Vegetation change analysis using Normalized Difference Vegetation Index (NDVI) in Sumedang Regency

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Abstract. Vegetation is a crucial element of livable and healthy cities and has been linked to a number of advantages, such as enhanced human health, habitat provision, and natural system regulation. Planning sustainable cities requires an understanding of and documentation of changes in urban vegetation. The Normalized Difference Vegetation Index (NDVI)'s spatial variance and driving force are useful for managing natural resources and protecting ecological environments. Using Sumedang Regency as the research area, the normalized vegetation index (NDVI) was computed using Landsat-7 ETM and Landsat 8 OLI/TIRS data from 2003 to 2023. The findings show that the high greenness index first declined and subsequently increased between 2003 and 2023. Sumedang Regency's high greenness index shrank in area between 2003 and 2018. In 2003, 144793.17 ha was categorised as high greenness index, but in 2018 the high greenness index was only 122392.08 ha. Furthermore, the index with non-vegetated land increases every year. This shows that Sumedang Regency continues to experience land use change into non-vegetated areas, such as settlements and bare land. This research can provide assistance for the development of a sustainable natural environment in Sumedang Regency.

1 Introduction

The primary component of the terrestrial ecosystem, vegetation is vital to the cycles of materials and energy in the hydrosphere, biosphere, and atmosphere [1]. Furthermore, vegetation has an impact on the carbon sink in the carbon cycle and can, to some extent, demonstrate the ecological environment [2]. Plant suppression in biomes, ecosystems, and tropical forests can cause climate change at local, regional, and global scales [3]. The balance of water, carbon, and energy between the land and the atmosphere is regulated by vegetation, which functions as a feedback mechanism [4]. It is crucial to systematically monitor the changes and driving forces behind the spatiotemporal dynamics of vegetation in order to comprehend regional ecological changes and create ecological conservation plans. For the dynamic monitoring of large-scale vegetation coverage, remote sensing is a crucial tool.

Long time series and large-scale remote sensing image data can yield a variety of feature information due to the growing number of high-resolution remote sensing satellites in service and the quick development of quantitative remote sensing technology. The Remote Sensing data has many application areas including: land cover classification, soil moisture measurement, forest type classification, measurement of liquid water content of vegetation, snow mapping, sea ice type classification, oceanography [5]. The multispectral remote sensing images carry essential integrating spectral and spatial features of the objects [6]. Normalized difference vegetation index (NDVI), lidar change detection, and high-resolution land cover datasets are a few frequently utilized techniques. Of these, NDVI is the simplest and most widely available method for assessing green vegetation, as lidar and high-resolution imagery are less available worldwide [7].

Through the use of various mathematical indices and algorithms, digital image processing of satellite data offers instruments for image analysis. Reflectance characteristics serve as the basis for features, and indices have been developed to draw attention to the image's noteworthy features [8]. To identify vegetation-bearing areas on a remote sensing scene, there are a number of indices available. A popular and extensively used index is the NDVI [9]. It is a significant vegetation index that is frequently used in studies on climatic and environmental change worldwide [9]. The difference between the measured canopy reflectance in the red and near-infrared bands, respectively, is used to compute the NDVI [10].

The normalised vegetation index (NDVI) is a remotely sensed index used to measure vegetation cover and growth status. To calculate it, vegetation reflectance in the visible and near-infrared regions of the electromagnetic spectrum is used. According to [5], the lusher and healthier the vegetation, the higher the NDVI number. Many industries, including forestry, agriculture and ecological monitoring, have made extensive use of NDVI. In arid regions, such vegetation has a significant impact on the ecological environment and climate change [6]. NDVI is a useful tool for monitoring vegetation conditions in the field. NDVI can accurately capture changes in biomass, land cover, growth and other aspects of vegetation.

At regional and global scales, NDVI is often used to track dynamic shifts in crop cover and land use [7]. Researchers from around the world have studied the temporal and spatial distribution of regional vegetation using NDVI values in recent decades [8]. In Indonesia, studies on temporal changes in vegetation cover have analysed vegetation cover in relation to agroforestry structure, composition and diversity in Agusen Village, Gayo Lues District, and Alur Durin Village, East Aceh District, Aceh Province, and satellite remote sensing data and NDVI processing have been used to quantitatively analyse vegetation status [9].

