Land Cover Analysis of Percut Watershed of North Sumatra Province using Sentinel-2 Imagery

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Abstract: The purpose of this research was undertaken to identify the type of land covers and evaluate the use of forest area in Percut Watershed using Sentinel 2 satellite imagery. Image classification in this study was divided into 14 classes, namely forests, gardens, rice fields, oil palm, shrubs, open area, dryland agriculture, settlements, mangroves, ponds, clouds, and cloud shadows. The value of overall accuracy obtained is equal to 97.11%, while the kappa accuracy is 96.52%. The results of this accuracy test indicate that the land cover classification was acceptable. The dominant land cover in the Percut watershed is forests, gardens, settlements and oil palm plantations. The percentage of forest area in the Percut watershed is only 29.5%, below 30% of the minimum area of good watershed criteria. The land use that not in accordance with its ability wherein slopes above 45% were found as oil palm plantations.

1 INTRODUCTION

The land cover is important information in the planning activities management of river basin areas. This information needed in determining recommendations best allocation of land use planning. One of the watersheds in the province of North Sumatra in critical condition is Percut Watershed. Land use is the main problem of Percut Watershed management, especially the use of land without soil conservation practices.

Administratively, the Percut Watershed covers three administrative regions, namely Karo District, Deli Serdang Regency and Medan City. The upstream of Percut watershed located in Karo District and Deiserdang, while the middle and downstream area is located in the Medan. Identification of land use undertaken to gain information conformity human activity to potential and carrying capacity. The purpose of this research was undertaken to identify the type of land covers and evaluate the use of forest area in Percut Watershed using Sentinel 2 satellite imagery.

2 RESEARCH AREA DESCRIPTION AND METHODS

The study was conducted in the Percut watershed of North Sumatra Province. Field data collection was carried out in April 2018. Administratively the Percut watershed area included Karo Regency, Deliserdang Regency, and Medan City (Fig. 1).

The tool used in this study consisted of data collection tools and data analysis tools. Field data collection tools include global positioning system (GPS), compass, camera, and tally sheet. Image analysis is done using ESA SNAP and ArcGIS 10.5 software. Sentinel-2 satellite imagery used in this study was recorded in October 2017 and Digital Elevation Model (DEM) data used are from SRTM. The data used in this study are tabulated in Table 1.

Sentinel-2 imagery data was obtained free from the website www.scihub.copernicus.eu. The satellite imagery used in this study was recorded on October 19, 2017. There is no satellite imagery with good conditions of the study area that recorded in 2018 because of its large cloud cover.

Table 1: The source of data

| No	Data	Source
1.	Ground control point	GPS and digital cameras
2	Sentinel-2 Satellite imagery	www.scihub.copernicus.eu
3.	Indicative Map of Administrative Boundaries of Deli Serdang District	Central Bureau of Statistics
4.	Indicative Map of Administrative Boundaries of Medan City	Central Bureau of Statistics
5.	Indicative Map of Administrative Boundaries of Karo District	Central Bureau of Statistics
6.	Map of the North Sumatra provincial river network	Ministry of Environment and Forestry
7.	Map of Percut watershed boundary	Ministry of Environment and Forestry
8.	Map of North Sumatra Province Forest Area	Ministry of Environment and Forestry
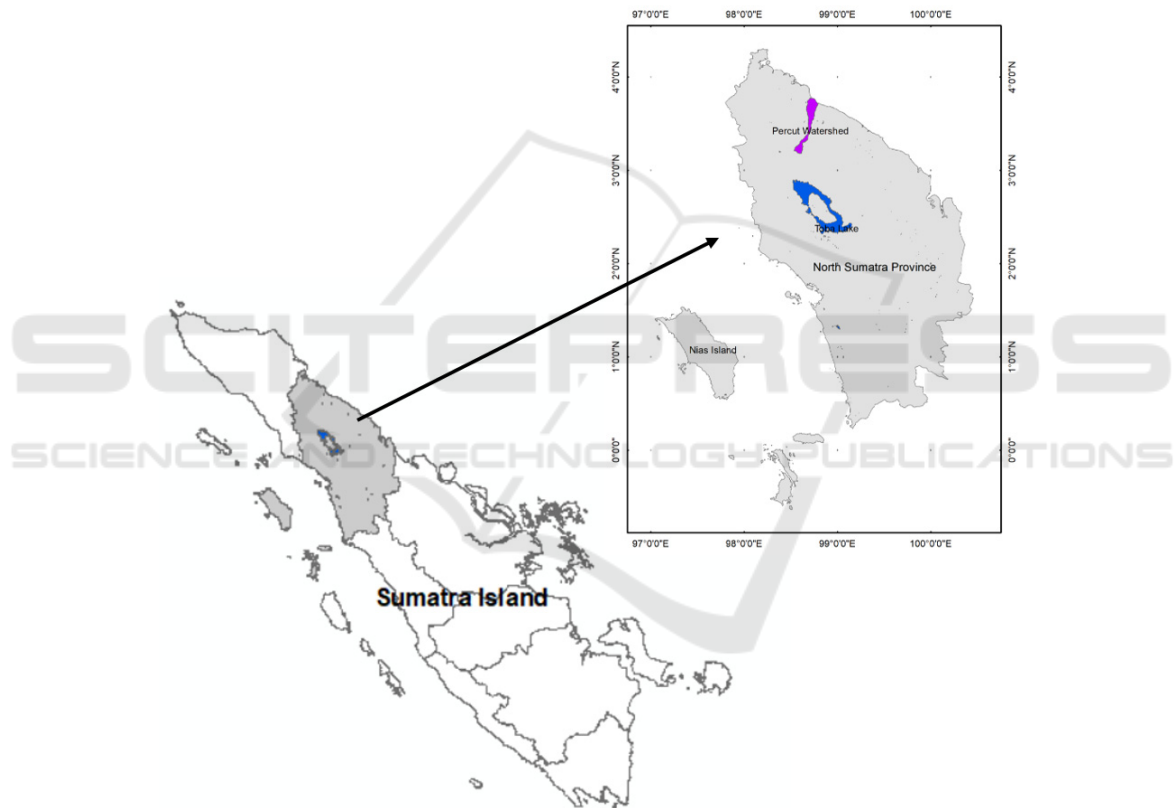
Figure 1: Map of Research location

