MONITORING MODEL OF LAND COVER CHANGE FOR THE INDICATION OF DEVEGETATION AND REVEGETATION USING SENTINEL-2

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Abstract. Information on land cover change is very important for various purposes, including the monitoring of changes for environmental sustainability. The objective of this study is to create a monitoring model of land cover change for the indication of devegetation and revegetation using data from Sentinel-2 from 2017 to 2018 of the Brantas watershed. This is one of the priority watersheds in Indonesia, so it is necessary to observe changes in its environment, including land cover change. Such change can be detected using remote sensing data. The method used is a hybrid between Normalized Difference Vegetation Index (NDVI) and Normalized Burn Ratio (NBR) which aims to detect land changes with a focus on devegetation and revegetation by determining the threshold value for vegetation index (ΔNDVI) and open land index (ΔNBR). The study found that the best thresholds to detect revegetation were Δ NDVI > 0.0309 and Δ NBR < 0.0176 and to detect devegetation Δ NDVI < - 0.0206 and Δ NBR > 0.0314. It is concluded that Sentinel-2 data can be used to monitor land changes indicating devegetation and revegetation with established NDVI and NBR threshold conditions.

Keywords*: Model, Monitoring. Land Cover, Sentinel-2, devegetation, revegetation*

1 INTRODUCTION

Geobiophysics is one of the parameters for determining the phenomenon of land surface change. It has been applied by several researchers using the vegetation index and open/burned land index from optical satellite data. The vegetation index describes the level of greenness of plants, using a mathematical combination of the red band and NIR (Near-Infrared) band (Lillesand & Kiefe, 1997). According to Ryan (1997), the calculation of the Normalized Difference Vegetation Index (NDVI) is based on the principle that green plants grow very effectively by absorbing radiation in the red spectrum region of Photosynthetic Active Radiation (PAR), and strongly reflect sunlight from the infrared region close to the range value indices -1 to 1. The vegetation index has been used in numerous studies on a global scale of vegetation and to map drought, devegetation and deforestation (Horning , Juli. Robinson, Eleanor Sterling, Turner, and Spector, 2010; Kartika et al., 2018). Determination of the extraction of forest identification geobiophysical parameters can be made using the NDVI model with a threshold value with SATELIT LAPAN -3 data (Arifin, S., Kartika, T., & Carolita, I., 2019).

In general, NDVI with a combination of red and infrared specimens is an index that is widely used to identify signs of burning land (Chuvieco, E., Martin, M.P., & Palacios, A ., 2002., 2002). In addition, there have been many developments in the method of identifying burnt land/forests through the single band method (Near IR, Mid IR, Spectral thermal temperature Brightness) and the ratio band vegetation index. Research on the detection of burnt land has been widely conducted globally

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using low to medium resolution remote sensing satellite data, such as that from MODIS (Martín M.P., & Díaz-Delgado R., 2002; Roy, D.P, Boschettm, L., & Triffm, S.N., 2002; Chuvieco et al., 2005); from NOAA-AVHRR (Barbosa, P.M., Pereira, J.M.C., & Grégoire, J. M., 1998); Nielsen, T.T., Mbow, C., & Kane R., 2002);; Nielsen et al., 2002); and from SPOT VEGETATION (Silva, J.M.N, Cadima, J.F.C.L., Pereira, J.M.C. M. Grégoire., 2004). This study aims to map mangrove density in Arakan village and to determine the best NDVI results from the band combination used (Philiani, I, Saputra, L, Harvianto, L., & Muzaki, A.A., 2016). However, it should be noted that low and medium resolution data cannot detect burnt areas of less than 25 ha well (Miettinen, 2007). NDVI, the Normalized Burn Ratio (NBR), Soil-adjusted Vegetation Index (SAVI), Modified Soil-Adjusted Vegetation Index (MSAVI), and multivariate component (Principle Component Analysis, Tasseled Cap-greenness, Tasseled Cap-wetness) (Escuin, 2007) will be compared by the calculation of field data using the Composite Burn Index (CBI) method. The results show that the NBR index using the Near Infrared (NIR) and Shortwave Infrared (SWIR) spectral has a high correlation with the field data (CBI), especially in forest vegetation, in comparison to other indices. NIR and SWIR radiation spectral are exceptionally good at separating burnt and unburned land. Decreases in the tree canopy and water content after changes due to fire can be represented well by the SWIR spectrum, which has increased reflection (Key & Benson 1999; Escuin et al., 2007).NBR can be used to identify burned areas using SPOT-4 (Parwati et al., 2012). According to the index theory, NBR would be optimal in quantifying fire severity. Although previous studies have reported a high correlation between fire severity as measured in the field and satellite-derived

