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Vegetation and Built-Up Area Monitoring in Bandung City Using Multitemporal Imagery

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ABSTRACT
Bandung is West Java's largest metropolitan city and Indonesia's third largest. The city of Bandung is very strategic in various aspects, such as accessibility, communication, public facilities, and the economy. The Increased population in Bandung indicates more complex ongoing human activities, which can then affect changes in land use. The land covers in urban areas tend to change more drastically over a short period e than in rural areas because of rapid urbanization. Therefore, urban phenomenon changes are ideally monitored and detected from satellite images with a multitemporal resolution. Vegetation greenness and built-up areas can identify through multitemporal remote sensing imagery. Changes in vegetation and built-up area can monitor using remote sensing with multitemporal imagery. The analysis of changes in vegetation and built-up area studied in Bandung City represents an area with rapid population growth. This study aims to: 1) Identify changes in vegetation greenness in Bandung City between 2014 and 2021, 2) Identify built-up area changes in Bandung City between 2014 and 2021, 3) Analyze the relevance between vegetation greenness and the built-up area in Bandung City—the correlation between NDBI and NDVI through selected samples is representative of all data in Landsat 8 imagery. The proportion between the values of NDBI and NDVI samples is 0.9034. So, it is concluded that the two variables are positively correlated. Therefore, the study's results recommend preserving vegetated land cover to conserve natural resources and prevent increased land surface temperature.

INTRODUCTION

Developing countries, including Indonesia, usually experience rapid urbanization, especially in big cities on Java island. Urbanization causes changes in land use and an increase in a built-up area (Safariah, Majid, & Rusli, 2022). The Contribution of Housing Area to Land Surface. Journal of Sustainability Science and Management Volume 17 Number 7, July 2022: 62-72. Bandung is West Java's largest metropolitan city and Indonesia's third largest. The city of Bandung is very strategic in various aspects, such as accessibility, communication, public facilities, and the economy. This is related to the location of Bandung between the east-west highways, which facilitates relations with Jakarta as the capital city of Indonesia (Rusnandar, 2010). The conversion of built-up areas in urban areas is high-speed. Urbanization causes changes in land use from vegetation to built-up areas in urban areas. Changes in the built area like this can be reviewed using remote sensing data, which has the advantage of temporal resolution (Hidayati et al., 2017). This also happened in Bandung, which experienced an increase in population. This increase indicates more complex ongoing human activities, which can then affect changes in land use.

The total population in Bandung in 2014 was 2,436,576 people, with an area of 16,731 ha, and the entire population density was 4,684 people/ha. The sub-district with the lowest population is Rancasari, with 7,806 people, while the highest is Babakan Ciparay, with 148,084 people. The total population in 2021 increased from the previous year, which was 2,526,476, and the population density is 4,788 people/ha. The district with the lowest population is Cinambo, with 25,586 people; the highest is Babakan Ciparay, with 142,528 people (BPS, 2014).

Vegetation is an essential component of terrestrial ecosystems. Factors that may affect vegetation include climate change which has harmful effects on vegetation, such as; changes in temperature and rainfall, extreme heat, flash floods, and migration of people from villages to cities. Besides that, the economy and demographics also play an essential role in climate change and vegetation (Hussain, 2022). Likewise, the built-up area in urban areas continues to grow, changing the vegetation area due to the drastic increase in urban population, whether natural or migratory (Puspitasari, 2013). Surface cover in the city is a complex feature, a combination of vegetation, water body, impervious surface materials, and exposed soil area (Rasul et al., 2017).

Remote sensing has been recognized as a valuable tool for viewing, identifying, analyzing, and making decisions about our environment. The land covers in urban areas tends to change more drastically over a short period than in rural areas because of rapid urbanization. Therefore, urban phenomenon changes are ideally monitored and detected from satellite images with a multitemporal resolution (Karanam, 2018; Lynch, Blesius, & Hines, 2020). The use of remote sensing imagery to land use and land cover classification in an urban environment is a mature sub-discipline of remote sensing research (Akinrinola, 2019; Neyns & Canters, 2022).

