RESIDENTIAL CLASSIFICATION USING GEOBIA IN PART OF JAKARTA SUBURBAN AREA

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Received: 23-02-2023; Revised: 27-12-2023; Approved: 27-12-2023

Abstract. The increasing of urban population followed by socioeconomic problems leads to emerging various number of researchs in urban area, especially in Jakarta Metropolitan Area. One of them are escalated tension-conflict due to rise of newly Gated Communities residential that sprawl across local residents (Kampung Kota). There is urgency to map all 3 types of residential (Kampung Kota, Perumnas, Cluster) through satellite imagery on a wide-scale. This study uses WorldView-2 imagery data recorded for 2020. The method used is an object-based method, namely GEOBIA using the eCognition Developer 64 software. The Geographic Object-Based Image Analysis (GEOBIA) is carried out through three stages, firstly the segmentation to separate residential blocks from surrounding land cover objects (water body, vegetation, open land, non-residential built-up land) as well as exploring the variable values of each object, then sample-based classification using the Support Vector Machine (SVM) algorithm on Google Earth Engine application, and accuracy test to evaluate semantic and geometric accuracy levels. The results of the mapping are 3 classes of residential types followed by 4 classes of land cover. The overall accuracy of the three types of residential is 80% which means that the GEOBIA approach is able to show good performance.

Keywords: *GEOBIA, SVM, eCognition, google earth engine, worldview-2*

1 INTRODUCTION

Rapid urbanization rate and uncontrolled regulation of housing are the two phenomenas lead to the rise of Gated Communities in which the residents isolate themselves from surrounding neighbor for safety and convenience reason (Roitman, 2010). If not treated, this will create the increasing of spatial segregation rates and widen the inequality among urban citizen (Stiglitz, 2012). Hence, extractive research are needed to provide data on types of residential from three classes (Informal settlements, Government projects, and Gated Communities) and its spatial distribution. Several research are conducted, one of them is using visual interpretation as Hamann and others (2020) did. However, these methods face another limitation such as ineffective and longer workflow for widescale area. Pixel-based image analysis cannot provide clearer results and interpretation of each housing types in block units, both in middle and low resolution and produce more noise such as salt-and-pepper in high resolution, a condition where misclassification happened in the place it shouldn't be and didn't representate a whole object. This problem leads to the next question: How do we produce housing type block with as little error as possible?

GEOBIA (Geographic Object-Based Image Analysis) is a remote sensing data processing technique in which an analyst can break down the image display into various uniform image objects (segments) using image segmentation methods (Blaschke et al., 2014). GEOBIA is a novel way to classify the object based on its spatial, spectral and textural features, rather than pixel-based classification which classifies object based on spectral characteristics only. In this research, several features are chosen such as spectral, geometry, and textures parameters. It also could minimize the noise produced by algorithm thus give clearer boundary of each object class.

This study aims to explore the procedure of residential mapping using GEOBIA and calculate its accuracy using area-based accuracy assessment. The accuracy assessment is conducted not only for the semantic, but also geometric properties.

2 MATERIALS AND METHODOLOGY

2.1 Location and Data

This research was conducted in Sukabakti Village, Curug Subdistrict, Tangerang Regency, Banten. Astronomically, the location of this study is at 676147 - 673572.0 E and 9308083.4 - 9309734.0 S with the total area of the study site is 427.45 Ha. The research location is located near Lippo Village Township and Jakarta - Merak Toll Road in north and consisting of three types of residential such as Perumahan Binong Permai, Kampung Babakan, and Complex of Aryana Residence.

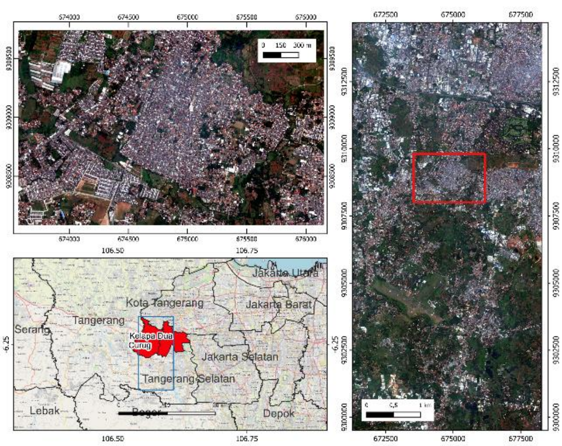

Figure 2-1: Study site Curug District, Tangerang

This area is well known for its long history as a first settlement in modern Jakarta Metropolitan Area era. The first kampung kota (Kampung Babakan) was recorded in 1900 topographical map of Dutch East Indies (Topographisch Bureau, 1900) and its boundary form is still persisted today.

