IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

Analysis of Vegetation Indices Using Metric Landsat-8 Data to Identify Tree Cover Change in Riau Province

IOP Conf. Series: Earth and Environmental Science **280** (2019) 012013 doi:10.1088/1755-1315/280/1/012013

Analysis of Vegetation Indices Using Metric Landsat-8 Data to Identify Tree Cover Change in Riau Province

T Kartika[1], S Arifin[1], I L Sari[2], A Tosiani[3], R Firmansyah[4], Kustiyo[2], I Carolita[1], K Adi[2], A F Daryanto[3] and Z Said[4]

[1]Remote Sensing Application Center LAPAN, Jakarta, 13710
[2]Remote Sensing Data and Technology Center LAPAN, Jakarta, 13710
[3]Ministry of Environment and Forestry Indonesia, Jakarta, 10270
[4]World Resources Institute Indonesia, Jakarta, 12160

Email: tatik.kartika@lapan.go.id

Abstract. Landsat-8 has various channels that function to identify an object. The vegetation index algorithm which is based on remote sensing involves several bands and can describe the percentage of canopy and density of vegetation. More than 100 vegetation index algorithms and each can be used in accordance with the research objectives. In this paper we will discuss the utilization of Landsat-8 metric data with the parameters of Normalized Difference Vegetation Index (NDVI) and Normalized Burn Ratio (NBR) and several parameters in metric data with various features to produce indications of rapid land change, especially to detect changes in tree cover area to lose tree cover and vice versa. For this purpose, the annual Landsat-8 metrics data is located in Riau Province. To compare both NDVI and NBR parameters, the trial and error method is used and the results are compared visually to the two different images of the year. The result is that the NBR parameters with a maximum-70 feature and the threshold for tree cover loss and tree cover gain respectively more than -0.1 provide tangible results in looking at the tree cover changes in Riau Province. In the analysis, other information is needed, for example, a map of the Forest Area to see further whether the changes that occur are in the forest area or not, which will certainly provide different treatment.

1. Introduction

The Landsat-8 remote sensing data, which were launched in 2013, have a temporal resolution of 16 days, therefore approximately 23 data will be produced annually. Considering the high volume of data, its utilization shall be optimized, among others by establishing metric data in the form of the annual time series data made based on layers with various parameters such as Red, Green, Blue, Normalized Difference Vegetation Index (NDVI), Normalized Burn Ratio (NBR), NIR, SWIR, etc. A feature is made in each of these parameters, among others: minimum, maximum, mean, median, regression, standard deviation, etc. Therefore, if the metric data have 7 parameters and each parameter has 7 features, a total of 49 data will be ready for analysis depending on the research objective.

Law Number 21 of 2013 concerning Space Activities states that the Agency is obliged to provide cloud-free remote sensing data and establish standardization of national remote sensing processing methods. To achieve this, a research was conducted to identify rapid land cover change, the results could be used as references and used to support the updating of annual land use and land cover which are one of the responsibilities of the Indonesian Ministry of Environment and Forestry (MoEF).

Therefore, in this case, LAPAN provides annual mosaic Landsat data and metric Landsat data. LAPAN also jointly conducts research to obtain information on indications of land cover change, especially changes in tree cover area that will help identify changes in land cover.

Information on changes in land cover is considered to be very important information in supporting sustainable national development in Indonesia. Remote sensing technology refers to technology that has good temporal and spatial resolution for rapid acquisition with broad coverage, and has spectral resolution with certain characteristics that are able to identify the conditions of objects on the surface of the earth [1, 2, 3].

From the description above, by utilizing the availability of Landsat-8 data, this research aims to determine the model for the rapid identification of land cover changes using Landsat-8 metric data to obtain indications of tree cover changes. The output is information on tree cover loss, tree cover gain, and unchanged land. Tree cover loss is the removal of tree canopy due to human or natural causes, including fire and it does not always equal with deforestation [4]. Tree cover gain refers to an increase in vegetation canopy in an area as a result of human intervention or natural growth. Information about tree cover changes can be applied to identify devegetation and revegetation.

