COMPARISON OF PIXEL AND OBJECT-BASED APPROACH FOR BUILDING ROOF MAPPING USING MULTI-SPECTRAL AND PAN-SHARPENED WORLDVIEW-2 IMAGES

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KEY WORDS: building rooftop, object-based, pixel-based, mapping, spatial resolution

ABSTRACT: The detailed scale mapping on building roofs using remote sensing imagery for information extraction. The geographic Based-Image Analysis (GEOBIA) classification method is known as an alternative pixel-based classification method such as Random Forest. This study aims to compare the effectiveness of pixel-based and object-based classification methods in obtaining information on building rooftop classes mapped using images with different spatial resolutions. The research results indicate that: 1) GEOBIA classification yields higher overall accuracy for multispectral and pan-sharpened images than the Random Forest method. 2) WorldView-2 Multispectral imagery produces lower accuracy compared to WorldView-2 Pan-sharpened imagery.

1. INTRODUCTION

The importance of urban studies for more efficient urban planning policies is related to the current massive urban sprawl. This affects changes in conditions and variations of objects on the earth's surface due to the interaction of socioeconomic activities and spatial changes in the environment. One of the basic data of urban planning is urban land cover maps that can be obtained from remote sensing data because it is up to date, more effective and efficient, and able to reduce the cost of expensive terrestris surveys. Technological developments have influenced remote sensing technology, for example, the development of satellite sensors that produce images with high spatial resolution. High spatial resolution imagery is capable of supporting detailed scale mapping. One of the important objects of urban detail to identify is the roof of the building because it is an object that is easily at risk of disaster; for the basis of tax calculation. Worldview-2 images were chosen because they have high spatial resolution in multispectral images of 1.84 meters and panchromatic images of 0.46 meters and have 8 spectral channels that can distinguish objects with varying colors and hues. Increased spatial resolution of the image can be obtained from the pan-sharpening method.

The image obtained from remote sensing satellites is a collection of pixels with values that vary based on the value of the reflection of objects on the Earth's surface. Information extraction using pixel-based classification is based on spectral features only. In high spatial resolution images, pixel-based classification results will experience salt and pepper due to misclassification. This is because the unit of classification is in the form of pixels. Object-based classification methods are more advantageous for the classification of high spatial-resolution images (Blaschke, 2010). The unit of classification in the GEOBIA method is a segment of objects or sets of pixels that have similar values. Compared to pixel-based classification which only utilizes spectral response, object-based classification also adds features such as shape, texture, and relationships with other objects. Therefore, we hypothesize that object-based classification results will have higher accuracy than pixel-based classification

Extraction of building roof information has been carried out by several previous researchers such as those carried out by Setiani et al (2016) who compared images of different spatial resolutions, namely Landsat 7 ETM+ and Alos Palsar with GEOBIA segmentation and nearest neighbor classification methods. The results are segmentation and classification on Landsat 7 ETM imagery which is better for identifying industrial building roof objects than ALOS PALSAR imagery. This suggests that imagery that has a higher spatial resolution results in higher accuracy. Another study is research from Waspadi &; Danoedoro (2020) on the comparison of pixel-based and object-based classifications for cover extraction and land use using Landsat-8 OLI in Kulonprogo. The pixel-based classification algorithm used is maximum likelihood and the object-based classification algorithm used is K-Nearest Neighbors (KNN). The classification results show that GEOBIA provides greater advantages, namely higher accuracy results and a reduction in the presence of salt and pepper due to classification errors that occur in many pixel-based classifications.

Some previous studies have only examined the effect of image differences for rooftop extraction and others have only examined the effectiveness of pixel-based and object-based classification approaches for rooftop information extraction. The difference is that this study will use the same image but with different spatial resolutions obtained through the pan-sharpening method. The purpose of this study is to determine the effectiveness of pixel-based and object-based classification to obtain building roof information and determine the effect of image spatial resolution on the accuracy of classification results.

