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Spatial Distribution of Urban Tree Canopy in Private Residential Property in Jakarta Bay Reclamation using Google Earth Engine Cloud Computing

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Abstract: Jakarta Bay reclamation is a solution to Jakarta flood control and development of business units including property business. Reclamation was carried out with the construction of 18 small islands in front of the coastline and giant embankments. Pantai Indah Kapuk (one of the developers) has invested in the Jakarta Bay reclamation program with plans to build islands A, B, C, D, and E as residential and entertainment areas. However, until 2022 only Islands C and D were almost ready. Jakarta Bay Reclamation presents various threats, especially in terms of ecology. Pantai Indah Kapuk should have a green open space as an urban area. The purpose of this study was to look at the distribution of trees in the private residential property area of Pantai Indah Kapuk in the reclamation of Jakarta Bay C and D Islands. The research uses the Google Earth Engine Cloud Computing application with Sentinel-2A image data source and classification by using several indexes to obtain the area of vegetation. The results showed that the classification area of water bodies, vegetation, land area, and buildings were 622.14 ha, 63.27 ha, 220.23 ha, and 139.71 ha, respectively. The accuracy test obtained an overall accuracy of 87.5% and a Kappa accuracy of 83.3%. The conclusion of this study is vegetation area in the private residential property area of Pantai Indah Kapuk covers 63.27 ha. The results of this study can be used as a basis for making reclamation management policies that prioritize ecological roles and functions to minimize negative impacts on the environment.

Keyword: Cloud Computing, Google Earth Engine, Jakarta Bay Reclamation, Sentinel-2 MSI

INTRODUCTION

Land reclamation is the technique of converting a marine area into a land area to expand urban capital. Land reclamation is being massively carried out, especially in Jakarta Bay. The governor of DKI Jakarta, Anies Baswedan, was already giving permission related to the island development of DKI Jakarta, explicitly focusing on the Thousand Islands area enlargement. It is recorded in Article 165 of Governor Regulation (Pergub) No. 31 in 2022 about the Detailed Spatial Plan (RDTR) of the DKI Jakarta Planning Area.

The function of land reclamation is to make the untapped marine area beneficial for various economic needs and other strategic purposes. The use of water space is the same as the use of the island area in the form of recreational and tourism activities, housing, education, conservation, and defense. Land reclamation is a solution for DKI Jakarta Province in overcoming land constraints. The negative impact of land reclamation is damaging marine ecosystems that have the potential to threaten the population of a species in the affected area. In addition, seawater will rise to areas prone to tidal flooding. Reclamation can effect the changes of shape inevitably and will influence the formation of marine erosion. Therefore, the social situation of people in coastal areas, especially in Jakarta Bay, will become more diverse and develop because other facilities have been built, such as schools, health centers, and open places that can be used for coastal community recreation. Researchers found problems in policies made to facilitate reclamation in Melaka, Malaysia (Yusup *et al.* 2015). The reclamation projects need to be supported by adequate development directives and merely involve the instinct of market forces to form new urban spaces in marine waters (Kamim 2020).

The Reclamation Area of North Jakarta is a new land development area in the sea waters of Jakarta Bay by forming islands through reclamation activities. It functioned to increase the benefits of land resources from environmental and socio-economic aspects. In order to realize these benefits, the Governor of DKI Jakarta issued Governor Regulation number 121 in 2012 concerning the spatial planning of the north bay reclamation area of Jakarta, specifically in 3 parts: the west, central, and east sub-regions. Each sub-region is then divided into smaller islands with different main functions. However, the primary function that each sub-region must own is to make it a horizontal and vertical housing area.

