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REVIEW ARTICLE

Green Open Space and Barren Land Mapping for Flood Mitigation in Jakarta, the Capital of Indonesia

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Abstract. High levels of rainfall, tidal flooding, land subsidence, intensified urban development, scarce barren land and a shortage of green open spaces (GOS) are contributing factors to the persistent flooding in Jakarta. Therefore, this study was conducted to map the GOS, built-up, and barren land in the city in order to calculate the biopore infiltration hole (LRB) potential for water infiltration as part of Jakarta's flood mitigation efforts using the Landsat 8 operational land imager (OLI). The Landsat data acquired on September 11, 2019, with path/row 122/064 were processed using the Fast Line-of-Sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) method for the radiometric correction, and geometric correction with a root mean square error (RMSE) of 7.57 meters. Moreover, the normalized difference vegetation index (NDVI) was applied to classify the GOS, the normalized difference built-up index (NDBI) for the built-up areas, and the normalized difference barren land index (NDBaI) for barren land areas which were further confirmed using NDBI to distinguish them from the built-up areas. It is also important to note that the LRB potential was calculated by adding the GOS and barren land, dividing the result by the ideal land area multiplied by the ideal number of holes. The results showed that the GOS, built-up area, and barren land were 8.34%, 85.29%, and 2.48%, respectively. Furthermore, the LRB potential through the optimization of GOS and barren land was found to be 70.06 km^2 and produced 16,816,248 LRB (18.27% of total needed). The realization of this value is expected to reduce the potential inundation in Jakarta by 15.6%.

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1. Introduction

The global development of urban areas has increased significantly in the past 50 years. This has caused the loss of the numerous permeable soils for water infiltration due to the existence of buildings, thereby leading to an increase in the risk of flooding (Galderisi & Treccozzi, 2017). The condition was also exacerbated by climate change which is triggering sea level rise (Perkins-Kirkpatrick & Gibson, 2017) and land subsidence in urban areas (Abidin, Andreas, Gumilar, & Brinkman, 2015). It is important to note that coastal areas are the most vulnerable location for flooding with an estimate of over 10 million victims each year. The recent occurrence was recorded in Bangladesh in 1997 which caused the death of 140,000 people and rendered 10 million homeless. Other cases include Myanmar in 2007 with 146,000 deaths, Jakarta and Manila with 70-80% of land areas inundated (Fuchs, Conran, & Louis, 2011), and Fukuoka, Japan in 2009 (Yamashita, Watanabe, & Shimatani, 2015).

This means there is a need for flood mitigation efforts to prevent victimization in the watershed and local inundation areas. These can be in the form of soil conservation, reforestation, natural dykes, and construction of dams in order to enhance land productivity by improving ecological conditions and ensuring accordance between the hydrogeological and biophysical attributes of the watershed (Reddy, 2019). It has been suggested that a study be conducted to integrate spatial planning processes through multi-disciplinary institutions and cross-border administration (Asdak, Supian, & Subiyanto, 2018). Furthermore, there is a need for watershed management to balance water availability and needs, land cover and groundwater, and quality of surface water and groundwater (Safarina, Karnisah, Permana, & Sufianto, 2019). It is also possible to reduce local floods through natural and/or artificial water infiltration methods. The natural aspect involves planting trees to restrain water flow and increase water absorption as well as through waste management (Chandrawati et al., 2020). Meanwhile, the artificial aspect focuses on the implementation of biopore infiltration holes (LRB) in GOS and barren lands. This is in line with the findings of a previous study that LRB increased water absorption twice more than the barren land area and reduced inundation (Khusna, Amin, & Sekarrini, 2020). Moreover, local floods can also be prevented by harvesting and storing rainwater in tanks or ponds (Yamashita et al., 2015).

LRB is an effective, low-cost, and simple method of reducing flood inundation without using extensive land (Latief, 2012). It also has the ability to accelerate the infiltration of surface water into the aquifers, thereby maintaining groundwater balance and preventing seawater intrusion. GOS is the lengthwise area and/or grouping of land based on the open characteristics or a place where trees can grow effectively when planted intentionally or naturally. It is pertinent to state that GOS produces oxygen, absorbs carbon dioxide, and allows water infiltration (Law Number 26/2007 about Spatial Planning). Meanwhile, barren land is land not covered by buildings or vegetation. There is a need to optimize these GOS and barren land as an LRB potential location. A previous study showed that LRB has a diameter of ten to thirty centimeters and a depth of 100 cm with an infiltration rate of around 3 liters/minute or 180 liters/hour (Biopore Team of IPB, 2020). Therefore, this study focuses on mitigating floods in Jakarta through the artificial application of LRB to GOS and barren land areas. The built-up area was also mapped and distinguished from the barren land.

