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Correlation between Land Surface Temperature and Vegetation Greenness using Multi-temporal Images

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Abstract. Urban areas tend to have significant temperature differences with the surrounding area. The city of Bandung is surrounded by mountains and forms the Bandung Basin. Land cover differences between Bandung City and surrounding area caused a temperature differences that can identified with remote sensing imagery. The aim of this research are to analyse the change of land surface temperature and the vegetation greenness level in Bandung Basin using Landsat multi-temporal image also to identify correlation between surface temperature change with greenness level in Bandung Basin. In Bandung Basin, there is an increase in temperature in various land covers (Vegetation in flat areas, Vegetation in steep and high altitude areas, Water, Built-up area, and Open Land area) from 1990-2018. Meanwhile, there is less green vegetation in Bandung Basin from 1990-2018. The results of the analysis show a better correlation between Land Surface Tempertare (LST) and Simple Ratio Index (SRI) than the correlation between Land Surface Tempertare (LST) and Normalized Difference Vegetation Index (NDVI). The conclution of this research that preservation of vegetated areas can be done in Bandung Basin to address the increasing of Land Surface Temperature.

1. Introduction

Worldwide urbanization has significantly reshaped the landscape, which has important climatic implications across all scales due to the simultaneous transformation of natural land cover and introduction of urban materials [1]. Urbanization will bring some changes, such as changes in land use into built-up lands or difficult surfaces to evaporate. This will bring a change in the average air temperature in the city, where reduced vegetation replaced by built-up land and then trigger a contrast in surface radiance and air temperature in urban areas when compared to the village area [2]. Urban areas generally have higher solar radiation absorption and a greater thermal capacity and conductivity as they are comprised of buildings, roads and other impervious surfaces. Therefore, urban areas tend to experience a relatively higher temperature compared to the surrounding rural areas [3].

Detection of surface temperature by considering the emissivity of vegetation and emissivity of soils known as "Land surface temperature" [3]. Remote sensing Thermal Infra Red as a part of the electromagnetic spectrum is one of the best observations of Land surface temperature (LST) to determine the temperature distribution and the change in local or global scale, used in climate and climate change models in particular. LST, calculated from remote sensing data, is used in many areas of science; such as; hydrology, agriculture, climate change, urban planning, forestry, oceanography [4] [5]. Thermal infrared remote sensing provides a unique method for obtaining LST information at the regional and global scales since most of the energy detected by the sensor in this spectral region is directly emitted by the land surface [6].

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Bandung basin experienced an increase in surface temperature in urban areas due to uncontrolled urban development [7]. Urban areas tend to have significant temperature differences with the surrounding area. The city of Bandung is surrounded by mountains and forms the Bandung Basin. Land cover differences between Bandung City and surrounding area caused a temperature differences that can identified with remote sensing imagery (Thermal Infrared Band). Bandung City temperature tends to increase along with a city growth, meanwhile the surrounding area (mountains and vegetation) has a stable temperature. The aim of this research are: 1) to analyze the change of surface temperature in Bandung Basin using Landsat multi temporal image, 2) to analyze the vegetation greenness level in Bandung Basin using Landsat multi temporal image; 3) to identify correlation between surface temperature change with greenness level in Bandung Basin.

2. Study Area

The Bandung Basin consists of several administrative regions: Bandung City, Bandung Regency, Cimahi City and Bandung Barat Regency. Most of the Bandung Basin area is mountainous, with a tropical climate. The Bandung Basin experienced very rapid development, this was related to the role of Bandung City as the provincial capital of West Java. Rapid city development results in land changes that will result in changes in climate components, namely temperature [8].

This research was conducted in the city of Bandung and its surrounding areas or identified as Bandung Basin which has a variety of topographic features. The central area of the basin tends to be flat compared to the area around it, it affects the character of the climate including in terms of the surface temperature of the land. Based on this uniqueness, Bandung Basin was chosen as the study area. It showed in Figure 1.

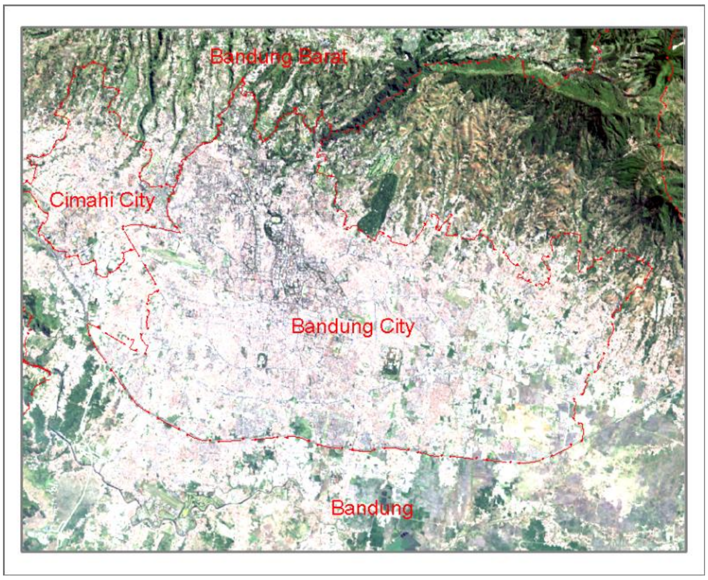

Figure 1. Study Area

3. Methods

The method of this research is Land Surface Temperature (LST) and generate vegetation indices with Landsat image of 2000-2018 to obtain changes in surface temperature and greenness of vegetation. The result of thermal index transformation correlated with result of vegetation index using regression test.

