Comparison of land cover classification in Pakpak Bharat Regency using Landsat 8 OLI and Sentinel 1A satellite imagery

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Abstract. The increase in population impacts the need for land as a source of living that is increasing. The area of forest in Pakpak Bharat District decreased by 17.4% for the period 2011 to 2015. This study aims to identify land cover in Pakpak Bharat District by using Landsat 8 OLI Optical Imagery and Citra Radar Sentinel 1A. Sentinel SAR images 1A are converted first to be visually analyzed, and classification can be performed using the maximum likelihood method. The analysis carried out is a separability test, kappa accuracy test, and validation test. The calculation of kappa accuracy and validation shows that Landsat 8 OLI imagery has higher accuracy, which for Landsat 8 OLI and Citra Radar Sentinel 1A were 95.26% and 4.92%, respectively. Validation test results for Landsat 8 OLI and Citra Radar Sentinel 1A were 83.87% and 18.28%. The results indicate that the classification of land cover from Citra Sentinel 1A using the maximum likelihood supervised classification method does not provide satisfactory classification results. Although constrained by clouds, Landsat 8 OLI imagery for land cover classification using the maximum likelihood method is still better.

1. Introduction

An increase in population has an impact on increasing land requirements. The conversion of forests to settlements, agriculture, and plantations is the most common. According to SK.579 / Menhut-II / 2014 concerning Forest Areas in North Sumatra Province, the total area of forest in Pakpak Bharat is 1288.24 Km². Thus, the percentage of area that can be legally utilized for non-forests is only about 19% of Regency's total area. Forest area decline occurred in Pakpak Bharat Regency. The decline in forest area occurred by 17.4% from 2011 to 2015. The increase in population from 2010 to 2015 was 11.76. The use of community land, which is used as agricultural land, improves the economy of the community, such as coffee fields, rice fields, and seasonal crops [1].

Pakpak Bharat is one of the districts in North Sumatra with an altitude of 700-1500 meters above sea level with rough geographical conditions and relatively close to the equator. Geographically, Pakpak Bharat Regency is located between coordinates 2° 15’ – 3° 32’ North Latitude and 96° 00’ - 98° 31’ East Longitude [1]. This region has a high vulnerability level, so in the study of land cover, it often loses essential information from the object behind the area covered by the cloud. Indonesia's tropical regions make clouds a classic problem in scanning the earth's surface using optical sensing remote sensing satellites. Satellites with Synthetic Aperture Radar (SAR) sensors can penetrate the cloud so
that it becomes a solution to cloud cover [2]. SAR is suitable for use in the Pakpak Bharat District because it is an area that has a high rainfall and fog intensity.

Landsat satellite imagery is the most widely used in the land cover analysis. Classification of land cover from Landsat imagery is influenced by atmospheric and topographic errors and requires correction [3]. Landsat 8 OLI was developed using ten band infrared thermal sensor data that presents an algorithm for mapping land use or land cover [4].

SAR (Synthetic Aperture Radar) has been widely used for earth observation, such as vegetation monitoring, ice plate movement monitoring, geomorphological monitoring, and water condition monitoring. SAR data has advantages of penetrating clouds where passive sensors are generally not able to penetrate clouds. SAR is also an active sensor, which means it is not affected by day or night conditions, the acquisition is fast, which can be applied to monitoring that requires a fast temporal, capable of producing a synoptic view.

Retrieval of SAR data that forms an angle provides a different perspective from vertical imagery in general. The utilization of SAR data still faces many obstacles compared to the optical system remote sensing data, especially in geometry problems. These geometric problems result from sideways SAR data retrieval that causes many errors, such as layover, foreshortening, and shadow [2]. This study aims to identify land cover in Pakpak Bharat Regency using Optical Landsat 8 OLI (Operational Land Imager) images and Sentinel-1 SAR (Synthetic Aperture Radar) images.

2. Materials and Method

2.1. Study site
The research was carried out in Pakpak Bharat Regency, North Sumatra Province, which geographically located between coordinates 2°15’ - 3 32’ North Latitude and 90°00’ - 98°31’ East Longitude, with an area of administration 1,218.30 km2 consists of 8 districts and divided into 52 villages.

