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Identification of Banana Plants from Unmanned Aerial Vehicles (UAV) Photos Using Object Based Image Analysis (OBIA) Method (A Case Study in Sayang Village, Jatinangor District, West Java)

Agung Budi Harto[1,3], Prila Ayu Dwi Prastiwi[1,3], Farah Nafisa Ariadji[1,3], Deni Suwardhi[1,3,5,6], Fenny M. Dwivany[1,2,5,6], I Wayan Nuarsa[4,6], Ketut Wikantika[1,3,5,6]*

[1]*Center for Remote Sensing, Institut Teknologi Bandung, Bandung, Indonesia*
[2]*School of Life Sciences and Technology, Institut Teknologi Bandung, Bandung, Indonesia*
[3]*Faculty of Earth Sciences and Technology, Institut Teknologi Bandung, Bandung, Indonesia*
[4]*Faculty of Agriculture, Udayana University, Bali, Indonesia*
[5]*ForMIND Institute (Indonesian Young Researcher Forum), Bandung, Indonesia*
[6]*Bali International Research Center for Banana (BIRCB), Udayana University, Bali, Indonesia*

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ABSTRACT

Banana is one of the leading fruit commodities of Indonesia and ranks the sixth position as one of the largest banana producers in the world. There are more than 200 types of banana in Indonesia. The utilization of bananas is influenced by the local culture, where in every 10 horticultural households, 5 of them plant bananas both as garden plants or field plants. This horticultural crop is expectantly being one of the actions to improve economic prosperity especially in rural areas. In maintaining the diversity of the growing bananas in rural areas, a geospatial approach to identify the vegetation is required. Remote sensing technology is one of the solutions to observe and to develop banana plants with one of the methods namely Object Based Image Analysis (OBIA). This method consists of segmentation, classification, and validation. In classification process, the OBIA method distinguishes objects not only based on pixel values but also on the basis of the shape, area, and texture around them. This research has proven that the classification using OBIA method is better than the traditional classification such as maximum likelihood classification method to identify banana plants. OBIA method can quickly identifies the vegetation and non-vegetation, also the regular plants and banana plants.

1. Introduction

Indonesia is a tropical archipelago with 13,466 verified islands out of 17,499 islands, with a land area of 2.01 million km^2 and a water area of about 5.8 million km^2 consisting of 3.25 million km^2 of Indonesian waters and 2.55 million km^2 of Exclusive Economic Zone and an 80,791 km long coastline (Dihidros-Indonesian Navy 2012, in the Marine and Fisheries Figures 2013). Indonesia is also flanked by the Pacific Ocean and the Indian Ocean which makes Indonesia rich in biodiversity and is also known as a megadiversity country. Indonesia's biodiversity includes the diversity of living things with their variety of resources, in terrestrial, marine and aquatic ecosystems as well as their ecological complexity (LIPI 2014). Indonesian biodiversity has been utilized to support livelihoods, especially for food, health and energy, and basic industrial materials that ultimately aim to meet human necessities. Indonesia as one of the centres of origin of some crops like rice and banana has put attention to established safety duplication of rice and banana accessions collected throughout Indonesia.

Bananas Musa species are one of the most consumed fruits in the world. It is one of the oldest cultivated plants (Kumar *et al.* 2012). Bananas have a large source of potassium. Potassium benefits the muscles as it helps maintain their proper working (Kumar *et al.* 2012). This mineral is also essential for maintaining proper heart function, regulating normal blood pressure, reducing risk of stroke, and protecting against loss of muscle mass. Bananas are also rich in vitamins, especially vitamin B6 (Chandler 1995). Vitamin B6 helps the body's immune system, promotes brain and heart health. Other than vitamin B6, bananas contain vitamin A, C, and D. These

* Corresponding Author
E-mail Address: wikantika.ketut@gmail.com

vitamins aid in healthy teeth and bones, healing, help combat the formation of free radicals known to cause cancer, help the body to absorb calcium, and slow the aging of skin.

