The use of obia for extraction of land cover and land use in the city of palu

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Abstract. The City of Palu, a seaside urban area with active physical development, continues to face land use complexity. Since the availability of detailed data is the key to dealing with the impact of land cover change, OBIA offers an alternative to object-based image processing. Extracting land cover/land use information on the coast of Palu is a new challenge. This study used SPOT-6 recorded on September 22, 2018, that had been processed through mosaicking and cloud masking to produce a cloud-free multispectral image. Spectral channels from SPOT-6 served as an input to two research stages, namely, data segmentation and classification. The former used the Multiresolution Segmentation algorithm, while the latter applied a series of multilevel thresholds arranged into a classification-based decision tree. The extraction product, i.e., land cover/land use data, had an overall accuracy of >70%. However, there is an assumption that by performing the maximum likelihood classification technique before OBIA, the accuracy can increase. On a detailed scale, certain classes had high accuracy, including water body and vegetation. These results indicate that the combination of maximum likelihood classification and OBIA provides an alternative for identifying and extracting land cover information for coastal area mapping.

1. Introduction
Land, as a dynamic concept, is not only an ecosystem but also part of the ecosystem itself. The land is a manifestation of material resources, which are part of the ecosystem and generate the most benefits to humans [1]. Land management is always fascinating to study because diverse interests in land that, eventually, raise conflicts in its utilization. Growing population and intensive development deteriorate and create pressure on the environment around Palu Bay (e.g., pollution, overfishing, and physical degradation of coral reef habitats and mangroves). As captured in satellite images, land cover data represent extensive regional development in the City of Palu that raises the complexity in land utilization. Activities like reclamation also change the local ecosystems and lead to environmental changes, such as biophysical damages to coral reef ecosystems, seagrass beds, mangroves/coastal vegetation, and coastal zones and a decrease in the capacity of natural resources supply in coastal and marine areas [2].

In management, the availability of supporting data is an essential consideration. The integration of remote sensing data and Geographic Information Systems (GIS) for planning and management in Indonesia has developed rapidly. Remote sensing images have varying spatial, spectral, spectral, and temporal properties and, consequently, play a unique role in the acquisition of environmental data, including natural disaster events that are crucial in planning and management [3].

The Object-Based Image Analysis (OBIA) technology has progressed fast and become a new paradigm in image processing [4]. OBIA is a combination of visual and pixel-based interpretations whose overlay is arranged into homogeneous areas that are accurate and visually appealing with objective, automatic, and repeatable methods [5]. Digital classification using the OBIA of SPOT-6 can
improve the accuracy of object classification and provide details on land cover types [6]. Moreover, identifying settlement in urban areas with a high-resolution image is believed to produce data with high accuracy [7] [8] [9].

High-resolution imagery is expected to generate extensive information on land cover classes. Among various developments in the analysis, OBIA has become one way to extract land cover information. Nevertheless, some obstacles remain to exist, such as unclear spatial and spectral classes [8]. When determining feature class, classifiers need to pay attention to the characteristics of the observed object and the right combination of parameters to produce proper segmentation [9]. Uncertainty in supervised object-based classification mainly stems from diversity in technique and method and parameter variability (spatial scales, segmentation parameters, and data sources). [10] emphasizes the importance of exploring classification methods based on objects in urban areas.

Assessing the accuracy of object-based classification needs to first focus on object labeling. The use of the OBIA method has been carried out by several researchers before, including: [6] developing a map of Nagan Raya Aceh land cover with an overall accuracy of 83% which is better than using conventional visual and spectral classification. Furthermore, [8] the extraction of land cover in urban areas using OBIA, can analyze it well, as well as object-based classification effectively address the spatial and spectral heterogeneity in the CARTOSAT1 image. Object Base Image Analysis approach as early identification of objects in urban settlements using WorldView-2 images were also obtained an accuracy of 82% [7].

