Investigation method for shaded coffee plantation detection using aerial photography

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Abstract. Coffee plantation is one of the main agricultural sectors in the world, especially in Indonesia. For sustainable coffee management, it is important to obtain an assessment of the spatial distribution of coffee plantation. In fact, most of the coffee trees planted under the forest canopy as jungle coffee. However, remote sensing studies devoted to coffee in Indonesia have been limited due to spectral similarity with forest. Hence, the shaded coffee plantation has been difficult to be mapped. This condition takes aerial photography as an alternative solution to detect the distribution of shaded coffee plantation with high spatial resolution. This paper presents an assessment of the classification method of aerial photography for detecting shaded coffee plantation. The data used in this study is aerial photography captured in a shaded coffee field located in Gunung Puntang. Some classification methods namely Pixel-Based and Object-Based Image Analysis (OBIA) were used. Those method performances were evaluated by comparing the classification result as overall accuracy. The result shows that OBIA is the best method for detecting shaded coffee plantation. It produces an overall accuracy of 73.01%.

1. Introduction
Indonesia is the fourth largest coffee producer in the world, therefore coffee plays an important role in the economy sector [1]. For sustainable coffee management, it is important to obtain an assessment of the spatial distribution of coffee plantation. According to [2], the study on a coffee plantation in Indonesia is only descriptive, therefore coffee distribution map is not yet available. Remote sensing is the technology that plays an important role that providing spatial data and managing plantations [3]. The use of remote sensing can provide a low-cost information about land planning and contribute significantly to land mapping through relationships between reflectance and vegetation structure [4]. Commonly, a classification technique is used for mapping coffee plantation.

Moran et al., [5] stated that identification of a coffee plantation with remote sensing is very difficult because it has relatively similar spectral with forests. Several studies have attempted to identify coffee plantation using low-resolution images (30 meters) both using a pixel-based classification method [6] [7] and also using an object-based classification method [8]. Nevertheless, recently coffee plants mapping using low-
resolution satellite images have no optimal results. This condition takes aerial photography as an alternative solution to detect the distribution of shaded coffee plantation with high spatial resolution. A low-cost Unmanned Aerial Vehicle (UAV) system would be efficient aid for remote sensing of crop fields to perform site-specific farm management operation with high spatial resolution and fills the gap between large-scale satellite and small-scale near-surface remote sensing options.

On wholes our study to present a preliminary methodology to acquire and process high-resolution data for detecting shaded coffee plantation by an aerial photography based on some classification methods. The classification methods, namely pixel-based and object-based image analysis (OBIA) were implemented and compared to detect shaded coffee plantation. For accuracy assessment, the confusion matrix is used for each method.

2. Materials and Methods
In this study, we focused on application of different image classification methods for detecting shaded coffee plantation using aerial photography. Table 1 show the characteristics of data used in this study.

| Sensor          | Focus Length | Imagery Band | CCD Size       | GSD            | Output Coordinate System     |
|-----------------|--------------|--------------|----------------|----------------|-------------------------------|
| 1” CMOS         | 8.6 mm       | Red, Green, Blue | 5472 x 3648 px | 6.16 cm/2.43 in | WGS 84 / UTM zone 48S (EGM 96 Geoid) |
Related to the methods applied, we used ISODATA [9], Maximum likelihood [10], and Object-Based Image Analysis. In this case, we used ten classes including coffee, wet rice, waterbody, road, soil, grass, pine, mix vegetation forest, building area, and dry field. Then, we collected Region of Interest (ROI) based on the class that will be used in the classification process using the fundamental elements of image interpretation [11]. This is due to the high-resolution image that can show the object in detail (figure 1.D). We selected a total of 3457665 training pixels covering the geographic extent randomly to detect coffee plants using the maximum likelihood algorithm. For the object-based classification method, we used multiresolution segmentation. The edge detection segmentation algorithm we used are scale level of 25.0, compactness of 5.0, and the shape of 5.0 to detect coffee plants and distinguish it to other land covers. Then, those method performances will be evaluated by comparing the classification result as and ground truth using confusion Matrix.

The study area is part of Gunung Puntang (Figure 1) located in Banjaran District, Jawa Barat Province. The study area stretches over an area of about 15 Ha. It has annual average temperatures ranging between 18-30°C and the mean annual rainfall is 2500 mm. The terrain is flat to undulating, with altitude ranging between 1000 and 1200 m above sea level. The main agronomical crops grown in the area are coffee, corn, pine, wet rice, and others.

3. Result and Discussion
The results of this study (Table 2) indicate that the OBIA is the best method for coffee detection with (75.00% producer accuracy and 60.08% user accuracy) compared to the maximal likelihood algorithm.
(76.40% producer accuracy and 6.89% user accuracy) and unsupervised algorithm classification of (44.64% producer accuracy and 8.52% user accuracy).

