Vegetation density analysis in Banda Aceh city before and after the tsunami using satellite imagery data

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Abstract. Vegetation density in Banda Aceh is an important aspect of monitoring the recovery process after being hit by a tsunami on December 26, 2004. The tsunami disaster had a tremendous impact on Banda Aceh city, both physical and non-physical damage. As a result, a lot of vegetation was swept away by the tsunami waves. After the tsunami disaster, Banda Aceh City carried out rehabilitation and reconstruction to change the land cover. The increasing population growth in the city also has affected land cover. Changes in land use not following the spatial plan of the Banda Aceh can reduce the quality of the environment, e.g., reducing the vegetation density in some areas. This paper presents the utilization of Landsat 7 and Landsat 8 images to analyze the vegetation density in Banda Aceh city before and after the tsunami in the last 15 years. This study aims to determine the ability of satellite imagery to detect vegetation density in Banda Aceh in designated years before and after the tsunami. This study uses the Normalized Difference Vegetation Index analysis to observe the trend of vegetation density in the Banda Aceh. Results show that the vegetation density in Banda Aceh City in 2004, 2005, 2009, 2015, and 2020 was dominated by low-density classes. Still, in 2015 and 2020, there was an increase in medium and high vegetation density classes. This finding shows the pattern of the vegetation density follows the progress of the recovery after 15 years hit by a tsunami.

1. Introduction
Vegetation density in Banda Aceh is vital to monitoring the recovery process after being hit by a tsunami on December 26, 2004. The damage to the area, both physical and non-physical, was very devastated, especially for vegetation cover across the city. Even though Banda Aceh has recovered from the disaster, the information about the vegetation cover recovery from pre-disaster and post-disaster after the tsunami is worth being evaluated. The tsunami disaster phase consists of pre-disaster, during the disaster, post-disaster, including rehabilitation and reconstruction stages and normal period [1]. This may impact the progress of land use. Consequently, the vegetation density may also have been the subject of change.
The impact of the tsunami disaster in Banda Aceh City in 2004 has caused physical and non-physical damage. The tsunami waves damaged many vegetation spaces. In turn, many places in Banda Aceh became open spaces with low vegetation density. However, Banda Aceh city and other agencies carried out urban rehabilitation and reconstruction after the tsunami disaster. The rehabilitation was supported by implementing Banda Aceh City government policies so that there was a very rapid development of land-use change [2]. This land change has an impact on changes in vegetation density in Banda Aceh City.

In addition to land changes after the tsunami disaster, the increase in population that continues to increase every year has caused a high demand for housing. Consequently, it has an impact on changes in various fields of the city [3]. Vegetation is a collection of plants that live together in a place of various types. Plants interact with each other both with the plants themselves and with animals called communities [4]. The vegetation across the city is different depending on the composition of the constituents. Vegetation density is one of the factors that can affect the surface temperature in an area because the vegetation can provide coolness to land use [5]. Detection of land cover change is one of the most important factors for management and planning problems. There are so many methods to do it, but Common change detection methods include (1) comparison of land cover classification, (2) vegetation differentiating, and (3) vegetation index [6].

The high and low vegetation density can be determined using the vegetation index. The vegetation index calculated from satellite images can monitor temporal changes associated with vegetation [7]. The vegetation index is a method of quantitatively measuring biomass and vegetation health by adding, dividing, and multiplying one channel with another to form several spectral channels to obtain a channel that can reflect plant abundance or health. Thus, the condition value is measured. A high vegetation index value indicates a higher degree of greenery, such as dense forest areas, in the observed area. On the other hand, a low vegetation index value indicates that land is monitored for low greenery, sparse vegetation, or land without vegetation [8].

The normalized difference vegetation index (NDVI) is the most widespread vegetation index used to describe green plant condition, health, and vegetation density. NDVI is based on the difference in the reflection values of the infrared band with the red band. Green plants will absorb waves in the red spectrum for photosynthesis and reflect waves in the infrared spectrum. NDVI is a combination of the offset technique with the image reduction technique. Image balancing can produce certain effects concerning the protrusion of the impact of shadows and lithological protrusions [9]. The range of NDVI values is -1 to 1. Values greater than 0.1 mean an increase in greenery and vegetation intensity. Values between 0 and 0.1 are usually rock and open space. The value may be less than 0, representing ice clouds, water clouds, and snow. Surface vegetation has NDVI Values ranging from 0.1 to 0.8 grasslands and tropical rainforest areas [10].