The LRB was investigated using Landsat 8 operational land imager (OLI), the GOS analyzed through a normalized difference vegetation index (NDVI) (Rouse, Haas, Schell, Deering, & Deering, 1974), built-up area through a normalized difference built-up index (NDBI) (Zha, Guo, & Ni, 2003), and barren land using a normalized difference bareness index (NDBaI) (Zhao & Chen, 2005). The application of Landsat technology was due to its ability to analyze large areas and repeated measurements (Verstraete & Pinty, 1991). Moreover, an integrated analysis was conducted to produce comprehensive information on LRB using GOS, built-up areas, and barren land maps. The findings of this study are expected to be considered in flood mitigation and urban planning in Jakarta, the capital of Indonesia.

2. The Methods

Study Area

The study area includes the West, Central, South, East, and North Jakarta districts located in Jakarta, the capital city of Indonesia, which is sited on the northern coast of Java as indicated in Figure 1. There is usually floods in this area almost every year because of tides, high rainfall in the Ciliwung watershed (>3000 mm/year), the flow of more than ten rivers into Jakarta, and changes in landscape due to economic pressure (Asdak et al., 2018). Jakarta also has a groundwater basin with a thickness of up to 300 m divided into several levels including the lowest aquifer at 0 m to 20 m depth (Nugraha, Handayani, Lubis, Wardhana, & Gaol, 2020). Moreover, the residents normally use more than 80% of groundwater for daily needs which causes a reduction in the quantity and subsequently leads to seawater intrusion (Kamil & Willis, 2013). It was noted that the western and central coastal areas experienced seawater intrusion in 2018 while land subsidence occurred at the north and center (Nursyirwan, Bisri, Montarcih, & Suhartanto, 2019).

Data and Pre-Processing

The remote sensing data used were Landsat 8 OLI acquired on September 11, 2019 with a path/row 122/64, L1TP-level. The data have been calibrated radiometrically, while the images were ortho-rectified using ground control points (GCPs) and digital elevation model (DEM) data to correct the relief displacement. The radiometric correction is a multi-step process to convert digital numbers to surface reflectance. The first aspect of the process was a radiometric calibration conducted by calculating the digital number of the Top of Atmosphere (ToA) radiance value. The second aspect was the atmospheric correction which involved using the Fast Line-of-Sight Atmospheric Analysis of Spectral Hypercubes (FLAASH) method to change the radiance value of ToA into surface reflectance (Vermote, Saleous, & Justice, 2002). Moreover, the 219 GCPs used for Landsat 8 OLI - L1TP level correction were derived from the Global Land Survey 2000 (GLS2000) dataset with a root mean square error (RMSE) of 7.57 m.

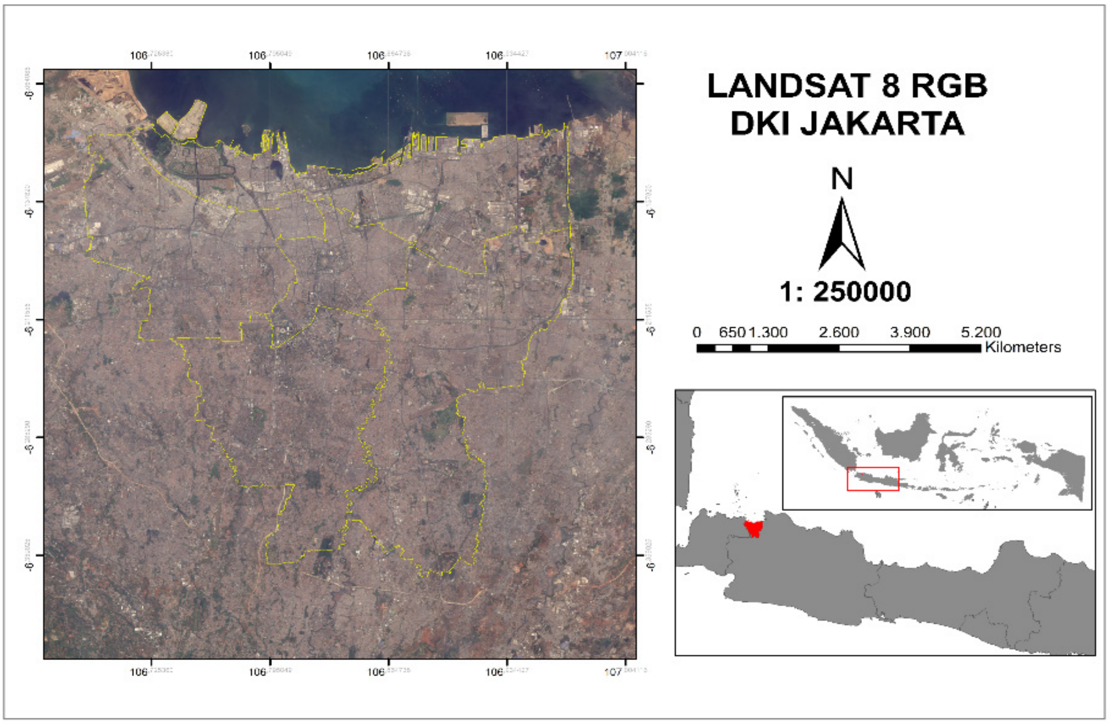


Figure 1. Study area in Jakarta, the capital of Indonesia, overlaid with Landsat 8 OLI 432 RGB.