The practice of coastal reclamation development is a familiar thing to do. Reclamation is built to set optimal environmental conditions for development purposes. For example, most of the territory of the Netherlands and much of the coastline along North Korea, mainland China, and Hong Kong are reclaimed land. Furthermore, significant parts of Yas Island in Abu Dhabi and Eko Atlantic in Nigeria are among the many cases of existing coastal reclamation activities in the world (Ifeoluwa et al. 2021). In other words, coastal reclamation activities have given rise to various perspectives in academia, such as the impact of land reclamation activities on the north coast of Batam (Priyandes & Majid 2009). The results showed that coastal reclamation decreased fishery productivity, disrupted the coastal balance, changed current patterns and water quality, and caused flooding and sedimentation. As a result, this shows that coastal reclamation has an absolute negative influence on the region's physical-chemical environment, biological environment, and social aspects.

The role of Geographic Information System (GIS) technology as a tool to map a geographical phenomenon and phenomenon has been widely used, which is essential in facilitating spatial information—representing a location that is useful and beneficial to humans. The information formed as digital data is obtained through various methods of data collection, either primary data through the survey process, secondary data through satellite data interpretation, or data from another source that can be spatialized (Amor *et al.* 2021). Geospatial technology provides spatial and territorial information about all events on Earth by visualizing location-based information that makes it feasible to study various themes. This technology can be used to visualize the potential of groundwater pollution, expose information on the potential of water resources (Riasasi & Sejati 2019), identify the distribution of social and economic conditions in disaster-prone areas (Permatasari 2018).

Areas that experience significant changes in land use due to the expansion of built-up land, one of which is Solok City. Solok had 1,254 hectares of rice fields in 2004, but it was reduced to 876 hectares in 2015. It must be a significant problem because Solok City is famous for agricultural products, especially rice (Indonesia Statistics Agency 2015). On the other hand, land development of built-up land continues to occur due to population activities. Efforts that can be made to reduce the impact of problems like this is to conduct a study on the development of built land in Solok City and its impact on sustainable agricultural land using Geospatial information technology. These technologies can include Geographic Information Science (GIS) and Remote Sensing.

METHODOLOGY

Study Area

The research location is in the reclamation area of Jakarta Bay, specifically on island C and island D in North Jakarta. Island C and Island D are in the reclamation process of 276 ha and 3112 ha, respectively, by PT. Kapuk Niaga Indah as one of the investor (Zamil *et al.* 2020). As already known, Jakarta is the center of economics (businesses, trades, and industries), politics, cultures, and many activities. The rapid growth of Jakarta caused much development that crowded public spaces, leading to urban planning changes. Water catchment areas, green spaces, and the function of urban parks are changing (Adisasmita 2014).

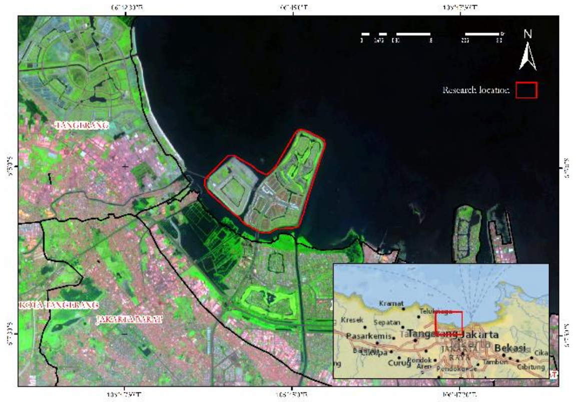

Figure 1. Location research map

Table 1. Data training and validation

No	Types of Land Use	Data	
		Training	Validation
1	Water body	50	25
2	Vegetation	50	25
3	Barren land	50	25
4	Built-up	50	25
Total		200	100

Data Source

The data source used MSI Sentinel-2 satellite images with a recording range of 2020-2022. The classification was carried out with the help of sample data which was divided into four types of land cover: water body, vegetation canopy, barren land, and built-up. Each type uses 50 trained samples. Indexes are selected based on specific functions and objectives corresponding to the coastal characteristics and land reclamation activities. The building index is used to consider the coastal reclamation activities, whereas the water index is used due to the influence of water on the coastal area. The validation data used by each variable is 25 (Table 1). All these samples become hyperparameters used by machine learning in later classification.