NBR, our results provide no evidence for this (Roy et al., 2006). The formula is similar to a NDVI, except that it uses NIR and SWIR portions of the electromagnetic spectrum (Key & Benson, 1999). The TIRS band has a 100-metre spatial resolution but can be resampled to 30 metres for it to be used to identify burned scar areas. SWIR bands (TM bands 5 and 7 in Landsat 5 and 7 systems) as an NBR composite can be used to detect and map burnt areas. The Thermal Infrared Sensor (TIRS) algorithm which was used to detect fires and SWIR, which was used to detect water stress in vegetation and burned vegetation, will be seen in green, and both will become darker when burning takes place. This method modifies the dNBR (pre-NBR-post-NBR) composite (Indratmoko & Rizqihandar, 2019).

Based on several examples of studies on the utilization of NDVI and NBR geobiophysical information extracts, it is necessary to use this geobiophysical combination as a requirement for the devegetation and revegetation of land.

The objective of this study is to create a monitoring model of land cover change for the indication of devegetation and revegetation using Sentinel-2 data from 2017 to 2018. The definition of devegetation used is when there is a decrease in the appearance of the green level in the image (Aldrian & Sucahyono, 2013), while revegetation is shown by an increase in the appearance of the green level in the image at a certain location compared to the previous time.

2   MATERIALS AND METHODOLOGY

The Sentinel-2 satellite uses remote sensing technology that is easily obtained for analysis of spatial information. The satellite is a medium resolution type and has a temporal resolution of 5 days. Sentinel-2 is faster than Landsat, which has temporal resolution of 16 days. The data can be used to monitor land and

coastal cover. The Sentinel-2 Multi-spectral Instrument (MSI) has 13 spectral bands: four bands (Bands 2, 3, 4 and 8) with a resolution of 10m; six (Bands 5, 6, 7, 8a, 11 and 12) with a spatial resolution of 20m; and three (Bands 1, 9 and 10) with a spatial resolution of 60m. Sentinel-2 is complements Landsat-7 and 8 and can also be used for other themes, such as spatial planning, agro/environmental monitoring, water resources, forests and vegetation, carbon resources, and global agricultural products (The European Spance Agency, 2015)

The research location was the Brantas watershed in East Java Province (Figure 2-1). The data used in the study were Sentinel-2A multi-temporal data for 2017 and 2018 (Figure 2-2).

2.3 Sentinel Characteristics

Sentinel-2 is a European wide-swath, high-resolution, multi-spectral imaging mission. The full mission specification of the twin satellites, flying in the same orbit but phased at 180°, is designed to give a high revisit frequency of 5 days at the Equator and with orbital swath width is 290 km.

2.3.1 Sentinel-2 MSI

The Sentinel-2 Multi-spectral Instrument (MSI) measures the earth's reflected radiance in 13 spectral bands consisting of three levels of spatial resolution: four bands at 10 meters , six bands at 20 meters and three bands at 60 meters. Sentinel-2 is supporting Copernicus land monitoring studies with an imaging mission to monitor vegetation, soil and water cover, as well as to observe inland waterways and coastal areas. The data is designed to be modified and adapted by users interested in areas such as spatial planning and the monitoring of the agro-environment, water, forests and vegetation, land carbon and natural resources, and global crops.

The spatial resolution of Sentinel-2 depends on the spectral band, as shown in Table 2.1.
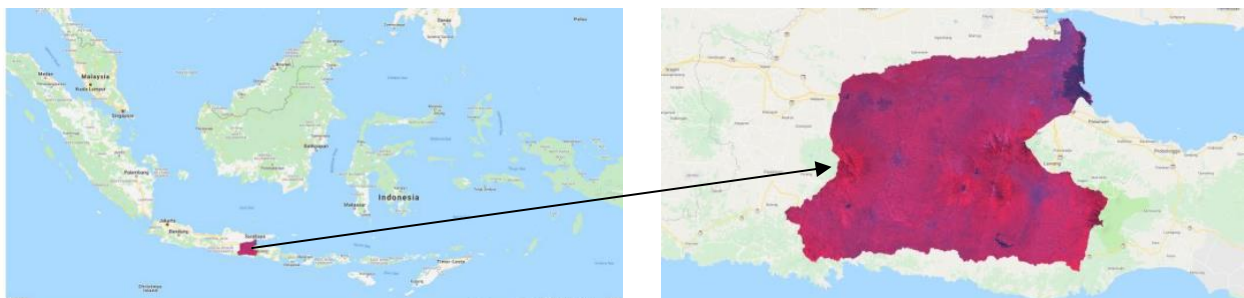