Based on previous studies, OBIA can be applied to high-resolution satellite imagery with general land covers such as forests, wetlands, and agricultural areas. This paper is part of the development of data extraction for land cover in coastal areas that have a variety of objects and the effort to improve data accuracy. It produces information on data extraction capabilities and the accuracy of extracted land cover data in the coastal area of Palu City.

2. Methods

Palu City is astronomically located between 0°36’-0°56’ S and 119°45’-121°1’ E and covers an area of 39,506 ha with plain morphology (valley). Overall, Palu Bay has an elongated shape, 9km width, a coastline stretching across nearly 100 km, and a total area of 20,700 ha. Its physical characteristics are relatively stable and protected, allowing human intervention to grow. This study took place in the coastal area of Palu City and its surroundings, covering an area of ±16,927.4 ha. Administratively, the research area consists of six districts (Figure 1).

Figure 1. Research area
2.1. Tools and Materials
The research used a set of computers equipped with image processing software and geographic information systems. The other research tools were GPS, cameras, and stationery. Meanwhile, the research materials included satellite images, maps, and other secondary data.

The main data were the SPOT-6 images recorded in September in 2018. Other supporting data were the topographic details derived from 2013 Indonesian Map Sheet Palu. The SPOT-6 images are captured with the NAOMI (New AstroSat Optical Modular Instrument) sensor, which was launched in 2012. The multispectral channel of this sensor has a spatial resolution of 6 m, while the panchromatic channel has a spatial resolution of 1.5 m. This satellite has several advantages. For instance, when compared with the previous generation, SPOT-6 has a higher spatial resolution and it has a better maneuverability (hence, a faster object-recording control system), broader area of coverage, and wider range of multispectral and panchromatic channels. Table 1 below describes the specifications of the SPOT-6 image.

| Table 1. SPOT-6 Image Specifications |
|--------------------------------------|
| Satellite | Spatial Resolution | Spectral Resolution | Temporal | Launching Date | Image |
| SPOT-6 | 1.5 m (Pan) | Pan: 0.45-0.74 | 26 days | CNES |
| | 6 m (VNIR) | H: 0.53-0.59 | M: 0.62-0.69 | B: 0.45-0.52 | IMD: 0.76-0.89 |
| | | | | September 9, 2012 | Land Use Mapping |

Source: Astrium Services, 2013

2.2. Methods
This study employed a combination of pixel- and object-based classifications. This technique was selected with an assumption that object-based classification tends to have low accuracy when applied over large areas with heterogeneous land cover. The combination was intended to achieve higher accuracy, particularly in high-resolution images. In this study, the pixel-based supervised classification used maximum likelihood, while the object-based classification was OBIA with multiresolution segmentation and nearest-neighbor techniques. In general, the research flow diagram is as depicted in Figure 2.
The stage of the research were:

1. **Inputting satellite image**
   At this stage, the multispectral SPOT-6 image with a resolution of 6 m was input to the software. Then, a composit of true and false colors was compiled.

2. **Determining the land cover class**
   The reference for the land cover class was SNI 7645-1:2014 (Indonesian National Standard) with modifications [12]. Several classes in the SNI were adjusted to the existing condition in the research area. The classes in question are presented in Table 2.

#### Table 2. Land Cover Class by Level of Classification

| Level 1                  | Level 2                      | Level 3                      |
|--------------------------|------------------------------|------------------------------|
| Natural/semi-natural non-vegetated area | Natural/semi-natural water body | Coastal waters               |
|                          |                              | Rivers                       |
|                          | Managed non-vegetated area   | Other water bodies           |
|                          | Managed bare soil/hardened surface | Beach sand                   |
|                          |                              | Other bare ground            |
|                          |                              | Asphalt                      |
|                          |                              | Other artificial surfaces    |

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**Figure 2. Research Stage Diagram**
3. Identifying samples (ROI)
The sample or ROI (region of interest) referred to the predetermined classes, and then it was applied to the region or area in each class.

4. Executing a supervised classification
The execution was the final stage in supervised classification. It used the maximum likelihood technique based on the assumption that it is the most accurate in the field of land cover.