2. METHODOLOGY

2.1 Study Area

The location of this research is in part of South Magelang District, Magelang City, Central Java Province. The selection of this location is based on the presence of variations in the land use of buildings that make it possible to analyze the influence of features on the classification results. The study area is not too broad, because the focus of research lies on technical problems regarding the ability of methods and images for extraction of building roof objects. The boundaries of the study area are at coordinates 411900 - 412500 mT, and 9170500 - 9171100 mU (UTM coordinate system zone 49M). The image map of the study location used by this study is shown in Figure 1.

Figure 1. Study Area

2.2 Data Collection

The image data used in this study is WorldView-2 recording on June 8, 2022 with correction level "ORStandard2A" covering the study area. This image has eight multispectral channels with a pixel size of 1.84 m and one panchromatic channel with a pixel size of 0.46 m. In addition, an aerial photo image of the Magelang City area was recorded in September, 2021 with a pixel size of 0.065 m as the basis for making reference maps through visual interpretation. WorldView-2 imagery is then processed to convert DN values into TOA Radiance through radiometric correction and converted into at surface reflectance values through atmospheric correction using the FLAASH method. This study used the Gram-Schmidt algorithm to increase the spatial resolution of multispectral images but maintain the number of channels so that new images with a spatial resolution of 0.5 m were obtained. The "Standard 2A" level image has been

corrected for earth coordinates but can be improved in accuracy by orthorectification or geometric correction again (Brahmantara, 2018). This study uses the image-to-image registration method with aerial photography images as reference images to equalize the coordinates of objects. This is because the aerial photo has been orthorectified and corrected with coordinates on the ground.

2.3 Methods

The scheme of this research is described on Figure 2.