Green Open Space Mapping

NDVI used to classify GOS on Landsat 8 OLI was selected by pre-analyzing NDVI (Equation 1) and GDVI (Equation 2). The basic concept for both indices is the ability of the red light absorbed by chlorophyll and near-infrared light reflected by mesophyll tissue contained in the leaves to produce very different brightness values for the satellite sensors on these channels (Sudiana & Diasmara, 2008). Therefore, the selection was based on the accuracy assessment conducted using Google Earth imagery as the reference with 400 sample points obtained through the Slovin method in Equation 3 (Tejada, Raymond, & Punzalan, 2012) and the location determined using a proportional random sampling technique. The process showed that NDVI was better than GDVI with overall accuracy and kappa coefficient of 89.75% and 0.72 compared to 79% and 0.4, respectively. This was observed to be similar to the findings of Susantoro, Wikantika, Puspitasari, & Saepuloh (2017) that NDVI was good to classify vegetation cover and to show the density level of plants. It also has the ability to summarize information from several other vegetation indices such as Enhanced Vegetation Index (EVI), Green Ratio Vegetation Index (GRVI), Atmospherically Resistant Vegetation Index (ARVI), Green Atmospherically Resistant Index (GARI), Green Normalized Difference Vegetation Index (GNDVI) and others. This was proved through a statistical analysis conducted using the coefficient of determination with the values between NDVI and other indices found to be above 80% (Susantoro, Wikantika, Saepuloh, & Harsolumakso, 2018).

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{R})}{(\mathrm{NIR} + \mathrm{R})} \quad (1)$$

$$\mathrm{GDVI} = \frac{(\mathrm{NIR}^2 - \mathrm{R}^2)}{(\mathrm{NIR}^2 + \mathrm{R}^2)} \quad (2)$$

$$\mathrm{n} = \frac{N}{(1 + \mathrm{N}e^2)} \quad (3)$$

Where, NIR is the reflectance of the near-infrared band, R is the reflectance of the red band, n is the sample size, N is the population size, and e is the margin of error.

Build-Up and Barren Land Mapping

NDBI was used to automatically classify built-up areas on Landsat 8 OLI. The index was based on the unique spectral response to built-up areas which has a higher reflectance at short infrared wavelengths (SWIR) than at NIR wavelengths (Equation 4). Moreover, the NDBI is an algorithm to show the density of built-up areas or barren land (Guo et al., 2015; Xu, 2007).

$$\mathrm{NDBI} = \frac{(\mathrm{SWIR} - \mathrm{NIR})}{(\mathrm{SWIR} + \mathrm{NIR})} \quad (4)$$

Where, SWIR is the shortwave infrared band and NIR is the near-infrared band. It is pertinent to state that NDBI value is usually between -1 to 1 with the non-building area having -1 to 0 while the building area has 0 to 1.

NDBaI was used on Landsat 8 OLI to classify the barren land (Equation 5) which was later distinguished from the built-up areas through a confirmation using NDBI (Chen, Zhao, Li, Yin, & Yin, 2006). It is an index developed to recognize different types of barren land (Zhao & Chen, 2005) including primary and secondary types as well as cultivated land. The primary type includes the areas with no plants due to physiographic factors such as climate and hydrology. The secondary type involves the areas mainly influenced by anthropogenic factors such as economic development, intensive farming, and urban construction while cultivated land is the area managed for a small number of agricultural products to be used for different purposes such as food, feed, fiber, or energy. The main difference between these categories is the spectral reflectance in the shortwave infrared (SWIR) and thermal infrared (TIR) band, which is typically affected by factors such as humus content, surface conditions, and thermal capacity.

$$\mathrm{NDBaI} = \frac{\mathrm{SWIR} - \mathrm{TIR}}{\mathrm{SWIR} + \mathrm{TIR}} \quad (5)$$

Where, SWIR is the shortwave infrared band while TIR is the thermal infrared band. It is important to note that barren areas usually have values between -0.02 and 0.04 as well as -0.37 and -0.3, respectively (Sulma, Nugroho, Zubaidah, Fitriana, & Haryani, 2017).

LRB Potential for Flood Mitigation

The potential application of LRB for flood mitigation was analyzed using the combination of GOS and barren land. The total LRB in Jakarta was estimated using Equation 6 (Brata & Nelistya, 2008). This concept also has the ability to convert organic waste into compost, reduce greenhouse gas emissions, and overcome problems caused by the inundation of water such as dengue and malaria through the implementation of soil fauna and plant roots (Biopore Team of IPB, 2020). It is important to note that LRB is the holes or small tunnels formed underground due to the activities of organisms such as worms, termites, and plant roots (Brata & Nelistya, 2008). It can be placed around trees, barren land, or areas through rainwater flows (Solihin & Sunarwan, 2010).

$$\Sigma\mathrm{LRB\ max} = (\mathrm{GOS} + \mathrm{BL}) / (\mathrm{LI})) \times \mathrm{LRB\ ideal} \quad (6)$$

Where, ΣLRB max is the maximum obtainable LRB, GOS is the area of green open space (m^2), BL is the area of barren land (m^2), LI is the ideal land (m^2), and LRB ideal is the ideal number of LRB in 100 m^2 which is 24 units (Widodo, 2007).