Ground check data was obtained from direct observation in the field which includes documentation of the existing land cover, marking of ground control point positions in the field, as well as recording into the tally sheet. Data collection was carried out by a survey with taking into account the distribution of the land cover type in that area.

For the analysis of land cover, all bands in Sentinel-2 imagery were selected. All bands from Sentinel-2 imagery are composited together to create a composite band image. The image composite process was done with Arc Gis 10.3 software.

The next step is the image subset which cuts the image with the Percut watershed boundary. The

image cutting process is done with Arc Gis 10.5 software.

Land cover classification conducted by Supervised Classification method with an area of interest (AOI) reference to the results of GPS point taking in the Field. The method used to separate land cover classes is the maximum likelihood.

Separation analysis is an evaluation of the separability of training areas from each class whether a class is worthy of merging or not. In this study the method used is transformed divergence. Minimum value means that it cannot be separated, while the maximum value shows excellent separation.

Criteria for the level of separation between classes according to Jaya in (Jaya and Kobayashi, 1995) are as follows:

  a. Unseparable: < 1600
  b. Poor: 1600 - < 1800
  c. Fair: 1800 - < 1900
  d. Good: 1900 - < 2000
  e. Excellent: 2000

Accuracy testing was used to evaluate the accuracy of the land cover classification based on training area of each class. The accuracy was analysed using a contingency matrix or a confusion matrix. The calculated accuracy consists of the producer's accuracy, user accuracy, overall accuracy and kappa accuracy.

Analysis of the relationship between altitude and slope to land cover was done by making the class the altitude above sea level and the slope class. Altitude and slope generated from DEM image with spatial resolution 1 arc-second for global coverage (~ 30 meters). The DEM image was a free to download from website https://earthexplorer.usgs.gov/. Altitude was classified to be 5 class as shown in Table 2. The slope was classified to be 5 class as shown in Table 3.

Table 2: Classification of altitude

Class	Altitude (m asl)	Remark
I	0 - 300	Lowland
II	300 - 600	Lowland
III	600 - 900	Hills
IV	900 - 1200	Mountains
V	>1200	Mountains

Table 3: Slope classification

Class	Slope (%)	Remark
I	0-8	Flat
II	8-15	Sloping
III	15-25	Moderate
IV	25-45	Steep
V	>45	Extremely steep

3 RESULT AND DISCUSSION

Image classification in this study was divided into 14 classes, namely forests, gardens, rice fields, oil palm, shrubs, open area, dryland agriculture, settlements, mangroves, ponds, clouds, and cloud shadows. Field observations obtained 384 coordinate points of existing land cover. The land cover separability value in this study shows that all land cover classes have good and very good separations. The lowest separability value occurs between bushland and plantations which has a separability value of 1,841.06 (fair).