Large areas are difficult to monitor conventionally, because they are considered ineffective and efficient. One of the steps for identifying sustainable land use changes in a large area is by utilizing remote sensing technology. Based on temporal and spectral resolutions, remote sensing data can be used to extract several geo-biophysical parameters. The parameters used in this research are NDVI and NBR. Hansen [5] states that from the collection of composites, a number of metrics are calculated for each band and NDVI. These characterize vegetation attributes such as greenness, phenology and surface temperature. In an iterative process with linear model trees, metrics are retained or eliminated based on their predictive ability. Therefore, the metric method is the right method for operational issues and consistency issues.

2. Material and Method

2.1. Study Area

The study area is Riau province, considering that this province has dynamic land use changes which are partly due to the fact that Riau is prone to forest fires [6, 7]. Riau Province is one of the richest regions of Indonesia in terms of natural resources, especially forests. However, another factor causing a dynamic land use change in this province is the rampant deforestation which has significantly reduced its forest area. Land conversion also takes place at a significant scale, with an average of 160,000 hectares of forest being cleared every year [8].

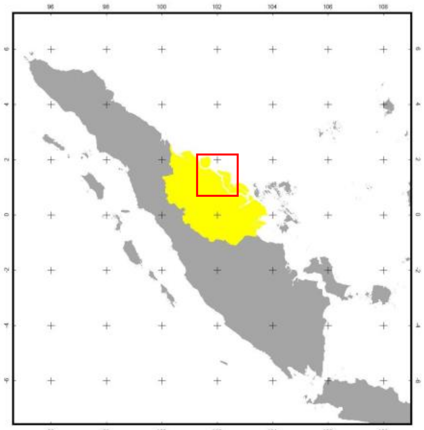


Figure 1. Study area in Riau Province in Sumatera Island Indonesia

The total area for Riau province is 87,023.66 km², which stretches from the slopes of the Bukit Barisan to the Strait of Malacca. Riau has a wet tropical climate with average rainfall ranging between

2000-3000 millimetres per year, and the average rainfall is approximately 160 days per year. Riau is currently one of the richest provinces in Indonesia and is rich in natural resources, particularly petroleum, natural gas, rubber, palm oil, and fibres plantations. Extensive logging and plantation development in Riau has led to a massive decline in forest cover, and associated fires have contributed to haze across the larger region. The study area is shown in red box in figure 1.

2.2. Data
The data used in this research are the Landsat-8 metric data (two years data) for Riau Province, the first data are the data for 2016 and 2017 while the second data is the data for July 2016-June 2017 and July 2017-June 2018. The characteristics of the Landsat-8 data are shown in Table 1.

Table 1. Landsat-8 characteristics

Band	Wavelength	Useful for mapping	Resolution (m)
Band 1 – Ultra Blue (Coastal Aerosol)	0.435 - 0.451	Coastal and aerosol studies	30
Band 2 – Blue	0.452 - 0.512	Bathymetric mapping, distinguishing soil from vegetation, and deciduous from coniferous vegetation	30
Band 3 – Green	0.533 - 0.590	Emphasizes peak vegetation, which is useful for assessing plant vigor	30
Band 4 – Red	0.636 - 0.673	Discriminates vegetation slopes	30
Band 5 - Near Infrared (NIR)	0.851 - 0.879	Emphasizes biomass content and shorelines	30
Band 6 - Short-wave Infrared (SWIR) 1	1.566 - 1.651	Discriminates moisture content of soil and vegetation; penetrates thin clouds	30
Band 7 - Short-wave Infrared (SWIR) 2	2.107 - 2.294	The improved moisture content of soil and vegetation and thin cloud penetration	30
Band 8 - Panchromatic	0.503 - 0.676	15 meter resolution, sharper image definition	15
Band 9 – Cirrus	1.363 - 1.384	Improved detection of cirrus cloud contamination	30
Band 10 – TIRS 1	10.60 – 11.19	The 100-meter resolution, thermal mapping and estimated soil moisture	100 * (30)
Band 11 – TIRS 2	11.50 - 12.51	The 100-meter resolution, Improved thermal mapping and estimated soil moisture	100 * (30)

Source: [9]

The metric data used has NDVI and NBR parameters and each has standard deviation, regression coefficient, and max-70 i.e. a maximum of 70% clear pixels NBR, as a determining factor in the identification of tree cover change.

