Impact of Vegetation Density Change on Land Surface Temperature in Kuta Utara Subdistrict, Badung Regency, Bali Province

Friscila Aginta¹, Astrid Damayanti²*, Muhammad Dimyati²

¹ Bachelor Program of Geography, Universitas Indonesia, Depok, Indonesia
² Department of Geography, Faculty of Mathematics and Natural Science, Universitas Indonesia, Depok, Indonesia

*Corresponding author : astrid.damayanti@sci.ui.ac.id

Abstract. Land function change can impact on decreasing green open space and land surface temperature (LST), which is one of the important parameters in environmental change. This study aims to identify vegetation density change and its impacts on land surface temperature in Kuta Utara Subdistrict, by comparing two vegetation indices to decide which vegetation index is more suitable if it is associated with LST. The Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) were used to knowing vegetation density change. This study estimated the brightness temperature of the satellite to find out the land surface temperature. NDVI, EVI, and LST values were obtained through Landsat ETM+ and Landsat OLI in 2010, 2015, and 2020. The values are analyzed using the spatial-temporal analysis method to see the vegetation density change and LST. The results of NDVI and EVI analysis showed that there are changes in vegetation density for each year, especially in the east and west Kuta Utara Subdistrict. The decreased in vegetation density causing an increase in LST from 2010, 2015, and 2020. Based on the analysis results, vegetation density changes based on NDVI and EVI did not have a significant impact on LST in Kuta Utara Subdistrict.

1. Introduction

The conversion of land cover from green open space to build-up area decreased vegetation cover and density. The decreased vegetation cover and density can impact land surface temperature [1]. In areas with low vegetation cover and density, the land surface temperature is high. This means the land surface temperature is sensitive to vegetation [2] and vegetation have a role in decreasing or increasing the land surface temperature.

This study used two of the most popular vegetation indices to see the vegetation changes, which are the Normalized Difference Vegetation Index (NDVI) and Enhanced Vegetation Index (EVI) [3]. NDVI is the vegetation index that shows the greenness of vegetation cover; dense or sparse vegetation cover [2]. EVI is the vegetation index developed by NDVI, that can eliminate background and atmosphere noises [4][5]. Vegetation index can normalize the effect of differential illumination of features, which can help in extracting specific vegetation classes in one area [6]. Therefore, the vegetation index is the most appropriate index to identify the vegetation change.

Land surface temperature (LST) means the temperature between the land surface and the atmosphere. The variations of land surface temperature in each region are different, depending on vegetation cover,
humidity, soil type, topography, and meteorological conditions in that region. Research on land surface temperature has been carried out using various methods, such as the split-window algorithm [7][8], mono-window algorithm [10-12], and brightness temperature [1][13]. The method used in this study is the brightness temperature because it is considered simpler to apply in this study.

Remote sensing and GIS technology are used to obtain vegetation and surface temperature data. This data can be obtained from Landsat 7 ETM+ and Landsat 8 OLI satellite imagery in 2010, 2015, and 2020, then analyzed using spatial-temporal analysis. This study aims to identify the vegetation density change and its impact on land surface temperature in Kuta Utara Subdistrict, by comparing two vegetation indices to know which vegetation index that has a more significant effect on land surface temperature in Kuta Utara Subdistrict.

2. Materials and Methods

2.1. Study Area
Kuta Utara Subdistrict is located in Badung Regency, Bali Province. The study area is geographically located between 8° 38’ 56” S to 115° 9’ 33” E, with a total area of 33,86 km². The altitude of the Kuta Utara Subdistrict is 65 meters above sea level. The zone’s climate is tropical that has two seasons, the dry season in April to October and the rainy season from November to March.

![Figure 1. Location Maps of Study Area](image)

2.2. Data and Processing
This study employs several types of remote sensing data. This includes multispectral images from Landsat 7 ETM+ for 2010 and Landsat 8 OLI for 2015 and 2020. Landsat satellite imagery has been chosen because it is easy to access, has a medium resolution, multispectral, and the process is not complicated.
Table 1. Data Acquired

| Remote Sensing Data | Sensor   | Resolution (m) | Source | Path / Row | Date of Acquisition |
|---------------------|----------|----------------|--------|------------|---------------------|
| Landsat 7 ETM+      | ETM+     | 15 (Panchromatic), 30, 60 (TIR) | USGS   | 116 / 66 | 2010 (04/02)        |
| Landsat 8 OLI       | OLI      | 15 (Panchromatic), 30, 100 (TIRS) |        | 116 / 66 | 2015 (10/02), 2020 (24/02) |

Landsat satellite imagery processed in Envi 5.3 software, start form layer stacking to combined all bands in Landsat 7 ETM+ and Landsat 8 OLI, to the radiometric calibration of each satellite imagery. The process of radiometric calibration to convert the Digital Number (DN) into spectral radiance and reflectance data, so it can be obtained the NDVI, EVI, and LST values.

