LAPAN-A3 SATELLITE DATA ANALYSIS FOR LAND COVER CLASSIFICATION (CASE STUDY: TOBA LAKE AREA, NORTH SUMATRA)

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Received: 6 November 2017; Revised: 11 May 2018; Approved: 22 June 2018

Abstract. LAPAN-A3 is the 3rd generation satellite for remote sensing developed by National Institute of Aeronautics and Space (LAPAN). The camera provides imagery with 15 m spatial resolution and able to view a swath 120 km wide. This research analyzes the performance of LAPAN-A3 satellite data to classify land cover in Toba Lake area, North Sumatera. Data processing starts from the selection of region of interest up to the assessment of accuracy. Supervised classification with maximum likelihood approach and confusion matrix method was applied to classify and evaluate the assessment results. The land cover is classified into five classes; water, bare land, agriculture, forest and secondary forest. The result of accuracy test is 93.71%. It proves that LAPAN-A3 data could classify the land cover accurately. The data is expected to complement the need of the satellite data with medium spatial resolution.

Keywords: *LAPAN-A3 micro satellite, land cover, pixel-based classification*

1 INTRODUCTION

The LAPAN-A3 satellite, also known as LAPAN-IPB, is a third-generation satellite created by LAPAN as a successor of two previous satellites, LAPAN-A2 (LAPAN-Orari) and LAPAN-A1 (LAPAN-Tubsat) were launched on June 22, 2016, from the Institute of Aeronautics and Space Satish Dhawan Sriharikota, India. This satellite has a weight of about 115 kg, so it can be categorized as a mini satellite because it weights between 100 kg to 1000 kg (Sandau and Brieb 2008). Small satellite technology, which is a satellite weighing between 1 kg to 1000 kg, has been pioneered since the 1980s and continues until today. In general, this technology is widely used by countries that have just developed space technology and have limited experiences and cost (Xue *et al.* 2008). Payloads on small satellites can be adjusted to the missions that will be achieved and with many kinds of utilized potential including remote sensing applications such as land cover classification (Qian 2008), identification of agricultural, coast and urban areas (Laguarde *et al.* 2010), monitoring such as cyclones, floods, droughts and landslides (Sandhu and Brieb 2008; Xue *et al.* 2008), volcanic activity (Blackett 2017) and earthquake detection and monitoring (Chmyrev *et al.* 2013).

As the first experimental satellite devoted to remote sensing, LAPAN-A3 has the following missions: (a) Earth monitoring in particular the covered classification and utilized of agricultural land and environmental monitoring; (b)

http://dx.doi.org/10.30536/j.ijreses.2018.v15.a2782

monitoring of ships using AIS (Automatic Identification System) technology and (c) scientific mission related to the measurement of the earth's magnetic field. Equipped with a multispectral Line Imager Space Application (LISA) sensor capable of recording data into four bands. The satellite is capable of producing images with a spatial resolution of 15 m and a swath 120 km wide (Satellite Technology Center 2017). The spatial resolution in LAPAN-A3 is categorized as well as medium resolution on Landsat-8, with a resolution of 30 m (multispectral) and 15 m (panchromatic). The sensor characteristics of LAPAN-A3 and Landsat-8 is compared in Table 1-1. The table also shows that the wide of the spectrum in each corresponding band has a similarity thus the Landsat-8 data application is expected to be adopted in the LAPAN-A3 data. Zylshal *et al.* (2017) in the previous study has also found moderate correlation about 0.65 between LAPAN-A3 and Sentinel-2A spectral. Indonesia geographic position is in the tropics and between two oceans are potentially occurred an extreme weather such as cloud cover and high rainfall or drought that trigger smoke hazed from forest fires can limit the performance of optical-based remote sensing satellites. The LAPAN-A3 data is expected to be complementary to Landsat-8 data as well as medium resolution data from other operational satellites. A previous study of LAPAN-A2 shows that the accuracy obtained in the identification of urban land cover (case study of Semarang, Central Java) when the satellite is in off-nadir position reaches more than 60%, both using visual interpretation (Nugroho *et al.* 2017a) or digital classification (Nugroho *et al.* 2017b).