2.3. Method
Research stages generally selecting suitable parameters and features to show the tree cover change in the 2016 and 2017 data, determining the threshold for the two years to show tree cover loss and tree cover gain, applying the threshold on the data for July 2016-June 2017 and July 2017-June 2018, and the of spatial information indicating land cover changes. The metric data to be examined are NDVI and NBR, where;

$$\text{NDVI} = \frac{NIR - RED}{NIR + RED}$$

$$\text{NBR} = \frac{SWIR1 - NIR}{SWIR1 + NIR}$$

Those formulas use Red, NIR and SWIR bands, where their characteristics can be seen in Table 1.

Vegetation is an important component in monitoring ecosystem dynamics [10]. NDVI and NBR were selected for this research, NDVI was selected because this vegetation index can show changes in the vegetation area [10] and can differentiate vegetation, non-vegetation [11, 12] also in open or developed areas [13]. On the other hand, NBR in accordance with its name is widely used for the detection of former forest/land fires [14, 15, 16] and [17] uses NBR although he believes that the Linear Spectral Mixture Model method is better for his case. The research flowchart is shown in figure 2.

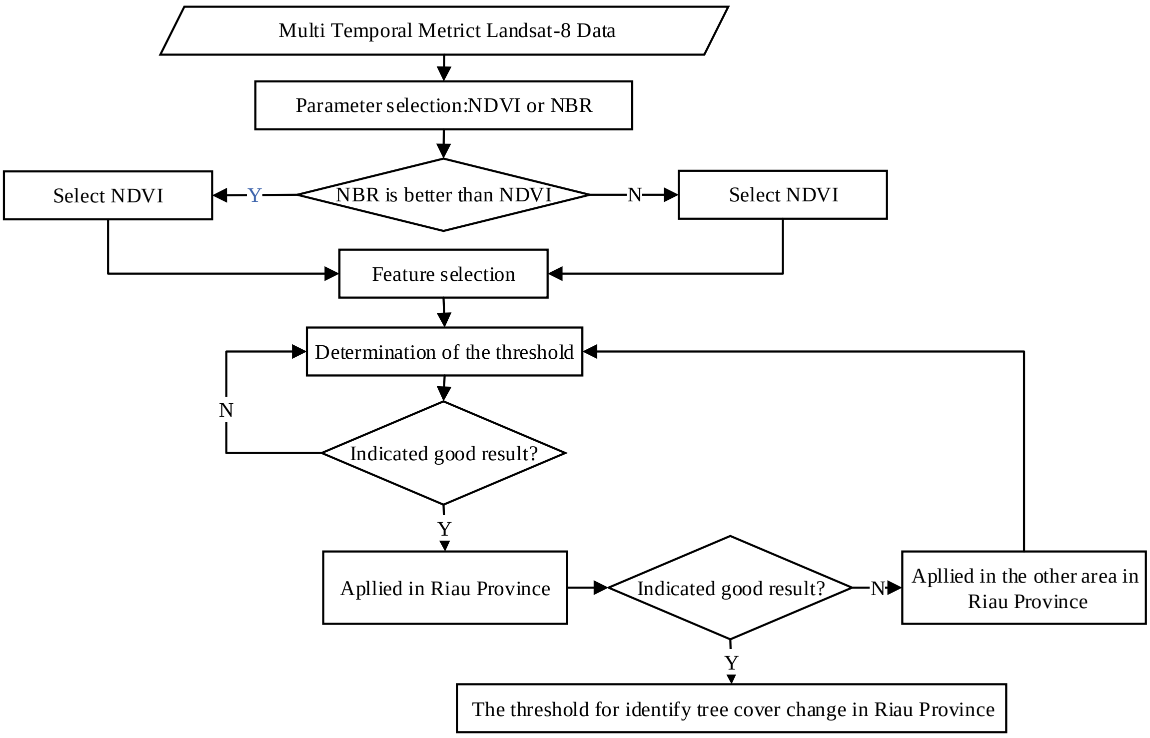


Figure 2. Research flow chart

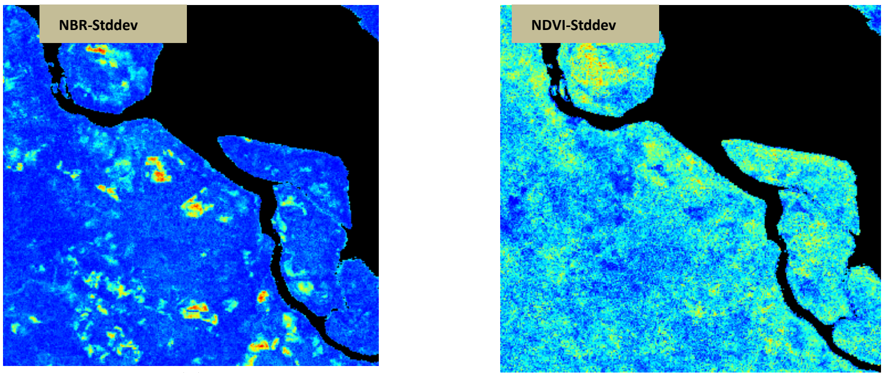
3. Result and Analysis

Figure 3 shows the 2016 and 2017 Landsat-8 mosaic images. These two images visually show that there is a change in either the tree cover loss (shown by the red circle) or the tree cover gain (shown by the blue circle) in a number of locations. This research compares the NDVI and NBR parameters that can provide a significant indication of tree cover change. Once selected, the feature and threshold will be determined to obtain an indication of changes in