The ability of LRB to absorb water into the ground (inundation reduction) was calculated using Equation 7 to assess its effectiveness in the study area.

$$\%\ \text{reduction} = \frac{\text{Debit of water flows in LRB} \left(\frac{m^3}{\text{hour}}\right) \text{x max LRB}}{\text{Rainfall intensity} \left(\frac{m}{\text{hour}}\right) \text{x area } (m^2)} \quad (7)$$

It was assumed that the maximum water flows into LRB is 180 liters/hour (0.18 cubic meters/hour), the rainfall intensity is 30 mm/hour or 0.03 m/hour, and there is even rainfall in Jakarta (647.5 km^2).

3. Results and Discussions

Green Open Space Mapping

GOS was analyzed using the NDVI algorithm based on a modified classification developed by Putra (2012). The classification includes (1) water bodies with NDVI values <0,

(2) Open land covered by asphalt, paving blocks, concrete roads, and industrial areas such as ports with 0 to 0.10, (3) open land, settlements, and fields with low vegetation with 0.11 to 0.50, (4) medium vegetated land, city parks, and protective trees with 0.51 to 0.70, and (5) densely vegetated land such as urban forests with values > 0.71. A total of 400 Google Earth image samples were used for verification and the overall accuracy and Kappa coefficient were found to be 89.75% and 0.72, respectively as indicated in Table 1. Moreover, NDVI was found to have good accuracy for vegetation mapping and this is in line with the findings of a previous study that the index had good accuracy for classifying the vegetation in the different density levels (Susantoro, Wikantika, Yayusman, Tan, & Ghozali, 2020). The verification of the NDVI results further showed that the GOS area has medium and densely vegetated lands as presented in Table 1. An overlay was also conducted and the barren area inside the GOS was categorized as a GOS area.

The results showed that the GOS in Jakarta in 2019 was 54.02 km^2 representing 8.34% of the total area as indicated in Figure 2. The largest was recorded in East Jakarta with 19.57 km^2 or 3.02% while the West, South, Central, and North had 5.78, 15.31, 2.22, and 11.13 km^2, respectively. However, these values are far below the minimum of 30% required by Law No. 26 of 2007 about Spatial Planning with the public green space set at 20% while private green space is 10% (Ajrina and Kustiwan, 2019). This is necessary due to the ecological function of GOS in absolving water into the ground in order to prevent flood (Angelia, 2017). The low value recorded means there is an increase in the probability of flooding in Jakarta. It has been previously stated that the chance of flooding at 16% GOS was 74% and a reduction in the figure to 9% increased the possibility of rainwater being flooded to over 86% (Sarbidi, 2012). It is also important to note that the rainfall data obtained from Meteorology, Climatology and Geophysical Agency (BMKG) in Kemayoran station showed that the city had 925.6 mm rain in January 2014 and the annual rainfall was 2837.1 mm while Halim Perdana Kusuma Station recorded 3236.8 mm.

The green space in Jakarta has been reducing for over 50 years due to intensive urban development (Galderisi & Treccozzi, 2017). It was also observed that the green space usually allocated in the RTRW has changed because of the increase in health facilities, migrants, population density,

Table 1. GOS classification and accuracy assessment.

GOS Classification	Omission Error (%)	Commission Error (%)	Producer Accuracy (%)	User Accuracy (%)	Kappa	Overall Accuracy	Area	
							Km^2	%
Water bodies	0	0	100	100			3.59	0.55
Open lands covered by asphalt	0	48.44	100	51.56			53.93	8.33
Open land covered by buildings with low vegetation	9.97	0	90.03	100	0.72	89.75	535.96	82.77
Medium Vegetated lands (GOS 1)	27.58	12.5	72.41	87.5			46.79	7.23
Dense Vegetated Lands (GOS 2)	0	63.64	100	36.36			7.22	1.16