2.3. Methods

2.3.1. NDVI

NDVI is a general index of vegetation index because it can identify the vegetation area simply used multispectral remote sensing data [13]. NDVI could predict quantity, quality, and vegetation development, by used the red (R) band and near-infrared (NIR) band from satellite imagery. Red and NIR bands on Landsat 7 ETM+ and Landsat 8 OLI have different bands, on Landsat ETM+ Red band is in band 3 and NIR in band 4. While in Landsat OLI, the Red band is in band 4 and NIR in band5. In this study, NDVI was calculated according to equation (1).

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

(1)

NDVI pixel values variations from -1 to +1 [14]: the higher the NDVI value in an area, the level of vegetation density is also higher. Meanwhile, the values closer to 0 and -1, correspond to a water body or barren areas [2].

2.3.2. EVI

EVI has advantages on calculated the vegetation activity, according to the ability to reduce sensitivity soil, non-photosynthetic vegetation, and atmospheric effect ability. EVI is more sensitive to the canopy density variations and the areas with high biomass than NDVI [4][15]. The calculation of EVI used the blue (B), red (R), and near-infrared (NIR) bands as in equation (2).

\[
EVI = 2.5 \times \left( \frac{NIR - RED}{(NIR + 6R - 7.5B) + 1} \right)
\]  

(2)

2.3.3. LST

LST data obtained from TOA Brightness Temperature on Landsat 7 ETM+ and Landsat 8 OLI. To obtained brightness temperature values, it necessary to convert the digital number into spectral radiance on each satellite image [7].

2.3.3.1. Conversion of DN to Spectral Radiance
There are differences in converting the DN into spectral radiance on Landsat ETM+ and Landsat OLI. Landsat 7 ETM+ used Band 6 as in equation (3), whereas Landsat 8 OLI used Band 10 or Band 11 as in equation (4) [1][13][16].

\[
L = \left( \frac{L_{\text{max}} - L_{\text{min}}}{\text{QCAL}_{\text{max}} - \text{QCAL}_{\text{min}}} \right) x (DN - \text{QCAL}_{\text{min}}) + L_{\text{min}}
\]  

(3)

L is the spectral radiance value; Lmax is the maximum value of spectral radiance; Lmin is the minimum value of spectral radiance; DN is the digital number (Band 6); QCALmax is the pixel maximum value (255); QCALmin is the pixel minimum value (1).

\[
L = Ml \times \text{QCAL} + Al
\]  

(4)

Ml is the multiplicative radiance from DN; QCAL is the DN (Band 10 or Band 11); Al is the additive radiance from DN.

2.3.3.2. Conversion of Spectral Radiance to Brightness Temperature

Calculated the land surface temperature values according to equation (5), using spectral radiance value that has been obtained [1].

\[
TB = \left( \frac{K2}{\text{Ln} \left( \frac{K1}{T} \right) + 1} \right)
\]  

(5)

TB is brightness temperature at-satellite; K1 is calibration constant 1, for Landsat 7 ETM+ is 666.09 whereas for Landsat 8 OLI is 774.8853; K2 is calibration constant 2, for Landsat 7 ETM+ 128.71 and Landsat 8 OLI 1321.0789; L is the radiance spectral value.

2.3.3.3. Conversion of Temperature in Celsius

The result of TB is the temperature in Kelvin, it should be converted to degree Celsius by reducing the TB yield (TB – 273). After the reduction, the land surface temperature values will be obtained in degrees Celsius.