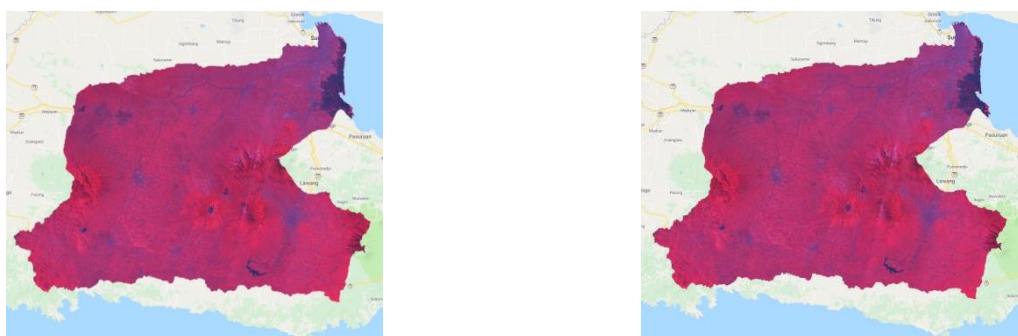Figure 2-1: Research location: the Brantas Watershed in East Java

Figure 2-2: Sentinel-2 Data 2017-2018

Table 2-1. Spatial Resolution of Sentinel-2

Sentinel-2 Bands	Central Wavelength (µ)	Resolution (m)
Band 1: Coastal Aerosol	0.443	60
Band 2: Blue	0.490	10
Band 3: Green	0.560	10
Band 4: Red	0.665	10
Band 5: Vegetation Red Edge	0.705	20
Band 6: Vegetation Red Edge	0.740	20
Band 7: Vegetation Red Edge	0.783	20
Band 8: NIR	0.842	10
Band 8A: Vegetation Red Edge	0.865	20
Band 9: Water Vapour	0.945	60
Band 10: SWIR-Cirrus	1.375	60
Band 11: SWIR	1.610	20
Band 12: SWIR	2.190	20

2.3.3 Normalized Difference Vegetation Index (NDVI)

The NDVI quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). As shown below, NDVI uses the NIR and red channels in its formula:

$$NDVI = \frac{NIR - Red}{NIR + Red} \qquad (2\text{-}1)$$

Healthy vegetation (chlorophyll) reflects more near-infrared (NIR) and green light compared to other wavelengths, but absorbs more red and blue light. Therefore, we see vegetation as green. If it were possible to see near-infrared, this would also show strong vegetation. The satellite sensors of Sentinel-2 both have the necessary NIR and red bands. The result of this formula generates a value between -1 and +1.

$$\Delta NDVI = NDVI_{t1} - NDVI_{t2} \qquad (2\text{-}2)$$

where $NDVI_{t1}$ is NDVI at the initial time and $NDVI_{t2}$ is NDVI at the final time.

2.3.4 Normalized Burn Ratio (NBR)

The NBR is used to identify burned areas. The formula is similar to a NDVI, except that it uses near-infrared (NIR) and shortwave-infrared (SWIR) portions of the electromagnetic spectrum (Key & Benson, 1999).

$$NBR = \frac{NIR - SWI}{NIR + SWIR} \qquad (2\text{-}3)$$

$$\Delta NBR = NBR_{t1} - NBR_{t2} \qquad (2\text{-}4)$$

where NBR_{t1} is NBR at the initial time and NBR_{t2} is NBR at the final time.

The NIR and SWIR parts of the electromagnetic spectrum are a powerful combination of bands for the index to use, given that vegetation is reflected strongly in the NIR region of the electromagnetic spectrum and weakly in the SWIR (see Figure 2-3).

Plants are reflected very strongly on the NIR spectrum, but weak on the SWIR spectrum, the combination of the NIR and SWIR spectra is excellent for identifying areas of burned land (wood / bark burnt) and soil / earth US Forest Service