The identification process of vegetation density can be done using remote sensing data in satellite images. The use of remote sensing data makes it easy to identify large areas, costs less, and takes less time. When compared to manual identification (direct measurement), it requires more money and takes longer. One of the remote sensing technologies is utilizing imagery from the Landsat satellite.

2. Materials and methods
This study uses descriptive quantitative analysis and interpretations on Landsat 7 and Landsat 8 Satellite Imagery of Banda Aceh City, zone 46S datum WGS 1984, path/row: 131/56 in 2004 for pre-disaster, 2005 for post-disaster, 2009 period. Rehabilitation and reconstruction and 2015 and 2020 for normal times were obtained from The US Geological Survey (USGS) [11]. Spatial data analysis by using calculations on the NDVI value. The stages of satellite analysis start from image pre-processing, including radiometric correction. The location of the study is presented in Figure 1.
Image processing was carried out of Landsat imagery, consisting of multiple Landsat 7 6 bands and Landsat 8 11 bands. Layer stacking is done to get a picture with a combination of bands. All processes are carried out using ENVI 5.3. Some corrections have been made to reduce the atmospheric effect in shadows. Use radiometric correction. Image cropping was delineated using ArcGIS 10.5.

Calculations are carried out using the NDVI vegetation index to obtain the vegetation density, using the following equation [12]. NDVI is the most widely used vegetation index for retrieval of vegetation canopy biophysical properties.

\[
\text{NDVI} = \frac{(\text{NIR} - \text{RED})}{(\text{NIR} + \text{RED})}
\]

Description:

NDVI: Normalized difference vegetation index
NIR : Band 3 (Landsat 7), Band 4 (Landsat 8)
RED : Band 4 (Landsat 7), Band 5 (Landsat 8)

The calculation obtained from formula (1) is further classified according to the vegetation density level according to the forestry department [13]. The story of vegetation density is divided into three; for more details, see Table 1.

| Class | Range    | Density Level |
|-------|----------|---------------|
| 1     | -1.00 - 0.25 | Rare          |
| 2     | 0.26 - 0.35  | Medium        |
| 3     | 0.36 - 1.00  | High          |
The methodology is as described in Figure 2:

![Figure 2. Research flowchart.](image)

3. Results and discussion
Banda Aceh is one of the city in Aceh Province that acts as the gateway to the western part of the Republic of Indonesia because it has a strategic position because it deals with countries in the South of the Asian Continent. Aceh Regional Planning Board states that Banda Aceh City is located at places 05°30' - 05°35' N and 95°30' - 99°16' E. Banda Aceh City is the Capital of Aceh Province, has nine sub-districts with a total area of 61.36 km². As the capital of Aceh Province, Banda Aceh City focuses on services and activities for residents in other cities and districts of Aceh. As a result, Banda Aceh City has experienced very rapid development.
Vegetation density is the extent of how much vegetation is in a unit area of measurement. The occurrence of changes in vegetation density in Banda Aceh City can be caused by the tsunami that swept the surface of Banda Aceh City in 2004 and the high demand for land for settlements so that there is a lot of land clearing. The level of vegetation density in Banda Aceh City is obtained from the results of NDVI calculations by processing Landsat 7 and Landsat 8 images. Based on the processing results obtained from NDVI, the level of vegetation density in Banda Aceh City is classified into three classes shown in Table 2.

| Class | Range      | Year         | 2004     | 2005     | 2009    | 2015     | 2020     |
|-------|------------|--------------|----------|----------|---------|----------|----------|
| 1     | -1.00 - 0.25 | 4,302.36     | 4,369    | 4,477.05 | 3,107.25 | 3,596.94 |
| 2     | 0.25 - 0.35 | 234.54       | 136      | 79, 11   | 1,461.33 | 1,270.89 |
| 3     | 0.35 - 1.00 | 34.38        | 12       | 5.13     | 1,076.67 | 777.24   |
|       | Total      | 4,571.28     | 4,517    | 4,561.29 | 5,645.07 | 5,645.07 |