The sensor's ability and the object's characteristics can influence the object's spectral response on the earth's surface. Reflections of objects commonly discussed in remote sensing studies are soil, water, and vegetation. These three objects are the three main objects that can be recognized directly through remote sensing images (Swain & Davis, 1978). The foliage has unique characteristics that remote sensing sensors can record. Tropical rainforests have a greater diversity of species than other vegetation types and are a significant emitter of CO_2, helping to maintain the global climate (Morley, 2005).

The Normalized Difference Built-up Index (NDBI) is the method to identify the built-up area. At the same time, vegetated regions can be identified through the Normalized Difference Vegetation Index (NDVI). The underlying assumption of NDBI is spectral reflection involving SWIR and NIR channels. NDBI is an effective transformation for automatically mapping urban built-up areas. The spectral reflection characteristics in urban areas are also affected by the season. However, the image extraction or transformation method in urban areas is relatively unaffected by seasonal differences, apart from the transformation of urban vegetation. The original NDBI offers convenience for users working in urban areas. However, this approach has weaknesses: the decomposition of derived NDBI values and NDVI images cannot separate built-up land from vacant land (Hidayati et al., 2017).

Vegetation greenness and built-up areas can identify through multitemporal remote sensing imagery. Changes in vegetation and built-up area can monitor using remote sensing with multitemporal imagery. This research uses a vegetation index algorithm and built-up area index in areas with topographical variations characterized by the city of Bandung in a relatively flat topography with hilly and steep surrounding regions. These topographical variations are assumed to affect the results of the vegetation index and built-up area index algorithms. The accuracy is tested by collecting primary data through field surveys.

The analysis of changes in vegetation and built-up area studied in Bandung City represents an area with rapid population growth. This study aims to: 1) Identify changes in vegetation greenness in Bandung City between 2014 and 2021, and 2) Identify built-up area changes in Bandung City between 2014 and 2021, 3) Analyze the relevance between vegetation greenness and the built-up area in Bandung City.

RESEARCH METHODS

Bandung, the capital city of West Java Province, will have a maximum temperature of 33°C in 2021. The highest point in Bandung is Ledeng (892 meters above sea level), and the lowest is in Rancanumpang (666 meters above sea level) (BPS, 2021). Regarding geographic position, Bandung City or Bandung Municipality has boundaries with Bandung Regency, West Bandung Regency, and Cimahi Municipality. The total area of Bandung Municipality is 167,31 km2. It is divided into 30 districts covering 151 sub-districts (BPS, 2022).

The commonly used statistical formula should not be written if the research uses statistical analysis. Instead, the researchers should explain a specific approach to collecting and analyzing data in this section by citing the source of the references used.