This research will take a case study in Sumedang Regency, West Java Indonesia. Based on the [10], there are several development plans in the Sumedang area. One of them is quoted from [11] in the aspect of National Medium-Term Strategic Activities, that there will be Construction of the Bandung-Tanjungsari, Sumedang-Kertajati-Kadipaten-Cirebon Railway and Construction of the Cileunyi-Sumedang Dawuan Toll Road. In the aspect of Urban National Strategic Area priority locations as regional growth centres in Java-Bali, Sumedang Regency is directed to become a global-scale National Activity Centre (PKN) oriented towards increasing the specialisation of educational services, information system technology, industry, and urban tourism. This development is feared to disrupt ecosystem stability in Sumedang Regency, even though according to [12], The area has various traditional agricultural bioproduction systems that embody the concept of sustainable development in Sumedang Regency.

Based on this, this paper will discuss the analysis of vegetation change using NDVI in Sumedang Regency. Vegetation indices can accurately reflect information on land vegetation cover and are commonly used as a key indicator of land vegetation change. NDVI calculates vegetation index based on infrared and near infrared reflectance received by Landsat. This study aims to (1) obtain the vegetation index in the period 2003 - 2023, (2) determine changes in the greenness index area in Sumedang Regency in the period 2002 - 2023.

2 Methodology

2.1 Study Area

Sumedang Regency is located at the geographical coordinates 107є21'-108є21' East longitude and 6є44'-70є83' South latitude. Sumedang Regency is mostly hilly and mountainous, except for a small part in the northern region. The peak of Mount Tampomas, which rises approximately 1,684 metres above sea level, is the highest point, while the lowest point is only 26 metres above sea level. The total area of Sumedang Regency is 155,872 hectares, divided into 26 sub-districts with 270 villages and 7 urban villages, in accordance with the Regional Spatial Plan of Sumedang Regency 2018-2038. With an area of 11,392 hectares, Jatigede Sub-district is the largest sub-district, while Cisarua Sub-district is the smallest, at 1,450 hectares.

The population density in Sumedang Regency in 2017 reached 753 people/km2. The population density in 26 sub-districts is quite diverse with the highest population density in Jatinangor Sub-district with a density of 4,348 people/km2 and the lowest in Jatigede Sub-district at 215 people/km2.

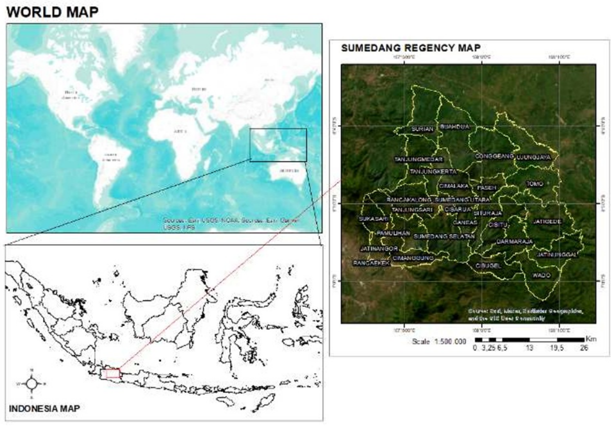


Fig. 1. Study Site

2.2 Data Collecting

The Landsat images were downloaded from the United State Geological Survey (USGS) website (http://earthexplorer.usgs.gov/) with the Sumedang District located on path 121 and row 65. Landsat thematic mapper (TM) imagery was selected for 2003, 2005, and Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) for 2013, 2018, and 2023 which are open source data. All these data are publicly available. Bands 1 to 7 of the seven spectral bands in Landsat TM imagery have a spatial resolution of 30 metres, while Band 6, which is thermal infrared, has a spatial resolution of 120 metres. Landsat 8 OLI-TIRS consists of 9 spectral bands. The spatial resolution is 30 metres for bands 1 to 7 and 9. Band 8 is a panchromatic band with a resolution of 15 metres.

2.3 Image Processing

The Landsat images had to be stacked, as they consist of several bands, especially band 11. To obtain images with a combination of bands, layer stacking was performed. Radiometric correction is done to reduce the effects of the atmosphere on the image. Clouds, dust, or other particles in the atmosphere refract the reflected waves. Based on the refraction that occurs, before analysing the image, radiometric correction is carried out, with the Radiometric Calibration tool. After that, image correction is carried out, namely atmospheric correction to eliminate radiance errors recorded in the image as a result of atmospheric scattering (path radiance) with the FLAASH atmospheric correction tool. The entire procedure was performed using ENVI 5.3.