2.4. Analysis Data

Simple linear regression was used to determine the relationship between the vegetation density on the NDVI and EVI indices, with land surface temperature. In this study, the calculation of simple linear regression according to equation (6), that result in the determination coefficient (R²). The determination coefficient will show how significant the impact of vegetation density changes in each vegetation indices is, on land surface temperature. The more R² approaches the value 1, the more significant impact between the dependent variable (LST) and the independent variable (vegetation density from NDVI and EVI indices).

\[
Y = ax + b
\]  

(6)

3. Results and Discussion

The vegetation density in this study was classified into 3 classes with different ranges (Table 2). The classes are barren areas (water bodies or barren land), sparse vegetation (rice fields, farm), and dense vegetation (forest). The classification was adapted based on Rokni & Musa, 2015 and Calle, et al., 2017 [3][17], that adjusted according to the study area.
Table 2. Classification of Vegetation Density

| Type of cover   | Range   |
|----------------|---------|
| Barren areas   | -1 – 0  |
| Sparse Vegetation | 0 – 0.5 |
| Dense Vegetation | 0.5 – 1 |  

Vegetation density changes used NDVI for 2010, 2015, and 2020, can be seen from the map in Figure 2. The vegetation density changes were evident from 2010 to 2020. In 2010, the NDVI covered an area of 3492.02 ha with barren areas 0.48 ha, sparse vegetation of 2854 ha, and dense vegetation covered 637.53 ha. Sparse vegetation is distributed throughout the entirety of the study area, whereas dense vegetation mostly spread in the west of the study area, in Canggu Village and there are a few barren areas in the eastern and southwestern of the study area. In 2015, the NDVI area was reduced to 3491.77 ha with the barren areas increased to 1.78 ha. The most noticeable increase in barren areas occurred in the southwestern, in Tibuneneng Village. Sparse vegetation decreased to 1883.44 ha and dense vegetation 1606.53 ha. Dense vegetation in 2015 increased to 1606.53 ha, an increase in vegetation density that was noticeable in the southern to western of the study area. In 2020, the NDVI area was reduced by 0.18 ha to 3491.59 ha with the barren areas increased to 25.18 ha, noticeable in the eastern of the study area specifically in Dalung dan Kerobokan Kaja Villages. The area of sparse vegetation increased to 2040.80 ha, while the area of dense vegetation decreased to 1425.60 ha. In 2020, the decreasing of dense vegetation most noticeable in the southwestern of the study area, in Canggu Village and has changed to sparse vegetation.

Figure 2. Map of NDVI for year (a) 2010, (b) 2015, (c) 2020.
The results of vegetation density used EVI can be seen from the map in Figure 3 that shows vegetation density changes for each year 2010, 2015, and 2020. The covered area of EVI in 2010 was 3491.68 ha with barren areas 4.15 ha, sparse vegetation 2346.15 ha, and dense vegetation 1141.38 ha. The spread of vegetation density in the EVI index in 2010 is almost the same as the spread of vegetation density in NDVI. In 2015, the EVI covered area was reduced to 3491.53 ha, with barren areas increased to 4.35 ha. The increased in barren areas noticeable in the northern of the study area, in Dalung Village and the southwestern, in Tibuneneng Village. Meanwhile, the sparse vegetation decreased to 2308.99 ha and dense vegetation 1178.19 ha. In 2020, the area of EVI reduced by 0.14 ha to 3491.40 ha. Barren areas in 2020 have increased by 83% to 25.35 ha, that noticeable in the eastern of the study area, in Dalung and Kerobokan Kaja Villages. Sparse vegetation in 2020 increased to 2424.44 ha and dense vegetation decreased to 1041.61 ha. The decreased in the dense vegetation area by 12% can be seen in the western of the study area, in Canggu Village. In 2015, the vegetation density in Canggu Village was quite dense, but in 2020 the vegetation density decreased. This can be seen on the map in Figure 3.

Based on the LST map in Figure 4, it can be seen that there was an increase in both the maximum and minimum temperatures in 2010, 2015 to 2020. The areas closest to eastern, southern, and southeastern, appear to have the highest temperatures each year, and the western part appears to have lower temperatures. In 2010, the minimum temperature was 15°C and the maximum temperature was 26.48°C. The temperatures with a range of 15°C – 18°C are mostly located in the western, while temperatures with a range of 22.1°C – 26.48°C are mostly located in the southeastern. In 2015, the minimum temperature increased to 17°C and the maximum temperature to 28.2°C. The temperature ranges between 17°C – 20°C is only a few located in the southwestern and northeastern. Meanwhile, the temperature in the range of 24.1°C is mostly located in the eastern and southern of the study area. In 2020 the minimum temperature also increased to 24°C and the maximum temperature to be 31.1°C. Temperature ranges from 24°C – 26.4°C is located in the western and eastern. Meanwhile, the
temperature ranges from 28.5°C to 31.1°C, are mostly located in the northern, eastern, and southern Kuta Utara Subdistrict.