Some studies of Landsat-8 data utilization that can be applied to LAPAN-A3 such as visible spectrum and NIR related to a rice growth phase (Suwargana and Manalu 2017), monitoring of lake ecosystem (Trisakti *et al.* 2014), mapping of burned areas (Suwarsono 2014), identification and monitoring of mangroves (Widagti *et al.* 2011) and identification of oil palm tree and forest areas (Torbick *et al.* 2016).

Table 1-1: Comparison of LAPAN-A3 and Landsat-8 characteristics

LAPAN-A3*		**Characteristics**	**Landsat-8****	
21 days		Temporal	16 days	
15 m		Resolution	30 m (multispectrals)	
16 bit		Spatial Resolution	12 bits	
		Radiometric		
		Resolution		
		Spectral Resolution		
λ	**Resolution**	**Band**	**λ**	**Resolution**
		1	0.435-0.451	30 m Coastal/Aerosol
0.41-0.49	15 m Blue	2	0.452-0.512	30 m Blue
0.51-0.58	15 m Green	3	0.533-0.590	30 m Green
0.63-0.70	15 m Red	4	0.636-0.673	30 m Red
0.77-0.90	15 m NIR	5	0.851-0.879	30 m NIR
		6	1.566-1.651	30 m SWIR-1
		7	2.107-2.294	30 m SWIR-2
		8	0.503-0.676	15 m Pan
		9	1.363-1.384	30 m Cirrus
		10	10.60-11.19	100 m TIR-1
		11	11.50-12.51	100 m TIR-2
100 km		Swath wide	185 km	
505 km		Height/Altitude	705 km	

Source: * Satellite Technology Center (2017)
** NASA (2017)

Monitoring of land cover around forests is also necessary because forests have an important role in human life. Furthermore as the world's lungs and the habitat for the forest area flora-fauna it also has an important role as the catchment area. The over function of forest into fields, rice fields, and settlements will have an impact on the degradation of environmental quality. For example, the land forest in the Lake Toba region of North Sumatra has decreased significantly from 28% of the total river basin (78,558 ha) in 1985 only became 12% in 2012 (Ministry of Environment Republic of Indonesia 2014). This study is aimed to evaluate the quality of LAPAN-A3 data in identifying land cover in Lake Toba, North Sumatra. The results of this study are expected to be input for LAPAN satellite technology program.

2 MATERIALS AND METHODOLOGY

2.1 Location and Data

This research used LAPAN-A3 satellite data acquired on January 6, 2017. The selected of the study was the Lake Toba, North Sumatera with latitude coordinates 2°41'20.77"N - 2°31'48.53"N and longitude 98°37'52.69"E - 98°48'12.81"E (Figure 2-1). Lake Toba itself is the largest lake in Southeast Asia and is a volcano-tectonic lake that formed about 75,000 years ago. The topography of Lake Toba river basin is dominated by hills and mountains (Ministry of Environment Republic of Indonesia 2014). For the comparison that used Landsat-8 data which was also acquired on January 9, 2017. The band Landsat-8 used 2345 adapted to the band in LAPAN-A3. The status of the data has been corrected geometrically. The LAPAN-A3 satellite data is obtained from Satellite Technology Center, LAPAN meanwhile Landsat-8 data is obtained from Technology and Data Center, LAPAN. The land cover map of North Sumatera Province that sourced from Landsat satellite was used as supporting data.