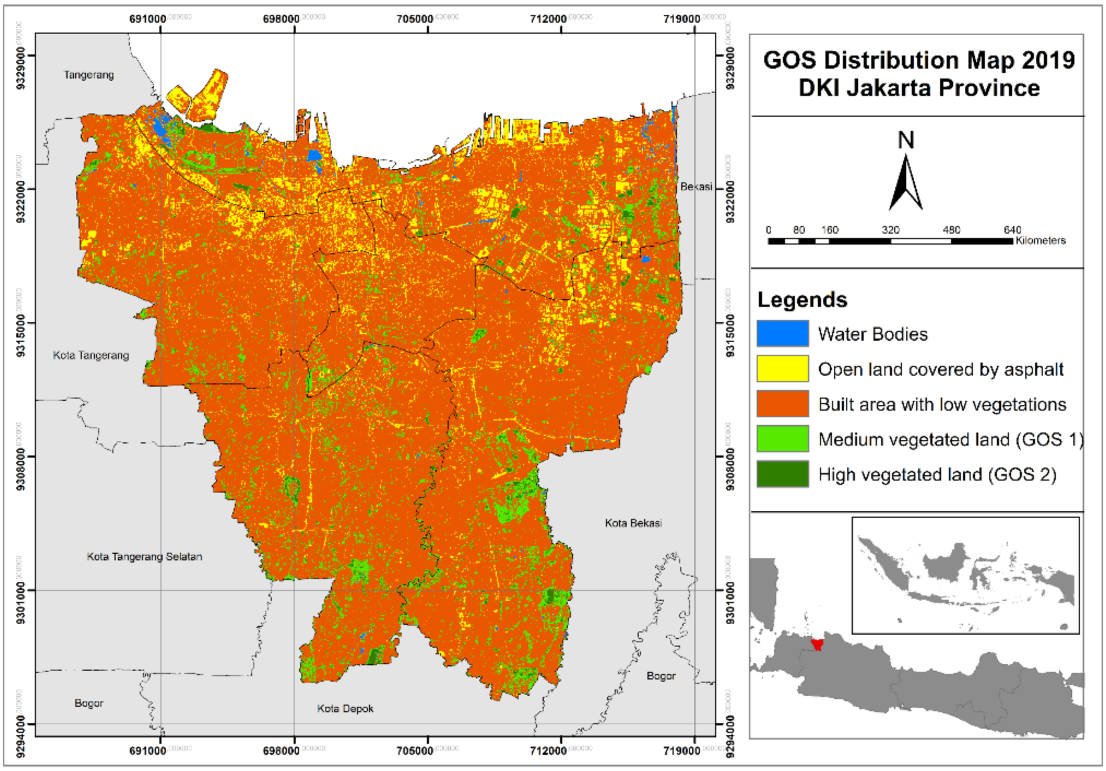


Figure 2. GOS Classification based on NDVI.

and education facilities (Sitorus, Aurelia, & Panuju, 2011). A previous study showed that the GOS in Jakarta specifically reduced by 57.5% from 1982 - 2013 and this means there has been a reduction of 1.8 %/year (Budiman, Sulistyantara, & Zain, 2014). The decline was associated with the development of industrial and trade areas such as Tanjung Priok, Mangga Dua, and Sunter, as well as Central Business Development areas such as Sudirman, Kuningan, and Thamrin (Budiman et al., 2014). Jakarta has a lower GOS compared to several other major cities in the world including Singapore, Kuala Lumpur, Seoul, Vienna, Tokyo, London, New York, and Hong Kong (Setiowati, Hasibuan, & Koestoer, 2018).

