

Urban Forest Distribution in Metropolitan City at Java Island: A Study of the Application of Google Earth Engine Geospatial Technology

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Abstract: Google Earth Engine (GEE) is a geospatial technology based on cloud computing that has various advantages compared to using software manually. Data usage on this platform is integrated with free-access satellite imagery data sources such as ESA's Sentinel-2 Multispectral Instrument (MSI) imagery. In addition, the ability to run a combination of index algorithms (vegetation, water, and built land indices) and Random Forest (RF) classification algorithms can help detect the distribution of urban forests. This research took place from April to May 2022 by taking case studies in several metropolitan cities on the Java Island. The combination of indices involving the EVI, SAVI, NDWI, and IBI indices can distinguish forest vegetation from other land covers. This index algorithm was successful in detecting urban forests spread over five metropolitan cities, namely Jakarta, Bandung, Semarang, Yogyakarta, and Surabaya. Sentinel-2 MSI imagery with a medium resolution of 10 x 10 meters is considered capable of quickly detecting urban forests in the study area with good classification results.

Keyword: Geospatial technology, Java Island, Metropolitan city, Urban forest

INTRODUCTION

The urban forest is a vegetated area that creates a microclimate in the urban area. Endreny (2018) mentions that urban forests generally include all trees in urban areas, including vegetation on roadsides, tree clusters in parks, and suburban forests. In Indonesia, the term urban forest is generally better known as green open space. In Government Regulation of the Republic of Indonesia Number 26 of 2008 about National Spatial Planning, urban green open spaces include urban forests, urban parks, and green lanes along the road network. The urban forests have several crucial roles in maintaining urban ecosystems, especially becoming carbon stores in urban areas. Urban forests provide considerable environmental benefits to the residents, especially in protection, aesthetics, recreation, and other exceptional uses.

Several large cities classified as metropolitan cities on Java Island, namely Jakarta, Bandung, Semarang, Yogyakarta, and Surabaya, show the dynamics of land use activities and expeditious population growth. It increases the need for land for economic centers and development settlements, which ultimately encourages changes in land use, particularly the decrease in the area of urban forests as green open spaces. Budiman *et al.* (2014) show that urban forests are presently the most vulnerable targets for land conversion. The often encountered examples are urban forest conversion into residential and industrial areas. Those conversion activities can create sustainable environmental damage in urban areas. If land conversion activities are not monitored carefully, it can threaten not to realize the minimum amount of urban forest area that each city needs to have as stated in the Law of the Republic of Indonesia Number 26 of 2007.



