Accuracy Assessment of Land Cover Fraction Map Derived from Landsat 8 Imagery Using Linear Spectral Mixture Analysis Method

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Abstract. Accuracy assessment is conducted to assess how well a classification method is. One of the land cover classification method for mixed pixel problem is Linear Spectral Mixture Analysis (LSMA). Error matrix is commonly used accuracy assessment of categorical data. But accuracy assessment for fraction map as result of LSMA processing is not really examined yet. LSMA method produces map fraction which contains land cover proportion. This experiment aims to examine the effect of sampling unit on land cover fraction map accuracy assessment result. 70 samples were taken using stratified random sampling. Geoeye 1 image is used as reference data corresponding to ground truth data. Accuracy assessment was performed in two scenario sampling unit which is single pixel area and a cluster of pixels area. The accuracy of LSMA model was influenced by position error between classified map and the reference data. Selection the right sampling unit is a one way to minimize the deviation caused by positional error corresponding reference data.

Keywords: Accuracy Assessment, Land Cover, Fraction Map, Linear Spectral Mixture Analysis

1. Introduction
Remote sensing technology has become a data source of land cover/land use mapping because of easy data acquisition compared to field surveys. The land cover information and thematic map can be extracted through image classification methods [1]. The classification method commonly used in land cover assessments is pixel-based classification, including per-pixel classification and sub-pixel classification. The per-pixel classification assumes that one pixel has the one class. However, the reality showed that one pixel contains information more than one type of land cover. Medium resolution imagery provides low accuracy in this methods, especially used for heterogeneous areas [2]. This is because the existing of mixed pixel forced classified into one class. The development of remote sensing data processing techniques introduces a classification of sub-pixels that classifies one pixel into several different classes [3]. Sub-pixel classification is able to overcome the lack of per-pixel classification by providing predictions of the proportion of object classes in a single pixel [4].
One of the commonly used methods in sub-pixel classification is Linear Spectral Mixture Analysis (LSMA). This method is widely used to overcome mixed spectral problems which produce land cover fraction map [5]. The accuracy of land cover fraction map needs to assessed to knowing the reliance of the LSMA classification result. The reliance of LSMA method to be applied is showed by its accuracy [6]. The accuracy assessment method of sub-pixel classification is different from the per-pixel classification. The confusion matrix is widely used to assess the accuracy of categorical data/ per-pixel classification [7]. Meanwhile, the previous study has been used error measurements to assess subpixel classification, like expected sub-pixel class overlap constrained to the unmatched sub-pixel fraction [8]. Wu (2004) used two type of error measurement, root-mean-square error (RMSE) and systematic error (SE) to evaluate urban composition [9]. Weng et al. (2009) calculate the accuracy of land cover fraction map using RMSE and mean average error (MAE) [10]. Yang et al (2010) employed RMSE to assess the impervious surface area for four different methods – SMA, NSMA, MESMA, and PNMESMA[11]. The RMSE were used in this study to calculate the accuracy of land cover fraction map.

Low accuracy might happen because of an external factor such as an error in reference data. Generally, the accuracy results can be affected by error sources that caused by the positional error between classified map and reference data. The positional errors between the references and map affected on the low accuracy of the thematic map. This issue needs to be a consideration in determining the sample for accuracy assessment. Therefore, the influence factors on accuracy assessment are very important to identify to improve the objectivity of the assessment.

There are some very important considerations in determining the sample of accuracy assessment, including the appropriate sampling unit, number of samples, and sample scheme [7]. The sampling unit is a small part of the map used for the accuracy assessment, it can be a single pixel and a cluster of pixels. The sampling unit is an important aspect to consider the possible errors [12]. The errors indicate the classification errors on the result of the map. This study aims to map the land cover fraction and calculate the accuracy assessment using two scenarios of sampling unit.

2. Materials and Methods

2.1. Materials

This study used Landsat 8 OLI Level 1TP as the main data sources and GeoEye Image level 2A as a reference for maps. Processing of the 1TP level has gone through image calibration which is radiometric and geometric corrections. Landsat 8 OLI Level 1TP show pixel value at level surface reflectance value. Therefore, the radiometric correction was not performed in this study. The study used Landsat Image 8 multispectral channel consisting of seven bands. The wavelengths used in the analysis, in more detail are described in Table 1.

| Table 1. Specification of multispectral bands of Landsat 8 OLI imagery |
|-----------------------------|-----------------------------|
| Bands | Ranges of Wavelength (µm) |
| Band 1 Coastal/aerosol | 0,435-0,451 |
| Band 2 Blue | 0,452-0,512 |
| Band 3 Green | 0,533-0,59 |
| Band 4 Red | 0,636-0,673 |
| Band 5 Near infrared | 0,851-0,879 |
| Band 6 SWIR 1 | 1,566-1,651 |
| Band 7 SWIR 2 | 1,566-1,651 |
The image acquisition on June 23, 2015, cut into 450x390 pixels covering the urban area of Surakarta. Selection of the study area considering the heterogeneity of land cover. Recording result in medium resolution imagery such as Landsat with 30 meter resolution produced dominated by mixed pixels. The study area located in the 49 M zone UTM 472884 - 486320 mT and 9158020 - 9169533 mU, presented in Figure 1 below.