This analysis used Sentinel-2 MSI images, which produce multispectral high-resolution up to 10 m x 10 m. The Sentinel-2 has a single Multispectral Instrument (MSI) that can produce recordings of up to 13 spectral bands (Table 2). These spectral bands consist of three spectral bands that have 60 m resolution (Ultra blue, Water Vapor, and Cirrus), six spectral bands that have 20 m resolution (Red-Edge, Re1, Re2, Nirn, SWIR1, SWIR2), and four bands that have 10 m resolution (B, G, R, and NIR) (Astola *et al.* 2021). Therefore, Sentinel-2 MSI is the best used for monitoring, classifying, or detecting land changes (Blaschke *et al.* 2014).

Google Earth Engine Platform: Classification

Google Earth Engine (GEE) is an open-source remote sensing data processing platform using a web-based Application Programming Interface (API). The application of remote sensing data contained in GEE has been widely used in various studies of change detection (Yang *et al.* 2022; Madinu *et al* 2024; Asy'Ari *et al.* 2023A; Asy'Ari *et al.* 2023B) and urban classification (Nguyen 2020; Rivai *et al.* 2023). Earth Engine public data catalog is a widely used geospatial or multi-petabyte set. Most of the catalog consists of remote sensing imagery of Earth observations, including the entire archive of data from Sentinel-1 and Sentinel-2, even including land cover data, climate forecasts, and more (Gorelick *et al.* 2017). The mapping process is faster because there is no need

Table 2. Band spectral Sentinel-2

Band	Band Description Number	Wavelength Range	Resolution
B1	Ultra Blue (Coastal aerosol)	433 nm – 453 nm	60 m
B2	Blue (B)	458 nm – 523 nm	10 m
B3	Green (G)	543 nm – 578 nm	10 m
B4	Red (R)	650 nm – 680 nm	10 m
B5	Red-Edge 1 (Re1)	698 nm – 713 nm	20 m
B6	Red-Edge 2 (Re2)	733 nm – 748 nm	20 m
B7	Red-Edge	773 nm – 793 nm	20 m
B8	Near Infrared (NIR)	785 nm – 900 nm	10 m
B8a B9	Near Infrared narrow (NIRn)	855 nm – 875 nm	20 m
B10	Water vapor	935 nm – 955 nm	60 m
B11	Shortwave Infrared/Cirrus	1360 nm – 1390 nm	60 m
B12	Shortwave Infrared 1 (SWIR1)	1565 nm – 1655 nm	20 m
	Shortwave Infrared 2 (SWIR2)	2100 nm – 2280 nm	20 m

to download satellite images, pre-process images and use a supercomputer (Fariz *et al.* 2021).

The results of the study by Fariz *et al.* (2021) has been proven that the random forest (RF) algorithms are the best among other algorithms spatial such as CART (Classification and Regression Tree) and SVM (Voting), due to it is based on nonlinearity and the classification results are free from error (Pelletier *et al.* 2016). Random Forest has an advantage in predictability compared to a single decision tree. Single decision trees tend to have a less stable model, so the slightest change in the data will affect the prediction results and tend to be overfitting (Dhawangkhara and Riksakomara 2017).

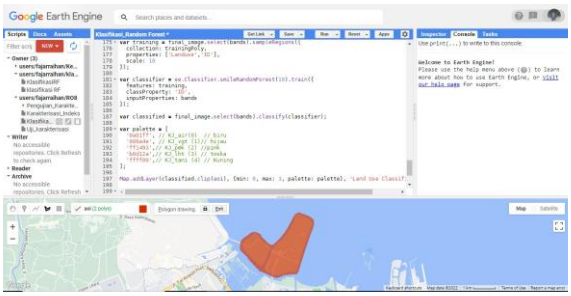

Figure 3. Google earth engine platform

Variation of Index

Index formulas tested in this study include NDWI, MNDWI, EVI, SAVI, SLAVI, GNDVI, and IBI. Vegetation indices used to determine the distribution of tree cover are EVI, SAVI, SLAVI, and GNDVI. The vegetation index is an algorithm applied to the image to highlight vegetation density and other related aspects, such as chlorophyll concentration, water cover. High vegetation index values give an idea that in the observed area, there is vegetation that has a high level of green matter, such as dense forest areas. Conversely, a low vegetation index value indicates that the land that is the object of observation has a low level of greenish vegetation value or land with scarce vegetation or, most likely, not a vegetation object. Based on results from Arhatin & Wahyuningrum (2013), vegetation index estimation from Green Normalized Difference Vegetation Index (GNDVI) is the best transformation of vegetation index to see the density of the mangrove canopy case study in Berau Regency.