2.2. Tools
The tool used in this study is GPS (Global Positioning System). Hardware such as laptops as data processing devices, SNAP 6.0 software, ArcGis (ArcMap) 10.3, Microsoft Excel, and Microsoft Word for data processing. The data type and source in this study are presented in table 1.

| No. | Data                          | Source                      | Acquisition   |
|-----|-------------------------------|-----------------------------|---------------|
| 1.  | Ground truth coordinate       | GPS                         | 2018          |
| 2.  | Landsat 8 OLI/TIRS level 1    | https://earthexplorer.usgs.gov/ | July 2017     |
| 3.  | Citra Sentinel-1A product type IW GRDH | http://scihub.copernicus.eu/dhus | July 2017     |
| 4.  | Administration Map            | tanahair.indonesia.go.id    | 2018          |

Landsat 8 satellite imagery data was obtained by downloading through the USGS (the United States Geological Survey) site. The research area found in Landsat 8 path 129 and row 58 images. Sentinel-1 satellite imagery was obtained by downloading via the European Space Agency (ESA) website or the Copernicus website by creating a Region of interest (ROI) in the study location area.

2.3. Method
The SAR Sentinel 1 image preprocessing is calibration, Speckle Filter, Terrain Correction, and backscatter conversion to decibels (Fig 2). Radiometric calibration is to convert DN (Digital Number) values into backscatter coefficients. The backscatter coefficient value is calculated by backscatter calibration in the standard area. The calibration process divided into three, including sigma nought,
gamma nought and beta nought). SAR (Synthetic Aperture Radar) band calibration aims to provide an image where pixel values can be directly related to radar backscatter from the scene to obtain quantitative SAR data [5]. Radiometric calibration carried out with the following equation [6]:

\[
\sigma^0 = \frac{\text{DN}^2 \sin \Theta}{A^2 \Delta nK}
\]

Where \(\sigma^0\) = sigma nought (backscatter radar), DN = digital number, \(\Theta\) = incidence angle, A = Amplitude, and K = Calibration constant.

Speckle Filter is an operator stage where each project will cling like texture like spots that degrade image quality and make interpretation of features more difficult to overcome the constructive and destructive interference of random but coherent de-phase waves that are scattered in each cell resolution. In this case, the filter used is Lee with filter size x (odd number), and filter size y (odd number) is 3 [7]. Terrain Correction is an action to compensate the sensor for a distorted image or experience geometry damage so that the geometric representation of the image will be closer and reduce the effects of topographic distortion. The image resampling method and DEM (Digital Elevation Model) resampling method using Binary Interpolation with DEM type are SRTM (Shuttle Radar Topography Mission) and Map Projection for Geodetic Datum WGS 1984.

Converting backscatter to decibels (Linear to from dB) is the final stage of operator action to convert the band to dB. The backscattering coefficient (in dB) is obtained by the following equation [8]:

\[
\sigma^0[\text{dB}] = 10 \times \log_{10} \left( \frac{\text{DN}^2 \sin \Theta}{A^2 \Delta nK} \right)
\]

Where \(\sigma^0\) dB = backscatter coefficient in decibel units (dB), K = Calibration coefficient, DN = Digital Number, \(\Theta\) = incidence angle and A = Amplitude.

The next stage is to create a 1A sentinel image visualization with a combination of RGB VV, VH, VV-VH bands.

**Figure 1.** Pre-processing of Sentinel 1A Imagery

Before Landsat 8 OLI imagery is used, pre-image processing is done, which includes radiometric correction, stacking, and cropping. Radiometric correction is performed to eliminate the interference that occurs in the image due to atmospheric influences. Radiometric correction is performed in a contrast sharpening process or radiometric enhancement with a linear model. Landsat satellite imagery downloaded from USGS has 11 bands, and each band is separate. The merging of the satellite imagery bands is done to obtain image visualization that facilitates land cover classification. The cropping process is carried out to get the image in the study area, Pakpak Bharat Regency.
The determination of the sample area is done to get the representative land cover point for each land cover class. This point is used to build a numerical description of the spectral for each land cover. Determination and sampling are based on data obtained from field inspections, then the determination and selection of training area locations for the collection of land cover type information on imagery (Jaya 2010). Retrieval of statistical information is done by taking a sample of pixels from each land cover class, and its location is determined on a composite image. Statistical information from each land cover class is used to perform the separability and accuracy functions.