The first government project based housing was built in 1990s, known as Perumahan Binong Permai by PT Purinusa Jayakusuma. The second one was built 20 years later by PT Purigraha Asri Permai as Perumahan Griya City Karawaci. 5 years later in 2015, the complex of luxury housing known as Aryana Residence was building until today by the same developer who built Perumahan Binong Permai before.

The data used in this study is the WorldView-2 satellite imagery Level 3D correction recorded on 25 August 2020. This data was obtained from Remote Sensing Research Center, BRIN as the official national research institution in Indonesia known for providing very high resolution satellite imagery.

2.2 Types of Residential

There are three types of residential in study area, such as Informal settlements, Government projects, and Gated Communities. Informal settelements, namely as Kampung Kota, is the first type of housing emerged in urban areas (Nugroho, 2009). As the time goes on, land change near the Kampungs, especially for housing purpose, leads to densification of Kampungs created the unregistered and poorly managed sanitation and land parcels. The densification driven by land change from paddy fields as main source of livelihood to well prepared, modern housing such as government project based housing (Perumnas) and exclusive housing i.e. Gated Communities. We could spot this housing types based on visual interpretation from its diverse color of tile roof, organic uncontrolled layout that leads to coarse texture, higher house density, and presence of uneven trees canopy distribution.

Government project based housing, namely as Perumahan Nasional (Perumnas) is housing that created by government with well planned housing layout and meets the bare minimum of national housing standardization, such as small-to-medium sized house (36/72 type) and decent facility for each house. Its residents come from the lower-to-middle to middle class, noted by their mainly job in government or office. Based on its typology, each house tends to have different look due to renovation, both in live view and via satellite imagery. The key point for interpreting this housing types is gridded layout, uniform tile roof colour, and fine texture but have little presence of vegetation.

Gated Community consist of middle-to-uppor to higher class housing with homogenous appearance and larger house size per unit. Its residents also have higher economic rates. Its distinct appearance comes to outside view where those housings have separator from surroundings such as high wall/fence, 24/7 security system, and less dense housing layouts. On high resolution imagery, this housing types is distinctive from surroundings based on its low building density, sprawled but organized layouting such as *cul-de-sac* or gridded, and the presence of more vegetation.

2.3 Segmentation

The first stage conducted is segmentation with the aim to group homogenous pixels that represent a single object into the same segment. The algorithm used in this research is multiresolution segmentation applied in eCognition. This algorithm has many advantages to extract object from imagery where the user can control its parameter and criterion such as color, scale, shape, smoothness, and compactness (Danoedoro, 2014). The following equation (Baatz & Schäpe, 2000) is shown below:

$S_f = w_{color} \times h_{color} + (1 - w_{color}) \times h_{shape}$.......(1)

Description:

S_f = Segmentation function

w_{color} = color factor

h_{color} = spectral heterogeneity factor

h_{shape} = spatial heterogeneity factor

For the configuration, we use the size; shape; and compactness configuration as follows: 100; 0.6; and 0.7. This configuration is modification from Zhao *et al.* (2020) research in which they use 320; 0.9; and 0.8 to obtain housing block objects, especially for cluster type. Smaller size value is chosen to adapt with the smaller patch of evey housing in Jakarta Metropolitan Area, in which some housing only has less than 10 house, occupying less than 1000m^2 of land.

2.4 Classification

The secondary step after segmentation in GEOBIA is classification. Classification aims to group segment image into submitted classes which meet the criteria and common statistical boundary system. This stage is conducted in Google Earth Engine platform.

The classification conducted in this research is sample-based classification. Each samples contains variables that represents their class. There are 3 class of residential types and 4 other land cover class (vegetation, barren land, waterbody, impervious surface). Each number of samples per class varies from 10-20 samples. The algorithm used in this classification is machine learning based algorithm such as Support Vector Machine (SVM) linear-type kernel. SVM algorithm shows good performance for ground objectbased detection and classification compared to other algorithm (Wu *et al.*, 2018). The linear kernel also has advantage to differentiate each class boldly while maintaining fewer additional setup into the algorithm as possible.