![Study Area](image)

**Figure 1. Study Area (Composite Band 452)**

The GeoEye imagery with processing level standard 2A has been orthorectification a using a rough DEM. The imagery is used as a reference in geometric correction and reference data for accuracy assessment. The pan-sharpening process applied in GeoEye imagery to increase the resolution to 0.5 meters.

Image processing in this study uses several tools including a laptop with i3 processor and Envi 5.3 software and Idrisi Selva 17.0. Envi 5.3 software is used for calibration, rectification, and transformation. The LSMA processing is done on the Idrisi Selva software because it is able to produce the total value of land cover fraction which constraint is equal to one. Fieldwork utilizes the Global Navigation System (GPS) as a navigation tool.

### 2.2. Methods

This study consists of two stages, such as mapping of land cover fraction using Linear Specific Mixture Analysis method and classification accuracy assessment. Land cover is divided into four classes, ie, built up area, vegetation, bare land, and water body. Each land cover class extracts the pure
spectral reflectance through image, called endmember. The accuracy assessment of LSMA done by calculating the RMS Error.

2.2.1 Land Cover Fraction Maps. There are three stages to produce the land cover fractions map, include image pre-processing, endmember determination, and Linear Spectral Mixture Analysis (LSMA) process. The extraction method of land cover using LSMA is described in detail as follows.

2.2.1.1 Geometric Correction. Geometric correction is performed to equalize the position of Landsat 8 OLI imagery with the correct position. The reference used in this correction is GeoEye's imagery that has assumed to have coordinates corresponding to the field. This geometric correction is done to reduce position error between GeoEye Image as the reference of accuracy assessment and Landsat Image 8. Geometric correction is done until the RMS Error reaches 0.3265, where there is error position as far as 10 meters.

2.2.1.2 Endmember Selection. Endmember selection is the essential process in the LSMA method. Endmember is the pure object whose the spectral reflection value will be used as a reference in LSMA process. Endmember obtained from the image itself. It used to extract the land cover map includes built-up area, bare land, water bodies, and vegetation. The process to determine the endmember is through a Minimum Noise Fraction transformation and Pixel Purity Index (PPI). The next process is manual selection on a pure pixel of PPI results by checking land cover on GeoEye imagery. The endmember for water bodies is taken from Cengklik Reservoir. The pure pixel of vegetation is found in the north of Surakarta City and rubber plantations. Endmember of bare land is taken from the ground before construction and rice fields that have not been planted. The high density of built-up area was found in the center of Surakarta City.

2.2.1.3 Linear Spectral Mixture Analysis (LSMA). LSMA is a technique to estimate the reflectance recorded on pixels. It can be modeled with linear combinations of summations of multiple endmembers [13]. The linear combination, formulated mathematically as follows [14].

\[ D_{ij} = E_{fi} + e_{ij} \]  

Where \( f_{ij} \) is endmember fraction pixel in position \( ij \), \( E \) is the pattern matrix of endmember spectral reflectance, \( D_{ij} \) is the reflectance value of a pixel \( ij \), \( e_{ij} \) is the error between the reflectance value of model and brightness value of measured band.

Formula (1) assumed that the number of fraction of all endmember is sum to 1.

\[ \sum_{i=1}^{l} f_{i} = 1 \]  

Beside that, each fractions must be positive, where

\[ f_{i} \geq 0 \]  

The LSMA method was used inputs of Landsat 8 image that has been corrected radiometric to surface reflectance value and endmember. In the LSMA processing, each mixed pixel will be separated into four land cover fractions. This analysis yielded land cover fraction maps of the built up area, vegetation, bare land, and RMSE. These maps show the percentage composition of each land cover on pixels whose value ranges from 0 to 1 or 0% to 100%.

2.2.2 Accuracy Assessment of Land Cover Fraction Map. Accuracy assessment was conducted by comparing the proportion of land cover with accurate results with the proportion of land cover in the field. The formula used in the test is the root-mean-square error (RSME) as follows.

\[ RMSE = \sqrt{\sum_{i=1}^{N} (v'_{i} - v_{i})^2 / N} \]
Where $v'_i$ is sample $i$’ percentage of land cover map fraction, $v_i$ is sample $i$’ percentage of actual land cover from reference images. $N$ sum of sample members.

The proportion of land cover in the field was obtained from the extraction of pan-sharpening GeoEye imagery. Reference image was classified into four classes of land cover – built up area, bare land, vegetation, and water body using visual interpretation. For each sample site, the sampling units are single pixel and cluster of pixels. Then, the percentage of land cover were extracted from each area of the sample unit. Ground truth percentage of land cover within sample unit can be calculated through a dividing area of each land cover by the total area of sample unit (900 m² or 8100 m²). This study used 70 samples which distribute in the entire study area. It was referred to Jensen (1996) which the minimum of sufficient samples for the variance-covariance matrix is 10 times the number of bands used. The sample determined using stratified random sampling method based on fraction class of each land cover map yields. Sample site was chosen in the homogenous area. This study examined the effect of sampling unit on the results of the accuracy assessment. The sampling unit used was single pixel and cluster of pixels with 3x3 pixel square. The figure 2 and figure 3 show how the sample unit is utilized.

