Land surface temperature changes in northern parts of Bandung Basin

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Abstract. Bandung Basin is unique because it consists of flat to mountainous areas. As in the northern parts of Bandung Basin, the north is steeply sloped and is located in the Tangkubanparahu volcano and Mount Burangrang. Topographic variations in the northern parts of Bandung Basin affect vegetation cover and temperature according to the height of the place. Various types of vegetation greenness and temperature can be analyzed by applying remote sensing. The aims of this study are: 1) Identification of land surface temperature in the northern area of Bandung Basin in 1990-2018, 2) Estimating the greenness of vegetation in the northern area of the Bandung Basin in 1990-2018. The method used is information extraction through multi-temporal remote sensing imagery to obtain land surface temperature and greenness of vegetation in the northern parts of Bandung Basin. The results of this research show temperature is getting hotter in the period of 1990 to 2018 while the greenness of the vegetation is decreasing, as indicated by forest vegetation, pine forests, tea plantations, grass, rice fields, and bushes increasing LST values and decreasing SR values. In contrast to agriculture, SRI values actually increase with LST. This can be caused by changes in agriculture to other land cover, or the type of plant is changes. It is recommended that the northern parts of the Bandung Basin should maintain the greenness of the vegetation to control the stability of the temperature because most types of vegetation have increased LST and decreased SRI especially in urban areas.

1. Introduction
Surface temperature is a parameter that affects the balance of the earth's surface energy. The diversity of surface temperatures is most affected by the type of vegetation cover [1]. The climate system should always be maintained as well as the role of the earth's surface ecosystems. Thus minimizing the occurrence of land surface temperature rise. Vegetation experiences complex biophysical exchanges such as the water cycle and evapotranspiration. The exchange will then have an impact on climatic conditions, such as hampering surface cooling [2].

Remote sensing uses imagery as a tool to identify objects or identify phenomena, such as vegetation. Remote sensing of vegetation includes agriculture and forest management, vegetation stress assessment, prediction of agricultural production, and identification of vegetation types. Vegetation is an object with a peak of spectral reflection that is recorded by a remote sensing satellite sensor through a near infrared channel. The chlorophyll content in green leaves is what causes vegetation to be most sensitive to near infrared channels [3].

The results of the spectral reflection of vegetation captured by satellite sensors can be used for various studies, such as identification of greening of leaves through transformation of Normalized Difference Vegetation Index (NDVI). NDVI not only signifies the greenness of leaves, but also biomass, vegetation cover and vegetation conditions (3). NDVI as one of the transformation of digital pixel image values is...
used to observe the condition of vegetation greenness which is assumed to experience changes due to land cover conversion.

Another case with the surface temperature of the earth captured by thermal sensors on remote sensing satellites. The distribution and change in temperature can be observed locally and globally by extracting spectral reflections in the thermal channel to Land Surface Temperature (LST). The spatial distribution of LSTs indirectly represents regional characteristics, and has benefits for agriculture, forestry, urban studies, and climate change [4-6].

Northen parts of Bandung Basin is an area that has various characteristics. The south tends to be flat and towards the north it gradually gets steeper. Areas with dense human activity have surface temperatures that tend to be hot due to high absorption of solar radiation, such as build-up areas that are generally found in urban areas. The opposite of vegetation areas that reflect cooler surface temperature conditions [7,8]. The flat area in the Northen parts of Bandung Basin represents a densely populated area of human activity, while the steep terrain represents an area with dense vegetation. However, these conditions can change according to regional development. As will be examined in this paper, namely: 1) Identification of land surface temperature in the northen area of Bandung Basin in 1990 - 2018, 2) Estimating the greenness of vegetation in the northen area of the Bandung Basin in 1990 - 2018.

2. Study Area
Bandung Basin is unique because it consists of flat to mountainous areas. As in the Northen parts of Bandung Basin, the north is steeply sloped and is located in the Tangkubanparahu volcano and Mount Burangrang. Topographic variations in the Northen parts of Bandung Basin affect vegetation cover and temperature according to the height of the place. Various type in vegetation greenness and temperature can be analyzed by applying remote sensing. This underlies the selection of the Northen parts of Bandung Basin as the area under study.