The change of land surface temperature from 2010, 2015, to 2020 varies. In Figure 4, we can see that the further south the temperature will be higher. For each year, the temperature in southern of the study area, precisely in Kerobokan Kelod Village, is higher than in other villages. Kerobokan Kelod Village has consistently high temperatures every year because Kerobokan Kelod Village is the most rapid development of tourism accommodation compared to other villages in Kuta Utara Subdistrict [18].

![Figure 4. Map of LST for year (a) 2010, (b) 2015, (c) 2020.](image)

There are 30 sample points scattered that were made throughout the villages in Kuta Utara Subdistrict. The sample points made based on random sampling used to perform linear regression calculations on the dependent and independent variables. The results of regression analysis (table 3) in 2010 for the NDVI index were $y = -0.0606x + 19.695$ and $R^2 = 3E-05$, while the EVI index $y = -1.3145x + 20.234$ and $R^2 = 0.0254$. In 2015, the results of the NDVI analysis were $y = -1.6997x + 25.198$ and $R^2 = 0.036$; EVI index $y = -3.4252x + 25.862$ and $R^2 = 0.1628$. In 2020, the regression value for the NDVI index $y = -2.677x + 28.731$ and $R^2 = 0.1455$; EVI index $y = -2.632x + 28.554$ and $R^2 = 0.1756$. Each regression analysis results are preceded by a negative sign (-), this indicates a negative (opposite) correlation between changes in vegetation density from the NDVI and EVI indices to land surface temperature. If the vegetation density changes to sparse vegetation land or becomes barren areas, it increased the land surface temperature. However, the impact of vegetation density based on the NDVI and EVI indices on land surface temperature in the Kuta Utara Subdistrict is not very significant. That is because when the vegetation change from dense vegetation to sparse areas or even become barren areas, the land surface temperature does not increase significantly. It can also be seen from the $R^2$, which the results values are not close to the value of 1.
In this study, the vegetation index with a higher correlation value to LST is the EVI. This refers to the explanation that EVI is more sensitive in areas with high biomass while NDVI is more saturated [4] [15]. The correlation of the vegetation index to LST can be different in each study area, depending on the characteristics of each area. In the research of Li, et al., 2010 [4] and Hua, et al., 2018 [7], the vegetation index that has a high correlation to LST is NDVI. Whereas, in the research of Ferreira & Duarte, 2019 [19], the vegetation index that has a high correlation to LST is EVI. In this study, the vegetation index is more suitable when it is associated with LST in Kuta Utara Subdistrict in the EVI.

### Table 3. Results of NDVI and EVI regression

| Vegetation Index | Years | Regression Equation | Correlation Coefficient ($R^2$) |
|------------------|-------|---------------------|-------------------------------|
| NDVI             | 2010  | $y = -0.0606x + 19.695$ | 0.00003                       |
|                  | 2015  | $y = -1.6997x + 25.198$ | 0.03600                       |
|                  | 2020  | $y = -2.677x + 28.731$  | 0.14550                       |
| EVI              | 2015  | $y = -3.4252x + 25.862$ | 0.16280                       |
|                  | 2020  | $y = -2.632x + 28.554$  | 0.17560                       |

### 4. Conclusion

Vegetation density changes from dense vegetation to barren areas occur in the east, specifically in Dalung and Kerobokan Kaja Villages. The change of land surface temperature varies, the temperature getting higher to the south of the Kuta Utara Subdistrict. Based on the results of the regression analysis, it is known that if the vegetated land with dense vegetation changes to vegetation with sparse vegetation or even becomes barren areas, it will increase the land surface temperature. However, the impact of vegetation density change based on the NDVI and EVI indices on land surface temperature in the Kuta Utara Subdistrict is not very significant, it can be seen from the LST which does not increase too high, and from the results of $R^2$. The more suitable vegetation index used in this study is the EVI.

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