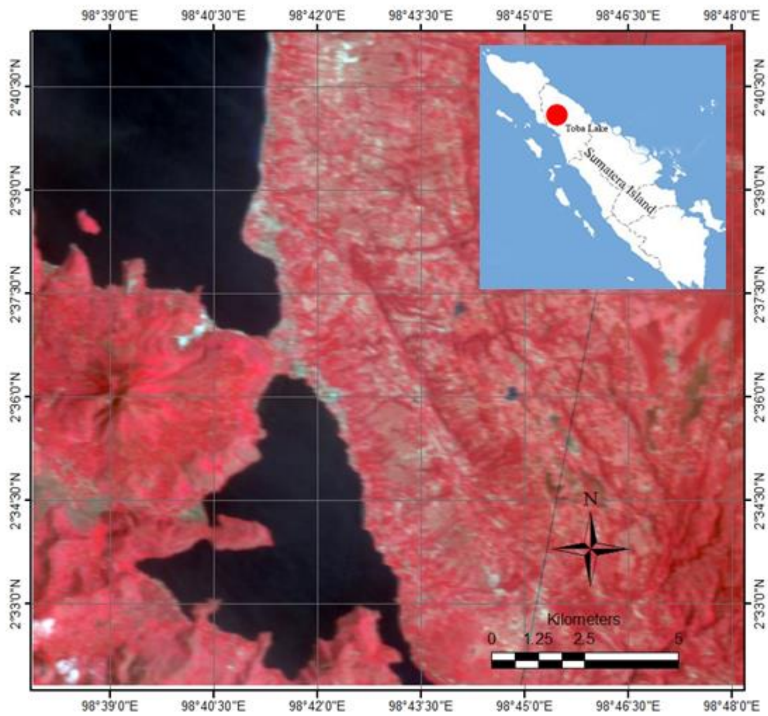


Figure 2-1: Research sites in the area of Lake Toba, North Sumatra derived from LAPAN-A3 satellite image (composite 423)

2.2 Methods

Phases of the research include the selection of a region of interest (ROI), classification of land cover, calculation accuracy and also analysis. The ROI selection is mainly based on the relative cloud-free condition of both data and around 20 km in size. The method classification of the data that is chosen is the slide classification method with the maximum likelihood approach. This method is defined as a digital image classification method that classifies of surface features based on the spectral value of each pixel in which the land cover class is determined by selecting visual sample training for each object (Rujoiu-Mare and Mihai 2016). This pixel-based classification has been commonly used in medium-resolution data where the potential for salt and pepper is not too large. To improve the accuracy of the selected area training is used supporting data in the form of land cover map of North Sumatra Province which is sourced from Landsat image. The determination of the object class in the LAPAN-A3 data is then the reference for class determination of Landsat-8 data.

After built the training data to generate a classification model then tested using test data to obtain the accuracy. Transformed Divergence (TD) method is applied to evaluate the quality of spectral separability between selected ROI. Overall accuracy and Kappa coefficient (κ) calculate with the following equation 2-1 and 2-2.

Where k is k categories in the remotely sensed classification, n_{ii} is diagonal elements in the error matrix and n is total number of samples in error matrix. The calculation results of the accuracy of the two data will then be compared with each other in order to make the analysis. From the total pixels for each class can also be calculated the value of producer's accuracy (omission error) which is defined as the ratio of right pixels to the total number of sample training pixels per class and the user's accuracy (commission error), the number of ratios between true pixels and total pixels for reference data. The flowchart used in this study is shown in Figure 2-2.

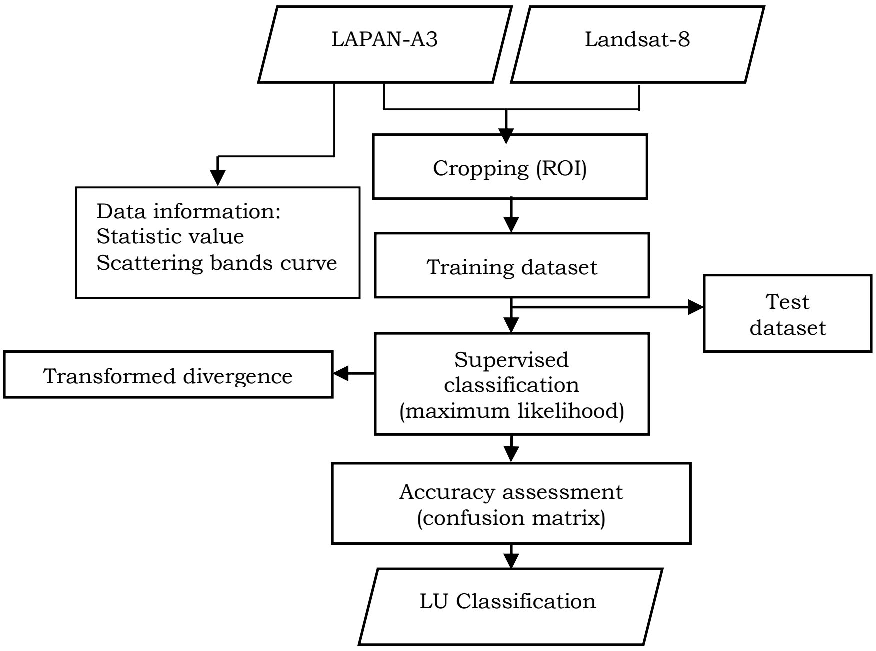


Figure 2-2: The flowchart of the research

$$Overall\ accuracy = \frac{\sum_{i=1}^{k} n_{ii}}{n} \quad \text{2-1}$$

$$\kappa = \frac{n\sum_{i=1}^{k} x_{ii} - \sum_{i=1}^{k} n_{i+}n_{+1}}{n^2 - \sum_{i=1}^{k} n_i n_{+1}} \quad \text{2-2}$$