Bananas are divided into two main categories: dessert and cooking bananas. Dessert bananas constitute of 43% of world production and are usually eaten fresh when ripe, as they are sugary and easily digestible. Cooking bananas make up 57% of world production, are usually starchier when ripe, and are boiled, fried, or roasted before being eaten (Jones 2000 in Pillay *et al.* 2004). There are more than 1000 varieties of banana worldwide, has risen through natural mutation, hybridization, and selection over many thousand years (Nelson *et al.* 2006).

Banana is a herbaceous fruit plant derived from Southeast Asia region including Indonesia. These plants then spread to Africa (Madagascar), Latin America and Caribbean (Data Center and Agricultural Information System Ministry of Agriculture 2016). Based on data from Food and Agriculture Organization (FAO), in 2009 until 2013 there are twelve countries with the largest harvested area of bananas in the world, which are India, Brazil, Tanzania, Phillipines, China, Equador, Burundi, Uganda, Thailand, Angola, Vietnam, and Indonesia. The total contribution to the total harvest area of banana in the world is up to 71.42%. India as the biggest banana producer, contributes 26.38% of world's banana production. Meanwhile Indonesia ranks sixth as one of the largest banana producers in the world with contribution of 5.67% of world's total banana production.

Based on data from the Ministry of Agriculture (2016), the development of banana production in Indonesia in the last 30 years has increased by 4.16% per year. Banana productivity in Java is generally higher than in outside Java. In reference to data on average of banana production during 2011-2015, there are eleven provinces which contribute up to 88.07% of banana production in Indonesia. The provinces are East Java, Lampung, Central Java, North Sumatra, Banten, Bali, South Sulawesi, East Nusa Tenggara, and West Sumatra.

Banana is one of the leading fruit commodities of Indonesia. In 2016, banana production occupied the first position with 7 million tons (Statistics Indonesia 2016). Moreover, Indonesia is also being the center of the diversity of banana. There are more than 200 types of bananas in Indonesia, which provides opportunities for the utilization and business of banana commodities for the consumer. Almost all of Indonesia regions are the largest banana production due to land suitability and climate, the availability of seeds, and the interest of farmers to cultivate bananas. The development and distribution of bananas are strongly influenced by climate, planting media, and altitude (Ministry of Agriculture 2016).

In Indonesia, the utilization of bananas is influenced by the local culture. According to Agriculture Census in 2013, in every 10 horticultural households, 5 of them plant bananas both as garden plants or field plants (Sholihah 2017). By 2015, the number of Indonesians who has lived in rural areas is 46.58% out of a total of 255 million people (Data Center and Agricultural Information System Ministry of Agriculture 2014). Thus far rural area has been relied on agricultural sector, not only in rice farming but also in fruit fields. There is an important role for government policy to reduce rural poverty through reducing risk, encouraging sustainable agriculture, education and skills, and implementing measures to tighten rural labour markets and improve access to land (Mitchell 2011).

One of the actions to improve rural economic prosperity is by developing horticultural crops that are focused on commodities which have economic value and have wide distribution also high market demand (Sholihah 2017). This research studies the banana commodity in Sayang Village, Jatinangor District, West Java. In maintaining the diversity of the growing bananas in rural areas, a geospatial approach to identify the vegetation is required. Remote sensing technology is one of the solutions to observe and to develop banana plants with one of the methods namely Object Based Image Analysis (OBIA).

Therefore, this study aims to discover how far the OBIA method can separate vegetation and non-vegetation, more particularly among regular plants and banana plants, in Sayang Village using aerial photographs acquired from UAV photos.