Accuration Assessment

Accuracy testing aims to assess the classification error so that it can be known the percentage of accuracy. The accuracy of classification can be calculated from the user's precision, producer's accuracy, overall accuracy, and Kappa accuracy. The higher value indicates, the higher the image classification results. The guidelines for processing digitally supervised multispectral satellite data for classification establish that land cover classification accuracy is, on average, above 75% (Lapan 2015). The maker accuracy value indicates the average percentage chance that a Pixel will be classified correctly and, on average, means how well each grade in the field has been organized. The user accuracy value (UA) shows the percentage chance that an average pixel of a classified image represents those classes in the field (Mulyaqin *et al.* 2022).

Table 3. Index of water

No	Method	Formula	References
1	Normalized Difference Water Index (NDWI)	NDWI = Green – NIR / Green + NIR	Gao 1996
2	Modified Normalized Difference Water Index (MNDWI)	MNDWI = Green – SWIR / Green + SWIR	Xu 2006

Table 4. Index of vegetation

No	Method	Formula	References
1	Enhanced Vegetation Index (EVI)	EVI = 2.5 x ((NIR – Red) / ((NIR) + (C1 x Red) – (C2 x Blue) + L))	Huete 2002
2	Soil Adjusted Vegetation Index (SAVI)	SAVI = ((NIR – Red) / (NIR + Red + L)) x (1 + L); L = 0.5	Huete 1988
3	Specific Leaf Area Vegetation Index (SLAVI)	SLAVI = NIR / Red + MIR	Lymburner *et al.* 2000
4	Green Normalized Difference Vegetation Index (GNDVI)	GNDVI = NIR – Green / NIR + Green	Gitelson *et al.* 1996

Table 5. Index of built up

No	Method	Formula	References
1	Index-Based Builtup Index (IBI)	IBI = NDBI − ((SAVI + MNDWI) / 2) / NDBI + ((SAVI + MNDWI) / 2)	Xu 2008

Note: Blue = blue band, Green = green band, Red = red band, RE = red-edge, NIR = nearinfrared band, SWIR = shortwave-infrared band, C1 C2 = the aerosol coefficients were 6.0 and 7.5, respectively, G = gain factor (value 2.5), S2 = Sentinel 2 MSI.

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

$$Kappa = \frac{N\sum_{i=1}^{r} X_{ii} - \sum_{i=1}^{r} X_{ii}\,(X_{i+} \times X_{+i})}{N^2 \sum_{i=1}^{r} X_{ii}\,(X_{i+} \times X_{+i})} \quad (2)$$

RESULTS AND DISCUSSION

Spatial Distribution of Urban Tree Canopy

Jakarta Bay is one of the strategic areas that reflects the capital of Indonesia. Jakarta is developing into a metropolitan city with rapid growth due to the center of the economy, industries, politics, and culture with various international activities (pull factors). According to Indonesia Statistics Agency (2021), the Jakarta population in 2021 rapidly grew to 10,609.68 people, with a population growth rate of 0.57 in 2021. Looking at the problem of Jakarta, where every year experiences population growth, the land area of the capital of Jakarta needs to be seen as insufficient as a place to provide space for elite residential areas, tourist attractions, business districts, etc. Seeing spatial and regional development limitations, the Government of Special Region Jakarta and the Central Government solved the problem by reclaiming Jakarta's north coast. The reclamation project was initiated from Jakarta General Spatial Plan 1985-2005, which stated that it was necessary to carry out reclamation on a small scale in Pademangan, Ancol, and Pluit (Pantai Mutiara) to meet the willingness of Jakarta's growing population. After experiencing several problems and mismatches of management objectives, the Special Region Jakarta Governor Regulation No. 121 of 2012 on Spatial Planning of the North Coast Reclamation Area of Jakarta includes 17 islands named Island A to island Q. The reclamation's purpose is increasing for international trade and services, housing for the upper middle class, and tourist ports.