The following equation based on Kete *et al.* (2019) are shown below:

$D(X^T) = \sum_i^l 1\, y_i \alpha_i X_i X^T$ ....(2)

Description:

y_i represents class label from support vector, $X_i X^T$ means data testing, αi represents numeric parameters that determined through SVM optimization. 1 represents number of vector support

2.6 Accuracy Test

The accuracy test used in this research is area-based accuracy test. It is the modification version of confusion matrix uses to measure the thematical and geometrical. The certain equation proposed by Kamal and Johansen (2017) are shown as below:

$$OQ = \frac{|C \cap R|}{|\neg C \cap R| + |C \cap \neg R| + |C \cap R|} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

$$UA = \frac{|C \cap R|}{|C|} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

$$PA = \frac{|C \cap R|}{|R|} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

$$OA = \frac{|C \cap R|}{|C \cup R|} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

Description:
OQ = Overall Quality
UA = User's Accuracy
PA = Producer's Accuracy
OA = Overall Accuracy
C is classification results, R is reference data, ¬C ∩ R means any R area that doesn't overlap with C area, C ∩ ¬R means any C area that doesn't overlap with R area, C ∩ R means overlap between C and R area, C ∪ R means overall area.

The research flowchart is seen below:

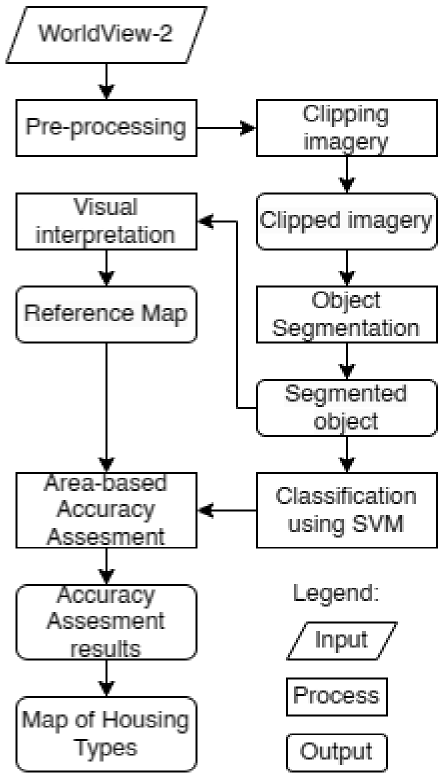

Figure 2-2: Research flowchart

3 RESULTS AND DISCUSSION

3.1 Segmentation and Image Classification

Segmentation

The segmentation is conducted with 4 layer of original WorldView-2 bands (R, G, B, and NIR) and one layer of vegetation index (NDVI) in eCognition. The process is carried out in only a stage with the value of weighted bands is 0.5 0.5 0.5 1 1; scale parameter is 100; colour and shape parameter is 0.6; smoothness and compactness is 0.7. The result of this stage is 315 individual segments. This configuration is meant to optimize the residential block extraction. The result of segmentantion is shown below:

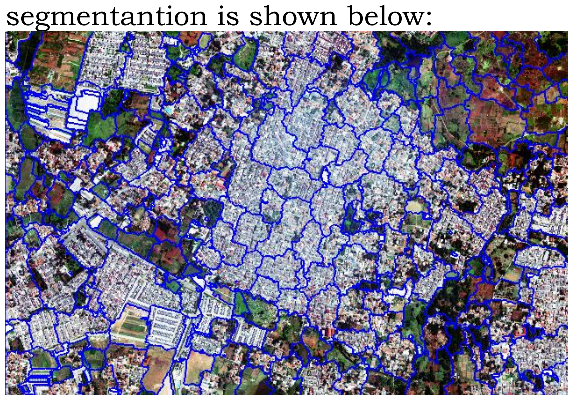

Figure 3-1: The result of segmentation

Image Classification

The classification produces three class of housing types and four class of land covers (vegetation, waterbody, barren land, impervious land). In this part, only three types of housing types were highlighted. The classification were conducted in Google Earth Engine with SVM configuration of linear type, and C kernel. The training and testing data were split into 70:30 proportion. The selected variables using in this classification along with the parameters are shown below:

Table 3-1: List of 20 variables of spectral, spatial, and texture parameters obtained by segmentation method

Parameter	Variable	Description (Refer to Zhao et al., 2020)
Spectral	Mean Red	Mean of pixel value in red band
	Mean Green	Mean of pixel value in green band
	Mean Blue	Mean of pixel value in blue band
	Mean NIR	Mean of pixel value in NIR band
	Mean NDVI	Mean of pixel value in NDVI band
	SD Red	Standard deviation of pixel values in red band
	SD Green	Standard deviation of pixel values in green band
	SD Blue	Standard deviation of pixel values in blue band
	SD NIR	Standard deviation of pixel values in NIR band
	SD NDVI	Standard deviation of pixel values in NDVI band
	Max. Diff	Maximum difference between all layers
	Brightness	Average of means from all layers
Spatial & Texture	Compactness	The index of square-shape geometry. The more an object is shaped like a square, the higher its value
	Density	Distribution in space of the pixels of an image object. The more an object is shaped like a filament, the lower its density
	Shape Index	Smoothness rate of object border. The smoother the border of an object is, the lower its shape index
	GLCM Homogeneity	Measure of the closeness of the element's distribution in the GLCM to the GLCM diagonal
	GLCM Mean	Measuring the average value of the appearance of the pixel gray level matrix
	GLCM StdDev	Measure of the dispersion of values around the mean
	GLCM Correlation	Measure of the linear dependency of gray levels of neighboring pixels
	GLCM Entropy	Measure of the disorder of an image