3 RESULTS AND DISCUSSION

The minimum, maximum, mean and standard deviation value as basic statistics information of LAPAN-A3 data is shown in Table 3-1. Figure 3-1 shows the scatter plot curve of LAPAN-A3 bands.

The LAPAN-A3 was classified into five classes: (1) water, (2) bare land, (3) agriculture, (4) forest (*hutan tanaman*) and (5) secondary forest refer to land cover map of North Sumatera. Table 3-2 shows the spectral separability calculation of selected ROI. Both the Jeffries-Matusita and Transformed Divergence separability measures are applied. Values greater than 1.9 in Table 3-2 indicate that the ROI pairs have good separability. Similar results are found in Landsat-8 data where the value of TD obtained is greater than 1.9.

Table 3.1: Basic statistics of LAPAN-A3 data

Basic Statistics	Min	Max	Mean	Standard Deviation	Coefficient of Variation (%)
Band 2 (Blue)	3708	17081	5463.8	664.8	12.2
Band 3 (Green)	12682	46854	17346.4	2245.3	12.9
Band 4 (Red)	8182	48463	13792.3	3260.7	23.6
Band 5 (NIR)	4524	38214	19799.0	7273.2	36.73

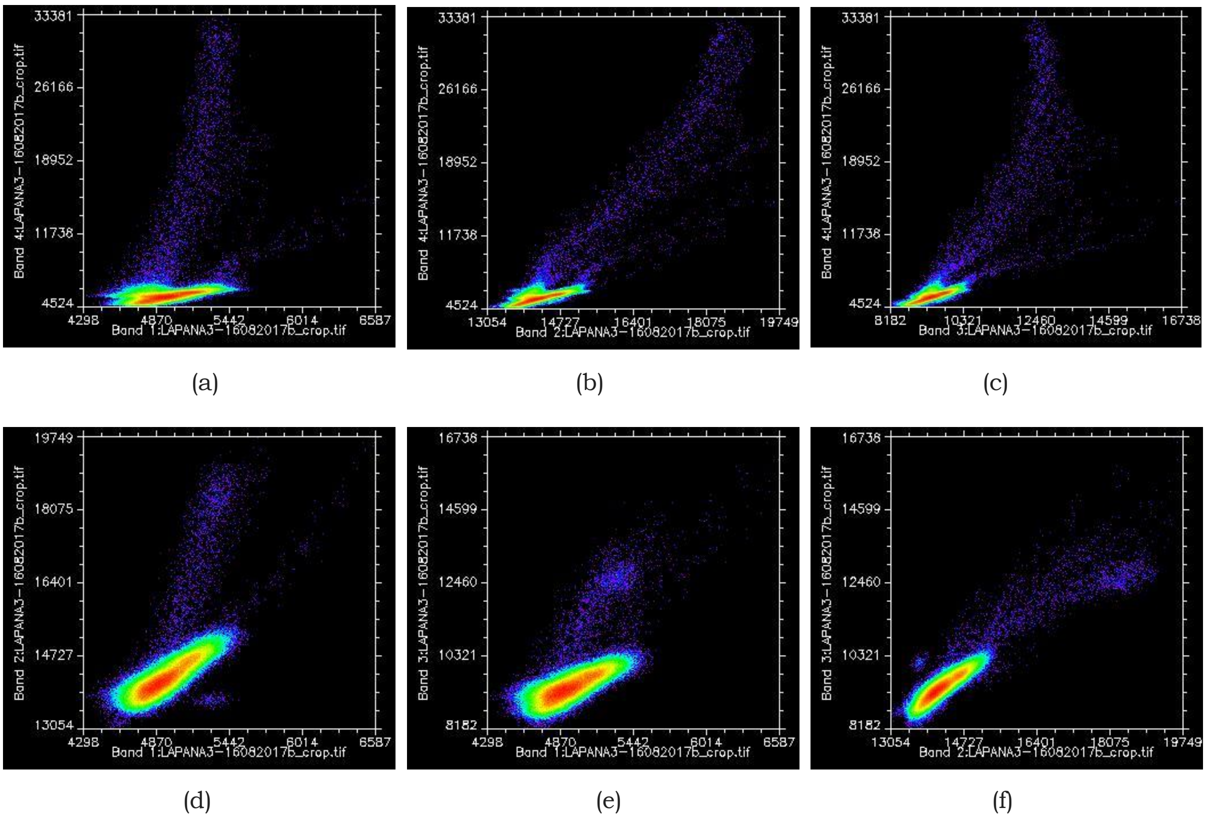
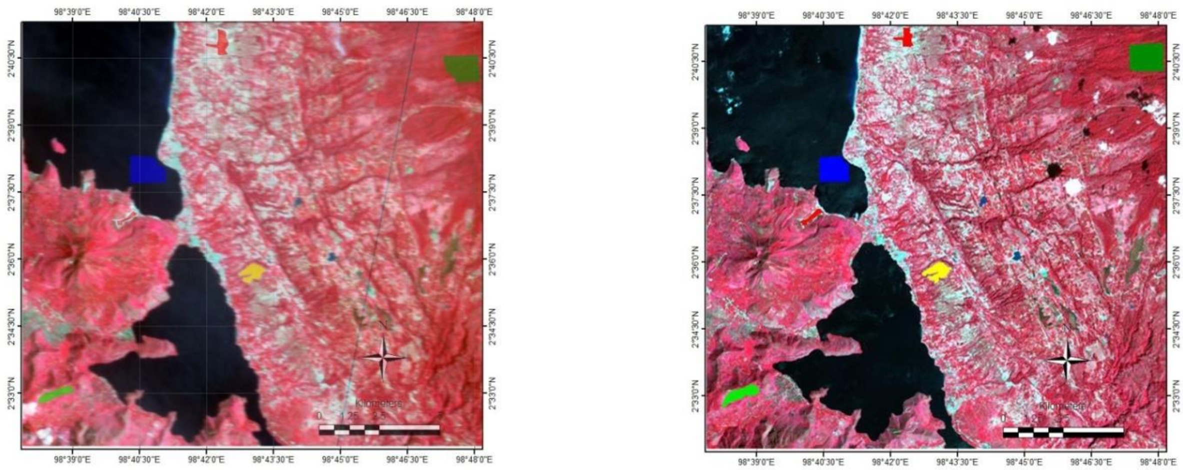


Figure 3-1: Bands scattering curve of LAPAN-A3 (a) NIR vs Blue, (b) NIR vs Green, (c) NIR vs Red, (d) Blue vs Green, (e) Blue vs Red and (f) Green vs Red

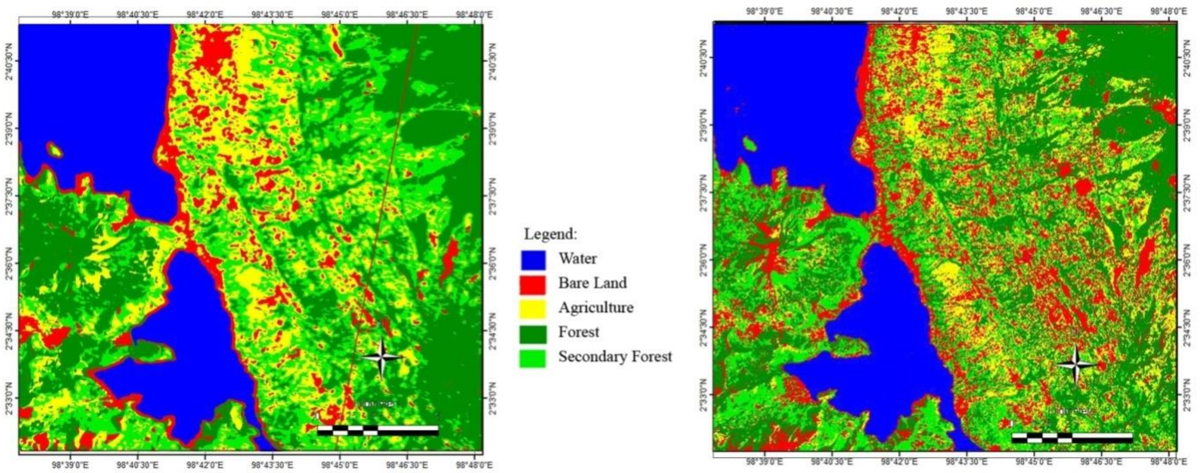
Table 3-2: Transformed divergence test result