![Figure 1. Study Area](image)

3. Methods

3.1. Processing of Thermal Infrared Channels
Each pixel of a remote sensing image has a spectral reflection value recorded by a satellite sensor. As a result of spectral reflection on thermal infrared channels that represent temperature conditions on the earth's surface. Temperature conditions are recorded by the sensor and then processed to produce land surface temperature (LST) which generally consists of not only temperature but also vegetation cover and soil moisture. LST obtained from thermal is the result of digital processing channels digital processing. Landsat 8 is one of the satellites that records the thermal reflection of Earth's surface objects
In addition, this study also uses Landsat 5 imagery to obtain LST information in the past (1990, 2000, and 2009). There are various methods to obtain LST through digital image processing, such as considering emissivity. Emisivitas adalah the relative energy of a surface to radiate heat. Emissivity value is influenced by the greenness of vegetation obtained from vegetation index transformation such as Normalized Difference Vegetation Index (NDVI). A positive NDVI values generally a dense vegetation area, while negative values indicate areas without vegetation with high emisivitation [10]. Through the diversity of NDVI values, it can be measured the emissivity value for various objects, for example the emissivity value of 0.97 is owned by the built area or open land, while the emissivity value of 0.99 is owned by the vegetation area. In addition to the three types of objects, the emissivity value is calculated by considering the proportion of vegetation, NDVI values, and reflectance values in the red channel. After obtaining the emissivity value, then calculate LST using the formula:

$$LST = \frac{T_B}{1 + (\lambda \times T_B/\rho) \ln \epsilon}$$ (1)

Some parameters used in the calculation of LST values include wavelength of emitted radiance ($\lambda$), Planck’s constant (h), velocity of light, and Boltzmann’s constant ($\sigma$).

3.2. Processing of Red and Near Infrared Channels
Greenness of vegetation in the study area is measured by a simple vegetation index, the Simple Ratio Index (SR). SR is the result of the ratio between the pixel value in the near infrared channel to the pixel value in the red channel in the Landsat images. Ratio Vegetation Index (RVI) or Simple Ratio Index (SRI) is a type of vegetation index that is known for its simple use. Healthy plants usually reflect near infrared waves well, which is the opposite of the absorption rate of chlorophyll recorded by the red channel. This relationship is measured by Simple Ratio. These measurements indicate that vegetation has a high index value, while objects other than vegetation have low value. The limitation of Simple Ratio is its simplicity which only describes the presence of green vegetation without considering the influence of the sun's illumination angle and topographic conditions [11,12]. Simple ratio is used in this study to process the red and near infrared channels in Landsat 5 and Landsat 8 imagery.

3.3. Identification of Vegetation Type and Surface Temperature
Vegetation is classified based on its type, into forests, agriculture, tea plantation, grass, and bush. Furthermore, the results of the classification will be observed and compared with the results of SR and LST to see how the three variables affect each other.

4. Results and Discussion
Remote sensing satellites have the ability to record in more than one acquisition time but on the same area (temporal resolution). Multi-temporal remote sensing usually applied to observe a phenomenon changes either a good or poor changes and to ensure certain changes in certain times. This technic use satellite images with more than one acquisition date. Term for observing phenomenon changes in remote sensing is called change detection. Change detection in this study is a process that help in monitoring land surface temperature and vegetation greeness with reference to multi-temporal remote sensing information. This research used a time series analysis as a change detection method to obtain trend of Land Surface Temperature and Vegetation Index changes of Bandung Basin based on remote sensing multitemporal data.

4.1. Land Surface Temperature Changes
Land surface temperature change detection with involving vegetation emissivity deemed appropriate to do in northen parts of Bandung Basin that represent a contrast between urban and rural area. So it can
be detected and analyzed changes in land temperature and how the influence of vegetation conditions on land temperature changes.

![Figure 2. Land Surface Temperature of Northern Parts of Bandung Basin 1990-2018](image)

Land surface temperature processing using Landsat 5 and Landsat 8 thermal channels produces temperature values in Celsius degrees. Between 1990 and 2018, the Northern parts of Bandung Basin had various LSTs and were displayed in 8 classes: below 14°C, 15-17°C, 18-20°C, 21-23°C, 24-26°C, 27-29°C, 30-32°C, and above 32°C. Eight LST classes are depicted with gradations of green, yellow and red.