The classification results show varieties between class assigned by algorithm. The highlighted three class of housing types are shown in the map and the rest is erased. There are three factors affecting the results, such as weighted band configuration, segment results, and sample used in algorithm training. The difference between the reference map and the classification result are shown below:

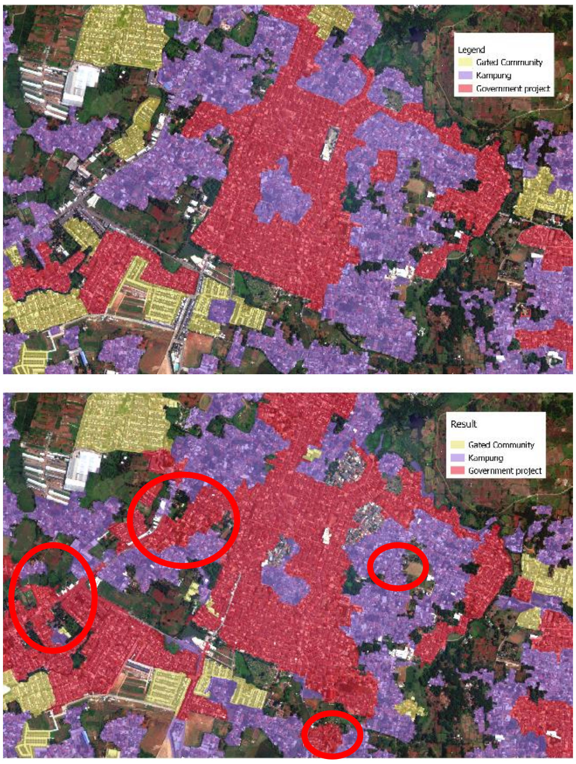

Figure 3-2: The reference map of housing types (above) and the result of classification using GEOBIA (under). Notice the difference highlighted by red circle.

Every object type has a sensitivity to certain spectral channels, which in an object-based classification scheme is represented by variables in the spectral parameters (mean, standard deviation, brightness, maximum difference). The four variables are influenced by the number of channels used and the weight configuration used. For example, the original multispectral WorldView-2 channels, besides RGB and NIR1 that are not present in the image product, are 4 with information of the coastal (400-450 nm), yellow (585-625 nm), red edge (705-745 nm), and NIR2 (860-1040nm) channels. There is an added modification channel to differentiate vegetation, water, and built-up land, called the NDVI channel. Thus, only 5 channels can be specifically set in the channel weighting stage in the segmentation process, closing the possibility of object sensitivity through other channels that are not present in the WorldView-2 image product.

In addition to the lack of channel variation, the configuration of the segmentation used also affects the segmentation result. The primary priority of the segmentation in this research is the division of housing object types into identified housing blocks so that land cover objects that are not segmented, such as vegetation and barren land, are combined into a housing block segment that becomes the assumption of determining the type of housing, especially the type of village housing (Kampung Kota). However, there is a rough boundary where at a certain minimum area limit, the vegetation object enters into a different class so the vegetation object becomes its own segment, either through automatic or manual segmentation features.

The most important factor influencing the performance of the classification algorithm is the selection of samples that represent all classes. The use of the Support Vector Machine (SVM) algorithm in classification has the advantage of good performance on samples with few but high dimensionalities. However, not all of these classes can be represented by existing samples. For example, Cluster Anggrek Permai as seen on Figure 3-3 is a GC type housing characterized by building homogeneity and a single entrance guarded directly by security guards and to not be directly visible from the main road, a commercial complex was built on the outside. Due to the similar spectral appearance with the row house class, the algorithm from the training result assigned the value object as a perum housing class. The misclassification resulted in perum housing class value also occurred in Figure 3-2. Some of the housing blocks have the similar spectral & textural features, make it less distinguishable with Perum class.