Classes	Transformed Divergence (x10^{-2})				
	Water	**Bare land**	**Agriculture**	**Forest**	**Secondary Forest**
Water		200	200	200	200
Bare land	200		200	200	200
Agriculture	200	199		200	200
Forest	200	200	200		199
Secondary forest	200	200	199	199	



(a) (b)

Figure 3-2: Appearance of test data made for each class on the image (a) LAPAN-A3 and (b) Landsat-8 (composite 423)



(a) (b)

Figure 3-3: Maximum likelihood is guided classification results for data (a) LAPAN-A3 and (b) Landsat-8.

Figure 3-2 displays the test data that is created for each class, both in (a) LAPAN-A3 and (b) Landsat-8 images. The colors blue, red, yellow, dark green and light green are consecutive of test data represent water classes, bare land, agriculture, forest (hutan tanaman) and secondary forests. Results of the classification are inserted with the maximum likelihood approach are displayed in Figure 3-3 for each image (a) LAPAN-A3 and (b) Landsat-8. It is obviously in Figure 3-2 (a) the stripping noise that is suspected to be due to internal errors in the system (sensor). Generally, this error is systematic (predictable) so it is possible to be identified and corrected using calibration results (previous to launched and periodic). Table 3-3 as details as the results of the calculation of land cover classification accuracy in the Lake Toba area of LAPAN-A3 data using the confusion matrix method. Overall accuracy that obtained is 93.71% with the Kappa coefficient of 0.91. Correct pixels for water classes, bare land, agriculture, and forest reach more than 90%. As a record for secondary forest classes, the correct pixel value is relatively low (less than 50%) and more dominantly classified as agricultural class. It can be understood that in secondary forests, defined as forest areas that have been exploited or even damaged, land conversion has taken place and one of them is agriculture.

Blurring effect in LAPAN-A3 image is assumed to be the cause of the boundary between objects is illegal so that the possibility of mixed pixels, especially on the boundary between objects increases and ultimately affect the spectral value of the pixel (Sari *et al.* 2017). Blurring effect may cause the ability in separating spectral (spatial separability) of land cover class becomes non-optimal. Limitations of bands owned. LAPAN-A3 has a limitation band that makes the capability to identify the variety of the objects, especially in ROI's analysis which also to be reduced. Compared to Landsat-8 data the overall accuracy of 95.46% of the land cover which is obtained with the Kappa 0.93 coefficient as display in Table 3-3. Correct pixels for the whole class reaches more than 80% and for the water class accuracy reaches 100%. These results prove that Landsat-8 data is excellent and consistent in identifying land cover classes. This result corresponds to previous research where the accuracy of classification of forest land cover using Landsat data is in the range of 72% to 97% (Sader *et al.* 1995; Wilson and Sader 2002; Souza *et al.* 2013).

In this study, the number of classes to be classified is adjusted to the potential of LAPAN-A3 data capability in identifying objects by considering the limitations of the bands so that the results that obtained have not yet optimized all the capabilities of Landsat-8 in classifying the object cover and land used. Further studies related to the identification of land used cover and the addition of the number of classes in different study areas needs to be done to find out how far the ability to classify objects in LAPAN-A3 and Landsat-8 data although as a consequence will decrease the accuracy of value. The difference in the accuracy value between the two data of 1.7% proves that with the limited band LAPAN-A3 data is able to provide a relatively equivalent level of accuracy with Landsat-8.