The NBR index was originally developed for use with Landsat TM and ETM+ bands 4 and 7, but it will work with any multi-spectral sensor with an NIR band between 760-900 nm and a SWIR band between 2080-2350 nm. Therefore, this index can be used with both Landsat-8, MODIS and other multi (and hyper) spectral sensors.
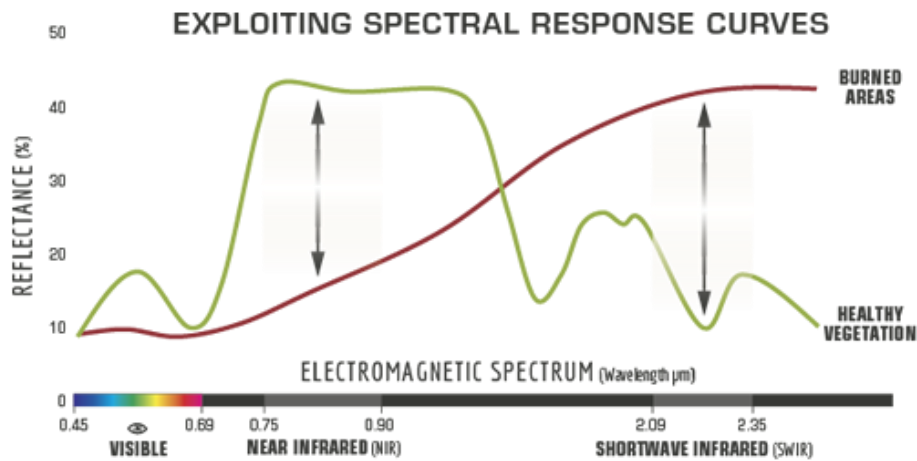
Figure 2-3: Exploiting Spectral Response Curves of Burned Areas with Healthy Vegetation
Source: US Forest Service, 2017

Based on the USGS, NBR succeeded to level 2 derived from Landsat from Landsat 4–5 (TM)), Landsat 7 (ETM +), and Landsat 8 (OLI) / (TIRS), so that it became a Level-2 Surface Reflectance product.

It is calculated as a ratio between the NIR and SWIR values in a traditional fashion (NIR - SWIR) / (NIR + SWIR). In Landsat 4-7, NBR = (Band 4 – Band 7) / (Band 4 + Band 7). In Landsat 8, NBR = (Band 5 – Band 7) / (Band 5 + Band 7).

NBR is delivered as a single band product, specified as shown in the Table 2-2.

Table 2-2: Landsat Surface Reflectance-derived Normalized Burn Ratio (NBR) Specifications

Atttribute	Value
Long Name	Normalized Burn Ratio
Short Name	LC8NBR, LE7NBR, LT5NBR, or LT4NBR
File Name	*_sr_nbr.tif
Data Type	Signed 16-bit Integer
Units	Spectral Index (Band Ratio)
Valid Range	-10,000 — 10,000
Fill Value	-9999
Saturate Value	20,000
Scale Factor	*0.0001

Source : USGS Earth Resources Observation and Science (EROS) Center Science Processing Architecture (ESPA) On Demand Interface (ESPA).

2.3.5 Determination of the Threshold

In previous example, the threshold of NDVI and NBR single data was ascertained visually by comparison between 2017 and 2018 using the trial and error

In previous studies that correlated between LAPAN, KLHK and WRI, the NDVI and NBR single data threshold was visually confirmed by comparison between 2017 and 2018 using trial and error. method. However, this research was conducted by observing changes in the vegetation index (NDVI) and in the open land index (NBR). Differences between NDVI and NBR between 2017 and 2018 were minimal as a threshold to identify indications of changes in land cover. This was determined by sampling the difference between the NDVI and NBR points.

To detect revegetation and devegetation, the threshold requirements of each index were used. Revegetation can be expressed using equation 5 and devegetation by equation 6.