Separability analysis is an evaluation of the separation of each class's training area, whether a class is worth joining or not. In this study, the method used is transformed divergence. Drink value means it cannot be separated, while the maximum value indicates excellent separability. According to Jaya and Kobayashi [9], the results of separability analysis are inseparable: <1600, poor: 1600 ≤ 1800, fair: 1800 ≤ 1900, good: 1900 ≤ 2000 and excellent: 2000.

An accuracy test is used to evaluate the accuracy of the land cover classification determined based on the training area. We were using a contingency matrix or confusion matrix that can be obtained from the contingency matrix, including the user's accuracy or user accuracy, producer's accuracy, overall accuracy, and kappa accuracy or kappa accuracy. Of the four accuracies, kappa accuracy is the recommended accuracy because it uses all the elements in the contingency matrix [10].

\[
\text{Kappa accuracy} = \frac{\sum_{i=1}^{n} X_{ii} - \sum_{i=1}^{n} X_{i+} X_{+i}}{N^2 \sum_{i=1}^{n} X_{ni} X_{in}}
\]

Where \( N \) = number of pixels in the example, \( X_{ii} \) = diagonal value of the \( i^{th} \) row contingency matrix and \( i^{th} \) Column, \( X_{i+} \) = number of pixels in the \( i^{th} \) row, \( X_{+i} \) = number of pixels in the \( i^{th} \) column.

The supervised classification is based on the field survey results by making polygon/training area samples in land cover classes. We used the Observation data of field land cover as many as 186 points samples of land cover coordinates.

3. Results and Discussion

3.1. Characteristics of land cover

In this land cover analysis study in Pakpak Bharat Regency, using Landsat 8 OLI RGB band 6.5.4 data and Sentinel-1 2017 combination of RGB VV; VH; VV-VH. Observation of land cover in the field obtained as many as 186 points of land cover coordinates and classified into five different land cover classes (Figure 2).

3.2. Separability test results

Land cover classification is done by grouping pixels that are considered similar based on the training area. The training area is based on observational data taken from the field. The training area created is said to be good if the grouped pixels can be appropriately separated. The separation between pixels can be seen from the analysis of separability with the transformed divergence method.

| Table 2. Separation values for land cover class classification using Landsat 8 OLI imagery in 2017 |
|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
|                | Cloud          | Cloud shadow   | Forest         | Plantation     | Settlement     | Dryland agriculture | Rice field   |
| Cloud          | 0              | 2000           | 2000           | 2000           | 2000           | 2000             | 2000          |
| Cloud shadow   | 2000           | 0              | 2000           | 2000           | 2000           | 1999.99          | 1999.94       |
| Forest         | 2000           | 2000           | 0              | 2000           | 2000           | 1998.44          | 1998.93       |
| Plantation     | 2000           | 2000           | 2000           | 0              | 2000           | 0                | 1849.76       |
| Settlement     | 2000           | 2000           | 2000           | 2000           | 0              | 1982.44          | 1849.76       |
| Dryland agriculture | 2000     | 1999.99      | 2000           | 1998.93       | 0              | 1849.76          | 0             |
| Rice field     | 2000           | 1999.94       | 2000           | 1998.93       | 1849.76        | 0                | 0             |
### Table 3. Separation values for land cover class classification using Sentinel 1A imagery in 2017

|             | Forest | Plantation | Settlement | Dryland agriculture | Rice field |
|-------------|--------|------------|------------|---------------------|------------|
| Forest      | 0      | 2000       | 1317.21    | 1993.9              | 2000       |
| Plantation  | 2000   | 0          | 2000       | 1866.31             | 1990.31    |
| Settlement  | 1317.21| 2000       | 0          | 2000                | 2000       |
| Dryland agriculture | 1993.9 | 1866.31    | 2000       | 0                   | 1998.54    |
| Rice field  | 2000   | 1990.31    | 2000       | 1998.54             | 0          |

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**Figure 2.** The visual appearance of land cover (a) Landsat 8 OLI image on RGB 6-5-4 (b) Sentinel 1A on RGB VV, VH, VV-VH (c) Land cover in the field

The highest separability value on the land cover using Landsat 8 OLI in 2017 was plantations, clouds, and cloud shading of 2000 included in the excellent criteria, and the lowest in mixed shrubland agriculture was 1849.76 (Table 2). The separability value for Sentinel 1A imagery ranges from 1317-2000. Forest land cover with settlements has the lowest separability of 1317.21 (Table 3), which means that the separation between the forest land cover and settlement pixels is included in the inseparable criteria.