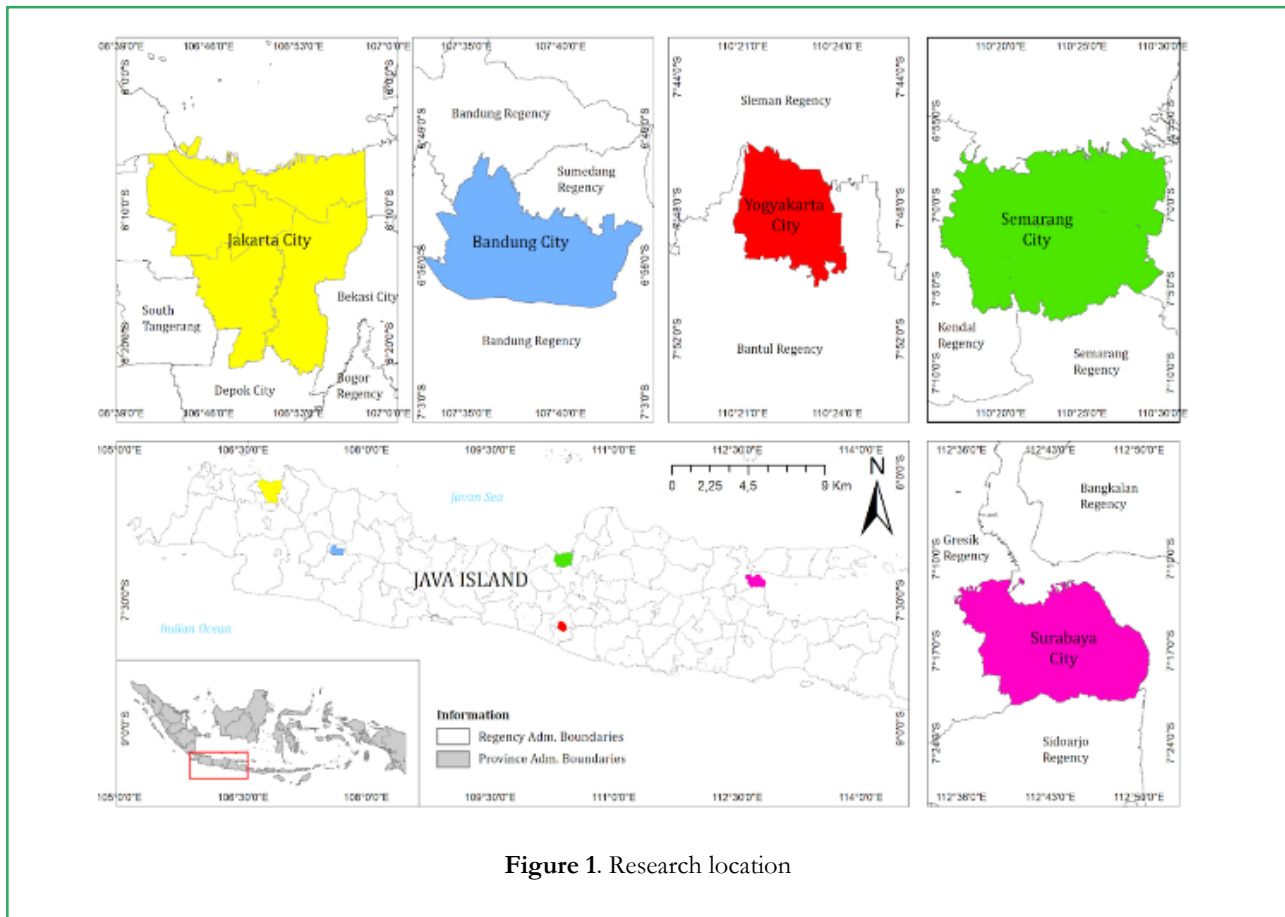


Figure 1. Research location

The regulation mandates the need for provision and utilization of urban forest, the proportion of which is set at least 30% of the city area, which is filled with plants both growing naturally or planted.

Urban forest development is supported through Government Regulation Number 63 of 2002 about Urban Forests and Minister of Forestry Regulation No. P.71/Menhut-II/2009 of 2009 about Guidelines for the Implementation of Urban Forests which aim at the sustainability, harmony, and balance of urban ecosystems, therefore, include environmental, social, and cultural elements with the function of improving and maintaining the microclimate and aesthetic value, permeating the water, create balance and harmony in the physical environment of the city and support the preservation of Indonesia's biodiversity. It indicates that urban forests have an essential role in maintaining a dynamic urban ecosystem. Seeing the importance and condition of urban forests which are actively undergoing land conversion, Subarudi *et al.* (2014) stated that the planning and management of urban forests in a sustainable manner must be executed with an ecological inventory and mapping.

This study involved Sentinel-2 with a spatial resolution of 10 to 60 meters (Phiri *et al.* 2020) with a classification process using the Random Forest (RF) algorithm through the Google Earth Engine (GEE) mapping platform to monitor the area of the urban forest in five metropolitan cities on Java Island, namely DKI Jakarta, Bandung, Semarang, Yogyakarta, and Surabaya. The resolution image source in this image is categorized as medium and can identify areas in detail compared to other free-access image sources. Therefore, it is hoped that urban forest monitoring can be carried out with high accuracy and detail and can provide recommendations for policymakers in determining appropriate and appropriate policies. In addition, the results of this study can be applied as reference material for further research on the combination of indices and their involvement in identifying urban forests.