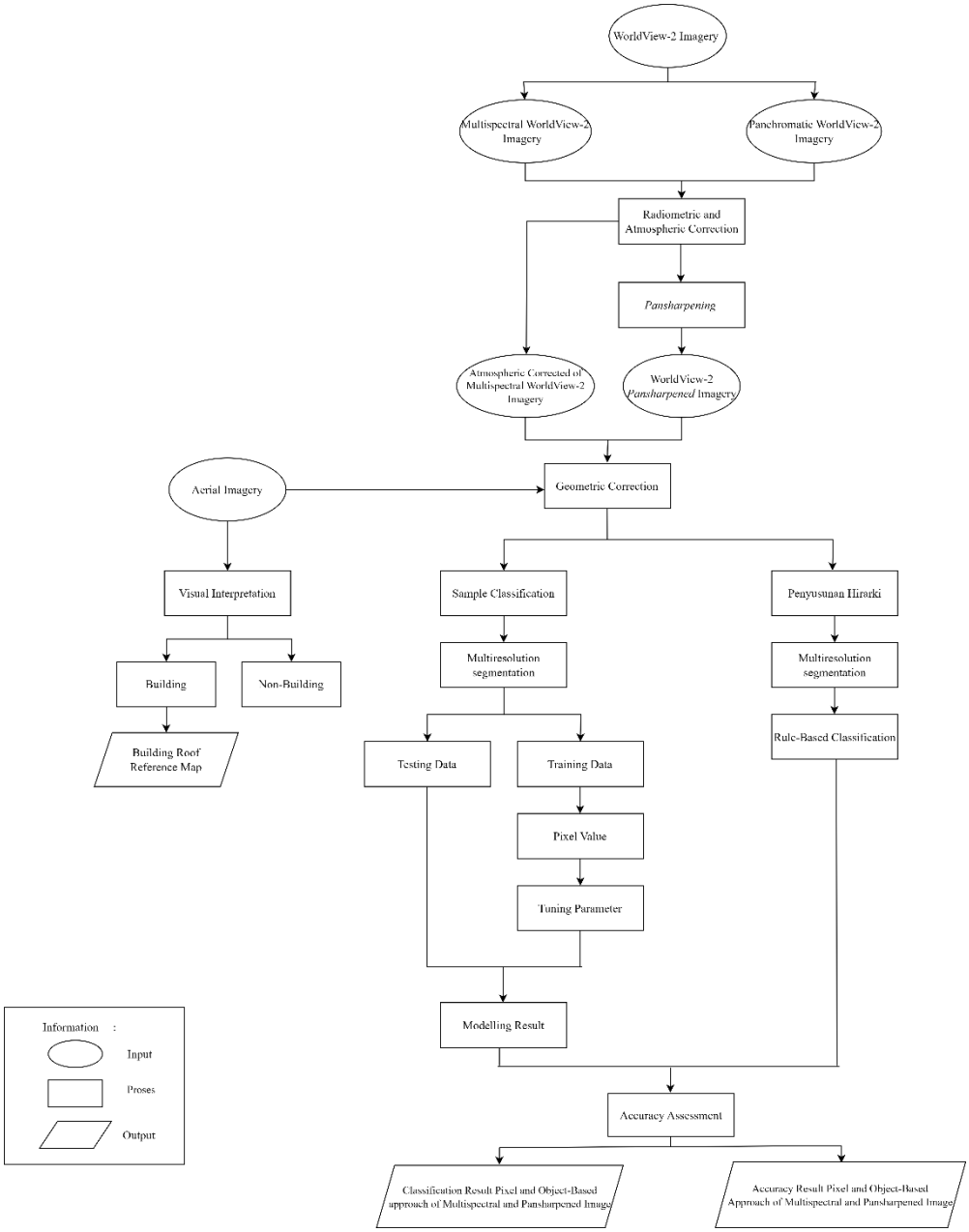


Figure 2. Research flow chart

2.4 Random Forest Classification

Random forest development of decision tree methods. This method is one of the combined tree methods where as many as k trees are grown so that a forest is formed, then analysis is carried out on the collection of trees by combining the prediction results of k trees formed 17 (Ramadhan, 2019). Random forests are able to deal with overfitting problems and can pinpoint variables that are important for the decision-making process.

2.5 GEOBIA Classification

The classification hierarchy scheme is used in the process of segmentation and classification to separate objects based on their characteristics. The use of hierarchical schemes so that the mapping process is more logical with clearer relationships between objects and minimizes segmentation and classification errors. The hierarchical scheme of such classifications is shown in Figure 3.