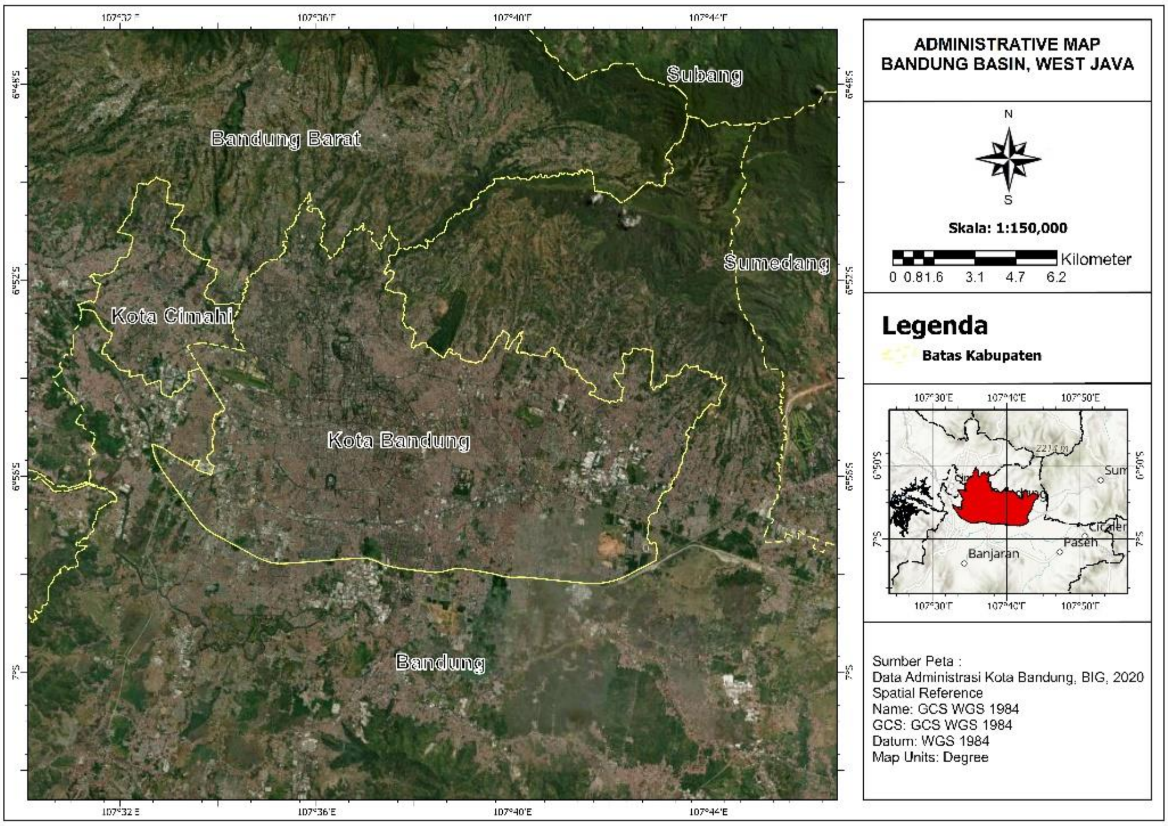

Figure 1. Studi Area (Source: Data Processing, 2022)

The development of Landsat 8 is a collaboration between the National Aeronautics and Space Administration (NASA) and the U.S. Geological Survey (USGS) and began providing open-access imagery products on May 30, 2013 (Fawzi & Husna, 2021). In this recent study, Landsat has a purpose for diverse fields such as agriculture, forestry, natural resources, land use, and land cover and environmental monitoring. Landsat 8, with the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), collects images in the visible, panchromatic band, shortwave infrared spectral bands, and thermal bands (Ridwan et al., 2018). Landsat imagery is a remote-sensing image of natural resources with medium spatial resolution. The advantage of

Landsat Imagery is that it is easily accessible via the United States Geological Survey website and provides data every 16 days. This study uses Landsat 8 imagery for 2014, 2017, and 2021. Landsat eight imagery is processed using the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Built-up Index (NDBI) algorithms.

Vegetation Index

The greenness of the vegetation can be represented through the vegetation index value. The vegetation index is a technique for obtaining quantitative information about the innocence of vegetation per pixel. The vegetation index is a spectral transformation applied to multi-channel images to highlight vegetation aspects such as chlorophyll density and concentration. The vegetation index consists of a combination of digital pixel values that are added, divided, or multiplied to obtain the value of the quantity of vegetation per pixel in remote sensing images (Chuvieco & Huete, 2010; Campbell & Wynne, 2011; Danoedoro, 2012). In addition, the Normalized Difference Vegetation Index (NDVI) was used to obtain a greenness level of vegetation. NDVI has a positive value representing a dense vegetation area, while negative values indicate a non-vegetation area (Ovyavuz, 2010).

$$\mathrm{NDVI} = \frac{(\mathrm{NIR} - \mathrm{RED})}{(NIR + RED)}$$

The equation used to obtain the NDVI value is the difference between the pixel values in the near-infrared channel (highly reflected by green vegetation and the red spectrum absorbed by vegetation) and the red track, then divided by the sum of the pixel values in the two channels (Mróz & Sobieraj, 2004; Malik et al., 2019).