Table 3-3: Accuracy calculation results of land cover of Lake Toba area for LAPAN-A3 data (%)

Class	Water	Bare land	Agriculture	Forest	Secondary forest	Total (%)
Water	100	0	0	0	0	33.47
Bare land	0	100	0	0	0	12.52
Agriculture	0	0	99.92	0	56.05	16.59
Forest	0	0	0	100	1.89	32.86
Secondary forest	0	0	0.08	0	42.07	4.56
Total (%)	100	100	100	100	100	100

Overall accuracy: 93.71%
Kappa coefficient: 0.91

Table 3-4: Results of land cover accuracy for Landsat-8 data (%)

Class	Water	Bare land	Agriculture	Forest	Secondary forest	Total (%)
Water	100	0	0	0	0	27.77
Bare land	0	89.6	3.79	0.17	2.61	10.97
Agriculture	0	10.22	94.58	0	7.99	13.03
Forest	0	0	0	99.66	8.91	37.15
Secondary forest	0	0.18	0.18	0.17	80.49	11.07
Total (%)	100	100	100	100	100	100

Overall accuracy: 95.46%
Kappa coefficient: 0.93

Table 3-5 shows the comparison of producer's and user's accuracy for LAPAN-A3 and Landsat-8 data. Table 3-2 shows the divergence test result of separation between classes using transformed divergence method.

In this research, the training data that used to classify land cover extracted from the image itself rather than imported from another data in order to reduce the discrepancies in terms of radiant quantities of incidence and reflections from two different acquired data (Lu *et al.* 2003; Li *et al.* 2013). Therefore, the field measurement is needed to validate the accuracy result.

Table 3-5: Comparison of producer's accuracy and user's accuracy LAPAN-A3 and Landsat-8

Class	Producer's Accuracy		User's Accuracy	
	LAPAN-A3	Landsat-8	LAPAN-A3	Landsat-8
	%	%	%	%
1	100	100	100	100
2	100	89.6	100	92.29
3	99.92	94.58	63.41	82.91
4	100	99.66	99.38	96.78
5	42.07	80.49	99.81	97.58

4 CONCLUSIONS

The LAPAN-A3 data could provide the accuracy value of land cover classification over Lake Toba area of North Sumatra, which was 93.71% (Kappa coefficient of 0.91). Further research is needed to explore deeply the potential of LAPAN-A3 data in classification, identification of geophysical parameters and to find out the most suitable processing methods so that they can be utilized as a complement to other medium resolution satellite data, such as Landsat-8. The results which obtained from this study are also expected to be used as a reference for the development of LAPAN satellite technology program.

ACKNOWLEDGEMENT

The authors would like to Satellite Technology Center as data provider.

REFERENCES

Blackett M., (2017), An Overview of Infrared Remote Sensing of Volcanic Activity. Journal of Imaging. Vol 3 (13), 1-24. doi:10.3390/jimaging3020013.

Chmyrev V., Smith A., Kataria D., *et al.*, (2013), Detection and monitoring of earthquake precursors: TwinSat, a Russia–UK satellite project. Advances in Space Research 52: 1135–1145.

Laguarde JP, *et al.*, (2010), Combining high spatial resolution and revisit capabilities in the thermal infrared: the MISTIGRI Mission Project. Paper presented at the 30th EARSeL Symposium Remote Sensing for Science, Education, and Natural and Cultural Heritage UNESCO, Paris (France).

Li G., Li X., Li G., *et al.*, (2013), Comparison of spectral characteristics between China HJ1-CCD and landsat 5 TM imagery. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing. Vol. 6(1): 139–48.

Lu D., Mausel P., Brondízio E., Moran E., *et al.*, (2003), Change detection techniques. International Journal of Remote Sensing. 25(12): 2365–407. doi.org/10.1080/0143116031000139863.

Ministry of Environment Republic of Indonesia, (2014), Gerakan Penyelamatan Danau (GERMADAN) Toba (Rescue Action of Lake (GERMADAN) Toba).

NASA, (2017) https://landsat.gsfc.nasa.gov/landsat-data-continuity-mission/. Accessed 13 September 2017.

Nugroho JT, *et al.*, (2017a), Performance of LAPAN-A2 Satellite Data to Classify Land Cover/Land Use in Semarang, Central Java. Paper presented at the 3rd International Symposium on LAPAN-IPB Satellite: For Food Security and Environment Monitoring, Bogor, Indonesia.

Nugroho JT, Zylshal, Sari NM, *et al.*, (2017b), A Comparison of Object-Based and Pixel-Based Approaches for Land Use/Cover Classification Using LAPAN-A2 Microsatellite Data. International Journal of Remote Sensing and Earth Sciences. Vol. 14 (1), 27-36.