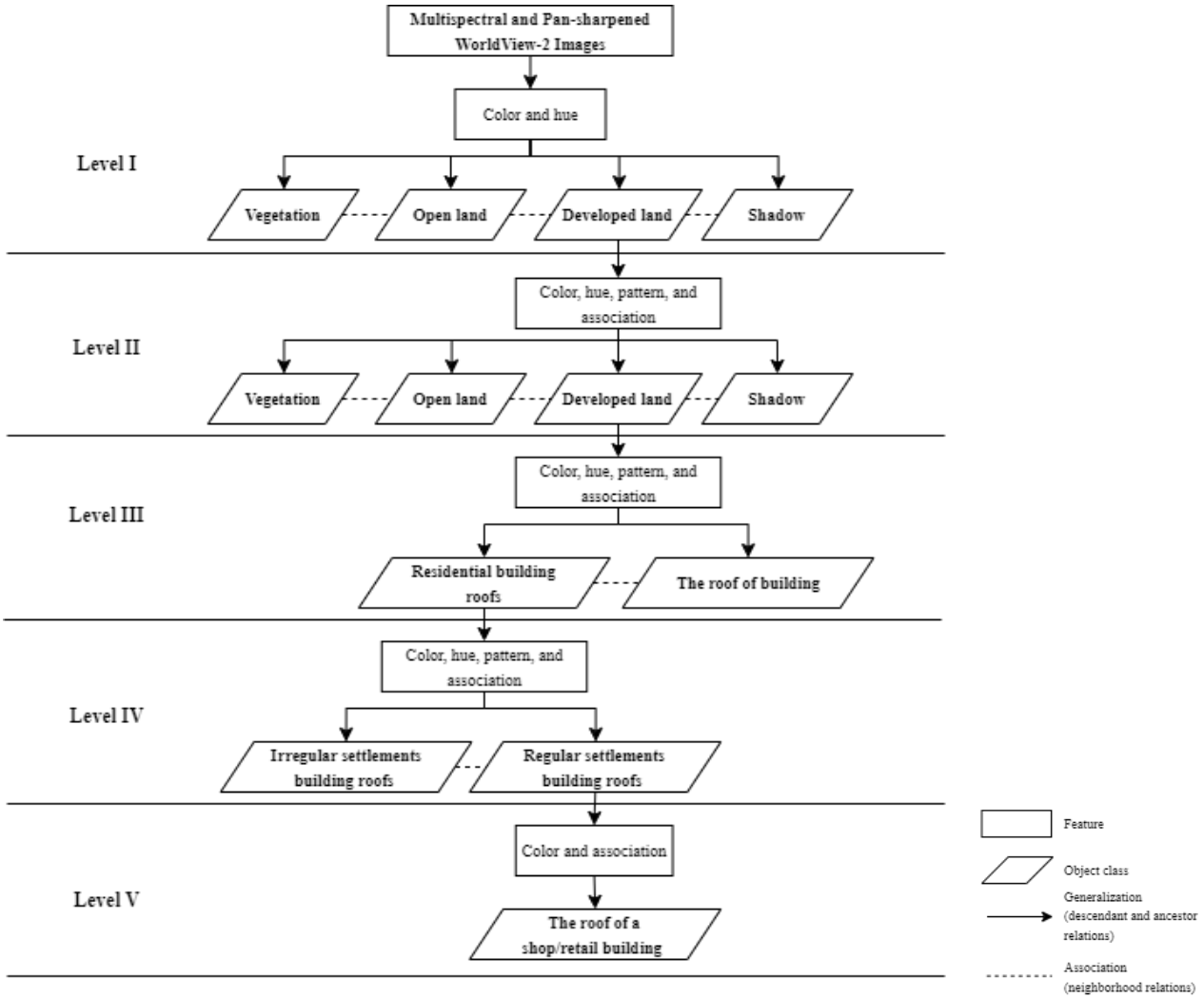


Figure 3. Hierarchical scheme classification of information extraction of roofs of buildings

The GEOBIA technique consists of two stages, namely segmentation and classification. Segmentation is used to form primitive objects consisting of collections of pixels that have similar characteristics. The segmentation algorithm used is multiresolution segmentation which is influenced by parameters of scale, shape, color, smoothness, and compactness. This segmentation method approach is bottom up which groups areas by homogeneity of criteria. The selection of the multiresolution segmentation method is because users can determine parameter values and judge based on visual observations. The weight of the segmentation parameter is obtained through trial and error until a visual appearance of the object that is close to the shape of the object in reference is obtained with the weighting of each level presented in Table 1.

Table 1. Weight of segmentation parameters

Classification level	Multispectral image *Rule-set*				Pan-sharpened image *Rule-set*			
	Band weight	Parameter scale	Shape : color	Compactness : fineness	Band weight	Parameter scale	Shape : color	Compactness : fineness
Level 1 Vegetation, open land, built-up land, and shadows	Blue, green, yellow, red edge, NIR2 = 1 red, NIR1 = 2	0,5	0,001 : 0,999	0,7 : 0,3	Blue, green, yellow, red edge, NIR2 = 1 red, NIR1 = 2	1	0,001 : 0,999	0,5 : 0,5
Level 2 Main roads, buildings, hardened surfaces, and unclassified	Blue, green, yellow, red edge = 1 red, NIR1, NIR2 = 2	0,5	0,001 : 0,999	0,7 : 0,3	Blue, green, yellow, red edge = 1 red, NIR1, NIR2 = 2	1	0,001 : 0,999	0,5 : 0,5
Level 3 Rooftops of residential buildings and buildings	Blue, green, yellow, red edge = 1 red, NIR1, NIR2 = 2	2	0,001 : 0,999	0,7 : 0,3	Blue, green, yellow, red edge = 1 red, NIR1, NIR2 = 2	7	0,001 : 0,999	0,5 : 0,5
Level 4 The roofs of regular residential buildings and the roofs of irregular settlement buildings	Blue, green, yellow, red edge = 1 red, NIR 1, NIR2 = 2	0,5	0,001 : 0,999	0,7 : 0,3	Blue, green, yellow, red edge = 1 red, NIR 1, NIR2 = 2	1	0,001 : 0,999	0,5 : 0,5
Level 5 The roof of the shop/shop building	Blue, green, yellow, red edge = 1 red, NIR1, NIR2 = 2	0,5	0,001 : 0,999	0,7 : 0,3	Blue, green, yellow, red edge = 1 red, NIR1, NIR2 = 2	1	0,001 : 0,999	0,5 : 0,5