Built-up area index

The built-up area index is obtained by transforming the Normalized Difference Built-Up Index (NDBI) resulting from remote sensing image processing. NDBI uses an equation involving Shortwave Infrared (SWIR) channels between 1.55-1.75 nm and Near-Infrared (NIR) between 0.76-0.9 nm, where the built-up area has a higher reflectance in the SWIR channel than in the NIR channel. Built-up areas and barren land experience a drastic increase in reflectance from the NIR channel to the SWIR channel, while vegetation has a slightly greater or lesser value in the SWIR channel than in the NIR channel. This rate of increase is very significant compared to other types of land cover. The NDBI equation involving SWIR and NIR will produce values close to 0 for forest and agricultural land pixels, negative values for water bodies, but positive values for built-up pixels, making it possible to separate land cover in the form of built-up areas from other land covers (Zha et al., 2003). NDBI is very useful for mapping urban built-up areas. The equation used is:

$$NDBI = \frac{SWIR - NIR}{SWIR + NIR}$$

SWIR is the mid-infrared reflectance, namely band six on Landsat 8. Meanwhile, NIR is the near-infrared reflectance (band five on Landsat 8). NDBI values range from -1 to 1. The greater the NDBI, the higher the proportion of built-up areas (Malik et al., 2019).

Field Surveying

Field survey to obtain actual temperature data in the study area and observations of land use types per sample point—a sample of 78 points in Bandung City and West Bandung Regency. The data taken during the survey included: coordinates, object temperature values, environmental temperature, type of land use, and presence of buildings and vegetation.

RESULTS AND DISCUSSION

Vegetation changes in Bandung City (2014-2021)

Bandung is a city with a reasonably average growth rate of 1.01% per year. The high population growth rate then affected the rapid development of the built environment, leading to temperature and changes in natural land cover (Indradjati & Aisha, 2019). Landsat 8 imagery has 11 spectral bands, some of which can be transformed into vegetation index values. The spectral band used is the green, red, or infrared channel for the Normalized Difference Vegetation Index algorithm. There are various kinds of vegetation index algorithms. This study uses a type of algorithm that is quite commonly used and represents the greenness of the vegetation. The city of Bandung continues to grow along with the increase in population and all related activities. Therefore, the increase in built-up land can be assumed to cause decreased vegetation area.