5. Inputting the classification results to the OBIA
The image produced from the supervised classification was input to image processing software by the OBIA method.

6. Segmentation
The segmentation was carried out by multiresolution segmentation.

\[ S_f = W_{\text{color}} \times H_{\text{color}} + (1-W_{\text{color}}) \times h_{\text{shape}} \]  

(1)

\( S_f \): segmentation functions
\( W_{\text{color}} \): the weight of color parameters
\( H_{\text{color}} \): color parameter
\( W_{\text{color}} \): the weight of shape parameters
\( h_{\text{shape}} \): shape parameter

The scale parameter needs to be determined carefully because it greatly affects the margins of objects. The higher the scale parameter in the segmentation, the more general the object selection will be. On the contrary, the lower the scale parameter, the more detailed the object sorting will be. The water body is a more homogeneous object than the land because the former has less heterogeneous land cover than the latter.

7. Identifying samples (ROI)
Similar to the identification of ROI in the supervised classification above, the OBIA classification used the same land cover class, which referred to SNI 7645-1:2014 and the existing condition in the research area.

8. Executing OBIA classification
This stage used the nearest neighbor technique, which assigns values based on similarity with the neighboring pixel values on each object. In this image processing, the extracted land cover class was processed into a tentative map.

9. Accuracy Test
This test aimed to re-check the tentative land cover map generated in the previous step. It evaluated the classification result and provided a reference for the re-classification process until the results of the image extraction had an acceptable accuracy (according to the spatial resolution of the image used in the study). In this test, the classification results were compared with the existing condition in the field based on the predetermined samples for each class of object.
3. Results and Discussion

3.1. Land cover/Land use

Land cover and land use are objects on the surface of the earth that can be directly recorded by satellite sensors or remote sensing. In general, these objects are grouped into three classes, namely water body, soil, and vegetation. Growing development or land utilization in, particularly, urban areas potentially affects the heterogeneity of land cover/land use. Based on the SPOT-6 image processing, there were six classes of land cover/land use in September 2018. Among these classes, coastal waters occupied the largest part of the research site because Palu Bay occupied half of the image—while the rest was mainland consisting mostly of coastal areas.

The initial stage in digital image processing and analysis employed a supervised classification. The results were six classes of heterogeneous land cover/land use. Each class represents nominal data with an equivalent value. In this case, supervised classification was needed to overcome the classification arrangement. According to [7], the challenge in object classification using a specific set of rules is the process of making the rules themselves. It also happened during the object classification in this study. Due to the extensive area, several classes of land cover had mixed pixel values.

![Figure 3. The Supervised Classification Results](image)

Figure 3 shows several classes of land cover/land use. The hardened surface is especially depicted with a reasonably good pattern. The visual impression of buildings, bare areas, and vegetation approaches the real object. Hardened surfaces, marked in red, are comparable to the appearance of the existing object pattern. However, in the land-water interface areas, beach sand appears to lie in coastal waters. This result is attributable to the accumulation of sediment that makes the pixel values of water were read or detected together with that of soil or rock (Figure 4).
Afterward, the OBIA was applied to increase the accuracy of the classification results. This stage was started with the supervised classification data and proceeded with constructing and determining the segments based on margins at each pixel of the used data. Segmentation functions to group several classes into one class and vice versa, this procedure concerned on determining the scale parameters, it was carried out several times as an attempt to achieve accurate results [9]. Based on the outcome of segmentation (Figure 5), previously random pixels appeared to form a more regular pattern. It is the effect of the majority of the surrounding pixel groups. As a conclusion, segmentation gives a more subtle effect when applied to the supervised classification results.
The image processing and analysis using object-based classification (OBIA) methods also used the same six classes as the previous classification. Figure 5 shows the results of image processing and analysis by OBIA. In this figure, some classes of objects were given certain symbols or colors. The water body was marked with blue, bare areas with white, hardened surfaces with red, buildings with yellow, natural vegetation with green, and cultivated vegetation with light green. As for the unclassified objects, they were colored gray.