2.4 Normalized Difference Vegetation Index (NDVI)

An NDVI image can be created by combining the reflectance of Red and Near Infrared (NIR) wavelengths with Eq. 1 of image calculation (Nouri et al., 2013). In the electromagnetic spectrum (EMS), healthy vegetation has a low reflectance in the red wavelength and a high reflectance in the near-infrared wavelength.

$$NDVI = \frac{NIR - Red}{NIR + Red} \quad (1)$$

The NDVI is primarily used to differentiate between vegetative and non-vegetative areas and has been shown to be a strong vegetation signal (Nath and Acharjee, 2013). The NDVI index has values between -1 and +1, with -1 and 0 denoting non-vegetative features like a bare surface, a body of water, and a built-up area. Nonetheless, vegetative cover is represented by an NDVI value greater than 0. This step's primary objective is to keep only the vegetated areas and isolate the non-vegetated ones, such as the built-up area, paved roads, and bare soil. In the following table 1 for the classification of NDVI values [13]:

Table 1. NDVI value and the greenness level of the vegetation

Classification Ranges	The greenness level of the vegetation
-1<NDVI<-0,03	Non-vegetation area, open area, waterbody
-0,03<NDVI<0,15	Very low dense vegetation
0,15<NDVI<0,25	Low dense vegetation
0,25<NDVI<0,35	Moderately dense vegetation
0,35<NDVI<1	Highly dense vegetation

3 Result and Discussion

The spatiotemporal dynamic change of NDVI is a hot research topic for global researchers, and as an important indicator for evaluating changes in the ecological environment, monitoring vegetation change is a dynamic process of long time series and spatial patterns [14]. The NDVI have been used widely to examine the relation between Spectral variability and the changes in vegetation growth rate. It is also useful to determine the production of green vegetation as well as detect vegetation changes [15]. The NDVI has certain advantages over other vegetation indices, since it is less dependent on soil properties [16] and can be simply calculated from canopy reflectance in infrared and near-infrared bands [17,18]. Thus, NDVI represents the most widely used in the literature for ecosystem monitoring

Based on the analysis conducted, in 2003, the study found that NDVI ranged from -0.104989 to 0.803567, with an average value of 0.326268, indicating that 2003 was categorised as Moderately dense vegetation. This value decreased in 2005, showing a mean value of 0.202422 with a range of NDVI values of -0.1632 to 0.81703. This shows that in 2005, the Sumedang Regency area included the greenness index category of Low dense vegetation. After that, from 2013 to 2023, the average vegetation density continued to increase by showing the average NDVI sequentially for 2013, 2018, 2023, namely 0.351147, 0.41965, 0.470035. This shows that the vegetation index of Sumedang Regency is categorised as Highly dense vegetation.

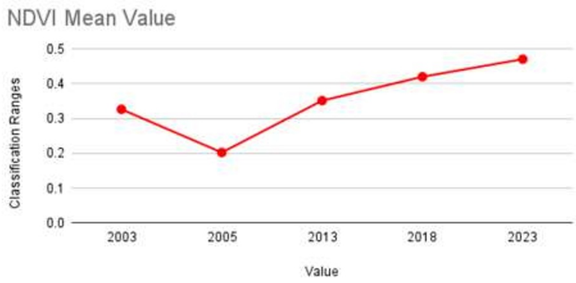
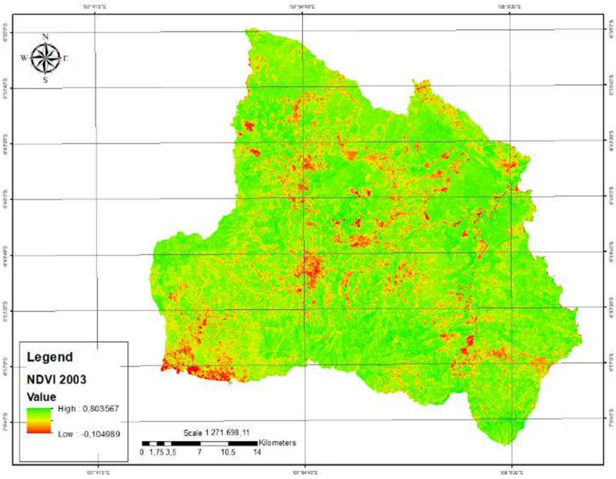
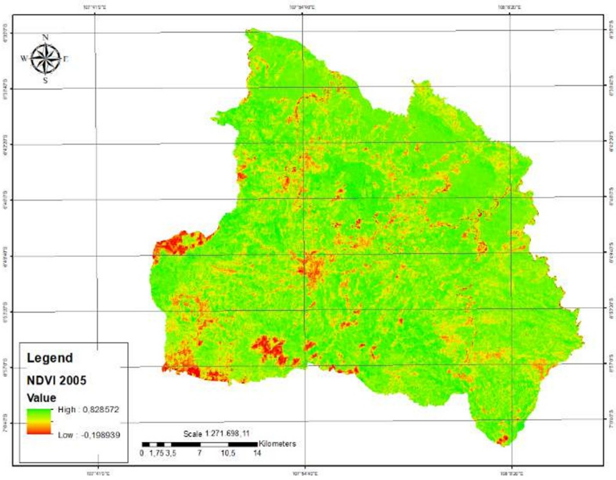