vegetation by identifying the changes that occur. Key and Benson, 1999 and 2006 in Warner et al (2016) stated that the NBR index which uses the Near Infrared Radiance (NIR) and Shortwave Infrared (SWIR) spectral is highly correlated with the field data, especially in forest vegetation compared to other indices. He also mentioned that the use of NIR and SWIR spectral is also very appropriate for differentiating burnt and unburned land. The decreasing tree canopy and water content after a fire can be well responded by the SWIR spectrum which increases its reflectivity.

(a) (b)

Figure 3. 2016 Landsat-8 mosaic image (a) and 2017 Landsat-8 mosaic image (b)

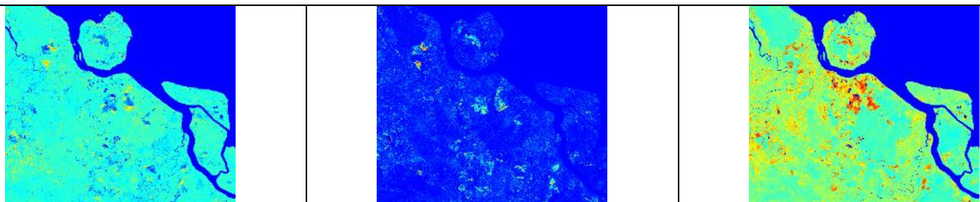
Figure 4 shows results for NBR and NDVI in the 1-year metric data. The visual analysis of the NBR parameter provides a clear picture of the tree cover change, hence the NBR parameter is selected to differentiate the changes in multitemporal data.



(a) (b)

Figure 4. Application of the NBR (a) and NDVI (b) vegetation index in the Landsat-8 mosaic image

The next step is to select the right feature that provides a good illustration of the change. For that, it was tried again by looking visually with the various features applied to NBR such as regression, standard deviation, and NBR max-70. Visually, figure 5 shows that the NBR Max-70 indicates significant land changes. Hence, the parameters and features of the NBR Max-70 are set as metric data used for determining the indication of tree cover change. The next step is analysing the threshold value to show tree cover loss and tree cover gain.

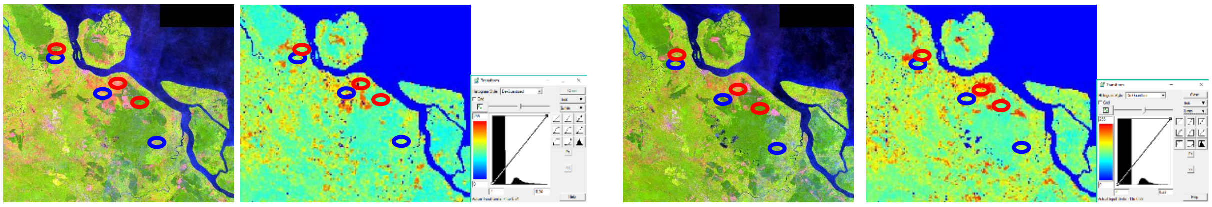


(a) NBR-Regression (b) NBR-Std Deviation (c) NBR-Max70

Figure 5. Comparison between the results of NBR-regression (a), NBR-standard deviation (b), and NBR-Max70 (c)