$$\textit{If (NDVI > n and NBR < m), then class 1} \qquad (2\text{-}5)$$

$$\textit{If (NDVI < n and NBR > m), then class 2} \qquad (2\text{-}6)$$

where n is the NDVI threshold, m is the NBR threshold. The revegetation area (class 1) is based on the result of equation 2-5, and the revegetation area (class 2) is based on the result of equation 2-6.
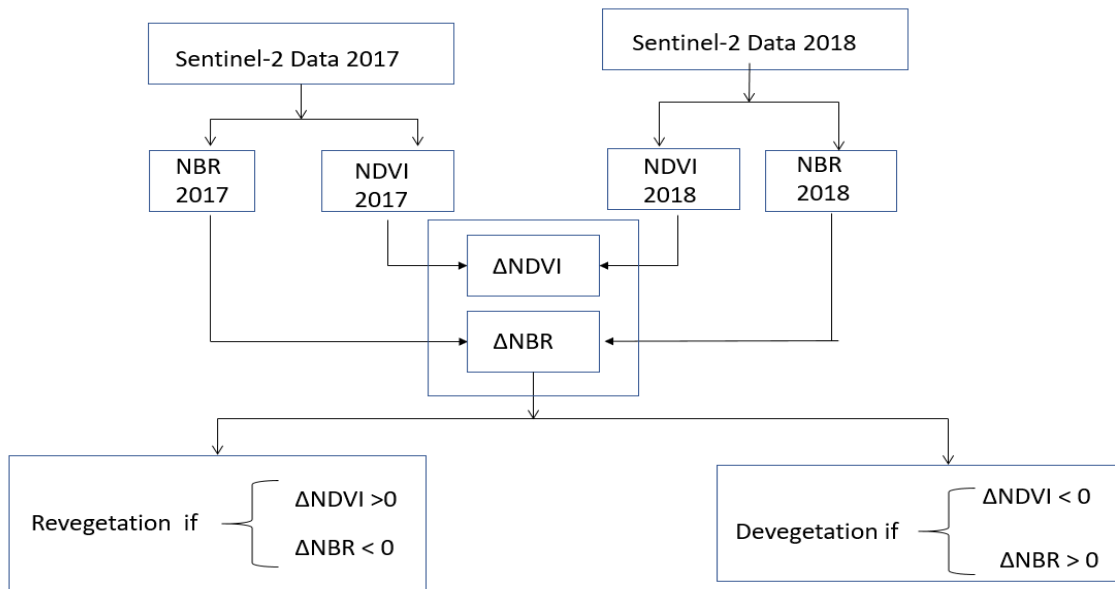
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┌─────────────────────┐                    ┌─────────────────────┐
│ Sentinel-2 Data 2017│                    │ Sentinel-2 Data 2018│
└─────────────────────┘                    └─────────────────────┘
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┌────────┐  ┌────────┐        ┌────────┐  ┌────────┐
│  NBR   │  │  NDVI  │        │  NDVI  │  │  NBR   │
│  2017  │  │  2017  │        │  2018  │  │  2018  │
└────────┘  └────────┘        └────────┘  └────────┘
```

```
                    ┌──────────┐
                    │   ΔNDVI   │
                    └──────────┘
                    ┌──────────┐
                    │   ΔNBR    │
                    └──────────┘
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┌───────────────────────────────┐      ┌───────────────────────────────┐
│                  ⌐ ΔNDVI >0    │      │                  ⌐ ΔNDVI < 0   │
│ Revegetation  if ⌐             │      │ Devegetation if  ⌐             │
│                  ⌐ ΔNBR < 0    │      │                  ⌐ ΔNBR > 0    │
└───────────────────────────────┘      └───────────────────────────────┘
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Figure 2-4: Flow diagram of the research development.

3   RESULTS AND DISCUSSION

The results from equations 1 and 3 are shown in Figures 3.1 and 3.2. Figure 3.1(a) shows the annual mean NDVI images for 2017, while 3.1(b) shows those for 2018 for the Brantas watershed. Figure 3.2(a) shows the annual mean NBR images for 2017 and 3.2(b) those for 2018. Visually, the NDVI and NBR imagery from 2017 and 2018 shows no changes in land cover. However, a digital assessment shows there is a change in land cover, indicated by a change in the NDVI and NBR values from 2017 to 2018. If the NDVI in 2018 is lower than that of 2017 and the NBR in 2018 is higher than that of 2017, then land cover is indicated to be devegetated; the sample data are shown in Figure 3.3. Conversely, if the value of NDVI in 2018 is higher than that of 2017 and if the NBR in 2018 is lower than that of 2017, then this indicates land cover revegetation, as shown in Figure 3-4. Figure 3-1 shows images of NDVI in 2017 and 2018, with an index value of -1 to 1. This value is depicted by the gradation of colour from light to dark, namely yellow, green and dark green, which shows the level of green of the vegetation.

Figure 3-2 shows NBR images from 2017 and 2018, with the NBR index value from -1 to 1, which shows the level of land openness. The light green colour indicates a greater level of land openness than that shown in dark green. Figure 3-3(a) shows an image of the results of the 2017 and 2018 NDVI change analysis. The level of vegetation change is divided into three classes based on the ΔNDVI value interval, as shown in Table 3.2. Figure 3-3(b) shows an image of the results of the analysis of NBR changes in 2017 and 2018. The level of vegetation change is also divided into three classes based on the ΔNBR value interval, as shown in Table 3.3.
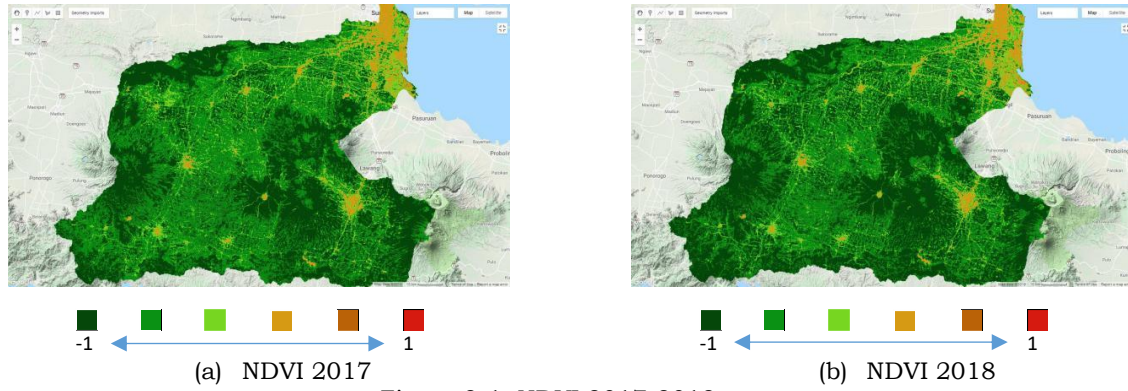
(a)   NDVI 2017