Fig. 2. NDVI Mean Value

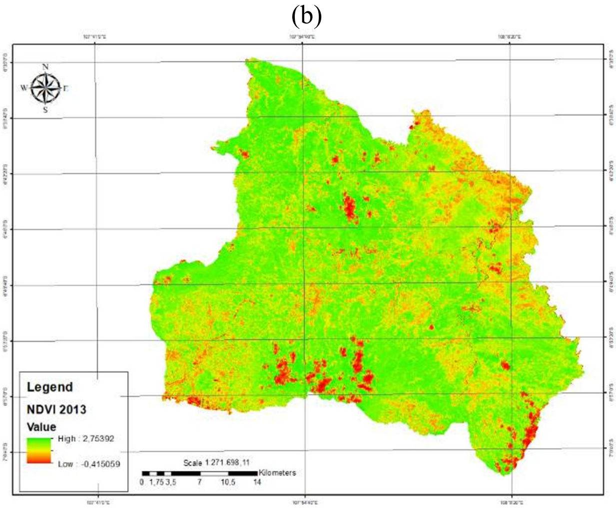
However, when viewed from the area, it can be seen that the area with the Non-vegetation area category continues to increase. In 2003, there were 48.42 ha in the non-vegetated area category. By 2023, there were 3507.12 ha categorised as non-vegetated areas. This is supported by the presence of reservoirs in Jatigede Sub-district, and increasing residential areas. In 2023 it is also shown that Jatinangor sub-district has a higher non-vegetated area.



(a)



(b)



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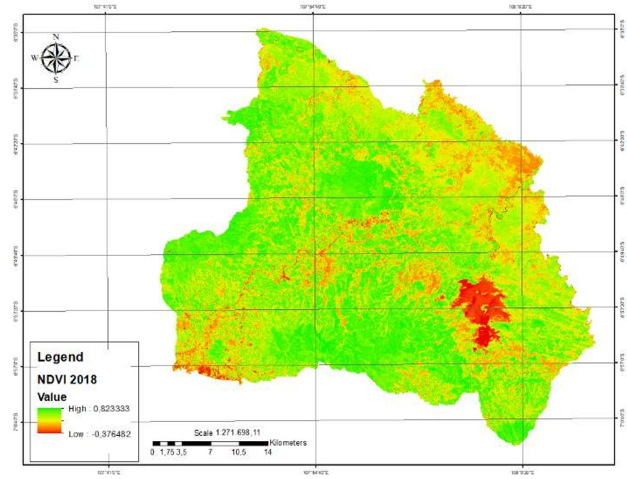

(d)

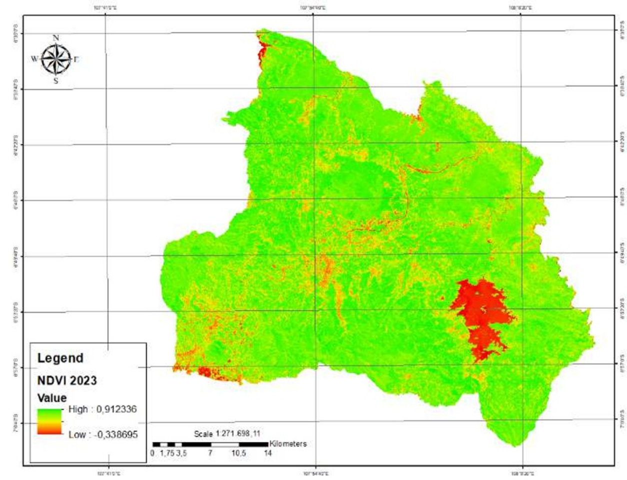

Fig. 2. Spatio-Temporal variation of the NDVI-based vegetation from (a) 2003, (b) 2005, (c) 2013, (d) 2018, and 2023 in Sumedang Regency.