**Figure 2.** Single pixel sampling unit (on Landsat 8 OLI image) (b) polygon with red line indicates digitized land cover.

**Figure 3.** Cluster of pixels sampling unit (on Landsat 8 OLI image) (b) polygon with red line indicates digitized land cover.
The methods used in this study is summarized by the flow chart in Figure 4.

![Flow Chart](image)

**Figure 4.** The flow chart of study.

3. Result and Discussion

3.1. Land Cover Fraction Maps

LSMA is a frequently used method to solve mixed pixel problems. This study applied the LSMA method to estimate the proportion of land cover class; vegetation, bare land, water body, and built up area in each pixel. The distribution of land cover fraction was presented in Fig. 5 to Fig. 8. The land cover fraction maps were presented using color gradations from red to dark blue. The color that closer to the red color indicated the low proportion of land cover. Meanwhile, the color which closer to the dark blue shown the high proportion of land cover.

Land cover was dominated by the class range in the proportion of 0.7 - 0.8. Most of the built-up land fraction was located in the urban areas dominated by buildings. The dominant of vegetation fraction was located in the urban fringes used as the paddy field. The highest of the bare land fraction
was in the range of 0.4 to 0.5. The bare land was relatively low due to few bare areas in the urban areas of Surakarta. Most of the water bodies were located in the river and irrigated fields.

Figure 5. Built up Land Fraction Map

Figure 6. Vegetation Fraction Map.
The LSMA processing generated residual imagery as shown in Figure 9. The residual value represents the difference between the modeled brightness value and the measured brightness value of the band. The building made from concrete had the high residual value. This is caused by the reflectance value of the building higher than average reflectance of built-up-area endmember.
3.2. Accuracy Assessment
To evaluate the accuracy of land cover fraction map, 70 samples were used. Geoeye pansharpening image with 0.5 meter resolution was used as a reference data corresponding ground truth to assess the accuracy of the land cover map fraction as LSMA result. Two scenarios of sampling unit were used to assess the model accuracy. Land cover fraction map use pixel as the analysis unit, so sampling unit could be pixel or cluster of pixels.

Table 2. The Accuracy of Land Cover Fraction in 3x3 pixels Sampling unit

| Land Cover | Land Cover | Overall Accuracy |
|------------|------------|------------------|
|            | Built up Area | Vegetation | Bare Land | Water Body |
| RMSE       | 26.93 | 15.21 | 24.39 | 28.09 | 23.66 |
| Accuracy (%) | 73.07 | 84.79 | 75.61 | 71.91 | 76.34 |

Table 2 shows the result of accuracy assessment of cluster of the pixel as the sampling unit. Overall accuracy derived from a cluster of pixels sampling unit is 76.34. Waterbody fraction map has the highest error among others map with RMSE 28.09. Low albedo impervious surface are similar to waterbody reflectance. Waterbody was estimated higher on low albedo with asphalt material.

Table 3. The Accuracy of Land Cover Fraction in single pixel Sampling unit

| Land Cover | Land Cover | Overall Accuracy |
|------------|------------|------------------|
|            | Built up Area | Vegetation | Bare Land | Water Body |
| RMSE       | 30.59 | 21.66 | 34.95 | 30.53 | 29.43 |
| Accuracy (%) | 69.41 | 78.34 | 65.05 | 69.47 | 70.57 |
The result of accuracy assessment for single pixel sampling unit was presented in Table 3. The accuracy of land cover fraction map using single sample unit is 70.57. The RMSE were 30.59, 21.66, 34.95, and 30.53 of built-up area fraction map, vegetation fraction map, bare land fraction map, and water body fraction map respectively. Bare land fraction map has the highest error among the others. The bare land was predominantly confused with the impervious surface. Dry soil has similar reflectance to high albedo.

The sample unit with 3x3 pixels square has higher overall accuracy than the single pixel. A pixel with 90 m² area may have less relation with the actual area in the ground. Besides that, low accuracy might happen because of positional error corresponding reference image and land cover map fraction. Meanwhile, using a cluster of pixels, the positional error can be minimized where the center pixel is measured precisely.

The previous study conducted by Powell (2007) used several windows size for sampling unit. Windows size is block of Landsat pixels square [15]. The size of sampling unit was varied from a single Landsat pixel to 17x17 pixel square. Sampling unit variation was used to investigate impact size of sampling unit on accuracy assessment based correlation between model and reference from high-resolution imagery. Based on the correlation between modeled fraction and reference, a single pixel has low correlation. As the size of sampling unit increased, the correlation increased.

4. Conclusion
The accuracy of LSMA model was influenced by the positional error between Landsat 8 imagery and the reference imagery. Selection the right sampling unit is a one way to minimize the deviation caused by position error corresponding reference data. In this study, other factors might have the influence on accuracy result.

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