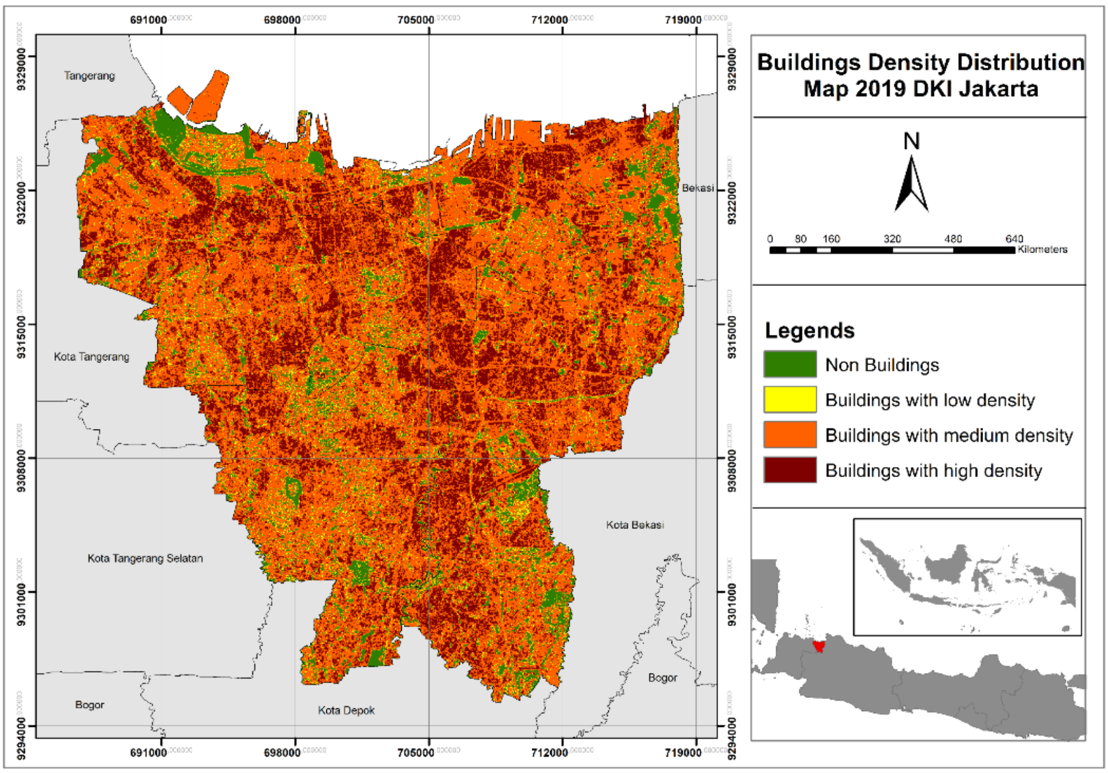
Built-Up Mapping

The result showed that the built-up areas classified using NDBI values ranged from -0.93 to 1 with those close to 1 representing areas having high density while those with -1 are non-building areas. Moreover, the built-up areas were classified into four which include (1) non-building consisting of water bodies, barren land, and vegetation areas, (2) low-density buildings, (3) medium-density buildings, and (4) high-density buildings, as presented in Table 2. This simply means the built-up areas have low, medium, and high building densities. The accuracy was also assessed using 400 samples with the point distribution determined through proportional random sampling and it was discovered that the overall accuracy and kappa coefficient were 82% and 0.69, respectively, as indicated in Table 2. These results showed that Jakarta was dominated by medium to high-density buildings in 2019 with the high-density buildings observed to be mainly located in East Jakarta covering an area of 53.90 km^2 while the West, South, Central, and North Jakarta, had 35.28, 33.22, 13.69, 30.23 km^2, respectively. Furthermore, the medium and high-density buildings were generally distributed along arterial roads and residential areas at the center of government facilities, economic, trade, and settlement activities. It is pertinent to note that the total built-up area in the city as of 2019 was 89.63% while the non-built-up area including water bodies, barren land, and vegetation was 10.37% as presented in Figure 3.

Table 2. Build-up Land Classification and Accuracy Assessment.

Classification	Omission Error (%)	Commission Error (%)	Producer Accuracy (%)	User Accuracy (%)	Kappa	Overall Accuracy (%)	Area	
							Km^2	%
Non-building	24.39	6.06	75.61	93.94			67.17	10.37
Buildings with low density	76	62.5	24	37.5			40.18	6.02
Buildings with medium density	15.58	12.56	84.42	87.44	0.69	82	373.73	57.72
Buildings with high density	6.79	25	93.20	75			166.42	25.70

Figure 3. Building Density Distribution Map using NDBI analysis.



It was also discovered that the domination of the city by built-up areas or non-permeable zones increased the potential for inundation, specifically during the rainy season. The condition became more critical due to the absence of GOS and this further influenced the occurrence of floods in Jakarta. This is in line with the findings of a previous study that almost every city in the world has the same experience due to the increase in rainfall caused by the island heat effect and global warming (Yamashita et al., 2015). Moreover, urban development has increased the need for groundwater to be used for daily needs and this has led to land subsidence, groundwater reduction, and seawater intrusion (Kagabu, Delinom, Lubis, Shimada, & Taniguchi, 2010).

Barren Land Mapping

Barren land was classified using a combination of NDBI and NDBaI and the values recorded were found to be between -0.02 and 0.04 as well as -0.37 and -0.3, respectively. These values have been reviewed by Sulma et al. (2016) based on the spectral approach using the barren land object of the training area. It was discovered that the barren land in Jakarta was 16.24 km^2 representing 2.5% of the total area as indicated in Table 3 at an overall accuracy and kappa coefficient of 98.25% and 0.62, respectively. The administration boundary showed that the most extensive barren land was located in North Jakarta with an area of 4.78 km^2 while the West, South, East, and Central had 3.84, 2.90, 4.06, and 0.65 km^2, respectively, as presented in Figure 4. The results were verified using Google Earth and it was observed that the barren land in the city was dominated by inappropriately utilized marginal land. It is important to note that these areas have the potential to be applied as an LRB.

Biopore Infiltration Hole Analysis

The LRB potential for water infiltration was analyzed based on the overlay of GOS, built-up land, and barren land as presented in Figure 5. The overlay produced a GOS, barren land, and extensive built land areas of 54.02 km^2 (8.34%), 16.04 km^2 (2.48%), and 552.23 km^2 (85.29%), respectively. It is important to note there was an intersection between barren land and GOS described as part of the GOS area while the intersection between barren land and built-up was also stated as part of the built-up area. The results showed that the LRB potential area for water infiltration based on the combination of GOS and barren lands was 70.06 km^2. The LRB potential Based on Figure 5 is marked in green color for GOS area, and red color for barren land area. The widest distribution of LRB is located in East Jakarta of 33%, followed by South Jakarta, North Jakarta, West Jakarta and Central Jakarta with the area of 28%, 19%, 13% and 8%, respectively. Statistical data shows

Table 3. Barren land classification and accuracy assessment.

