma} = 1.438 \times 10^{-2} \text{mK}
\] (7)

Where \(w\) is the wavelength of emitted radiance (11.5 µm), \(\sigma\) is the Boltzmann constant (1.38 \times 10^{-23})
J/K), \( h \) is Planck’s constant \((6.626 \times 10^{-34}\text{ J/s})\), and \( c \) is the velocity of light \((2.998 \times 10^8 \text{ m/s})\).

The UHI phenomenon defined as an area with land surface temperature is > 30°C [10]. So based from the LST result then will be classify into some classes of temperature to determined the UHI distribution.

3. Results and Discussion

3.1. Green Open Spaces (GOS) in Malang City

Land cover in Malang City dominated by built-up land with an area of 6,531 ha or around 60,50% of the total area of Malang City. The distribution of built-up land concentrated in the north and center of Malang City. Meanwhile, the plantation land scattered in the eastern and western parts of Malang City with 2,124 ha, followed by 1,028 ha of rice fields, parks or open spaces with 579 ha, and shrubs with 412 forests with 71 and rivers or water bodies 51 ha. The accuracy test resulted overall accuracy of 93% and kappa accuracy of 92%.

![Figure 1. Green Open Spaces Distribution in Malang City.](image)

Malang City has a total area of 4,214 ha of green open space, consisting of 2,635 ha of private GOS (34%) and 579 ha of public GOS (5%). In terms of proportion, the plantation is dominant, with a proportion of 50%. Meanwhile, the lowest proportion of green open space is a forest with a proportion of only 2% of the total area of green open space. The village with the highest proportion of green open space is Wonokoyo, with a value of 11.56% of the total area of green open space dominated by plantations (70.97%), rice fields (10.99%), shrubs (3.62%) and parks/open space (1.12%). Meanwhile, there are four villages with a proportion of green open space of 0%, which means they do not have green open space, Ciptomulyo, Rampalcakelat, Samaan, and Sukoharjo.

3.2. Need of GOS Development

Malang City has an area of 10,796 ha. The target proportion of public GOS is 20% of the total city area which means that Malang City still requires 2,159 ha. With the existing public GOS of 579 ha, the remaining public GOS needs for Malang City is 1,581 ha.
Table 1. Analysis of GOS Extent Need in Malang City

|                     | Existing GOS (ha) | Total  |
|---------------------|-------------------|--------|
| Public GOS          | 579               | 4214   |
| Private GOS         | 3635              |        |

|                     | Needs of GOS (ha) | Lack of GOS (ha) |
|---------------------|-------------------|------------------|
| Public GOS          | 2159              | 1581             |
| Private GOS         | 1080              | +2556            |

Moreover, based on Table 1, the need for GOS has fulfilled, the GOS still can keep decreasing. Therefore, to avoid the shortage of GOS in the future, it is necessary to convert private GOS into public GOS to maintain its existence.

3.3. Urban Heat Island (UHI) Phenomenon in Malang City

The village with the highest UHI area is Wonokoyo which is 314 ha with 55% of its total area. Furthermore, there are two villages with a proportion of UHI of 100%, which means that the whole area of these villages is the UHI area. These villages are Kesatrian and Sukoharjo. Finally, there is a village that does not have UHI, which is Tasikmadu.

Figure 2. Distribution of UHI in Malang City.
3.4. GOS Development Priority

The GOS development zone generated by comparing a percentage of GOS and UHI areas in each village, and the village with the higher proportion of GOS consists of 12 villages, and a lower proportion of GOS consists of 45 villages. These 45 villages are those that require the development of GOS. However, not every village can develop GOS, considering that not all village have sufficient land to add GOS. Therefore, one of the strategies proposed by the Green City Development Program (P2KH) is to acquire private GOS to become part of public GOS. Based on the availability of private GOS, there are 30 villages that can use as GOS development zones.

Carrying out land acquisition to increase public GOS development requires a long time considering the limited resources of local governments in developing GOS. Therefore, it is necessary to determine the priority areas that describe the order of interests of the village target for GOS development. The criteria used to determine priority in the development of GOS are the area with a high UHI that is above 32°C. Priorities in developing GOS divided into three priorities. Priority 1 shows the area experiencing a high UHI is the widest, while priority 3 shows the area experiencing a high UHI is the lowest.

![Image of Priority for GOS Development](image)

**Figure 3.** Priority for GOS Development.

Based on Figure 3, it can be seen that priority 1 has four villages, namely Gadang, Arjowinangun, Kesatrian, and Merjosari. Priority 2 has 14 villages, namely Pisangcandi, Ketawang Gede, Tlogomas, Lowokwaru, Purwantoro, Bunulejo, Bandungrejosari, Sukun, Sawojajar, Kebonsari, Polehan, Bandulan, Kasin and Madyopuro villages. While priority 3 has 12 villages, namely Arjosari, Blimbing, Dinoyo, Jatimulyo, Mojolangu, Polowijen, Purwodadi, Sumberkandang, Tunjungsekar, Karangbesuki, Tanjungrejo, and Pandanwangi villages.

4. Conclusion

Malang City has 4,214 hectares of green open space consisting of 3,635 hectares of private GOS (34%) and 579 hectares of public GOS (5%). Many private GOS found in the suburbs of Malang City can be in the form of rice fields or plantations. Meanwhile, many public GOS found around the city center in city parks, green roads and river protection green lanes. Villages with high land surface temperatures,
namely those experiencing UHI, cover all villages in Malang City except for Tasikmadu. As much as 59% area of Malang City experienced the UHI phenomenon. Areas with UHI mainly found in the center of Malang City.

The development of GOS in Malang City by counting the existing GOS resulted from 30 villages that allow as public GOS by converting from private GOS. Then, by considering the area with a high UHI, the village ranges into three priority groups: priority 1 includes four villages, priority 2 includes 14 villages, and priority 3 includes 12 villages, a priority village for GOS development located in the North and West of Malang City.

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