The classification in the GEOBIA method consists of sample-based and rule-based. The method chosen is rule-based because it can determine the characteristics of objects that are not easily identified using samples. Object-based classification pays attention not only to spectral but also to geometric and contextual features. The key interpretation of objects obtained from field activities is then translated into the form of rule-sets classification.

2.6 Accuracy Assessment

Assessment of the accuracy of classification results is carried out using the confusion matrix or error matrix method. This method is particularly effective for representing each of the categories described by commission error and emission error in classification (Congalton, 1991). The confusion matrix assesses three aspects, namely user's accuracy, producer's accuracy, and overall accuracy that can be mathematically described in equations 1, 2, and 3. The user's accuracy is derived from dividing the total number of correctly classified pixels by the total number of pixels classified in that category. The producer's accuracy is obtained by dividing the number of correctly classified category pixels by the pixel count of each training set. Total accuracy assesses the number of all correctly classified pixels against the total number of reference pixels. Example of an error matrix is presented in Figure 4.

i = Rows (Classification)	j = Columns (Reference) 1	2	k	Row Total n_{i+}
1	n_{11}	n_{12}	n_{1k}	n_{1+}
2	n_{21}	n_{22}	n_{2k}	n_{2+}
k	n_{k1}	n_{k2}	n_{kk}	n_{k+}
Column Total n_{+j}	n_{+1}	n_{+2}	n_{+k}	n

Figure 4. Table error matrix representation (Congalton & Green, 2019, hal. 75)

User's Accuracy (UA) $= \frac{n_{ii}}{n_{+i}}$ (1)

Producer's Accuracy (PA) $= \frac{n_{jj}}{n_{+j}}$ (2)

Overall Accuracy $= \frac{\sum_{i=1}^{k} n_{ii}}{n}$ (3)

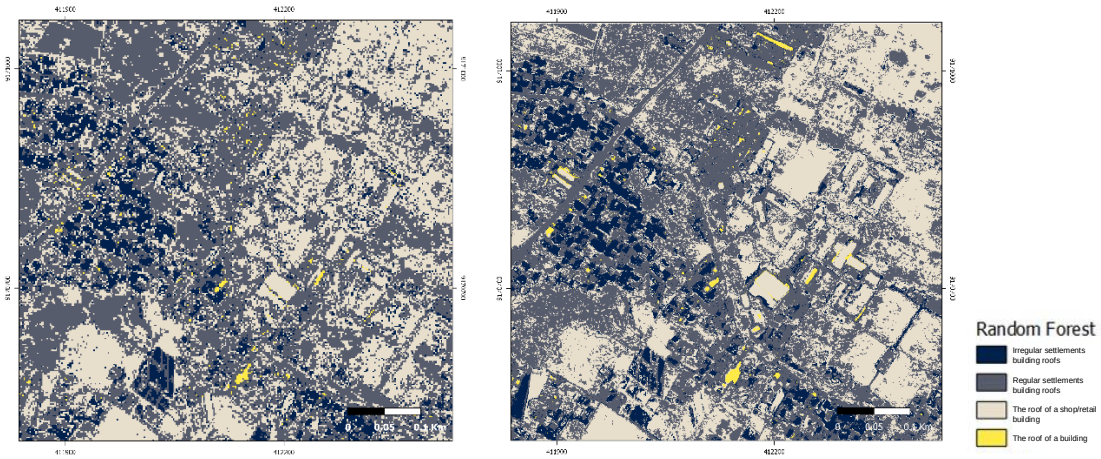
Where nii is the diagonal value of the contingency matrix of the i row and i column
n+i is the number of rows in the i row
njj the diagonal value of the contingency matrix of the i row and i column
n+j is the number of columns in the j row
n represents the grand total