2. Materials and Methods

2.1. Study Area

The study area is located in Sayang Village, Jatinangor District, West Java Province, Indonesia. District Jatinangor located in coordinates 6° 53′ 43.3″ - 6° 57′ 41.0″ S and 107° 45′ 8.5″ -107° 48′ 11.0″ E. The selected study area is an area planted with banana plants. According to Statistics Indonesia (2014), Sayang Village has a total area of 231 hectares. The area is divided into several types of land use, such as agricultural land and residential land. For agricultural land, Sayang Village has a regional composition of 72% of the total area and divided into two types of rice fields and non-farm land. The composition of each area is 19% of the total area of rice fields and 53% for non-agricultural land. The numbers are equivalent to 43.89 hectares in the form of rice fields and 122.43 hectares of non rice fields. The residential area of Desa Sayang covers a region with a composition of 31% or equivalent to an area of 71.61 hectares. The location of the study area can be seen in Figure 1.

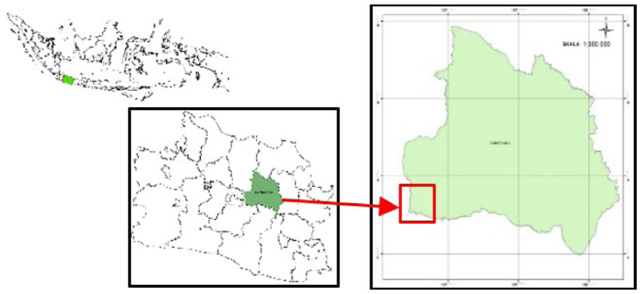

Figure 1. Study area of Sayang Village, Sumedang, West Java

2.2. Data and Methodology

The methodology used in this research consists of collecting data from related parties, followed by data processing, and data analysis using e-Cognition software. The first step was the data acquirement. There are three data used in this research:

1. Aerial photograph (true ortho) of Sayang Village with a 0.05 meter spatial resolution
2. DSM (Digital Surface Model) of Sayang Village with a 0.02 meter spatial resolution
3. nDSM (Surface Volume) of Sayang Village with a 2.5 meter spatial resolution

The next stage was data processing. This step was divided into three stages, namely segmentation, classification, and accuracy assessment. The first process in this research is segmentation. Segmentation is done by distinguishing objects in the image into separate areas in the form of polygons according to their respective characteristics. The second process is classification. In OBIA method, classification is the most important stage to classifying objects into separated class. The classification process in this research is divided into two levels. The first level of classification separates objects based on land type, such as vegetation land and non-vegetation land class. The second level of classification separates the banana plants and the regular plants that has been classified in the vegetation class. After banana plants and regular plant has been classified, the final process is accuracy assessment. The more details about procedure of the research can be seen in Figure 2.

2.3. Data Processing

Data processing in this research was using OBIA method. The steps in the OBIA method were as follows: (1) Segmentation, (2) Determination of Classification Parameters, (3) Classification, and (4) Accuracy Assessment (Marpu *et al.* 2006).

2.3.1. Image Segmentation

Image segmentation was the first step and a necessary prerequisite for OBIA method because it determines the size and shape of image objects. The selection of appropriate image segmentation parameters ultimately depends on the selected application, the underlying input imagery, and the environment under analysis (Li *et al.* 2015). In this research, segmentation process