The results of accuracy obtained showed that user's accuracy of the plantation was the lowest that is 87.93%, while the highest value is in the cloud shadow that is equal to 100%. The lowest producer's accuracy was found in the plantation that is 86.44% while the highest value was found in forest land cover that is 99.81%. The value of overall accuracy obtained is equal to 97.11%, while the kappa accuracy is 96.52%. The results of this accuracy test indicate that the land cover classification was acceptable (Jaya and Kobayashi, 1995).

The dominant land cover in the Percut watershed is forests, gardens, settlements and oil palm plantations. The area categorized as a bush in the Percut watershed was found to be 6.29% of the total watershed area (Table 4). Oil palm plantations reach an area of 35,802.55 ha (10.44%). Dryland agriculture reaches an area of 32,638 ha (9.52%). Dryland forests and mangrove forest respectively covers about 95,562.78 ha and 5,215.78 ha or about 27.93% and 1.52% from the total area of the watershed. The percentage of forest area remains in the Percut watershed is 29.5%. This area is still below 30%, a minimum area of good watershed criteria suggested by Tarigan. (2018). The spatial distribution of land cover type in Percut Watershed as shown in Fig. 2.
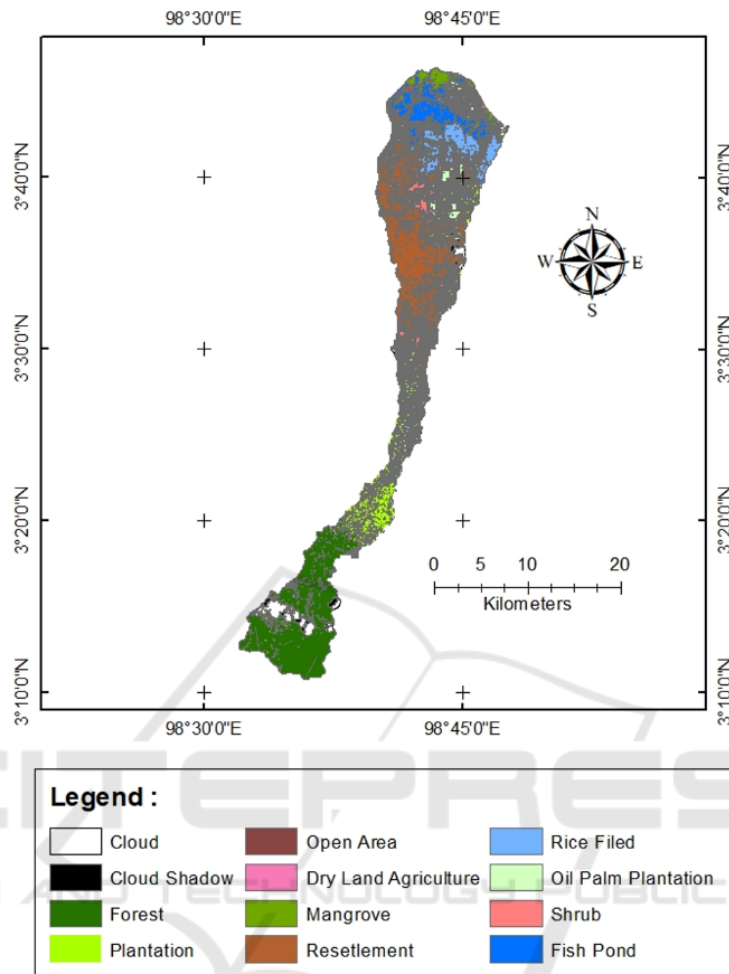
LANDCOVER MAP OF PERCUT WATERSHED

Figure 2. Land cover distribution in Percut Watershed

Table 4: Land cover in Percut Watershed based on Sentinel-2 Imagery

Land cover	Area	
	(hectares)	(%)
Cloud	8,497.61	2.47
Cloud shade	3,597.26	1.04
Forest	95,562.78	27.93
Plantation	66,418.38	19.38
Open area	3,257.63	0.95
Dry land agriculture	32,638.00	9.52
Mangrove	5,215.78	1.52
Resettlement	40,549.33	11.83
Rice field	18,890.51	5.51
Oil Palm	35,802.55	10.44
Shrub	21,562.89	6.29
Fish pond	10,707.05	3.12
Total	342,699.77	100.00

The upstream part of the Percut watershed at altitudes above 900 meters above sea level is still dominated by forests (Table 5). However, the percentage of forest area identified from Sentinel-2 image analysis is still less than 30% of the total area. This indicates that the Percut watershed categorized to the critical watershed. The large area of oil palm plantation must be followed by surface runoff management (Tarigan., 2016).