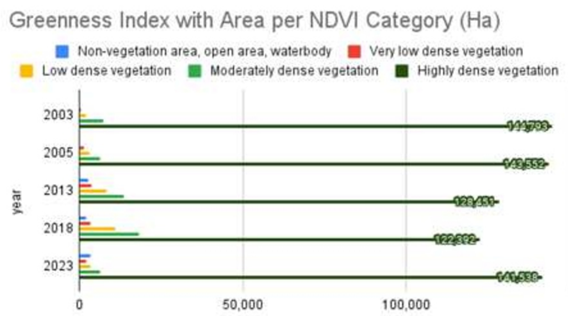

Fig. 3. Greeness Index Value in Hectare

These are areas with dense populations and more human activity. High accessibility is also found there, which can trigger and encourage people to change land use and land cover. Roads attract people to change land use and land cover. Humans will convert paddy fields into residential land thus triggering land use change. The construction of new roads will change the natural landscape [15]. According to [16], the high population growth in urban areas is due to urbanization which resulted in the high rate of conversion of land-use function.

The analysis of the vegetation index can yield insightful data. Sumedang Regency's vegetation conditions can be monitored, in part, through analysis of the vegetation index. This can assist in identifying areas that are vulnerable to disasters, need maintenance, and require restoration or reforestation. Monitoring land changes in Sumedang Regency can also be done with the use of vegetation index analysis. Changes in the value of the vegetation index in the area can be used to identify land changes such as mining, the encroachment of forests, and the expansion of settlements or agriculture. In order to enhance environmental quality and facilitate better plant management, the vegetation index can offer information about the health of the plants in Sumedang Regency [16]. As a result, the accuracy and certainty of the modeled NDVI data may differ from the real biophysical characteristics of vegetation canopy in various geographic regions. Nevertheless, in the Arctic region, the application of NDVI shows high overall correlation with real biophysical properties of vegetation [17].

The results of the vegetation index analysis in Sumedang Regency can be used to improve environmental and vegetation management policies and programs, to name a few potential remedies. This covers forest conservation, expanding the area of mixed gardens, reforestation, and land rehabilitation. Vegetation index analysis can be used to support agricultural development in Sumedang Regency by providing information on the state of the vegetation, the amount of soil moisture, the soil's capacity to absorb water, and other factors. According to [18] report that in the Yellow River Basin, precipitation and air temperature have a positive correlation with NDVI, with precipitation having a higher effect on plant development than temperature.Sumedang Regency, which has a lot of potential for bioproduction, supports this. Selecting the right plants for planting and boosting agricultural output can be aided by having knowledge of the state of the vegetation and the availability of suitable land. The findings of the analysis of the vegetation index can aid in lowering the risk of disaster. Disaster-prone areas can be located and the necessary preventive actions can be implemented by understanding the state of the vegetation and land changes.

Government, community, and other relevant institutions must work together to make decisions based on the findings of the vegetation index analysis in Sumedang Regency. This will make it possible to take comprehensive and long-term measures to protect the environment and advance Sumedang Regency's general development. The government and community can take action to guarantee that the development of built-up land in Sumedang Regency does not harm the environment and maintains a balance between built-up land and green land by routinely monitoring the Vegetation Index [17]. Additionally, keeping an eye on the Vegetation Index can assist in determining the effects of environmental and climate change in Sumedang Regency and in implementing the necessary mitigation measures to address these issues.

4 Conclusion

In summary, the study area's NDVI analysis yielded five distinct vegetation classes: class 1 consisted of non-vegetated areas, open spaces, and water bodies; classes 2 and 3 were very low dense vegetation, class 4 consisted of moderately dense vegetation, and class 5 consisted of highly dense vegetation.

The findings show that the high greenness index first declined and subsequently increased between 2003 and 2023. Sumedang Regency's high greenness index shrank in area between 2003 and 2018. In 2003, 144793.17 ha was categorised as high greenness index, but in 2018 the high greenness index was only 122392.08 ha. Furthermore, the index with non-vegetated land increases every year. This shows that Sumedang Regency continues to experience land use change into non-vegetated areas, such as settlements and bare land. This research can provide assistance for the development of a sustainable natural environment in Sumedang Regency.

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