Jakarta Bay has an area of 490 km2, with a beach length of about 40 kilometers and an average depth of 15 meters (Koropitan *et al.* 2009). Reclamation activities harm the surrounding environment, such as the degradation of mangrove vegetation cover in the Pantai Indah Kapuk area from 2010-2015 experienced a change in size consisting of a reduction of 38.79 Ha or 44% (Mulyaningsih *et al.* 2017). Angke Kapuk Mangrove area has a level of criticality categorized as damaged area, about 272.79 ha (Sofian *et al.* 2019). In addition, Yonviter & Imran (2006) stated that the benthos biotas that determine the water quality in Jakarta Bay are in heavily polluted conditions. The phytoplankton Diversity Index (DI) supports this in 2014-2016 by decreasing from 1.33 to 0.85 (Puspasari et al. 2017).

The analysis results obtained that the area of tree cover in the reclamation area of island C and island D is 63.27 ha. Based on the analysis (Figure 4.), the distribution of tree cover dominates the northern part of island D due to the north part as an area to play golf and the absence of housing development activities. According to Nibras (2019), on Island D, there are 932 buildings consisting of 409 residential houses and 212 office houses, 311 rukan, and unfinished residential houses. Island development activity in the southern area is very dense, with residential dwellings. Island C is in the stage of adding land, so the implementation of spatial planning has yet to be built; the spatial distribution of vegetation is in the island's coastal area because of the pioneer-type plants that grow naturally. According to the spatial and Regional Plan of Jakarta

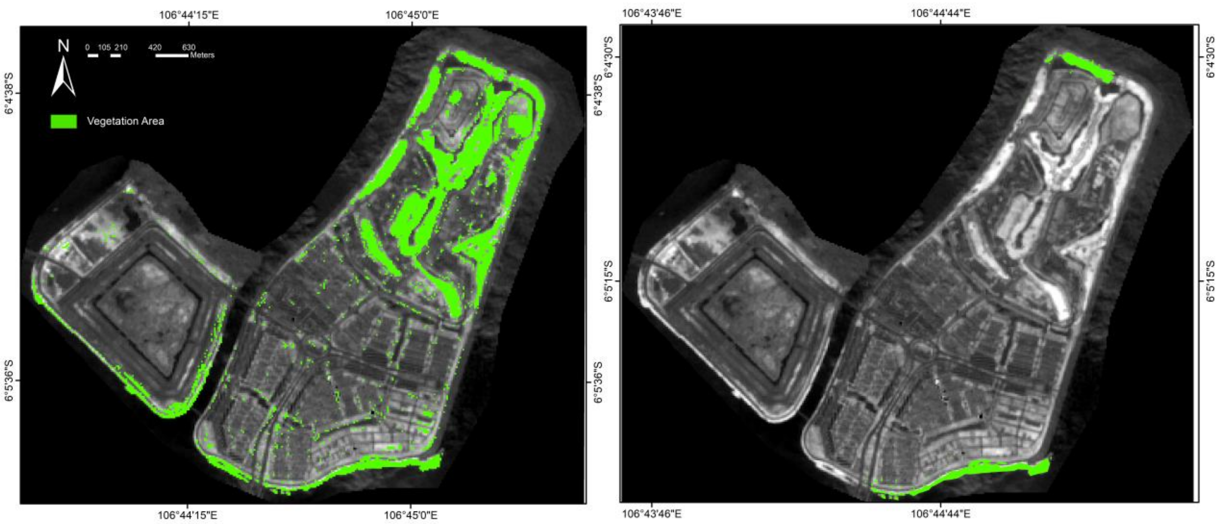

Figure 4. Spatial distribution map of urban tree canopy (a) after reclamation (b) before reclamation