IOP Conf. Series: Earth and Environmental Science **280** (2019) 012013 doi:10.1088/1755-1315/280/1/012013

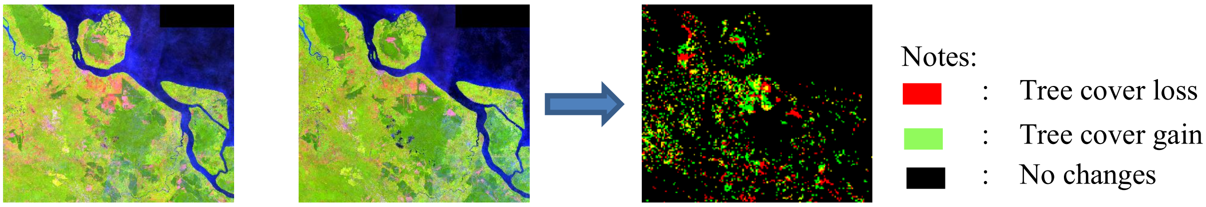
The threshold is determined by trial and error approach. Each change is compared against the composite RGB Landsat image shown in Figure 3, hence the places where the changes occur (red and blue circles) provide a correct indication of tree cover loss and tree cover gain. Figure 6 shows RGB Landsat-8 composite images and the results are subject to the NBR-Max70 formula. The left image is for 2016 and the right image is for 2017.



(a) 2016 Landsat image and NBR-Max70 (b) 2017 Landsat image and NBR-Max70

Figure 6. Landsat image RGB composite and NBR-Max70 image for 2016 (a) and 2017 (b)

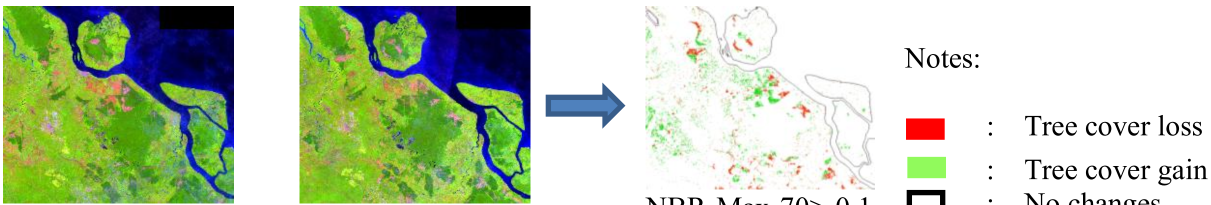
The histogram on the bottom of the Landsat image at Figure 6, the NBR-Max70 image shows that the color of the water body in the image is shown in dark blue, then the vegetation is shown in light blue to yellow, and open land is shown in red. To analyse the changes in the 2-year data, the two years are overlaid, and the threshold will be identified for each change, namely the tree cover loss and the tree cover gain. From the trial and error analysis, the threshold for both is > -0.1. Figure 7 is the result of changes from 2016 to 2017.



2016 Landsat-8 image 2017 Landsat-8 image NBR-Max-70>-0.1

Figure 7. The tree cover change from 2016 to 2017 as indicated by the tree cover loss and the tree cover gain with each threshold > -0.1

Based on the trial, the stated threshold applies to other data, namely for the data of July 2016-June 2017 and June 2017- June 2018 as shown in figure 8.



Landsat-8 Image July 2016-June 2017 Landsat-8 Image July 2017-June 2018 NBR-Max-70>-0.1

Figure 8. Tree cover change for July 2016-June 2017 and July 2017-June 2018 is indicated by tree cover loss and tree cover gain with each threshold > -0.1

This model in other locations in Riau Province is shown in figure 9 that tree cover loss and tree cover gain much had happened in the oil palm plantation area.