Based on LST measurement results, in 1990 the Northern parts of Bandung Basin were dominated by LST values below 20°C. But there are also a few areas with LST between 24 and 29°C which are displayed in bright yellow and orange. Contradictory to the LST results in 2000 which were dominated by temperature values above 27°C, especially in the flat area of Bandung Basin (south of the study area), and in the north of the study area there were LST values between 15 to 23°C. Usually the low LST value is vegetation cover, this is in accordance with that found in the study area.

LST image processing results in 2009 and 2018 have little difference. In 2018 there are more areas that have LST above 32°C (red color) especially in urban areas. The results of image processing in 2009
have an area with LST between 15-17°C in mountainous regions, while in 2018 the area has an LST between 18-20°C.

Overall LST estimation results show varied and fluctuating values. It can be concluded that in the flat area in the northern parts of Bandung Basin there is an increase in LST with variations in the temperature range between 21 to above 32°C. Likewise with the mountainous northern area (located Tangkubanparahu Vulcano), the area experienced an increase in temperature from the range of 15°C in 1990 to around 20°C in 2018.

4.2. Vegetation Greenness Changes

The SRI transformation have a value from 0 to more than 30. Figure 3 shows the SRI values in northern area of Bandung Basin in 1990, 2000, 2009, and 2018. Bare soil commonly has a SRI value near 1, if the amount of green vegetation increases then the SRI also will increase.

![Figure 3. Simple Ratio Index of Northern Parts of Bandung Basin 1990-2018](image)

Vegetation greenness indicated by a value of Simple Ratio Index (SRI). Figure 3 shows SRI in the northern area of Bandung Basin. As it can be seen from a figure, there are fewer areas with a higher SRI in 2018. This proves that there is a reduction in green vegetation in the northern area of Bandung Basin.
The southern part of the study area is an urban area and has decreased vegetation greenness, especially in the SRI range of 6 to 8 in 1990 to below 4 in 2018. This indicates the conversion of natural land into artificial land with higher sunlight radiation so that the SR value is lower.

A lack of green areas occur because of a poor regional planning, and it will be a wise choice if current green space should be protected, and the agricultural areas should not be converted for development for an urban purposes [13]

4.3. Comparison Between LST, SR and Vegetation Type

Type of vegetation in study area divided into forests, pine forests, tea plantation, agriculture, grass, rice fields, and bush. Figure 4 shows a LST value for every type of vegetation in 1990 until 2018. The line graphic (figure 4) data taken from a samples based on vegetation type in several altitude to get a variation of LST value.

![Land Surface Temperature of Different Vegetation Type](image)

**Figure 4.** Land Surface Temperature of Different Vegetation Type (1990-2018)

Forest samples are taken at various altitudes to calculate the average LST of the forest. The mean value of forest LST increased from 19.77°C in 1990 to 24.08°C in 2018. Pine forest vegetation types were found in several parts of the study area, and increased LST by 3.13°C in the period of 1990 to 2018. Tea plantations in the study area have LST with the least increase, from 19.62°C to 22.03°C. Agriculture and rice fields are mixed areas between vegetation canopy and soil that can sometimes be seen through imagery. LST agriculture increased from 18.71°C to 22.03°C while rice fields increased from 21.13°C to 24.54°C.

Bushes LST in 1990 is 20.12°C and it has increased for about 4.23°C in 2018. The most high LST of all vegetation types in study area is grass. In 1990, grass has a LST of 21.41°C and increased to 28.16°C in 2018. Possible cause of LST increase is because grass is a type of vegetation with narrow leaves, so the satellite sensor not only records grass but also the reflection of the soil beneath. In addition, it could be a change of grass into open land so that the temperature rises.

It can be concluded that all types of vegetation experienced an increase in temperature between 1990 and 2018. In addition there were anomalies in the results of processing in 2000, all types of vegetation have higher LST compared to 1990, 2009, and 2018.