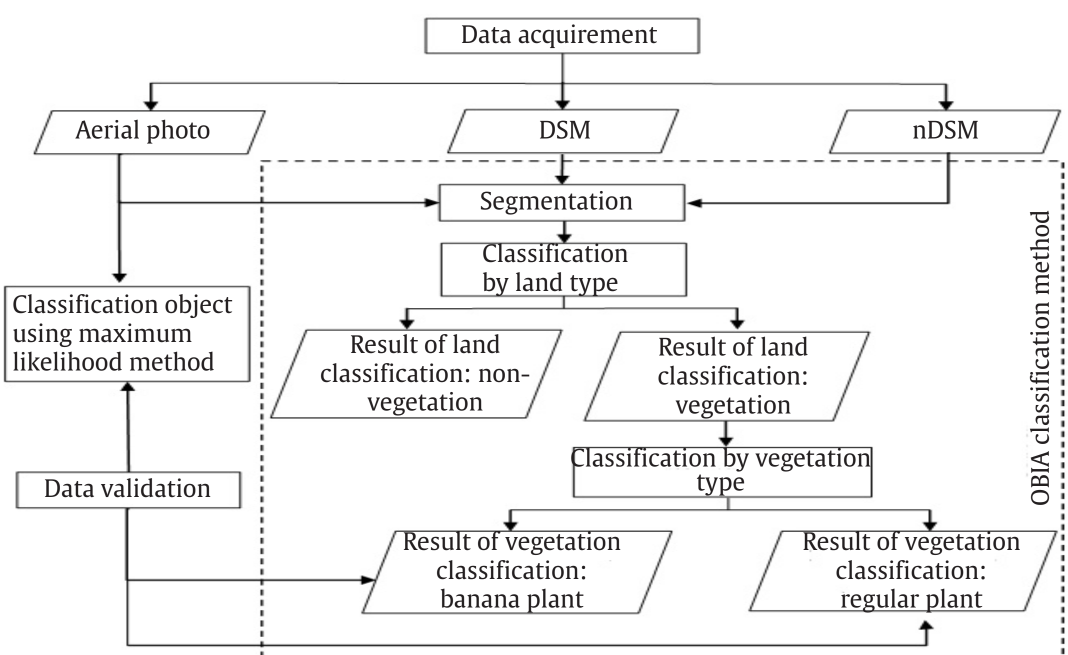

Figure 2. Research procedures

divided into pixel based segmentation and object-based segmentation.

Pixel-based segmentation was done using this multiresolution segmentation algorithm. Multiresolution segmentation is a heuristic optimization procedure that locally minimizes the average heterogeneity of the objects in the image (Parsa 2013). The parameters used in multiresolution segmentation procedures include scale, shape and compactness. The most important parameter is the scale parameter where this parameter determines how much the number of pixels that build one object (Parsa 2013). The scale parameter is a key control factor for the segmentation and classification of earth observation imagery because it controls the internal heterogeneity of image objects. Consequently, scale parameter controls the average size of the objects, directly affecting classification accuracy. The selection of the spectral parameter value is critical and has become a research focus in OBIA.

Object-based segmentation basically continuing the result of pixel-based segmentation. At this stage all objects that were segmented at pixel-based levels would be re-processed to generate new objects. Segmentation was included into the process of generalizing the object, a comparison of an object with its surroundings to know whether the object identified is the same object or not. The method used in this segmentation was the spectral difference segmentation (SDS) method. According to Wasil (2013), the spectral difference segmentation method will unify the image object that has been formed based on the similarity of the spectral value. Image objects with certain limit values will be grouped into one same polygon. The purpose of this method was to form a unity of the whole object based on the spectral value.

2.3.2. Classification

The most important step of this OBIA method was the classification stage. Classification aims to identify an object to produce a unique object that is different from other objects. The classification process using the OBIA method was based on the characteristics of each object to be classified. In this method the characteristics of the image object can be seen not only from the value of digital number only, but also from several other parameters used such as shape, size, area, and others.

In this study the classification was done in two stages, namely level one classification and level two classification. Level one classification was done by separating the object based on the type of land cover from the region, that were vegetation land and non-vegetation land. The parameters used to classify objects based on their type of land were using NDVI and Green Ratio band parameters. Calculations of the NDVI and green ratios were performed by the following formula (Johansen *et al.* 2014):

$$NDVI = \frac{NIR\text{-}Red}{NIR+Red} \qquad \text{(Eq.1)}$$

$$Ratio = \frac{Green}{((Red+Green+Blue)/3)} \qquad \text{(Eq.2)}$$

Second level classification was acquired from the classification on the type of vegetation land, where the objects in the class was separated into two different classes of further vegetation and rice fields. This second level classification aimed to separate plant objects that were classified into further vegetation and rice field objects. The parameters used in this second level classification stage were the layer value, i.e. the Green, DSM, and nDSM bands. Objects that were classified into further vegetation classes were reprocessed by separating banana plant objects from other types of plants. The separation phase of the banana plant with other plants was obtained by using some algorithm in e-Cognition software, such as edge extraction lee sigma, multi-threshold segmentation, and classification. The classification parameters used to detect objects identified as banana plants were as follows:

1. Layer value, consists of mean Green, mean nDSM, mean Ground
2. Geometry, consists of area, compactness, length, width, length/width

In this research, this method was compared to supervised classification methods to determine the quality of OBIA method. Maximum Likelihood was chosen as one of the supervised classification methods. Maximum Likelihood is a supervised classification method which is based on the Bayes theorem. It makes use of a discriminant function to assign pixel to the class with the highest likelihood. Class mean vector and covariance matrix are the key inputs to the function and can be estimated from the training pixels of a particular class (Ahmad and Quegan 2012).

2.3.3. Accuracy Assessment

The accuracy assessment stage was done to find out how accurate the classification conducted by OBIA classification method with the actual condition. Accuracy test in this research was obtained by taking some samples of banana object visually, then compared with result of classification which had been processed by OBIA method.

3. Results

3.1. Segmentation Result

In this research there are two results of segmentation, one is result of pixel-based segmentation and object-based segmentation. Pixel-based segmentation was completed by using multiresolution segmentation algorithm with the best parameter value selected is scale parameter (10), shape (0.2), compactness (0.5). Object-based segmentation itself was obtained to combine objects with the same spectral value, by using spectral difference segmentation algorithm with maximum spectral difference (3) parameter value. The results acquired from this segmentation stage can be seen in Figure 3.

3.2. Classification Result

Level one classification was done by separating between vegetation object with non-vegetation. This classification was based on the calculation of Green Ratio value. Refers to the calculation, it can be classified that the vegetation area has a Green Ratio value greater than or equal to 1.07, while for non-vegetation area has a Green Ratio value smaller than 1.07. The result of object classification based on its area type, i.e. vegetation and non vegetation can be seen in Figure 4.

The next stage was the second level classification by separating the object from the vegetation class into the rice field and the further vegetation class. The rice field object can be classified using the mean parameter of nDSM, for vegetation objects with mean nDSM less than 0.375 (mean nDSM < 0.375) would be classified into rice field. Likewise, vegetation objects that had a mean value of nDSM greater than 0.375 (mean nDSM ≥ 0.375) would be classified as further vegetation object. Normalized Digital Surface Model (nDSM) was the presentation of the object elevation

Figure 3. Aerial imagery before segmentation (above) and segmentation result (bottom)