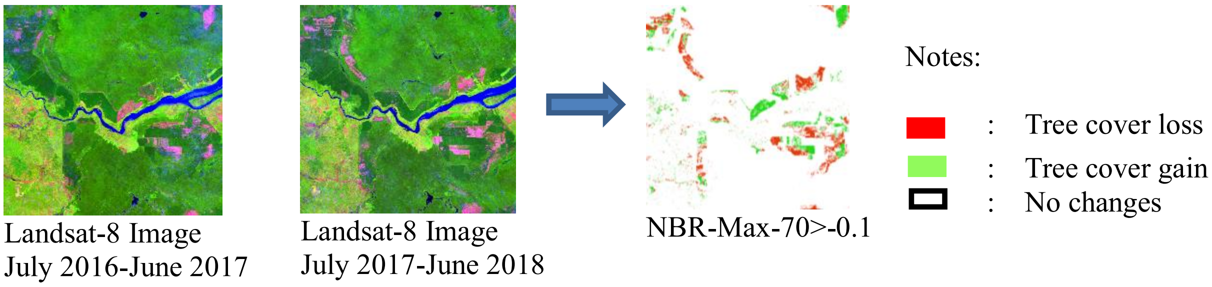


Figure 9. Tree cover change in other locations for July 2016-June 2017 and July 2017-June 2018 is indicated by tree cover loss and tree cover gain

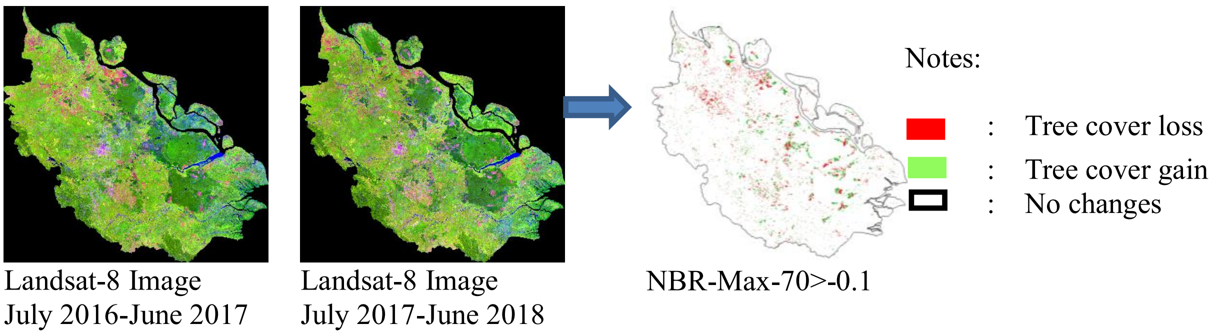


Figure 10. Tree cover change in Riau Province for July 2016-June 2017 and July 2017-June 2018 is indicated by tree cover loss and tree cover gain

Figure 10 shows the result of the application of the model established in other years in Riau Province. The research results show that the tree cover change with the NBR feature Max-70 metric data parameter and threshold > -0.1 for each output, i.e. the tree cover loss and the tree cover gain produce good results.

The resulting information can be used to identify, among other things, deforestation and replanting in the areas of oil palm plantation.

4. Conclusion

Land cover changes can be identified from two annual Landsat-8 metric data using the NBR and feature max-70 parameters. The threshold for each tree cover loss and tree cover gain is more than -0.1. This threshold applies to all years of change in Riau Province.

The information about tree cover loss and tree cover gain can be used to identify the deforestation and the replanting in plantation area as input to analysis rehabilitation on critical land.

Further suggestions will be tested for all of Sumatera and will also be analyzed to identify other thresholds for across Indonesia.

Acknowledgment

Thank you to Ministry of Research, Technology and Higher Education of the Republic Indonesia, Dr. Orbita Roswintiarti as Deputy of Remote Sensing at LAPAN, Mr. Dedi Irawadi as Director of the Remote Sensing Data Center at LAPAN, Dr. Rokhis Komarudin as Director of the Remote Sensing Utilization Center at LAPAN, Mr. Doni Sri Putra as Head of the Forestry Resources Monitoring Sub Directorate of the Ministry of Environment and Forestry, Mr. Judin Purwanto as Head of National Forest Resources Monitoring Section of the Ministry of Environment and Forestry, and Dr. Arief Wijaya as the Climate and Forests Senior Manager of WRI Indonesia, for all the support for the research and scientific paper on information on indications of land change.