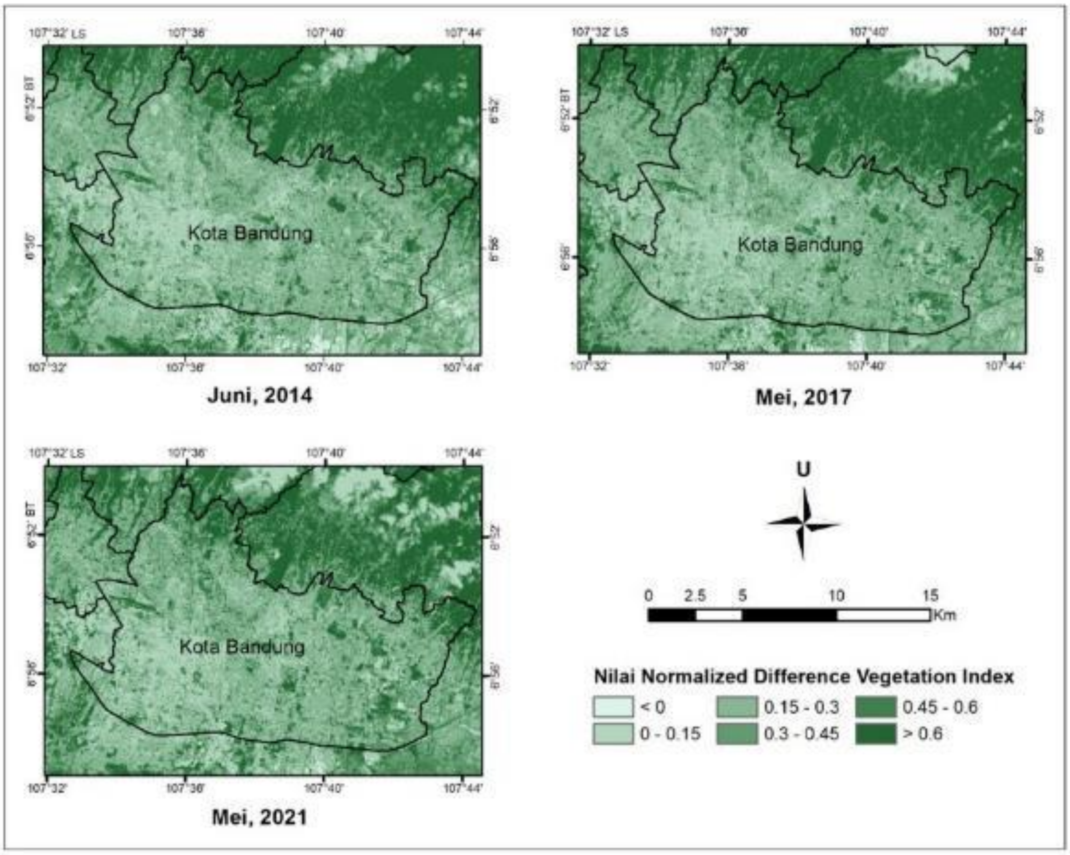

Figure 2. NDVI Changes 2014-2021 (Source: Data Processing, 2022).

The combination of several channels owned by satellite images will produce a vegetation index value reflecting the greenness level. The resulting index value is between minus 1 to 1, where the greater the value indicates, the thicker or greener the plants are (Prasetyo et al., 2017). Landsat image processing results with the Normalized Difference Vegetation Index algorithm are divided into six classes from values below 0 to more than 0.6. NDVI values between 0.2 to 0.8 are generally vegetation. The NDVI value changed between 2014 and 2021. In 2021, especially in the northern city of Bandung, the NDVI value decreased. This indicates a decrease in the greenery of vegetation or non-vegetated areas.

Built-up area changes in Bandung City (2014-2021)

Usually, land use change in urban areas replaces soil and vegetation with urban features such as buildings, concrete, and other built-up areas (Essien & Cyrus, 2019; Hosea et al., 2019; Darmaputra & Darwin, 2022). Normalized Difference Built Index (NDBI) is an algorithm for estimating building density. NDBI uses the mid-infrared and near-infrared spectral channels as its input. The resulting index values are in the range of -1 to 1. Values close to -1 indicate areas that are not built-up land, and built-up land that tends to be dense to very dense has a value close to 1 (Nurhuda et al., 2019).