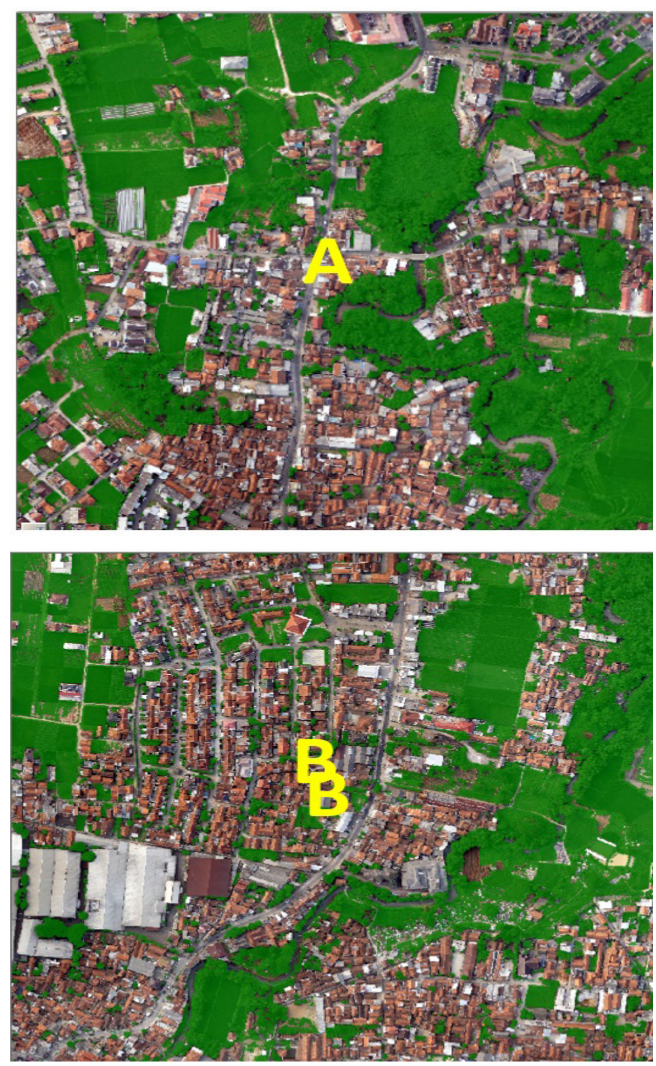

Figure 4. Classification result of land vegetation area A (above) and area B (bottom)

model on a flat surface. This model is obtained from the difference between DSM and DTM (Digital Terrain Model). nDSM is calculated by subtracting DSM by DTM (Grigillo and Kanjir 2012).

Objects whose classified in the advanced vegetation class will be re-classified to separate the identified objects as banana plants and regular plants. The first stage of this banana classification was using edge detection lee sigma algorithm. The algorithm can separate objects based on the outline shape of each segmented object. By looking from the shape of the leaves, banana plants can be separated from other types of plants that exist in the study area. The shape of the borders of the banana plants was more sharp when compared with regular plants, thus this algorithm was extracted into a new layer of plants identified as a banana plant. The next stage was multi-threshold segmentation based on the result of layer edge detection lee sigma bright by adding new parameter condition, that is length ≤ 75 pixels and width ≤ 20 pixels. These values were obtained because most banana plants have a leaf length less than 5 m and its width is less than 1 m (Johansen *et al.* 2014). Based on the results of the segmentation, the banana plants objects had been identified, but there were still some regular plants identified as banana plants, so that some additional parameters were needed to eliminate objects that have misclassified. The selected parameters were geometry parameters, such as area, length/width, compactness, and shape index, as well as layer value parameters, such as mean nDSM, mean green, and mean ground.

The physical properties of an object become one of the basic determination of classification parameters to be performed. Combinations of various parameters can represent objects according to their class. Therefore, the selection of these parameters became quite important at the classification stage. Based on the results, there was a combination of parameters along with the threshold values that can be classified the banana plants object based on its characteristics as in Table 1.

Based on the classification was done by combining several parameters to detect the banana plants, concluded the final classification results as shown in Figure 5.

Table 1. Threshold boundary value of banana plants

Parameter	Max. value (pixels)	Min. value (pixels)
Area	250	15
Border Index	20.25	2.8
Compactness	6	2.3
Length/Width	3	1
Width	475	94
Length	385	60

3.3. Accuracy Result

The final step after the classification obtained was accuracy assessment. Accuracy assessment intends to find out how much the accuracy level of the classification conducted using the OBIA classification method with the actual conditions. Accuracy assessment was conducted by taking the sample object points visually on orthophoto data, because the shape of the banana plants can be seen clearly. Then the sample points were compared with the classification results in OBIA presented in the error matrix below.

Figure 5. Classification result of banana plants

Table 2. Error matrix

		Reference data		Raw total
		Banana plants	Regular plants	
Classification result	Banana plants	24	6	30
	Banana plants	3	30	33
	Total	27	36	63

The error matrix can calculate producer accuracy, user, accuracy, and overall accuracy value. The overall accuracy value in this study is 82%. For the producer and user accuracy values of each object can be seen in Table 3. This value shows that the classification of banana objects using OBIA method has a high accuracy, therefore that OBIA method can be used as one of classification methods.