References

[1] Howari FM, Sherif MM, Singh VP, Al Asam MS. Application of GIS and remote sensing techniques in identification, assessment and development of groundwater resources. Groundwater: Springer; 2007. p. 1-25.
[2] Madhok V, Landgrebe DA. A process model for remote sensing data analysis. IEEE Transactions on Geoscience and Remote Sensing. 2002;40(3):680-6.
[3] Turdukulov UD, Tolpekinb V, Kraaka M. Visual exploration of time series of remote sensing data. Advances in Spatio-Temporal Analysis. 2007;5:147.
[4] Goldman ED, Weisse M. Technical to the 2016 Tree Cover Loss Data Explained. 2017.
[5] Hansen M, DiMiceli C, Sohlberg R. User Guide for the MEaSURES Vegetation Continuous Fields product, version 1. University of Maryland; 2017.
[6] Parwati P, Zubaidah A, Vetrita Y, Yulianto F, DS KA, Khomarudin MR. Kapasitas indeks lahan terbakar Normalized Burn Ratio (NBR) dan Normalized Difference vegetation Index (NDVI) dalam mengidentifikasi bekas lahan terbakar berdasarkan data SPOT-4. GEOMATIKA. 2012;18(1).
[7] Pirotti F, Parraga MA, Stuaro E, Dubbini M, Masiero A, Ramanzin M. NDVI FROM LANDSAT 8 VEGETATION INDICES TO STUDY MOVEMENT DYNAMICS OF CAPRA IBEX IN MOUNTAIN AREAS. International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences. 2014.
[8] Rizal Harahap. Logging moratorium `a must' to save Riau forests. The Jakarta Post. 2013 17 October 2013.
[9] Barsi JA, Lee K, Kvaran G, Markham BL, Pedelty JA. The spectral response of the Landsat-8 operational land imager. Remote Sensing. 2014;6(10):10232-51.
[10] Zaitunah A, Ahmad A, Safitri R, editors. Normalized difference vegetation index (ndvi) analysis for land cover types using landsat 8 oli in besitang watershed, Indonesia. IOP Conference Series: Earth and Environmental Science; 2018: IOP Publishing.
[11] Ganie MA, Nusrath A. Determining the Vegetation Indices (NDVI) from Landsat 8 Satellite Data. International Journal of Advanced Research. 2016;4(8):1459-63.
[12] Taufik A, Ahmad SSS, Ahmad A. Classification of Landsat 8 Satellite Data Using NDVI Tresholds. Journal of Telecommunication, Electronic and Computer Engineering (JTEC). 2016;8(4):37-40.
[13] Esau I, Miles VV, Davy R, Miles MW, Kurchatova A. Trends in normalized difference vegetation index (NDVI) associated with urban development in northern West Siberia. Atmospheric Chemistry and Physics. 2016;16(15):9563-77.
[14] Harris S, Veraverbeke S, Hook S. Evaluating spectral indices for assessing fire severity in chaparral ecosystems (Southern California) using MODIS/ASTER (MASTER) airborne simulator data. Remote sensing. 2011;3(11):2403-19.
[15] Zubaidah A, Sulma S, Suwarsono, Vetrita Y, Priyatna M, Diah KA. Burned Area Validation of Landsat-8 OLI Data in Kalimantan. Majalah Ilmiah Globë 2017.
[16] Wu Z, Middleton B, Hetzler R, Vogel J, Dye D. Vegetation burn severity mapping using Landsat-8 and WorldView-2. Photogrammetric Engineering & Remote Sensing. 2015;81(2):143-54.
[17] Vedovato LB, JACON AD, PESSÔA ACM, LIMA A, OLIVEIRA LE, DE ARAGÃO C. Detection of burned forests in Amazonia using the normalized burn ratio (NBR) and linear spectral mixture model from Landsat 8 images. Anais XVII Simpósio Brasileiro de Sensoriamento Remoto (SBSR). 2015.