![Figure 6. OBIA Classification Results](image)

When viewed in closer detail, waterbody, natural vegetation, and cultivated vegetation have the same appearances as the existing objects. Meanwhile, the other objects tend to be less representative of the corresponding features in the field. Hardened surfaces seem to be next to or joined with buildings. Hence, the classification results were sometimes random because both objects were assumed to be composed of the same materials (Figure 7). Also, some unclassified objects and water bodies were found within the building area. These issues inevitably disturb the accuracy of the classification results.

Referring to the development, Palu City, as a coastal region, has experienced an extensive transformation. However, the variation in land use does not increase significantly (Figure 8). This finding is confirmed by the resolution of the SPOT-6 image that allows the generation of detailed land use classes although the details have not entirely met the standard yet. In other words, the visible polygons are the product of the quantitative addition of the same objects, not with the other objects. Some of these random classes are most likely caused by the small number of training areas and samples that are difficult to access.
3.2. Accuracy Test
The results of the image extraction, i.e., land cover/land use map, were tested for accuracy. This test is necessary to ensure that the generated information represents the existing condition in the research area. It used 20 sample points that were spread in each variation of land cover/land use on the coast of Palu Bay and considered to be representative. Table 3 shows the accuracy test of the land cover/land use map.
Table 3. Accuracy test results

| Extraction Results | Land cover/land use | Ground check results | Sample size | Correct samples |
|--------------------|--------------------|----------------------|-------------|-----------------|
|                    |                    | A        | B    | C    | D    | E    | F    |             |             |
| A                  | 4                  | 4       |      |      |      |      |      |             |             |
| B                  | 3                  | 1       |      |      |      |      |      |             |             |
| C                  | 2                  | 4       |      |      |      |      |      |             |             |
| D                  |                    | 6       |      |      |      |      |      |             |             |
| E                  | 1                  | 2       | 2    |      |      |      |      |             |             |
| F                  |                    | 1       | 1    |      |      |      |      |             |             |
| Total              | 4                  | 3       | 4    | 6    | 2    | 1    | 1    | 20           | 14            |

Source: Data Analysis, 2019

Notes:
A = Coastal waters
B = Bare areas
C = Hardness surface
E = Natural vegetation
F = Cultivated vegetation

Accuracy = \( \frac{\text{total correct samples}}{\text{total sample size}} \times 100\% \)  \hspace{1cm} (2)

\[ = \frac{14}{20} \times 100\% \]
\[ = 70\% \]
In general, the extraction of land cover information and land use using OBIA has proven to be effective and has good accuracy. Especially on data sources from high-resolution images such as Worldview-2, Pleiades also SPOT6 Panchromatic channels. But once SPOT6 multispectral with a resolution of 6 meters, it requires deeper image processing techniques. Geometric and radiometric corrected images require polishing. Because at the time of segmentation, there are objects that have similarities, but this does not occur in the findings [6,13]. Likewise for the number of training areas that are not proportional to the area of study. This limitation affects the accuracy obtained. If the accuracy of land cover or urban objects from other researchers is above 80%, then the accuracy in the coastal areas of Palu is 70%. This is because validation time is limited, the coverage area is quite difficult on the outside of the area. Besides the character of the Palu coastal city is different from other regions in Indonesia, especially after the natural disaster in September 2018.

4. Conclusions
The OBIA method can produce data and information on land cover/land use. Based on the condition of the existing objects, there are six land cover/land use classes in the City of Palu, namely natural/semi-natural water bodies, natural/semi-natural body areas, managed bare areas/hardened surfaces, buildings, permanent natural vegetation, and cultivated vegetation. These objects occupy areas of 11,183.08 ha, 378.28 ha, 1,062.10 ha, 1,781.34 ha, 4,118.78 ha, and 2,787.08 ha, respectively. The land cover/land
use data extracted from high-resolution satellite image by OBIA have an accuracy of 70%, which is classified as medium. This level of accuracy represents the weakness of standard image operations, the effects of land use development, the mixing of objects with the same constituent materials, low number of training areas, and a relatively large research area.

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