3. RESULT AND DISCUSSION

3.2 Classification Results

The results of the classification per pixel have salt and pepper so that it gives a blurred appearance compared to maps from the same image as the GEOBIA classification. Although filtering methods have been carried out on a classification per pixel, it is still dominated by the salt and pepper effect as a consequence of the classification analysis units used. Classification per pixel uses units of analysis in the form of pixels and object-based classification (GEOBIA) uses units of analysis in the form of segments. A segment is a collection of pixels that have similar characteristics. So the appearance of salt and pepper effects is not too visible in the results of the OBIA classification which has the opportunity to increase accuracy. Although GEOBIA classification results tend to be more representative of reference maps, the rule-set complexity of GEOBIA classification takes longer to obtain results that resemble reference maps.

(a)



(b)

Figure 5. Results of object-based classification (a) multispectral imagery (b) pan-sharpened mind and pixel-based classification (c) multispectral image (d) pan-sharpened image

Based on Figure 3, the classification results on pan-sharpened images (b) and (d) tend to be neater and have firmer building roof boundaries than those on multispectral images (a) and (c). This difference is due to the spatial resolution of the image. The spatial resolution of the image is related to the mixed-pixel effect that affects the results of classification accuracy. The lower the spatial resolution of the image, the more pixels there will be in a variety of objects that have different pure pixels. The variety of objects in a pixel affects the reflection of its spectral resolution where more pixels are mixed as the spatial resolution decreases.

3.3 Accuracy Comparison

The accuracy test is based on a reference map as ground truth obtained from digitizing on-screen on an aerial photograph of a spatial resolution of 0.065 meters. According to Congalton (1991); Kamal, et al (2015), the use of aerial photographs as reference image making is able to present object information accurately, and the results of image interpretation from very high spatial resolution aerial photographs are accepted correctly without any form of accuracy assessment. The accuracy testing method was carried out using a confusion matrix with sample points of 196 polygons. The sample selection considers the sum of the number of objects of each class on the reference map. The greater the number of objects in a class, the greater the number of samples. The size of the accuracy test polygon is adjusted to the resolution of its image. In the original multispectral image, the polygon size test accuracy was 2 x 2 meters and in the pan-sharpened image, it was 0.5 x 0.5 meters. Accuracy assessment is adjusted to the dominance of object classes in an accuracy test polygon. The accuracy values of pixel-based and object-based classification results are shown in Table 2.

Table 2. Test the accuracy of classification results (a) multispectral images and (b) pan-sharpened images.

Class	Pixel		GEOBIA	
	UA	PA	UA	PA
Irregular settlements building roofs	88,41%	61%	91,18%	96,88%
Regular settlements building roofs	56,67%	80,95%	100%	91,04%
The roof of a building	0%	0%	93,75%	100%
The roof of a shop/retail building	0%	0%	82,35%	97,78%
Overall accuracy	56,85%		95,41%	

(a)

Class	Pixel		GEOBIA	
	UA	PA	UA	PA

Irregular settlements building roofs	85,13%	63,15%	97,06%	95,19%
Regular settlements building roofs	54,69%	77,84%	96,72%	95,16%
The roof of a building	6,25%	10,08%	82,35%	87,5%
The roof of a shop/retail building	0%	0%	87,5%	100%
Overall accuracy	57,99%		94,39%	