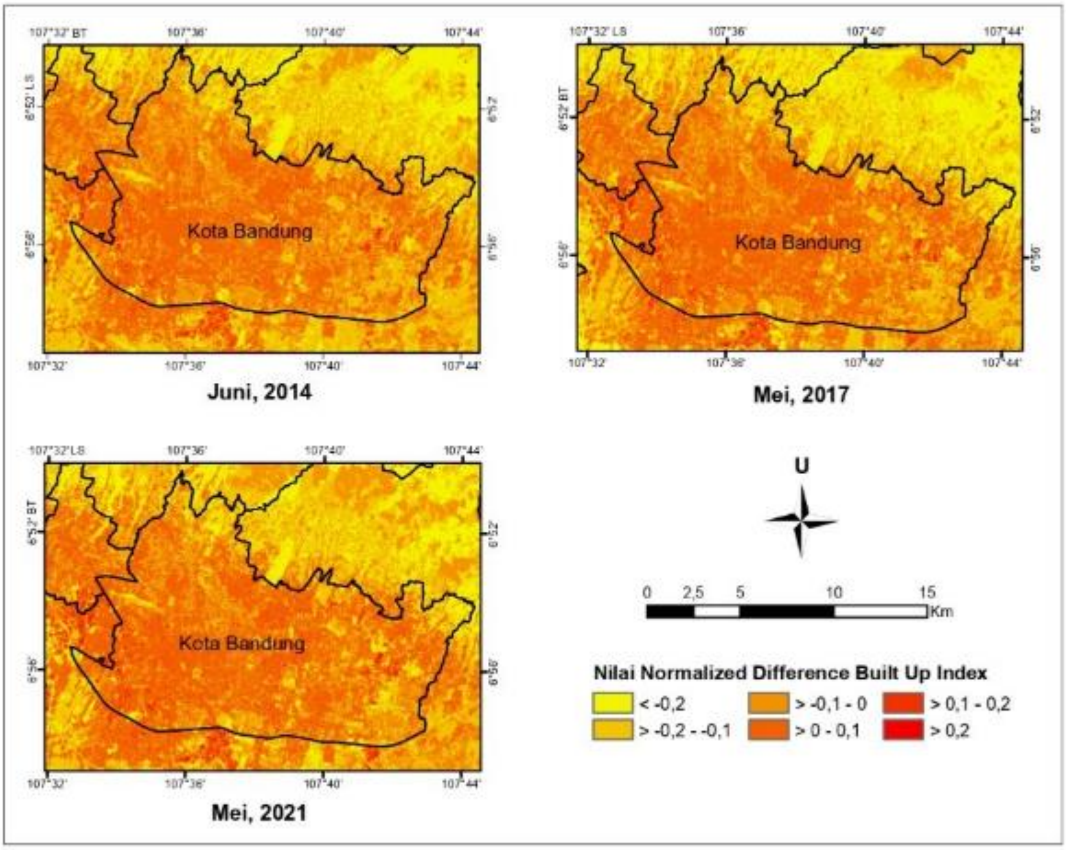

Figure 3. NDBI Changes 2014-2021 (Source: Data Processing, 2022)

NDBI in Bandung City in 2014, there was a wider area with an NDBI value of -0.2 – -0.1 representing non-built-up areas, and gradually decreasing in 2017 and 2021, especially in the north. This means a change in land use into a built-up area. On the other hand, Bandung had a reasonably high NDBI value in 2014, above zero, and expanded in 2021. The contributing factor is the denser built-up areas in the city of Bandung. This is inseparable from the increase in population along with various human activities.

Correlation Between NDVI and NDBI in Bandung City (2014-2021)

NDBI can effectively describe the land surface temperature with a positive correlation every season: the larger the urban built-up land, the higher NDBI and land surface temperature. Meanwhile, a robust negative correlation exists between NDVI and land surface temperature. The higher the NDVI value was, the lower the land surface temperature was. NDBI and NDVI had a significant negative correlation. It suggests that NDVI can respond to NDBI change and reflect the evolution of the urban area (Chen, 2013).

It is assumed that the higher the NDBI value (indicating a high-density built-up area), the lower the NDVI value. Vice versa, a high NDVI value is directly proportional to a low NDBI value. Figure 4. shows the correlation between NDBI and NDVI through selected samples representative of all data in Landsat 8 imagery. The proportion between the values of NDBI and NDVI samples is 0.9034. So, it is concluded that the two variables are relevant.