4. Discussion

The result of classification using OBIA methods was compared with traditional classification methods, such as Maximum Likelihood classification. After the accuracy assessment was completed, the result of classification was arranged into a map, called Land Cover Map of Sayang Village (Figure 7 and 8). Figure 6 shows the study area that would be classified using OBIA methods and Maximum Likelihood method. In Figure 6, it shows clearly the banana plants distribution and in Figure 7 and 8, the banana plants shown with yellow colour. The results of two classification methods show that OBIA method has a better output than Maximum Likelikehood, both in terms of visualization as well as accuracy (Figure 6 and 7). The overall accuracy of Maximum Likelihood method was 31%. As seen in Figure 7, there were many misclassification objects if visually compared to Figure 6.

Table 3. The calculation result of producer and user accuracy

Class	Producer accuracy (%)	User accuracy (%)
Banana plants	89	80
Regular plants	83	91

Figure 6. Aerial imagery of Sayang Village

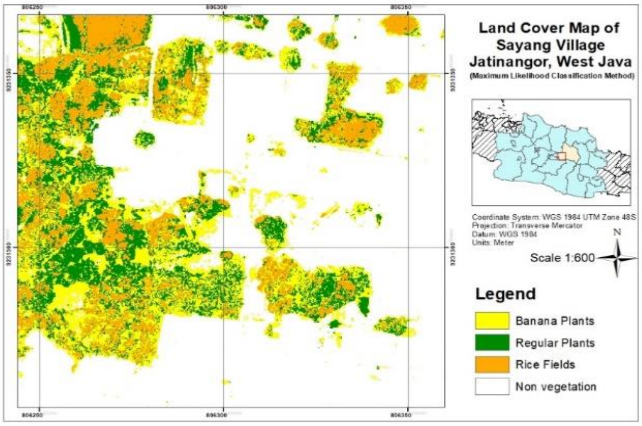

Figure 7. Land cover map of Sayang Village using maximum likelihood classification method

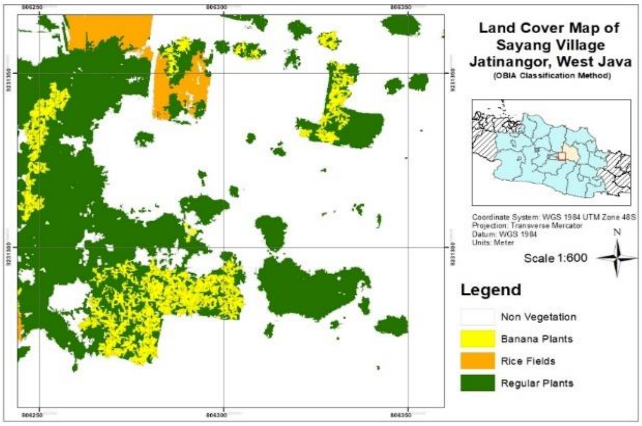

Figure 8. Land cover map of Sayang Village using OBIA classification method

Figure 9. The identified areas contained banana trees using OBIA classification method

This OBIA method can be used to perform more specific classifications, such as identification of banana plants which is conducted in this study. Based on the result of data processing that was done, separation of banana plants object with other regular plants can be done by using some parameter classification, that is geometry parameter, such as area, length / width, compactness, and shape index, and layer value parameter such as mean nDSM, mean Green, and mean Ground. With certain threshold values of the parameters already mentioned, banana and regular plants objects can be classified into different classes. The accuracy of banana plants classification using OBIA method is higher than Maximum Likelihood for the overall accuracy. This research has proven that the classification using OBIA method is better than the maximum likelihood classification method to identify banana plants.

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