METODOLOGI

Research Location and Time

In this study, the determination of the research location is based on the parameters of Doxiadis (1968),

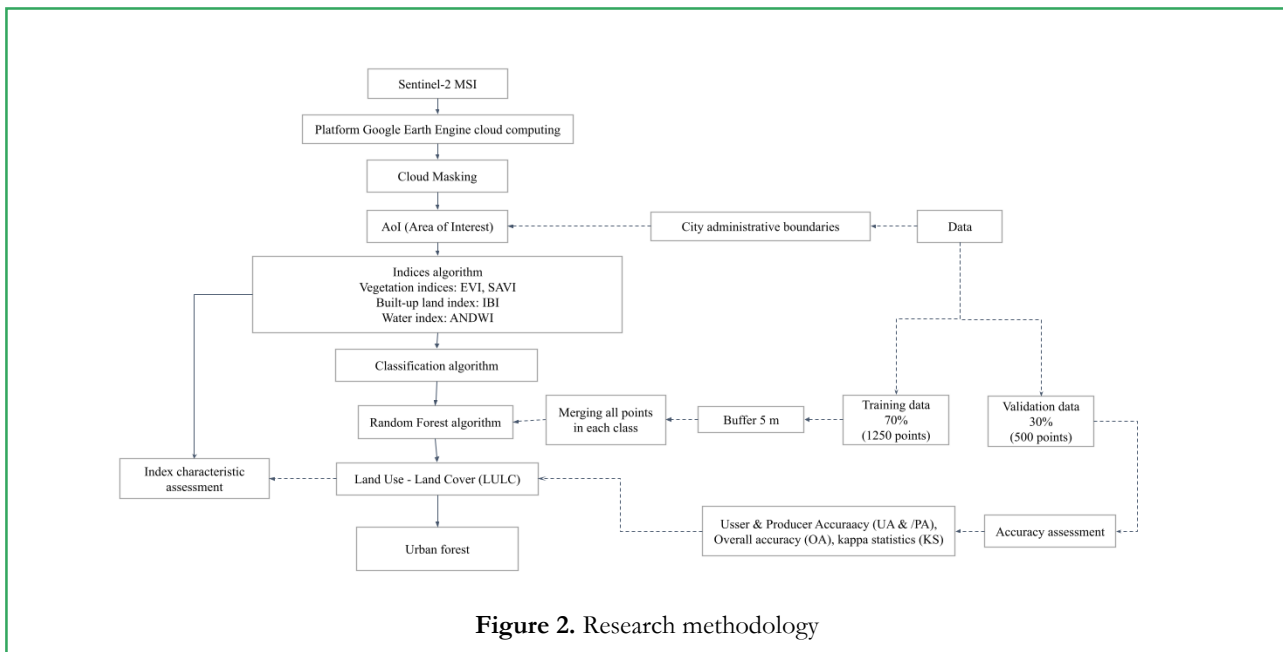


Figure 2. Research methodology

which states that the main requirement for a metropolitan city is a population of more than 50,000 inhabitants. Based on this, five metropolitan cities were selected in Java Island: Jakarta City, Bandung City, Semarang City, Yogyakarta City, and Surabaya City. Metropolitan cities were chosen because of population density that affects urban forests, and densely populated areas that may have green open space problems. This research was conducted for five months, starting from April to August 2022.ss

Data Collection

To analyze urban forest at the study site, the data involved in the research is the Sentinel-2 MSI (Multispectral Instrument) satellite imagery in January to December 2021 and administrative boundary data from each city. Supporting data is carried out through a literature study.

Data Analysis Method

Urban forests are identified by using a classification algorithm called the random forest (RF) algorithm. The classification process on GEE also involves an index algorithm in assessing land cover through satellite images. Several indices involved in this study were used to assist the identification process of the urban forest in the study location. The index can translate the spectral reflected by the earth's surface (Rees 1999), for example, urban forest. Some of these indices are involved and selected based on specific functions and purposes by the characteristics of

vegetation as the component of an urban forest. The building index is involved considering the study location is an urban area and has buildings. The indices used are presented in Table 1. Furthermore, the separation of the urban forest from the non-urban forest class is using ArcMap software.

Table 1. List of indices involved

Method	Formula	Reference
Enhanced Vegetation Index (EVI)	$EVI = G \left(\frac{NIR - Red}{NIR + C1 \times Red - C2 \times Blue + L} \right)$	Huete et al., 2002
Soil Adjusted Vegetation Index (SAVI)	$SAVI = 1.5 \frac{NIR - Red}{NIR + Red + 0.5}$	Rouse jr et al., 1973
Index-Based Built-up Index (IBI)	$IBI = \left(\frac{NIR}{NIR + Red} \right) + \left(\frac{Green}{Green + SWIR1} \right)$	Xu 2008
Normalized Difference Water Index (NDWI)	$NDWI = \frac{Blue + Green - NIR - SWIR1 - SWIR2}{Blue + Green + Red + NIR + SWIR1 + SWIR2}$	Rad et al., 2021