Qian W., (2008), Research on "Beijing 1" micro-satellite image quality and land use classification precision. Paper presented at the International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences XXXVII, B1, 941-944.

Rujoiu-Mare MR, Mihai BA, (2016), Mapping land cover using remote sensing data and GIS techniques: A case study of Prahova Subcarpathians. Procedia Environmental Sciences, 32, 244-255.

Sader SA, Ahl D., Liou W., (1995), Accuracy of landsat-TM and GIS rule-based methods for forest wetland classification in Maine. International Journal of Remote Sensing of Environment. Vol. 53 (3): 133-144.

Sandau R., Brieb K., (2008), Potential for advancements in remote sensing using small satellites. Paper presented at the International archives of the Photogrammetry, remote sensing and spatial information sciences. Vol. XXXVII Part B1, Beijing.

Sari NM, Chulafak GA, Zylshal., *et al.*, (2017) The Relationship between the Mixed Pixel Spectral Value of Landsat 8 OLI Data and LAPAN Surveillance Aircraft (LSA) Aerial-Photo Data. Forum Geografi, 31(1), 83-98.

Satellite Technology Center, (2017), Pusteksat.lapan.go.id/subblog/pages/2016/39/Spesisikasi-Teknis-Satelit-LAPAN-A3. Accessed 13 September 2017

Souza CMJr, Siqueira JV, Sales MH, *et al.*, (2013), Ten-Year Landsat Classification of Deforestation and Forest Degradation in the Brazilian Amazon. International Journal of Remote Sensing. Vol. 5 (11): 5493-5513. doi:10.3390/rs5115493.

Sulma S., Nugroho JT, Zubaidah A., *et al.*, (2016), Detection of Green Space Using Combination Index of Landsat 8 Data (Case Study: DKI Jakarta). International Journal of Remote Sensing and Earth Sciences, 13 (1), 1-8.

Suwargana N., Manalu J., (2017), Kalibrasi Reflektansi Data Landsat 8 dengan Menggunakan Alat Spektrometer (Calibration of Landsat 8 Data Reflectance by Using Spectrometer Tool). Pemanfaatan Data Penginderaan Jauh untuk Pertanian dan Kehutanan, IPB Press.

Suwarsono, (2014), Deteksi Daerah Bekas Kebakaran Hutan/Lahan (Burned Area) Menggunakan Citra Penginderaan Jauh, Suatu Tinjauan. Bunga Rampai Pemanfaatan Data Penginderaan Jauh untuk Mitigasi Bencana (Detecting of Burned Area Using Remote Sensing Image, an Overview). Remote Sensing Application for Disaster Mitigation, LAPAN.

Trisakti B., *et al.*, (2014), Pemanfaatan Data Penginderaan Jauh untuk Memantau Parameter Status Ekosistem Perairan Danau (Studi Kasus: Danau Rawa Pening) (Utilization of Remote Sensing Data to Monitor Parameter Status of Lake Lake Ecosystem (Case Study: Rawa

Pening Lake)). Paper presented at Seminar Nasional Penginderaan Jauh, Bogor, Indonesia.

Torbick N., Ledoux L., Salas W., *et al.*, (2016), Regional Mapping of Plantation Extent Using Multisensor Imagery. International Journal of Remote Sensing. Vol. 8 (236): 1-21. doi:10.3390/rs8030236.

Widagti N., (2011), Changes in Density of Mangrove Forest in Nusa Lembongan , Bali. Paper presented at the 2nd CReSOS International Symposium on South East Asia Environmental Problems and Satellite Remote Sensing, Bali, Indonesia.

Wilson EH, Sader SA, (2002), Detection of forest harvest type using multiple dates of Landsat TM imagery. International Journal of Remote Sensing of Environment. Vol. 80 (3): 385-396.

Xue Y., (2008), Small satellite remote sensing and applications – history, current and future. International Journal of Remote Sensing 29 (15): 4339–4372.

Zylshal *et al.*, (2017), Comparison of Spectral Characteristic between LAPAN-A3 and Sentinel-2A. Paper presented at the 5th Geoinformation Science Symposium. University of Gajah Mada, Yogyakarta.