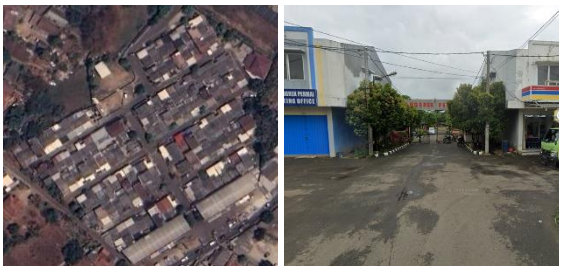

Figure 3-3: satellite imagery of Cluster Anggrek Permai (left) and its outer, covered by commercial complex (right)

Based on the Figure 3-4, it is known that several classes have quite optimal classification results with a record of underclassification of 11-22% of the reference geometry area, for example the impervious surface, Gated Communities, Kampung, and Barren land classes. Waterbody class obtained almost perfect classification quality in terms of the difference between the classification result and the reference even though the area is quite small. There are only two classes that experience overclassification, namely vegetation and Government project housing (Perumnas). The Vegetation class got misclassify with the open land class due to the algorithm cannot distinguish between vegetation classes which are upright plants when the open land class is filled with vacant land, grass, and paddy fields. The Perumnas class which experienced overclassification of 47% (39.5 Ha) of the reference area was due to the misclassification of the algorithm for other built-up land, both from residential (Gated Communities, Kampung Kota) and non-housing classes (Impervious surface).

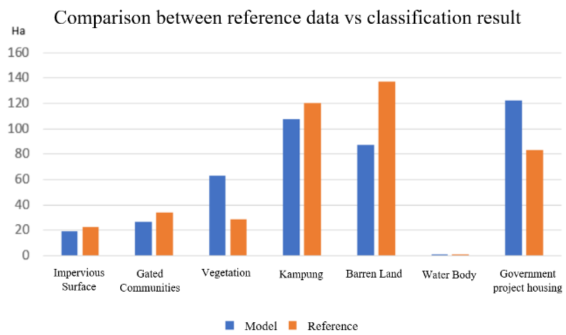

Figure 3-4: Graphic of comparison between reference data vs classification result area

3.2 Area-based Accuracy Assesment

The accuracy test performed on the classification result of the type of housing was based on the method used in the reference map accuracy test, which was the confusion matrix, with the modification of adjusting the classification of objects, resulting in the area-based accuracy assessment method. The area-based accuracy test method used needs to be done in order to determine the quality of geometry produced through the segmentation and classification process as a whole, as well as the quality of the semantics of each class as a whole. This process was obtained through an overlay between the GEOBIA classification results and the reference map of each object class. Based on the results of the classification for the three classes of housing type and four other land cover classes, the following GEOBIA-based classification test results were obtained:

Table 3-2: The result of Area-based Accuracy Assessment from highlighted three types of housing classes.

	Kampung Kota	Perumnas	GC
OQ	0.71	0.64	0.59
UA	0.75	0.93	0.64
PA	0.94	0.67	0.89
OA	0.80		

The overall accuracy test value reaches 80%. This value almost reaches the minimum eligibility limit of the map based on BIG Regulation No. 15 of 2014 on Technical Guidelines for Basic Map Accuracy, where the minimum accuracy test value for thematic maps is 85% for building and land cover classes.

The comparison map between the suitable classification and unsuitable are shown below:

Figure 3-5: Map of comparison between suitable vs unsuitable classification

According to the map above, it is revealed that the areas experiencing misclassification are in the southeast and south part of study area, with the majority located in the residential classes of "Kampung Kota" and "Gated Communities". This is due to the similarity in the physical appearance between the class of residential village and the impervious surface class where they both statistically have values with a range that is not significantly different. The same situation also occurs in the "Gated Communities" class.

4 CONCLUSION

The procedure for mapping residential types based on GEOBIA is to prepare high-resolution images such as WorldView-2, then perform segmentation with the aim of extracting the required variables based on the desired parameters (spectral, shape, texture), followed by sample-based classification, for example is the SVM algorithm, to classify types of residential efficiently and optimally. The results are tested for accuracy assessment. Based on the results obtained, it can be concluded that classification of residential types using GEOBIA shows good results (OA: 80%) accounted only by its housing types. This findings could contribute to the development of socioeconomic data extraction obtained from geospatial big data, mainly in agglomeration in Indonesia. Further development of this research should be put into account, such as utilization of Estimation for Scale Parameter II (ESP2) (Drăgu ̦t *et al.*, 2014)and variable importance.

ACKNOWLEDGEMENTS

This research was funded and mentored by the Remote Sensing Research Center, the National Research and Innovation Agency (BRIN). The authors also appreciate the reviewers of this paper for constructive comments.

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