Accuracy Analysis

Foody (2001) explains that the classification results show results that require accurate testing before being commercialized and distributed to the public. This research uses Overall Accuracy (OA) and Kappa Statistics (KS) to measure the accuracy. The overall accuracy rating is expressed as a percent and is

calculated based on the number of diagonal elements of the error, confusion, or misclassification matrix resulting from the application of the classifier (Fitzgerald and Lees 1994). Testing the accuracy of OA and KS is focused on formulas one (1) and two (2). This accuracy assessment involves 500 points, which are divided into two types of test classes for each metropolitan city. The results of OA calculations were divided into six interpretation classes (Table 2).

$$Kappa\ Statistic = \frac{N \sum_{i=1}^r X_{ii} - \sum_{i=1}^r X_{i+X_{i+1}}}{N \sum_{i=1}^r X_{i+X_{i+1}}} \dots (1)$$

$$Overall\ Accuracy = \frac{\sum_{i=1}^r X_{ii}}{N} \times 100\% \dots (2)$$

Table 2. Interpretation of kappa values

Kappa value	Description
<0.00	Poor
0.00 – 0.20	Slight
0.21 – 0.40	Fair
0.40 – 0.60	Moderate
0.61 – 0.80	Substantial
0.81 – 1.00	Almost perfect

RESULTS AND DISCUSSION

Study Location Conditions

According to Dardak et al. (2006), a metropolitan city is an urban area with prominent population characteristics compared to the surrounding rural population. It is used to provide a more precise picture of population size and concentration over a large area, which in order can show the number of centers that focus on a single country. In general, a metropolitan area is an area with a large population concentration, with an integrated economic and social unit that characterizes urban activities. Ekistics (Doxiadis 1968) explains a metropolitan as a large area consisting of one or more centers with a population of 50,000 or more and more characters larger than rural characters, with a density of 66 inhabitants per ha. Based on these parameters, this study took five metropolitan cities in Java Island, including Jakarta, Bandung, Semarang, Yogyakarta, and Surabaya as research objects.



Figure 3. Urban forest area in Jakarta City

Population and economic growth will affect the use of space in an area. The rapid development of built-up land due to the increasing population and economic demand is inversely proportional to the reduced presence of urban forests. Urban development patterns will affect urban forest patterns (Budiman et al. 2014). It has consequences for land use that is not under spatial planning and a decline in the carrying capacity of the environment. There are irregularities in function, aesthetics, circulation, and transportation movements that are not smooth, as well as the intensity of space that is irregular against a decrease in environmental quality (Prihatin 2015).

The pattern of the urban forest in the five metropolitan cities in the research of Budiman et al. (2014) from 1982, 2000, and 2013 changed. Changes in the pattern of the urban forest in Jakarta and Bandung are almost the same where the pattern of urban forest which was initially clustered and concentrated in the suburbs became spread over a smaller area. In 2013, Jakarta City experienced a decrease in the urban forest to 110.45 km², or about 17% of the area. In overcoming this, the government bought new land to add to the urban forest and implemented a reforestation program. Meanwhile in 2013, Bandung City only had 110.45 km² of urban forest left, or about 20% of the area of Bandung. Changes in the pattern of urban forests also occurred in Yogyakarta City, which initially had a large clustering pattern in the eastern and western regions into an evenly distributed pattern with small sizes due to changes in function in residential and business areas.

In 2013 the remaining urban forest was 10.40 km² or 32% of Yogyakarta City. In contrast, Semarang City and Surabaya City did not experience a change in the pattern of the urban forest. The pattern of the urban forest in Semarang City remained until 2013 when urban forest clustered in the western and southern regions and experienced a significant increase to 183.11 km² (47.84%) in 2013. Many open lands are planted with commercial trees in Semarang City. Likewise, Surabaya City in 2013 had a large cluster of urban forest patterns in the western and eastern regions and increased to 149.92 km² or 40% of the city area of Surabaya through a reforestation program by the government and the planting of mangrove forests around the coast of the city of Surabaya.