### Table 2. Result of Accuracy Assessment

| Method               | Coffee Producer’s Accuracy | Coffee User’s Accuracy | Land Cover Overall Accuracy | Kappa Coefficient |
|----------------------|---------------------------|------------------------|----------------------------|-------------------|
| Unsupervised Classification | 44.64 %                  | 8.52 %                 | 24.92 %                    | 0.17              |
| Supervised Classification   | 76.40 %                  | 6.89 %                 | 69.20 %                    | 0.68              |
| OBIA                  | 75.00 %                  | 60.08 %                | 73.01 %                    | 0.70              |

3.1. **Pixel-based Classification**

Based on the results of the accuracy assessment shown in Table 2, the ISODATA algorithm produces the lowest accuracy for land cover classification (overall accuracy of 24.92% and kappa coefficient of 0.17) compared to maximum likelihood and OBIA. Likewise, the ISODATA algorithm couldn’t give optimal results for coffee detection (producer’s accuracy of 44.64% and user’s accuracy of 8.52%). The producer’s accuracy indicates how the training area set from a class is classified. While user accuracy indicates the probability of a pixel that is classified into a particular class that represents that class in the field [12].

Although the maximum likelihood algorithm is better for mapping land cover (overall accuracy of 69.20% and kappa coefficient of 0.68) than ISODATA algorithm, the use of this method for coffee detection has not given optimal results (user accuracy of 6.89%). A human interpreter performing visual image interpretation may label the polygon of training samples and ground truth incorrectly. The reason we selected training samples and ground truth using visual interpretation are due to not only coffee plantation can be interpreted visually using very high spatial resolution (6.16 cm) but also difficulty visits all the sites identified in the random sample. Some sites selected in the random sample may be completely inaccessible due to the extremely rugged terrain.

Otherwise, the identification of a coffee plant is very difficult because it has relatively similar spectral and chlorophyll values with forests [7]. The spectral similarity between the cover classes is unavertable with both classification techniques, especially in land cover classes that have high heterogeneity. Especially in the study area (Figure 1), most of the coffee plantations are shaded with pine trees and sometimes in association with other perennial crops like banana trees. The density of vegetation around coffee makes it difficult to be identified even using high resolution aerial photograph. Further study with an integration between the aerial photograph and multispectral image needed to improve the accuracy.

3.2. **Object-based Classification**

The results of this study (Table 2) indicate that the OBIA is the best method for land cover classification with (overall accuracy of 73.01% and kappa coefficient of 0.70) compared to the supervised and unsupervised algorithm classification. Based on the result, both producer accuracy and user accuracy show that coffee can be mapped properly using object-based classification. The percentage obtained for producer accuracy and user accuracy is 75.00% and 60.08%.

Danoedoro [13] stated that an object-based classification method (OBIA) can define object based on spectral and spatial aspects in the form of segments, while the pixel method only relies on spectral aspects. Furthermore, the use of threshold value is important to give maximum result. The use of features contained in object-based methods makes it very easy to do the classification process between classes based on their...
characteristics so that the use of this method is more accurate than the pixel-based method. According to [14] the success of object-based classification approaches is very dependent on the quality of image segmentation. In this study, the edge detection segmentation algorithm we used is a scale level of 25.0, compactness of 5.0, and shape of 5.0 to detect and delineate coffee plants and distinguish it to other land cover. These values based on trial and error on the location of the study so that we focus on the use of the values above.

Based on the results of the classification, the three methods have not provided optimum results for the detection of coffee under the tree canopy due to the kappa coefficient obtained by all methods are below 0.8 [15]. This is due to the density of vegetation types, especially pine, is more dominating, making it difficult to identify the coffee plants below it. Further research with an integration between the aerial photograph and multispectral image added with Digital Surface Model (DSM), texture, and several vegetation indexes will improve the accuracy of detecting coffee plantation.

The high accuracy values indicate that the use of object-based classification (OBIA) can be used as an alternative in mapping the coffee area and surrounding land cover. But this method still cannot be used as the standard due to there are still errors in the classification of coffee with other classes. Coffee distribution map can be seen in Figure 2.

![Figure 2. Distribution of coffee plants based on OBIA Method](image)

4. Conclusions
The coffee plantation is one of the economically important sectors in the world especially in Indonesia, hence a low-cost Unmanned Aerial Vehicle (UAV) system would be efficient aid for remote sensing of crop fields to perform site-specific farm management operation with high spatial resolution and fills the gap between large-scale satellite options. In this study, we used ISODATA, maximum likelihood, and OBIA classification method for detecting shaded coffee from an Aerial photography derived from Unmanned Aerial Vehicle in part of Gunung Puntang. As the result, OBIA is the best method for detecting shaded coffee plantation with producer accuracy of 75% and user accuracy of 60.08%. Nevertheless, all methods
have not given optimum result in detecting shaded coffee plantation due to kappa coefficient obtained by all methods are below 0.8 [15]. It is difficult to distinguish coffee from pine and other vegetation which has the spectral similarity between land cover classes. For further work, we will collect the training sample and ground truth obtained by visiting the site on the ground that can then be compared with classification and combine the high-resolution aerial photograph and multispectral imagery to improve the accuracy of detecting coffee plantation.

5. Conflict of interest
The author declared that there is no conflict of interests regarding the publication of this paper.

6. Acknowledgement
The author would like to thanks to Department of Geomatics and Engineering of Bandung Institute of Technology (ITB), Center for Remote Sensing (CRS)- ITB, and KJSKB Ketut Tomy Suhari for supporting this research.

7. References
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