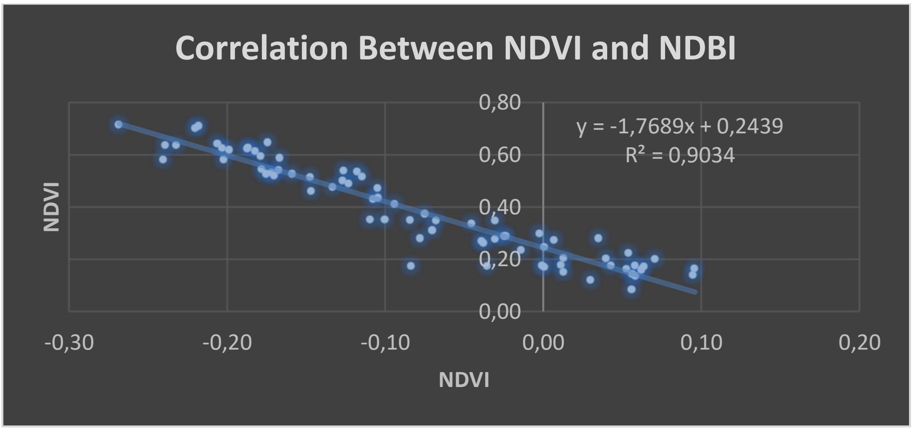

Figure 4. Correlation between NDVI and NDBI (Source: Data Processing, 2022)

Figure 5. Comparison between NDVI, NDBI, and land use (Source: Data Processing, 2022)

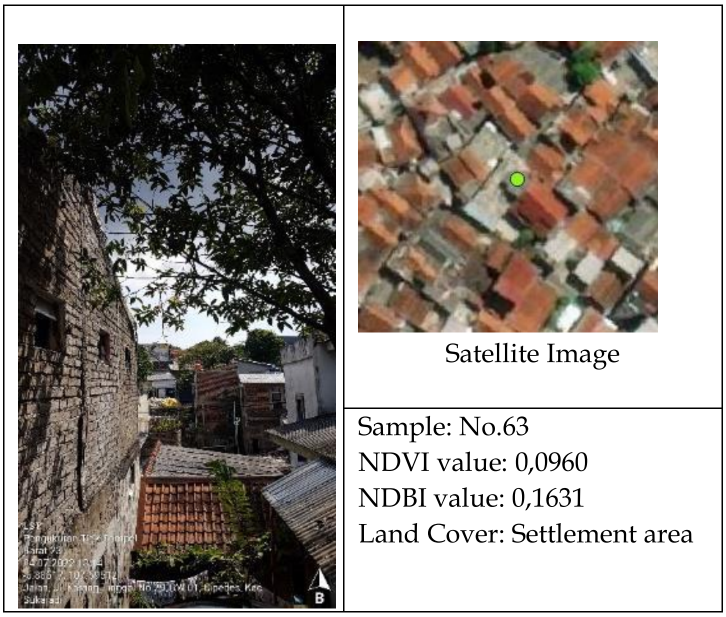

Figure 6. Comparison between NDVI, NDBI, and land use (Source: Data Processing, 2022)

The field survey aims to collect actual land cover data. Samples spread throughout Bandung, so the data obtained is more accurate and varied. The land cover was then compared with the NDVI and NDBI values resulting from Landsat 8 image processing. One of the samples in Ujung Berung District was vegetation, with an NDVI value of 0.7098 and an NDBI value of -0.2179. Both values are by the theory of comparison between NDVI and NDBI values. NDVI values close to 1 and NDBI close to minus 1 are vegetation. The matching results concluded that NDVI and NDBI processing using Landsat 8 imagery accurately represents objects on the earth's surface well.

CONCLUSION

Landsat image processing results with the Normalized Difference Vegetation Index algorithm are divided into six classes. NDVI values between 0.2 to 0.8 are generally vegetation. The NDVI value changed between 2014 and 2021. In 2021, especially in the northern city of Bandung, the NDVI value decreased. In addition, based on Landsat 8 Image processing result, there is a change in NDBI. In 2014 there was a wider area with an NDBI value of -0.2 – -0.1, representing non-built-up areas, and this will gradually decrease in 2021, especially in the north.

The correlation between NDBI and NDVI through selected samples represents all data in Landsat 8 imagery. The proportion between the values of NDBI and NDVI samples is 0.9034. So, it is concluded that the two variables are positively correlated. Therefore, the study's results recommend preserving vegetated land cover to conserve natural resources and prevent increased land surface temperature.

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