Urban Forest Distribution in City

The study area for DKI Jakarta covers an area of 65,383 ha, involving only the DKI Jakarta area with administrative city status. The study area in Bandung City covers an area of 16,730 ha. For Semarang City, the study area covers an area of 37,380 ha. The study area in Yogyakarta City is 3 250 ha. For Surabaya City, the study area covers an area of 37 410 ha. Sentinel-2 MSI succeeded in identifying urban forests in the five metropolitan cities. The process of identifying urban forests using geospatial technology involves four indices that are sensitive to land cover in urban areas. The four indices include SAVI, EVI, ANDWI, and IBI.

There are differences in the distribution and extent of urban forests (Figure 4; Table 4). The identification results show that the city of Semarang is a city that has the largest percentage of urban forest area compared to other cities, with an area of 13 933.45 ha. This area is equivalent to 37.28% of the total area of Semarang City. The second largest percentage is owned by the City of Bandung, which is 18.66% with a total area of 3 121.58 ha. The third largest percentage was followed by the City of Yogyakarta with a total percentage of 9.63% with a total area of 3131.13 ha. The fourth largest is the City of Surabaya with a percentage of 9.52% which is equivalent to an area of 3 112.72 ha. The last smallest percentage of urban forest is owned by the City of Jakarta with a percentage of 5.93% which is equal to 3 939.72 ha.

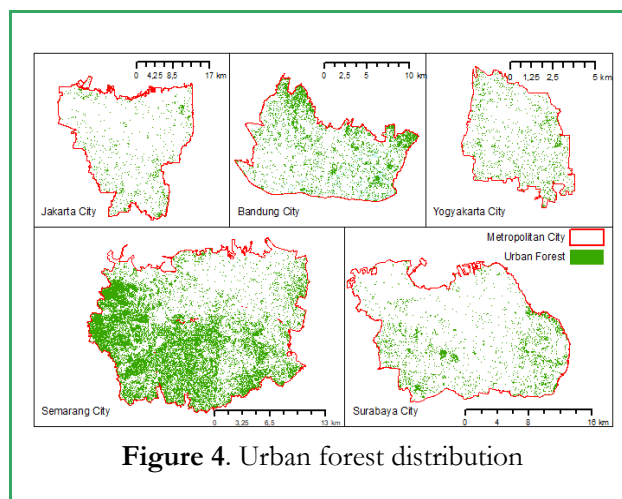


Figure 4. Urban forest distribution

Table 3. Total urban forest area for each metropolitan cities

Metropolitan city	Area (ha)	Percentage of city area (%)
Jakarta	3 939.72	5.93
Bandung	3 121.58	18.66
Yogyakarta	313.13	9.63
Semarang	13 933.45	37.28
Surabaya	3 112.72	9.52

The identification results show that the city of Semarang is the city that has the largest percentage of urban forest area compared to other cities, with an area of 13 933.45 ha. This area is equivalent to 37.28% of the total area of Semarang City. The second largest percentage is owned by the City of Bandung, which is 18.66% with a total area of 3 121.58 ha. The third largest percentage was followed by Yogyakarta City with a total percentage of 9.63% with a total area of 3131.13 ha. The fourth largest is Surabaya City with a percentage of 9.52% which is equivalent to an area of 3 112.72 ha. The last smallest percentage of the urban forest is owned by Jakarta City with a percentage of 5.93% which is equal to 3 939.72 ha.

Characteristic Indices

Each index has different characteristics in translating the earth's surface. It can show through the difference in the threshold values read in the urban forest through each index (Figure 5). The threshold value obtained has a different interval between the

indexes. The threshold values for the index are EVI (0.0007 - 0.0005), SAVI (0.0194 - 0.0216), ANDWI (0.0228 - 0.0171), and IBI (0.0142 - 0.0136). It is an advantage of the spectral index, which can translate the characteristic wavelengths of objects on the earth's surface that are reflected and received by satellite sensors.

The vegetation index is the amount of greenery value of vegetation sourced from digital signal processing of brightness value data of several channels of satellite sensor data (Sudiana and Diasmara 2008). This research involves SAVI and EVI indexes as vegetation indexes, in which there is a process of comparing the brightness level of the red light channel and the near-infrared light channel. Sudiana and Diasmara (2008) explained that there is a phenomenon of absorption of red light by chlorophyll and reflection of near-infrared light by mesophyll tissue found in leaves. It makes the brightness values received by satellite sensors on these channels will be much different. Non-vegetated land, including water areas, residential areas, open vacant land, and areas with damaged vegetation, will not show a high (minimum) ratio value. On the other hand, in areas with very dense vegetation, with healthy conditions, the ratio of the two canals will be very high (maximum). The spectral differences between the vegetated and non-vegetated regions on the SAVI and EVI indices are visible. The green spectral color that appears on the two indices indicates a vegetated area, while the blue spectral color indicates an unvegetated area.