Table 6. Total area across multiple land uses

No	Types of Land Use	Broad	
		Area (ha)	Percentage (%)
1	Water body	622.14	59.51
2	Vegetation	63.27	6.05
3	Burren land	220.23	21.07
4	Built-up	139.71	13.26
Total		1,045.35	100

province for 2010-2030, island C is intended as a sports, culture, entertainment, and Park area, while Island D is designed as a residential area (Rasminto & Nur 2018).

The results showed the classification of water bodies area, 622.14 ha; vegetation area, 63.27 ha; a land area, 220.23 ha; and buildings area, 139.71 ha. The vegetation area has only a percentage of 6.05% of the total area. The distribution of vegetation is dominant in the northeastern area of the island due to planting activities for aforestation. As a rule, according to the regulation of the Special Capital Region of Jakarta, Number 1 of 2012 concerning the 2030 Spatial Plan, the composition of the reclamation land use plan on Island C is at least 20% for public green space, at least 10% for private green space, at least 10% for blue open space, at least 10% for road networks, at least 5% for public and social service areas and a maximum of 40% for horizontal and vertical, mixed, supporting, Port, Industrial, and warehousing housing areas. Another regulation is the Jakarta Governor regulation number 206 of 2016 concerning City Design Guidelines for Island C, Island D, and Island E as a result of the reclamation of the strategic area of the north coast of Jakarta; article 6b states that it is necessary to provide green open space and public space on private land. The results of the analysis of vegetation areas do not comply with regulations where the percentage of green open space is a minimum of 30%. Compared with the province of Jakarta, the urban forests of DKI Jakarta province's known portion of its area is only about