Based on table 2, the value of vegetation density is obtained from NDVI calculation. In 2004 most areas of Banda Aceh City had low vegetation density. The value of vegetation density in 2004 ranged from -1.00 - 0.44. The image processing results in 2004 showed a low level of vegetation density with the largest area of 4,302.36 Ha spread over all sub-districts in Banda Aceh City and covering 94.12% of the whole area of Banda Aceh City. The second widest vegetation density is the medium vegetation density level with an area of 234.54 Ha and covers 5.13% spread over every sub-district. The vegetation density with the smallest area is at a high level of 34.38 Ha, which only covers 0.75% of the Banda Aceh City area. It is located in Kuta Raja, Jaya Baru, Banda Raya, Lueng Bata, and Ulee Kareng. In 2004 the condition of the Banda Aceh City area did not have too much vegetation space. The value of vegetation density obtained in 2004 is a pre-tsunami disaster.

In 2005 that most of the area of Banda Aceh City was included in the low vegetation density class. In 2005 the vegetation density was obtained with a value of -1.00 - 0.44. The image processing results in 2005 showed a low level of vegetation density with the largest area of 4369 Ha spread over all sub-districts in Banda Aceh City and covered 96.72% of the entire Banda Aceh City area. The second-largest vegetation density is the medium vegetation density level with an area of 136 Ha and covers 3.01% spread over every sub-district. The vegetation density with the smallest area is the high vegetation density level with an area of 12 Ha, which only covers 0.27% of the Banda Aceh City area, which is only found in the sub-districts of Ulee Kareng, Banda Raya, Lueng Bata, and Baiturrahman. The value of vegetation density obtained in 2005 is the state of Banda Aceh City after 19 days of the tsunami. The vegetation density in 2005 decreased from the vegetation density in 2004; this was caused by the tsunami that hit Banda Aceh City, which caused the vegetation to be swept away by the tsunami waves.

In 2009 that most areas of Banda Aceh City had low vegetation density. The results of image processing in 2009 obtained a vegetation density value of -1.00 - 0.43 with a low vegetation density level with the largest area of 4,477.05 Ha spread over all sub-districts in Banda Aceh City and covering 98.15% of the total area. Banda Aceh City. The second widest vegetation density is the medium vegetation density level with an area of 79.11 Ha and covers 1.73% found in each sub-district. The vegetation density with the smallest area is the high vegetation density level with an area of 5.13 Ha, which only covers 0.11% of the Banda Aceh City area, which is only found in the sub-districts of Ulee Kareng, Banda Raya, Lueng Bata, and Jaya Baru. The value of vegetation density obtained in 2009 is the state of the rehabilitation and reconstruction of Banda Aceh City. Vegetation density from 2004, 2005, and 2009 continued to experience a decrease in vegetation density; this could be because Banda Aceh City 2009 restored infrastructure damaged by the Tsunami disaster.
In 2015 most of the Banda Aceh City area was included in the low vegetation density class. The value of vegetation density was obtained with a range of -0.15 - 0.56; the results of image processing in 2015 showed a low level of vegetation density with the largest area of 3,107.25 Ha spread over all sub-districts in Banda Aceh City and covering 55.04% of them throughout the city of Banda Aceh. The second widest vegetation density is the medium vegetation density level with an area of 1,461.33 Ha and covers 25.89% spread over each sub-district. The vegetation density with the smallest area is the high vegetation density level with 1,076.67 Ha, which only covers 19.07% of the Banda Aceh City area, concentrated in the sub-districts Ulee Kareng, Banda Raya, Jaya Baru, Kuta Raja, and Syiah Kuala. The value of vegetation density obtained in 2015 starts to enter the normal period ten years after the tsunami disaster. Vegetation density results from Landsat 7 image processing in 2004, 2005, and 2009 have different values from Landsat 8 image processing in 2015. The results of the 2015 NDVI value have increased vegetation density; this is because some areas have been replanted with vegetation.