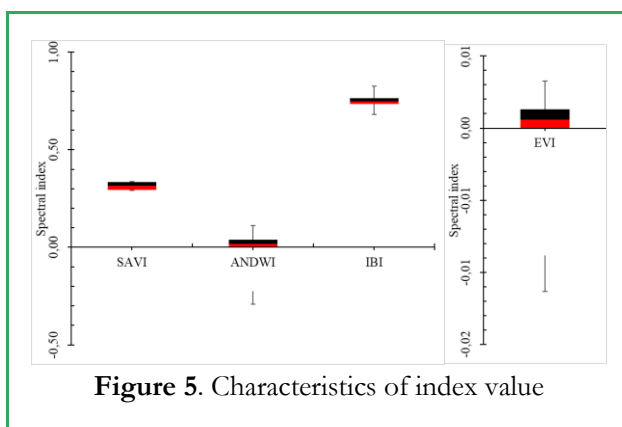


Figure 5. Characteristics of index value

The water index was included in this study considering that there is a water surface that is visible at the study site. NDWI is the most frequently used algorithm to distinguish between water and non-water objects (Mcfeeters, 2007). The water surface has a

darker blue spectral color when compared to the non-water surface. Spectrally identified water objects are dominated by rivers and lakes. The results of the NDWI analysis contained in Figure 6 show that the level of readability between the water and water surfaces is not maximized because several water surfaces are read as non-water surfaces. This happens because of the limitations of NDWI in extracting water bodies on the surrounding land cover in the form of built-up land as stated by Xu (2006) which is also supported by the results of this study, namely the limitations in extracting water lines with surrounding land covers in the form of residential buildings. However, the NDWI index is still considered suitable to be used as a water index, as stated by Wicaksono and Wicaksono (2019). The results of the research by Wicaksono and Wicaksono (2019) found that the NDWI index still has limitations in extracting the water surface around residential buildings, but it is still feasible to use. Therefore, it is recommended that in detecting water, a combination of water indices such as the Modified Normalized Difference Water Index (MNDWI) (Xu, 2006) and AWEI (Feyisa et al. 2014) should be used.

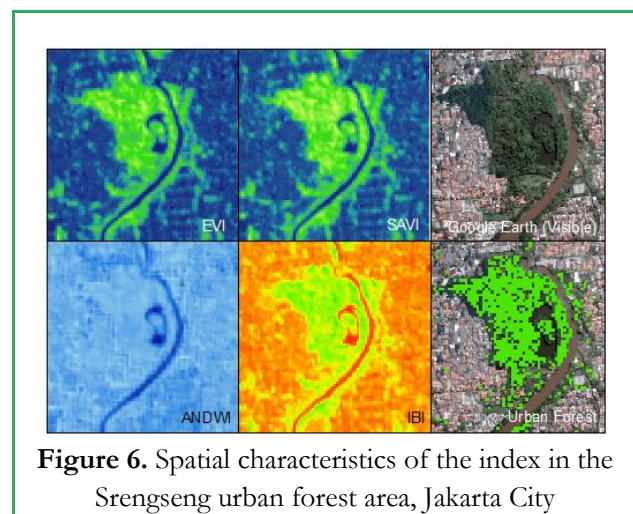


Figure 6. Spatial characteristics of the index in the Srengseng urban forest area, Jakarta City

The built-up land index used in this study is the IBI index. IBI is a combination of 3 algorithms, namely, Normalized Difference Built-up Index (NDBI), SAVI, and MNDWI (Ariefa et al. 2019). The combination results can combine urban land use which is grouped into three other generalization categories, namely: built-up land, vegetation, and water. The three categories were chosen in the hope of representing their respective land use classes (Xu, 2006). Based on the results of the analysis, the IBI index can read the visible built-up land