(b)   NDVI 2018

Figure 3-1: NDVI 2017-2018

NBR 2017

NBR 2018

Figure 3-2: NBR 2017-2018
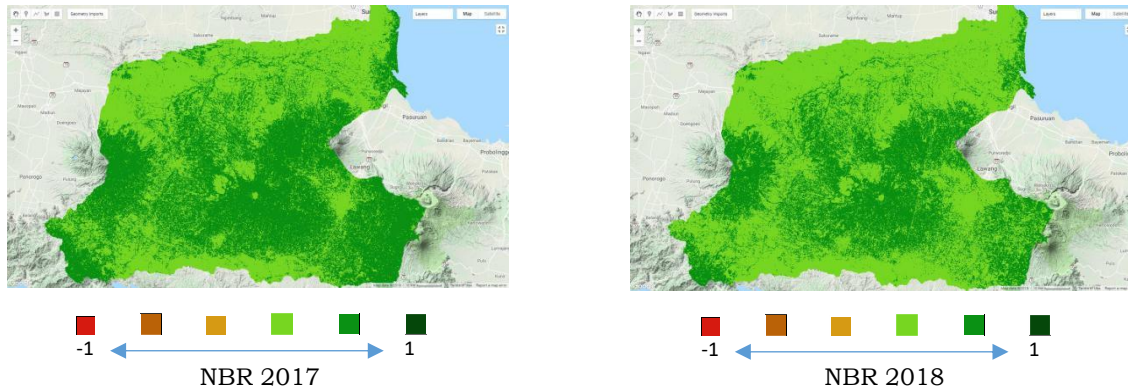

(a) Change in vegetation in 2017-2018

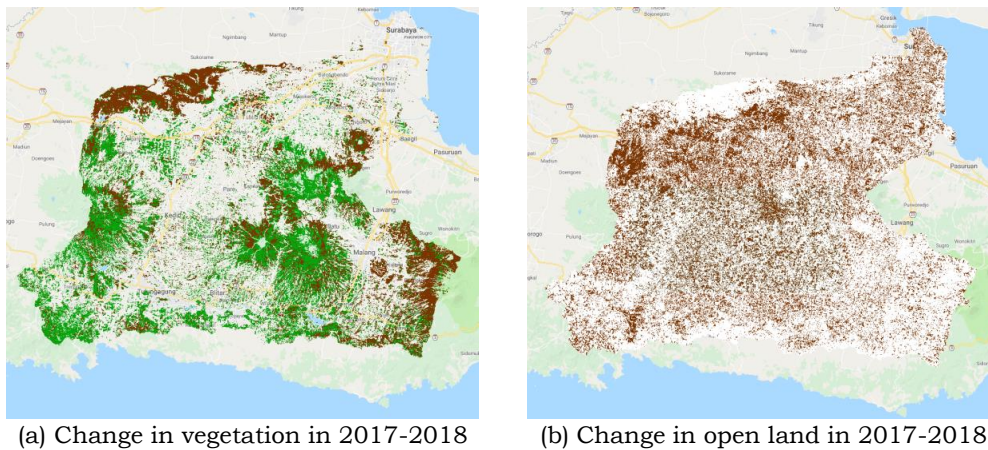(b) Change in open land in 2017-2018

Figure 3-3: Change in vegetation and open land 2017-2018.

Table 3-2. NDVI 2017-2018 Changes

No	ΔNDVI (2017-2018)	NDVI Change	Colour
1	>-1	No Change	
2	-1 to 0	Small Change	
3	0 to 1	Large Change	

Table 3-3. NBR 2017-2018 Changes

No	ΔNBR (2017-2018)	NBR Change	Colour
1	>-1	No Change	
2	-1 to 0	Small Change	
3	0 to 1	Large Change	

Revegetation and devegetation areas were determined by application of the threshold of Δ NDVI and Δ NDVI, obtained from several sample points which were visually experiencing changes, as shown in figures 3-3, 3-4 and 3-5 Example Revegetation and devegetation. The results of the sample points obtained by the threshold for identifying indications of revegetation and devegetation are shown in Figure 3-6.