#### 3.3. Contingency test results

The result of Landsat 8 OLI contingency value shows that the smallest User Accuracy found in the dryland agriculture that is 73.97%, while the most significant value is found in the use of plantation land, clouds, and cloud shadow by 100%. The smallest accuracy of the maker or producer's accuracy is found in the use of dryland agriculture equal to 81.41% while the highest value is found in clouds and cloud shadow, which is equal to 100% (Table 4). The overall accuracy value obtained is 84.33%, while the kappa accuracy is 95.26%. Accuracy test results recommended for use are kappa accuracy. Kappa accuracy uses all elements in the matrix with a high degree of accuracy. It is expected that the minimum accuracy is 85% [11].
Table 4. Calculation of the accuracy results for Landsat 8 OLI image classification

|               | Cloud | Cloud shadow | Forest | Plantation | Settlement | Dryland agriculture | Rice field | Total | User Accuracy (%) |
|---------------|-------|--------------|--------|------------|------------|---------------------|------------|-------|-------------------|
| Cloud         | 816   | 0            | 0      | 0          | 0          | 0                   | 0          | 816   | 100.00            |
| Cloud shadow  | 0     | 243          | 0      | 0          | 0          | 0                   | 0          | 243   | 100.00            |
| Forest        | 0     | 0            | 2282   | 1          | 0          | 19                  | 2          | 2304  | 99.05             |
| Plantation    | 0     | 0            | 0      | 119        | 0          | 0                   | 0          | 119   | 100.00            |
| Settlement    | 0     | 0            | 10     | 0          | 133        | 4                   | 1          | 148   | 89.86             |
| Dryland agriculture | 0 | 0            | 48     | 0          | 7          | 162                 | 2          | 219   | 73.97             |
| Rice field    | 0     | 0            | 3      | 0          | 8          | 14                  | 178        | 203   | 87.68             |
| Total         | 816   | 243          | 2343   | 120        | 148        | 199                 | 183        | 4052  |                   |

Producer Accuracy (%) 100.00 100.00 97.40 99.17 89.86 81.41 97.27

The contingency value of Sentinel 1A in 2017 has the smallest user's accuracy found in the plantation, which is 4.35%, while the most significant value is in the forest use of 95.03%. The lowest producer or accuracy of producer or accuracy is found in residential land use, which is 13.05%, while the most significant value is found in plantation land use, which is 75.93 (Table 5). The result of kappa accuracy value for Sentinel 1A satellite Imagery is only of 4.92%. Based on the kappa's accuracy, the classification does not fulfill the criteria [11]. The resulting accuracy is classified as low, and the classification results are not suitable for use.

Sentinel 1A imagery uses radio waves as the highest energy pulse, which makes the processing different from optical images [12]. Radar images that were corrected by Sigma Nought topographic elements were removed in order to produce land cover images that only display the relief appearance [13]. However, The kappa Accuracy of the land cover classification with SAR Sentinel 1A using maximum likelihood method does not meet the minimum accuracy value. That is no good classification results using the maximum likelihood method for Sentinel 1A imagery. Sentinel 1A should be used in plant monitoring applications in support of plant statistics, food security analysis, various commercial geoinformatics [14] ocean surveillance, ice monitoring and interferometric applications such as subsidence and landslide detection [15].

Table 5. Calculation of the accuracy results of the Sentinel 1A image classification

|               | Forest | Plantation | Settlement | Dryland agriculture | Rice field | Total | User Accuracy (%) |
|---------------|--------|------------|------------|---------------------|------------|-------|-------------------|
| Forest        | 497    | 11         | 0          | 0                   | 15         | 523   | 95.03             |
| Plantation    | 3127   | 183        | 538        | 171                 | 184        | 4203  | 4.35              |
| Settlement    | 339    | 9          | 127        | 37                  | 21         | 533   | 23.83             |
| Dryland agriculture | 728 | 36         | 297        | 132                 | 22         | 1215  | 10.86             |
| Rice field    | 231    | 2          | 11         | 4                   | 41         | 289   | 14.19             |
| Total         | 4922   | 241        | 973        | 344                 | 283        | 6763  |                   |