Simple ratio index represents greenness and the amount of vegetation. Vegetation types in the study area have varied and fluctuating SRI values. The SRI forest value slightly decreased from 4.84 to 4.15.
In 2018 pine forest, tea plantation, bush, and grass have an increase in SRI values of around 1.3 - 1.6 compared to 1990. Contrary to agriculture and rice fields, the SRI value has decreased. This can be caused by several factors such as: different climatic conditions between the time of remote sensing image acquisition, conversion to land cover types with less vegetation, or due to changing vegetation conditions.

The existence of vegetation keeps the urban environment at an ideal temperature, such as parks that have a role in decreasing air temperatures in urban areas. This is because vegetation saves a little heat and keeps the air layer moist through evaporation. The plant canopy functions like a filter of sunlight before it reaches the ground surface and then decreases the intensity of the reflected heat energy [14]. Based on these statements, this study intends to see a comparison between the results of LST, SRI, and vegetation types. Then how the three variables affect each other.

### Table 1. Land Surface Temperature, Simple Ratio Index, and Vegetation Type (1990-2018)

| Year | Forests LST | Pine Forests SR | Tea Plantation LST | Agriculture SR | Grass LST | Rice Fields SR | Vegetation LST | Bush SR |
|------|--------------|-----------------|--------------------|---------------|-----------|----------------|---------------|--------|
| 1990 | 19.77        | 4.84            | 16.88              | 5.38          | 19.62     | 6.79           | 18.71         | 2.84   |
| 2018 | 24.08        | 4.15            | 20.01              | 4.08          | 22.03     | 5.17           | 22.03         | 3.30   |

Ideally, the temperature is inversely proportional to the greenness of the vegetation. Areas that are not vegetated have higher temperatures than dense vegetation. Then the high LST value is usually found in non-vegetation areas, while the low LST is a dense vegetation area. This research then observes how the results of the processing of thermal channels, red channels, and infrared channels in accordance with the theories that have been written previously (Table 1). Forests, pine forests, tea plantations, grasses, rice fields, and bush have increased LST values and decreased SR values. This shows that the temperature is getting hotter in the period 1990 to 2018 while the greenness of the vegetation is decreasing. In contrast to agriculture, SRI values actually increase with LST. This could be due to the change in agriculture to other land covers, or the plant differed from 1990 to 2018.

Because most types of vegetation have increased LST and decreased SRI, it is concluded that the northern area of the Bandung Basin should maintain the greenness of the vegetation in order to control the stability of the temperature. The most recommended area to keep the vegetation green is an urban area (flat area in the south of study area). Examples of efforts to maintain the greenness of vegetation are minimizing the conversion of vegetated land into built land that lacks vegetation, maintaining and expanding green open space, especially in urban areas.

### 5. Conclusion

It can be concluded that all types of vegetation experienced an increase in temperature between 1990 and 2018. In addition there were anomalies in the results of processing in 2000, all types of vegetation have higher LST compared to 1990, 2009, and 2018. While the type of vegetation in the study area has SRI values are varied and fluctuating. SRI forest, pine forest, tea plantation, bush, and grass values declined slightly. Whereas agriculture and rice fields decreased in SR. This can be caused by several factors such as: different climatic conditions between the time of remote sensing image acquisition, conversion to land cover types with less vegetation, or due to changing vegetation conditions.

Forests, pine forests, tea plantations, grasses, rice fields, and bush have increased LST values and decreased SR values. The temperature is getting hotter in the period of 1990 to 2018 while the greenness of the vegetation is decreasing, as indicated by forest vegetation, pine forests, tea plantations, grass, rice fields, and bushes increasing LST values and decreasing SR values. In contrast to agriculture, SRI values actually increase with LST. This can be caused by changes in agriculture to other land cover, or the type of plant is changes.

It is recommended that the northern parts of the Bandung Basin should maintain the greenness of the vegetation to control the stability of the temperature because most types of vegetation have increased
LST and decreased SRI. The most recommended area to keep the vegetation green is urban areas. Examples of efforts to maintain vegetation greenness are by minimizing the conversion of vegetated land into built-up land that lacks vegetation, maintaining and expanding green open space, especially in urban areas. In addition, it can also use government regulations to control the presence of green open space.

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