The threshold obtained to determine the existence of revegetation was ΔNDVI= 0.0309 and ΔNBR= -0.0176, while ΔNDVI= -0.0206 and ΔNBR= 0.0314 was the threshold for devegetation. Based on these calculations, the spatial information of revegetation and devegetation obtained is shown in Figure 3-6.

Spatial revegetation locations can be determined using the equation 5 algorithm, namely if Δ NDVI > 0.0309 and Δ NBR < 0.0176; and the spatial location of devegetation can also be determined using the equation 5 algorithm, namely if Δ NDVI < - 0.0206 and Δ NBR > 0.0314.
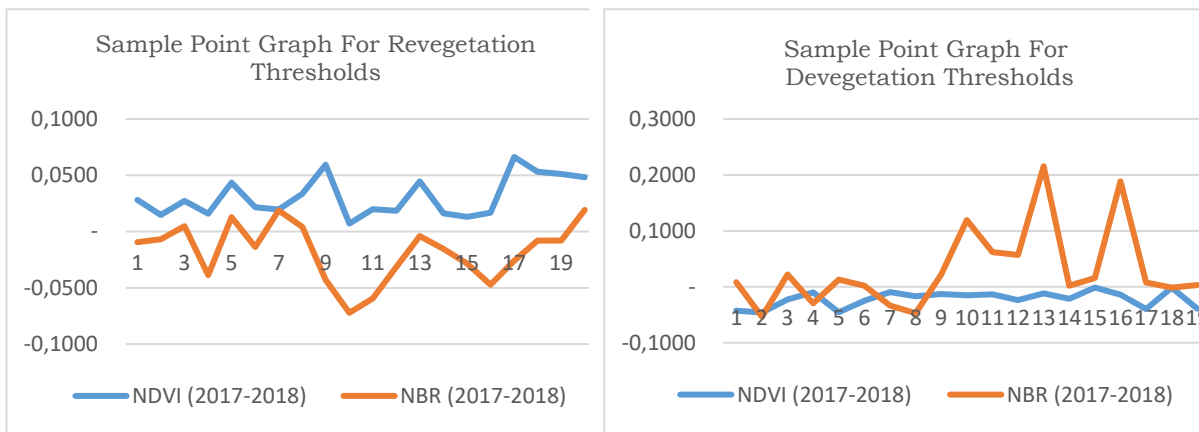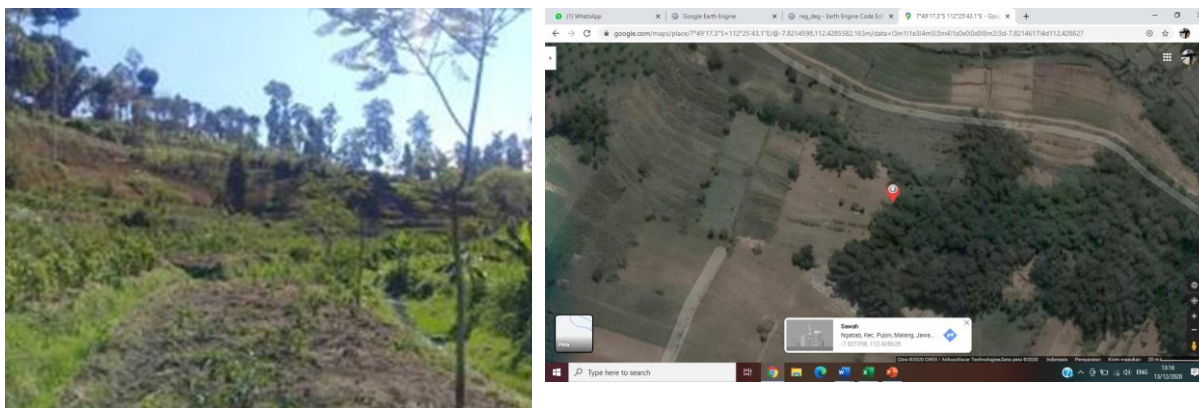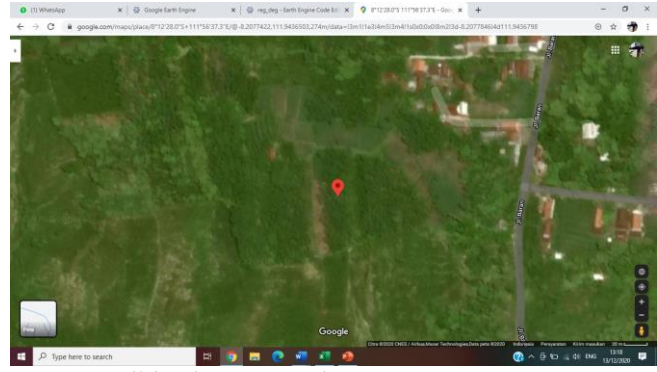
Figure 3-4: Graph of sample points for threshold determination