**Figure 3.** Multitemporal distribution of vegetation density of Banda Aceh city (a. 2004, b.2005, c. 2009, d.2015 and e. 2020.
The image processing results in 2020 obtained a vegetation density value of -0.28 - 0.57, a low vegetation density level with the largest area of 3,596.94 Ha spread over all sub-districts in Banda Aceh City, covering 63.72% of the entire City area. Banda Aceh. The second widest vegetation density is the medium vegetation density level with an area of 1,270.89 Ha and covers 22.51% found in each sub-district. The vegetation density with the smallest area is the high vegetation density level with 777.24 Ha, which only covers 13.77% of the Banda Aceh City area, spread over every sub-district. The results of the vegetation density obtained in 2020 are normal conditions after 15 years of the tsunami disaster. Vegetation density from 2015 to 2020 experienced a decrease in vegetation density.

The distribution of vegetation density in Banda Aceh City obtained from the results of the NDVI calculation can be seen in Figure 3.

4. Conclusions

The results show that using remote sensing data in the form of Landsat 7 and Landsat 8 images by utilizing NDVI calculations can determine the vegetation density of Banda Aceh City. In 2004 before the tsunami dominated the low-density class. In 2005 after 19 days, the tsunami was dominated by low-density types. In 2009 the rehabilitation and reconstruction phase was dominated by low-density classes. The vegetation density of Banda Aceh City continues to decline every year; in 2015 and 2020, low vegetation density classes still dominate it, but this has increased because some areas have regrown vegetation. Further research development can be carried out on the same case using different vegetation indices.

References

[1] Alexander, D. E. 2014. Principles of Emergency Planning and Management (Terra Publishing)
[2] Syamsidik, Nugroho A, Oktari R S and Fahmi M. 2019. Aceh Pasca Lima Belas Tahun Tsunami: Kilas Balik dan Prosess Pemulihan (Banda Aceh, Aceh: Tsunami and Disaster Research Center (TDMRC))
[3] Wulandari, E. and Safriana, D. 2017. Konsep pengembangan Kota Banda Aceh sebagai kota wisata tsunam J. Arsit. ARCADE 1 1–7
[4] Marsono. 1977. Deskripsi Vegetasi an Tipe-Tipe Vegetasi Tropika (Yogyakarta: Yayasan Pembinaan. Universitas Gadjah Mada)
[5] Becker, F. and Li, Z. L. 1990. Towards a local split window method over land surfaces. Int J Remote Sens. 11 369–93
[6] Jomaa, I. and Kheir, B. I. 2003 Multitemporal unsupervised classification and NDVI to monitor Land cover change in Lebanon (1987-1997) 49 43–9
[7] Elvidge C, Lyon J, Lunetta R, Brondizio E, Lyon J G, Yuan D, Lunetta R S and Elvidge C D. 1998 A change detection experiment using vegetation indices. Photogramm. Eng. Remote Sens. Cite 62 143–50
[8] Horning, N. 2004 Global Land Vegetation: An Electronic Textbook. NASA Goddard Space Flight Center Earth Sciences Directorate Scientific and Educational Endeavors (SEE)
[9] Danoedoro, P. 2012 Pengantar Penginderaan Jauh Digital (Yogyakarta: Andi Offset)
[10] Yacouba D, Guangdao H and Xingping W. 2009 Assessment of land use cover changes using Ndvi and dem in Puer And Simao Counties , Yunnan Province , China 1 1–11
[11] USGS What are the Band Designations for the Landsat Satellites?. https://www.usgs.gov/faqs/what-are-band-designations-landsat-satellites/? 2016
[12] Rouse J W, Haas R . H, Schell J . A and Deering D . W. 1973 Monitoring vegetation systems in the great plains with erts. In: Proceedings of the Third ERTS Symposium vol.351 pp 309–17
[13] Departemen Kehutanan. 2012 Peraturan Menteri Kehutanan Republik Indonesia nomor: P.12/MENHUT-II/2012 (Jakarta)