Classification	Omission Error (%)	Commission Error (%)	Producer Accuracy (%)	User Accuracy (%)	Kappa	Overall Accuracy	Area	
							Km^2	%
Barren land	40	33.33	60	66.67	98.25	0.62	16.24	2.5
Other lands	0.77	1.02	99.23	98.97			631.27	97.5
							647.5	100

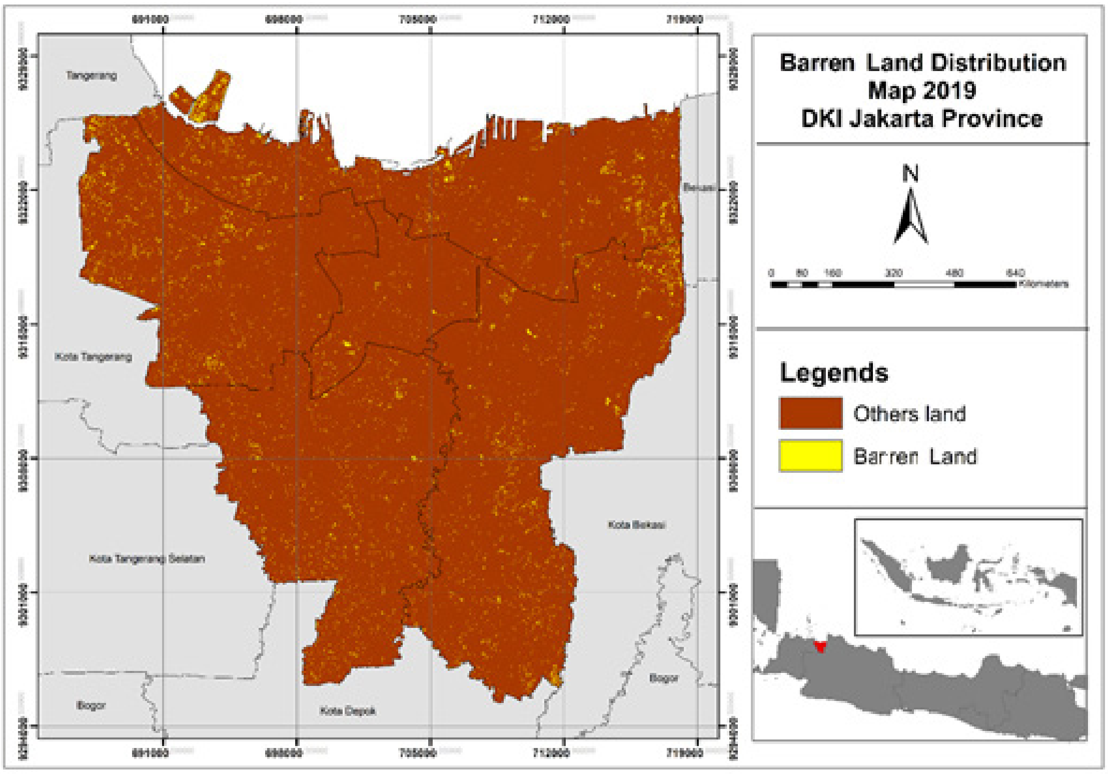


Figure 4. Barren Land Classification by Using Integration NDBI dan NDBaI Analysis.

that there are around 3,038 of GOS in Jakarta, excluding Kepulauan Seribu, which are generally divided into city parks, interactive parks, environmental parks, recreational parks, road greenbelts, waterfronts, and green open spaces around of cemeteries (Dinas Komunikasi Informatika dan Statistiks, 2015).

It is difficult to expand the GOS in Jakarta due to the focus of land-use practices on the industrial, government, and residential areas. This is the reason LRB is needed to mitigate flooding in the area and the analysis conducted using Equation 6 showed that the optimization of the GOS and barren land produced approximately 16,816,248 LRB or 18.27% of the 92,038,200 real LRB reported to be required in the city (Brata & Nelistya, 2008). It was discovered from the calculations made using Equation 7 that this value has the ability to reduce inundation by approximately 15.6% of even total rainfall in the city.

The results of this research showed that the utilization of GOS and barren land for LRB development cannot totally prevent flooding in Jakarta. But it is needed to reduce inundation during and after rainfall, and also critical for mitigating environmental damage (Hutabarat & Simanjuntak, 2022). Based on these considerations, LRB are to be planned and implemented in DKI Jakarta. The addition LRB also needs in flood mitigation by constructing LRB in the yards of houses, offices, and other public facilities. The data from the Central Statistics Agency of Jakarta (2020) showed that there were around 2,753,095 households in the city with an estimate of 1,297,258 houses or 47.12% considered to be suitable for LRB. Moreover, in the future, it is necessary to develop smart cities for flood prevention using rainwater-harvesting tanks in each house and rainwater-harvesting houses in public and private facilities with large land areas such as those developed in Fukuoka, Japan, in the future (Yamashita et al., 2015). However, the development of LRB in Jakarta only possible to reduce inundation and does not help for watersheds management.