(b)

Comparison of accuracy tests shows that the overall accuracy of the GEOBIA method is higher than the per-pixel method in both multispectral and pan-sharpened images. This is because GEOBIA not only pays attention to spectral features but also geometric and contextual features to be the key to object interpretation. In addition, the high accuracy results in GEOBIA are influenced by the use of a hierarchical scheme which is not used in the classification per pixel. The use of spatial dimension hierarchy schemes cannot be used properly in pixel-based classification methods (Putri &; Danoedoro, 2020). On the other hand, the comparison of the accuracy of classification results in pan-sharpened images tends to be higher than in multispectral images. This shows the influence of the spatial resolution of the image on the classification results. The higher the spatial resolution, the more accurate the classification results and high accuracy. The higher accuracy value of object-based classification compared to pixel-based classification also indicates that the GEOBIA classification method is more suitable than pixel-based classification in high spatial resolution images. The accuracy value of GEOBIA classification reaches the expected accuracy of 85%. According to Anderson (1971); Aronoff (1985), a good minimum accuracy value for mapping results using remote sensing data is 85%. However, the accuracy of pixel classification does not achieve such accuracy.

CONCLUSION

Based on this research, object-based and pixel-based classification methods have clear visualization differences so that they can find out the disadvantages and advantages of each method for the study of building roof types. Object-based classification has advantages in both accuracy and processing time over pixel-based classification. Object-based methods will have a greater advantage if using imagery with high spatial resolution. The results showed the effectiveness of increasing spatial resolution on the results of classification and accuracy tests.

ACKNOWLEDGEMENT

The WorldView-2 image used in this research was obtained through Rekognisi Tugas Akhir (RTA – Final Project Recognition Grant) 2023 from Universitas Gadjah Mada, Indonesia, under Grant number 5075/UN1.P.II/Dit-Lit/PT.01.01/2023. The authors would like to thank (1) Ministry of Public Works and Public Housing of Republic of Indonesia and DPMPTSP of Magelang City who have provided access to aerial photo data of Magelang City and granted the research permit, and (2) Department of Geographic Information Science, Faculty of Geography, and Gadjah Mada University for providing facilities for this research.

REFERENCES

Anderson, J. R. (1971). Land Use Classification Schemes Used in Selected Recent Geographic Applications of Remote Sensing. Photogrammetric Engineering, 37, 379-387.

Aronoff, S. (1985). The Minimum Accuracy Value as an Index of Classification Accuracy. Photogrammetric Engineering and Remote Sensing, 51(1), 99-111.

Blaschke, T. (2010). Object Based Image Analysis for Remote Sensing. *ISPRS Journal of Photogrammetry and Remote Sensing, 65*, 2-16.

Congalton, R. C. (1991). A Review of Assessing the Accuracy of Classifications of Remotely Sensed Data. *Remote sensing environment, 37*, 35-46.

Kamal, M., Phinn, S., & Johansen, K. (2015). Object-Based Approach for Multi-scale Mangrove Composition Mapping Using Multi-resolution Image Datasets. *Remote Sensing, 7*(4).

Ramadhan, A. (2019). *Pemodelan Klasifikasi Random Forest untuk Mengidentifikasi Faktor Penting dalam Meningkatkan Mutu Pendidikan.* Bogor: Doctoral dissertation, IPB University.

Setiani, A., Prasetyo, Y., & Subiyanto, S. (2016). Optimalisasi Parameter Segmentasi Berbasis Algoritma Multiresolusi untuk Identifikasi Kawasan Industri antara Citra Satelit Landsat dan ALOS PALSAR . *Geodesi Undip, 5*, 115-121.

Waspadi, E. A., & Danoedoro, P. (2020). Comparing Per-pixel and Object-Based Classification Results Using Two Different Land-Cover / Land-Use Classification Schemes : Case Study Using Landsat-8 OLI Imagery. *Sixth International Symposium on Lapan-IPB Satellite, 11372*, 36-43.