Producer Accuracy (%) 10,10 75.93 13.05 38.37 14.49

3.4. Supervised land cover classification results

The largest area of the land cover of Landsat 8 OLI imagery classification is the forest of 101,458.80 hectares or 78.76% of the total area of Pakpak Bharat Regency. The lowest area was found in plantation, which was 756.64 Ha or only 0.59% of the total (Table 6 and Fig 3). The largest Sentinel 1A classification is plantation land cover with an area of 79,413.26 Ha or 61.64% of the total area of Pakpak Bharat Regency. In contrast, the lowest area was found in rice field cover, which was 7,535.04 Ha or only 15.58% of the total (Table 6 and Fig 3).
Table 6. Comparison of the extent of land cover resulting from a classification using Landsat 8 OLI imagery and Sentinel 1A

| Land cover        | Landsat 8 OLI | Sentinel 1A |
|-------------------|--------------|-------------|
|                   | Luas (Ha)    | Persentase (%)| Luas (Ha) | Persentase (%) |
| Cloud             | 4125,50      | 3,20        | -         | -              |
| Cloud shadow      | 38,84        | 0,03        | -         | -              |
| Forest            | 101458,80    | 78,76       | 13474,42  | 10,46          |
| Plantation        | 756,64       | 0,59        | 79413,26  | 61,64          |
| Settlement        | 4699,10      | 3,65        | 9040,38   | 7,02           |
| Dryland agriculture| 14870,60     | 11,54       | 7535,04   | 5,85           |
| Rice field        | 2874,96      | 2,23        | 19361,34  | 15,03          |
| Total             | 128824,44    | 100,00      | 13474,42  | 10,46          |

The results of the land cover classification of Landsat 8 OLI and Sentinel 1A shows the different area of each land cover class (Table 7). For example, forests from Sentinel 1A image analysis are only 12,140 Ha or 11.97%, so that they are not following the results of Landsat 8 OLI analysis. It is better to conduct an analysis of land cover using Sentinel 1A, which is using a different method to give better results.

The GPS point of field land cover type was used to validate the accuracy with the classification results map. Validation results obtained from each Landsat 8 OLI and Sentinel 1A imagery were 83.87% and 18.28%, which Landsat 8 OLI gave better results than Sentinel 1A. Sentinel 1A has not given satisfactory results in the maximum likelihood supervised classification method. The maximum likelihood method will get maximum results if the training data is sufficient. Sentinel 1A is suitable for use with the Brovey transformation method, Intensity Hue Saturation (IHS) method, Principal Component Analysis (PCA) method [13], Spectral Similarity Measures (SSM) [16], methods Random Forest (RF), Support Vector Machine (SVM), k-Nearest Neighbor (KNN) [17].

Figure 3. Results of land cover classification in Pakpak Bharat Regency (a) using Landsat 8 OLI, (b) using Sentinel 1A
Table 7. Matrix comparisons of the image classification results of Sentinel 1A and Landsat 8 OLI in 2017

| Land cover               | Landsat 8 OLI (Hectares) | Sentinel 1A (Hectares) |
|--------------------------|--------------------------|------------------------|
|                          | Cloud                    | Cloud                  | Forest    | Plantation | Settlement | Dryland agriculture | Rice field | Total |
| Forest                   | 509                      | 0.74                   | 12140     | 33,9       | 295,3      | 401           | 94,48      | 13474,42 |
| Plantation               | 2339                     | 29,26                  | 62160     | 575        | 2986       | 9450          | 1874       | 79413,26  |
| Settlement               | 358                      | 0.33                   | 8213      | 10,97      | 185,1      | 217,6         | 55,38      | 9040,38   |
| Dryland agriculture      | 225,5                    | 3,01                   | 5150,8    | 46,63      | 336,8      | 1499          | 273,3      | 7535,04   |
| Rice field               | 694                      | 5,50                   | 1379,5    | 90,14      | 895,9      | 3303          | 577,8      | 19361,34  |
|                          | Total                     | 4125,5                 | 38,84     | 101458,8   | 756,64     | 4699,1       | 14870,6    | 2874,96   | 128824,44 |

4. Conclusions
Land cover classification in Pakpak Bharat Regency, namely forests, plantations, dryland agriculture mixed with bushes, rice fields, and settlements. Kappa accuracy test results and percentage of land cover validation using Landsat 8 OLI are higher than Sentinel 1A. The value of kappa accuracy and the percentage of Landsat 8 OLI results is 95.26% and 83.87%, while Sentinel 1A is 4.92% and 18.28%. The maximum likelihood method in land cover analysis for SAR Sentinel 1A imagery has not resulted in good accuracy results.

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