This study shows the existence of land use that not in accordance with its ability wherein slopes above 45% there is still found the land use for oil palm plantations in addition also found open areas and shrubs (Table 6). This condition tends to increase runoff and erosion coefficients, especially if the soil and water conservation techniques are not applied (Tarigan., 2016).

Based on the regulation of the Minister of

Environmental and Forestry No. SK.579/Menhut-II/2014 concerning Forest Areas in North Sumatra Province, we found the use of forest areas that not in accordance with their designation. Land use for oil palm plantations, rice fields, ponds and dryland agriculture in forest areas was found (Table 7). The main factor of forest conversion to oil palm plantations is an economic reason. Susanti and Maryudi (2016) Reported that the speed and the direction of land conversion to oil palm expansion in Indonesia were shaped by multiple factors. Development narratives and poverty alleviation have used by the various actor to build spaces and oil palm development opportunities. The actors were omitting the environmental services of forest to justify oil palm extension by forest conversion. The returns to oil palm are potentially high relative to other activities (Papenfus, 2000).

The use of forest areas that are not in accordance with their designation will lead to the degradation and criticality of the Percut watershed. Land conversions, especially from forest to others land use tends to increase the runoff coefficient of the watershed (Pradiko., 2015). The conversion of forests area to oil palm plantations would lead the soil erosion resulting in the loss of soil organic matter (Guillaume., 2015). Soil organic matter loss will trigger land degradation.

Table 5. Land cover based on elevation in Percut Watershed

Elevation (m Asl)	Land cover area (hectares)										
	Plantation	Open area	Rice field	Shrub	Fish pond	Mangrove	Resettlement	Dry land agriculture	Oil palm	Forest	Total
0-300	30,152.78	2,046.33	9,781.68	3,482.59	10,707.05	5,215.78	25,308.00	7,682.26	6,902.34	6,423.01	107,701.82
300-600	27,620.67	1,211.00	7,341.24	6,725.13			15,241.33	18,013.61	14,165.04	24,782.11	115,100.13
600-900	8,644.93		1,767.59	11,103.40				6,942.13	14,735.17	34,120.50	77,313.72
900-1200				251.77						28,352.21	28,603.98
>1200										1,883.95	1,883.95
Total	66,418.3	3,257.33	18,890.5	21,562.8	10,707.05	5,215.78	40,549.33	32,638.00	35,802.55	95,561.73	

	8		1	9						8	30,603.60

Table 6. Land cover based on slope class in Percut Watershed

Elevation (%)	Land cover area (hectares)										
	Plantation	Open area	Rice field	Shrub	Fish pond	Mangrove	Resettlement	Dry land agriculture	Oil palm	Forest	Total
0 - 8	30,570.33	1,257.63	7,426.08	8,152.78	10,707.05	5,215.78	16,931.22	6,001.04	2,407.49	7,583.61	96,253.01
8 - 15	28,207.46	1,103.57	8,112.78	6,689.73			16,861.39	26,118.34	19,638.50	9,455.81	116,187.58
15 - 25	7,199.86	420.12	3,267.21	4,413.70			6,462.40	266.21	4,433.70	15,324.73	41,787.93
25 - 45	441.06	311.67		1,321.43			454.96		5,312.41	21,836.31	29,677.84
> 45		164.64		1,002.67					1,572.31	37,320.87	40,060.49
Total	66,418.71	3,257.63	18,806.07	21,580.31	10,707.05	5,215.78	40,709.97	32,385.59	33,364.41	91,521.33	323,966.885

Table 7. The use of forest area in Percut Watershed

Forest Area	Land cover area (hectares)										
	Forest	Mangrove	Open area	Dry land agriculture	Plantation	Residential	Rice field	Oil palm	Shrub	Fish pond	Total
Protected Forest		342	7	7	39	16	53	20	49	248	781
Production Forest			1	369	4	9	181	174	6		745
Limited Production Forest		314	2		2	1	16		1	174	510
Conservation Forest	5			105	8		7				125

Total	5	656	10	481	53	26	257	194	56	422	2,160

4 CONCLUSIONS

Sentinel-2 satellite imagery is very helpful for identifying the land cover and the use of forest areas in the Percut watershed. The identified forest cover is still less than 30% of the watershed area. Land use was found that was not in accordance with its allocation, especially in slopes above 45% which were used as oil palm plantations.

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