Table 3. Total urban forest area for each metropolitan cities

Metropolitan city	OA		KS	
	Value	Class Interpretation	Value (x 100)	Class Interpretation
Jakarta	77.00	Poor	62,60	Substantial
Bandung	78.00	Poor	63,93	Substantial
Yogyakarta	70.00	Poor	53,85	Moderate
Semarang	90.00	Almost perfect	81,82	Almost perfect
Surabaya	91.00	Almost perfect	83,49	Almost perfect

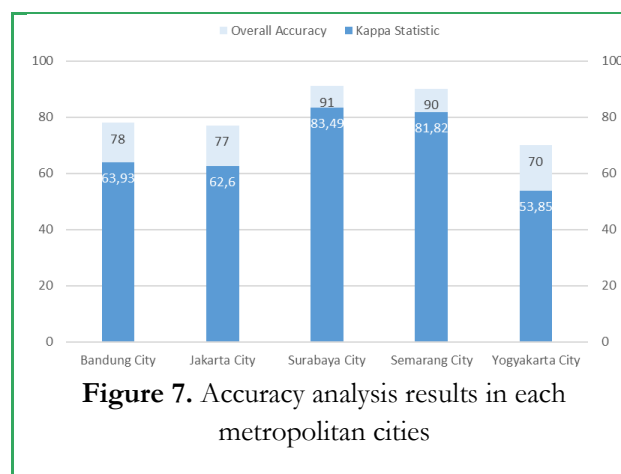
but is still not optimal. Some pixels should be built-up land but are detected as not built-up land.

Accuracy Assessment

The accuracy assessment is calculated by considering the value in the calculated error matrix. This calculation is executed to assess the classification results that have been calculated to produce reliable spatial information and methods that can be applied to urban forest classification. This study shows different accuracy values in each city (Figure 7). The highest accuracy value is in Surabaya City, namely 91 (OA) and 83.49 (KS) and followed by the City of Semarang, namely 81.82% (OA) and 90 (KS). Meanwhile, the other three cities, namely Bandung, Jakarta, and Yogyakarta, had the accuracy of 78% OA (63.93 KS), 77% OA (62.60 KS), and 70% (53.85 KS). Based on the KS scores in Table 2 and 4, the cities of Jakarta and Bandung are in the substantial class, Yogyakarta is in the moderate class, and Semarang and Surabaya are in the almost perfect class. Meanwhile, according to the recommendation of Scepun (1999), a good OA value is above 85%, so only Surabaya City and Semarang City are suitable

Different accuracy results are influenced by various factors and sometimes do not match the target (Foody 2002). Determination of the validation data sample is the main factor in testing this accuracy. Stehman (1999) explains that the sampling design in accuracy analysis affects the determination of the method and the classification process. In his research, 500 validation data were obtained from all cities in the study area with the same ratio, namely 50 data in the urban forest class and 50 data in the non-urban forest class. The error matrix shows that the validation data in the Yogyakarta City test case has an error of 30 data consisting of 28 non-urban forest data located in the

urban forest area and two urban forest data located in the non-urban forest area. The large number of validation data that shows misclassification results makes the OA and KS values very low compared to the cities of Surabaya and Semarang. In addition to the OA and KS values, the User's Accuracy (UA) value in the validation data class in the form of urban forest reached 44%, and the Producer's Accuracy (PA) for non-urban forest data reached 63%. Meanwhile, cities in the study area with high OA and KS values have high UA and PS values as well. According to the error matrix, for example, Surabaya City has UA and PS values for urban forest validation data of 86% and 96%, respectively, while for the non-urban forest it is 96% and 87%.



From this accuracy assessment, it concludes that there is a need to improve the sampling design when determining the training sample and modifying the method. In addition, it is necessary to test each index involvement in this case to obtain the appropriate classification results. It is useful for testing all SAVI, EVI, IBI, and ANDWI indices in assisting the classification algorithm in detecting urban forests.

CONCLUSIONS

Through GEE based on cloud computing and involving Sentinel-2 data, MSI managed to identify urban forests in various cities in the study area. There are differences in area and percentage in various metropolitan cities. Semarang City has a fairly high urban forest area compared to other cities. In addition, the resulting accuracy of this city reaches 90% on OA, and 82.82 on KS. While other cities have quite a few percentages and fewer accuracy values. Therefore, it is necessary to improve the sampling design during training and validation data collection to get a fairly high accuracy value. This research on the urban forest is expected to be information that can be used as consideration for the government in determining policies related to urban forests later.

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