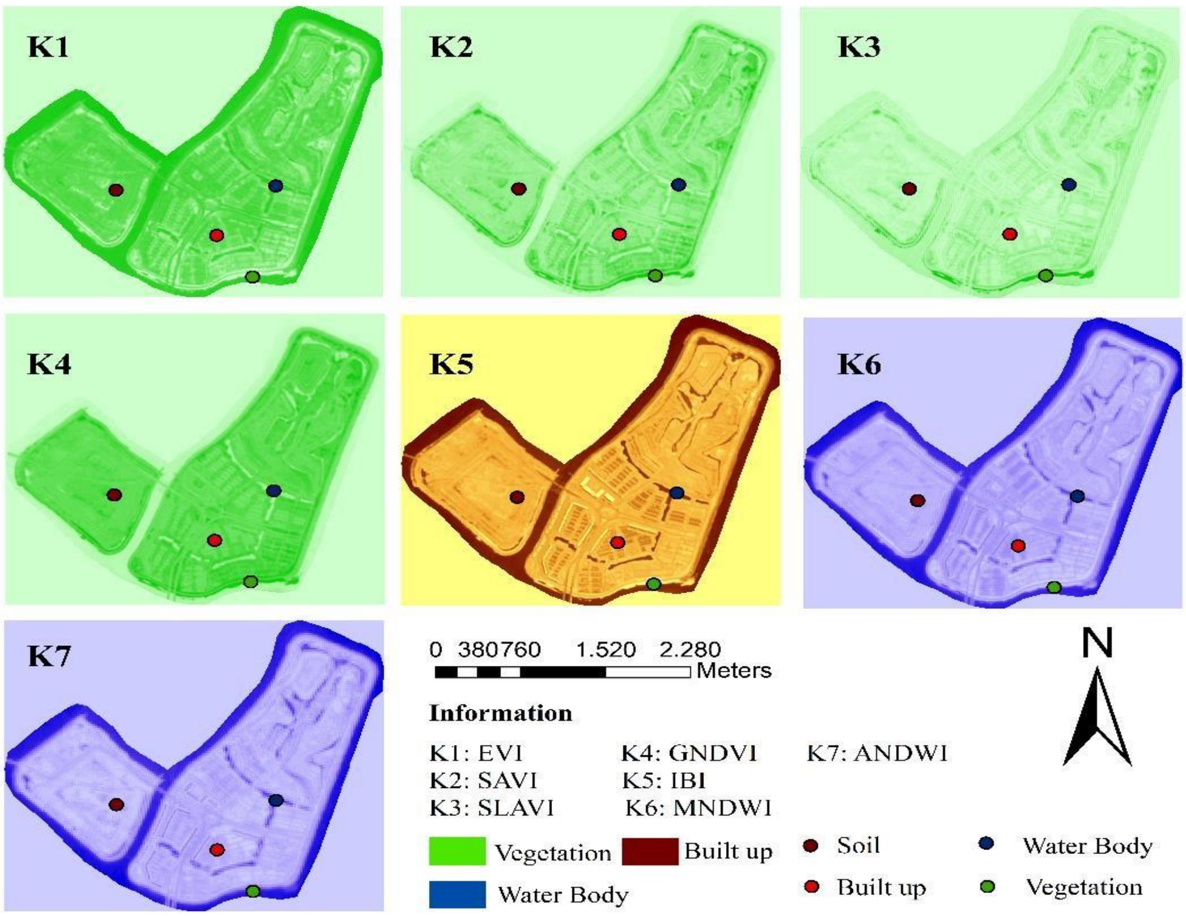

Figure 5. Index rating of each classification

Table 7. Confusion matrix

Type of Land Use	Water Body	Vegetation	Barren Land	Built Up	Sum (User's)
Water Body	9	0	0	1	10
Vegetation	0	9	1	0	10
Barren Land	0	0	10	0	10
Built Up	0	0	3	7	10
Sum (Producer's)	9	9	14	8	40

116.59 Ha or about 0.17% compared to the total size of the region (Jakarta Government - Environmental Agency 2022).

The results of this study can be used as a basis for making reclamation management policies that prioritize ecological roles and functions and minimize negative environmental impacts. It is in accordance with the purpose of Special Capital Region of Jakarta regulation, Number 1 of 2012, concerning the Spatial Plan 2030 Article 103 verse 1(h) that states the implementation/functioning of objects/installations/vital facilities in the north area of Java by paying attention to ecological aspects of the environment.

Characteristics and Capabilities Index

Some indexes have different characteristics in assessing land use. Picture 4. describes the ability of each index to evaluate land use in the Jakarta Bay reclamation area in Island C and island D spatially. The vegetation index consisting of EVI and GNDVI can distinguish land and water. In contrast, the SAVI and SLAVI indices can hardly distinguish the two land uses; this index puts water at almost the same spectral value as buildings. The building Class Index, namely IBI, almost perfectly indicates water and land. The water index, MNDWI, and ANDWI can completely distinguish these two types of land use.

Accuracy

Based on the Matrix confusion (Table 7), it can be seen that all Pixels are correct more than the pixels that error in the class or classification. Built-up land use type has the lowest producer accuracy among other land use types due to classification prediction errors. Most errors occur in the class of buildings, and then they are followed by water bodies and vegetation. Sampling used as a training area with samples used for accuracy tests should be taken in different places to get more acceptable accuracy (Wulansari 2017).

The research process worked well, producing informative maps with varied classifications, producing overall accuracy and a decent Kappa index using an accuracy reference that is considered feasible for the use of satellite imagery 80% - 85% (Sutanto 2013). The calculation of overall accuracy for 4 classes of land use is 87.5% while the Kappa index of 0.83.

CONCLUSIONS

Based on the spatial analysis results, vegetation area/tree cover on island C and island D of Jakarta Bay reclamation area has an extensive region of 63.27 ha or 6.05%. The distribution of vegetation on island D is dominant due to using as the object of golf sports in northern Jakarta and the absence of housing unit constructions. Jakarta's current reclamations are not following the regulations that set a minimum green open space of 30% of the total area.

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