Devegetation, Malang,Pujon,Ngabab
-7.8214617,112.428627

Revegetation Tulungagung,Kalidawir,Banyuurip
-8.2077846,111.9436798

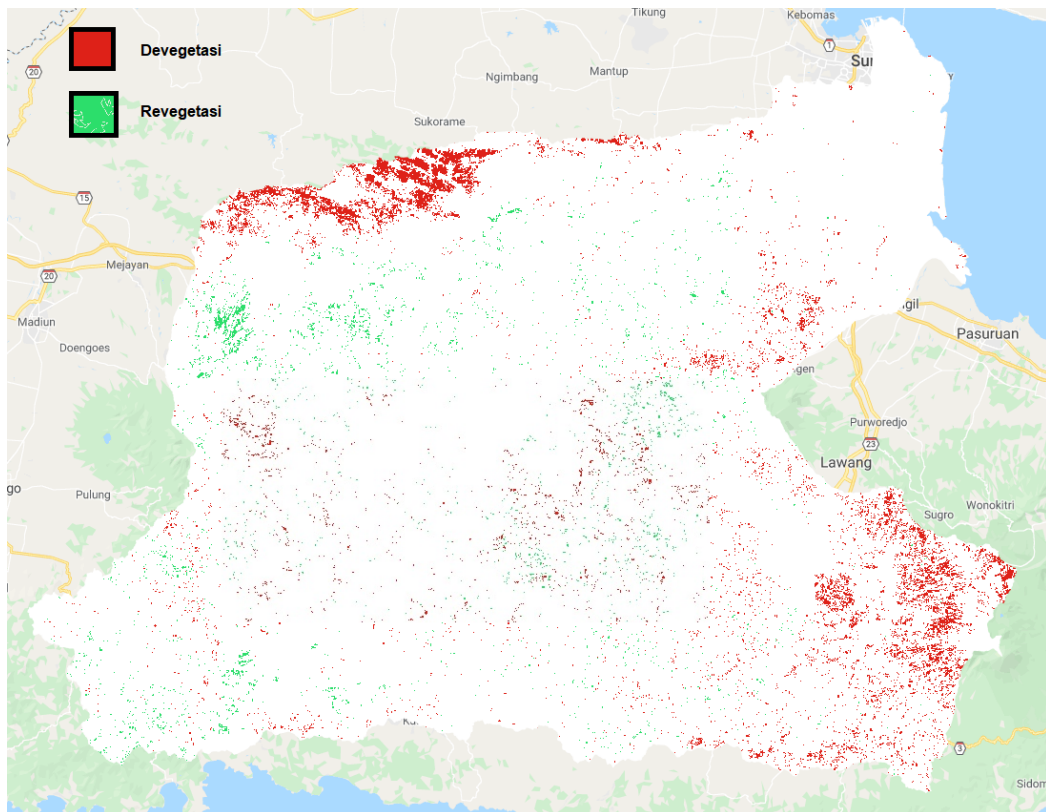Figure 3-5: Revegetation and devegetation spatial information

Figure 3-6: Revegetation and devegetation spatial information

In the study area, not all land-cover experienced revegetation or devegetation changes, as it includes cultivation and natural land. For example, rice fields are not considered to be devegated or revegetated due to the growth of the rice plant phase, or changes in teak forests can be due to changes between the rainy season and dry season, so such change in land cannot be said to be devegetation or revegetation.

4   CONCLUSION

Sentinel-2 MSI data with multi-temporal mosaic data can be used for monitoring changes in land cover dynamics, especially for tree cover loss. The results showed that revegetation can be determined by if Δ NDVI > 0.0309 and Δ NBR < 0.0176, and devegetation if Δ NDVI < - 0.0206 and Δ NBR > 0.0314. Based on the NDVI and NBR threshold requirements set in this study, it is shown that devegetation is more widespread

than revegetation. Devegetation generally occurs in the barren highlands and revegetation in the low and high lands/mountains, which often experience rain. The weakness of using the Sentinel satellite is that the method cannot detect land that is narrow or steep.

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AUTHOR CONTRIBUTIONS

The main authors of the scientific work of this research are Samsul Arifin and Tatik Kartika, while Dede Dirgahayu and Gatot Nugroho are contributing members.

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