To further optimize flood mitigation in Jakarta, it must be carried out along the watersheds. There are six watersheds, namely Ciliwung, Angke-Pesanggrahan, Buaran, Cakung, Krukut and Sunter watersheds (BPDASHL Citarum - Ciliwung, 2018). Ciliwung watershed has the length of its main river is 117 km, and 347 km^2 in the area plays an important role for flooding in Jakarta (Asdak et al., 2018; Harsoyo, 2013). This watershed crosses many villages, dense settlements, and slums and flows towards the Centre of Jakarta City, where the government is located. So that when it floods, the significant impact can paralyze the economic sector and social and government activities (Harsoyo, 2013). The implementation of comprehensive flood mitigation efforts in Jakarta also requires the cooperation of other districts along the watersheds to achieve proper watersheds management. This can be in the form of dam construction in several locations around the river and others tributaries to ensure proper management of water flowing to the city as well as tree plantation or naturalization of the rivers. However, the challenges to this plan include the degradation of the headwaters of the river leading to Jakarta between 2000 – 2009, a decline in the forest and plantation areas by 28%, and rice fields by 73%. These land use practices have the ability to ensure effective runoff water retention. Meanwhile, the development of settlements was found to have increased to 338% (Asdak et al., 2018). This simply shows that the implementation of LRBs in GOS and barren areas is not enough to resolve the flooding problem in DKI Jakarta and this means there is a need to study other alternatives such as the construction of a giant seawall or dams.

4. Conclusion

The LRB potential of GOS and barren land was analyzed using Landsat 8 OLI data and the results showed that Jakarta has 54.02 km^2 GOS (8.34%) and 16.04 km^2 barren land (2.48%). The optimization of both lands for LRB produced a maximum value of 16,816,248 which is 18.27% of the LRB needed in

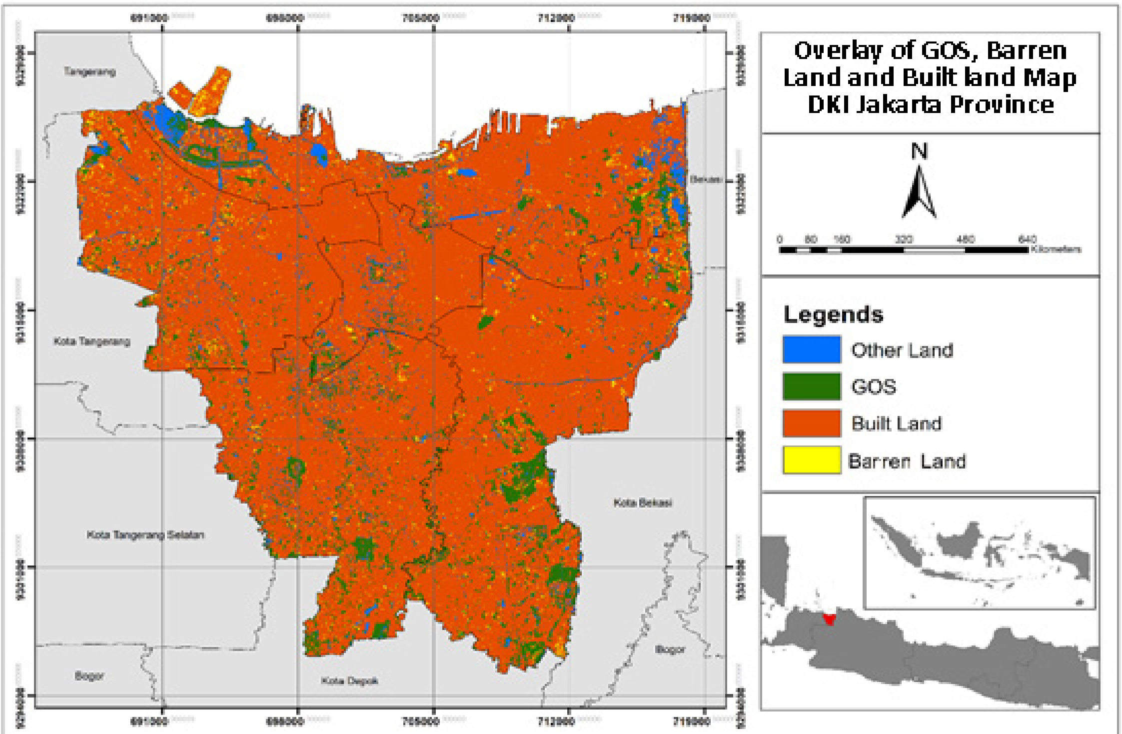


Figure 5. LRB potential in GOS Area (Green Color), and Barren Land (Yellow Color) in Jakarta.

the city but has the ability to eliminate approximately 15.6% inundation when rain fell evenly in Jakarta. However, a comprehensive flood mitigation effort requires an integrated study based on the watershed with a focus on all relevant administrative areas and the development of a Smart City with rainwater harvesting.

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