3.1. *Extraction of Land Surface Temperature*

Land Surface Temperature (LST) is the temperature of the surface which can be measured when the land surface is in direct contact to the measuring instrument. Land surface temperature (LST) is an essential factor in many areas like global climate change studies, urban land use/land cover, geo-

/biophysical and also a key input for climate models [1]. Surface temperature is a general, non-specific term referring to the aggregate temperature of all objects, comprising the existing surface. LST maintains by the incoming solar and long wave irradiation [9].

LST defines surface temperature of ground as pixel based derived observation. LST possesses soil surface temperature, canopy, and vegetation body [5]. Land surface temperature emissivity in thick forest, usually low and NDVI remarks as positive, and the bare soil without vegetation surface temperature emissivity become high as represented in the negative indices [10].

This study uses the LST extraction method by considering emissivity based on the value of the Normalized Difference Vegetation Index (NDVI). Pixel with NDVI values <0.2 will be considered as built-up and bare soil, and will be given emissivity value of 0.97. Pixel with NDVI values >0.5 will be considered as vegetation, and will be given emissivity value of 0.99. For 0.2≤NDVI≥0.5 is calculated using the following equation:

$$\varepsilon = 0.004\ P_v + 0.986 \quad (1)$$

Where,

$$P_V = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2 \quad (2)$$

Where

$$NDVI = \frac{\rho_{NIR} - \rho_{red}}{\rho_{NIR} + \rho_{red}} \quad (3)$$

ε is emissivity, P_v is proportion of vegetation, $NDVI_{max}$ is 0.5, $NDVI_{min}$ is 0.2 and ρ_{red} = reflectance values in the red channel.

The equation used for land surface temperature calculation:

$$LST = \frac{T_B}{1 + (\lambda \times T_B/\rho)\ln \varepsilon} \quad (4)$$

In this case, λ is wavelength of emitted radiance, ρ is hc/σ (1.438×10^{-2} mK), h is Planck's constant (6.626×10^{-34} Js), c is velocity of light (2.998×10^{8} m/s) and σ is Boltzmann's constant (1.38×10^{-23} J/K).

3.2. Vegetation Indices

The vegetation index is a technique to obtain quantitative information about the greenness of vegetation per pixel. The index is a spectral transformation that is applied to multi-channel images with the aim of highlighting aspects of vegetation such as chlorophyll density and concentration. The vegetation index is formed by a combination of several spectral values added, divided, or multiplied to get a value that states the quantity of vegetation per pixel [11] [12] [13]. The vegetation index is used in image classification to separate vegetation and non-vegetation areas, distinguish vegetation types and densities, monitor seasonal vegetation variations, abundant conditions, and distribution [12]. There are two types of vegetation indexes used in this study, namely Simple Ratio Index and Normalized Difference Vegetation Index. The two vegetation indices produce greennees values of vegetation.

3.2.1. Simple Ratio Index

The simplest ratio based Vegetation Index is called Simple Ratio Index (SRI) or Ratio Vegetation Index (RVI). Simple Ratio takes advantage of the inverse relationship between chlorophyll absorption in red band energy and increased reflection of near infrared energy for healthy plant canopies. The results of the transformation of the simple ratio index have a high value for vegetation, low for soil, ice, and water. This technique is characterized by limited applicability as for vegetation assessment and it does not allow to eliminate the effects of topography and variations in the sun illumination angle, so that the output images reflect only the presence of green vegetation [14] [15].

The near-infrared (NIR) to red simple ratio (SR) is the first true vegetation index:

$$SR = \frac{\rho_{NIR}}{\rho_{red}} \quad (5)$$

3.2.2. Normalized Difference Vegetation Index
NDVI is the most commonly used vegetation index, because it has the ability to eliminate the effects of topography and variations in the angle of illumination of the sun, and also other atmospheric elements such as fog [15]. The generic normalized difference vegetation index (NDVI):

$$NDVI = \frac{\rho_{NIR}-\rho_{red}}{\rho_{NIR}+\rho_{red}} \quad (6)$$

NDVI ranges from -1 to 1, indicates amount of vegetation and distinguishes vegetation from soil, but does not eliminate atmospheric effects. Calculation of NDVI is necessary to further calculate proportional vegetation (Pv) and emissivity (ε). NDVI-based emissivity method (NBEM) is based on a statistical relationship between the NDVI derived from the Near Infra Red bands and the Land Surface Emission in the TIR channels [9].

4. Results and Discussion

4.1. Multitemporal Satellite Images and Change detection
Remote sensing satellites have the ability to record the same area but at different times, this ability is termed temporal resolution. Multi temporal imagery can be used to observe and analyze changes in phenomena on the surface of the earth. The change can then be traced to the cause, defined as whether the change is beneficial or detrimental.

Digital change detection mainly consists of quantification of temporal phenomena obtained through multi-time images. Change detection is one of the important applications of remote sensing technology to ensure certain appearance changes in certain time intervals. This detection provides information on spatial distribution and changes in qualitative and quantitative appearance [16] [17]. There are various types of multispectral image data change detection methods. These methods are generally classified into three categories: analysis of spectral type characteristics, spectral change vector analysis and time series analysis [17]. 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 multi temporal data.

4.2. Land Surface Temperature of Bandung Basin 1990-2018

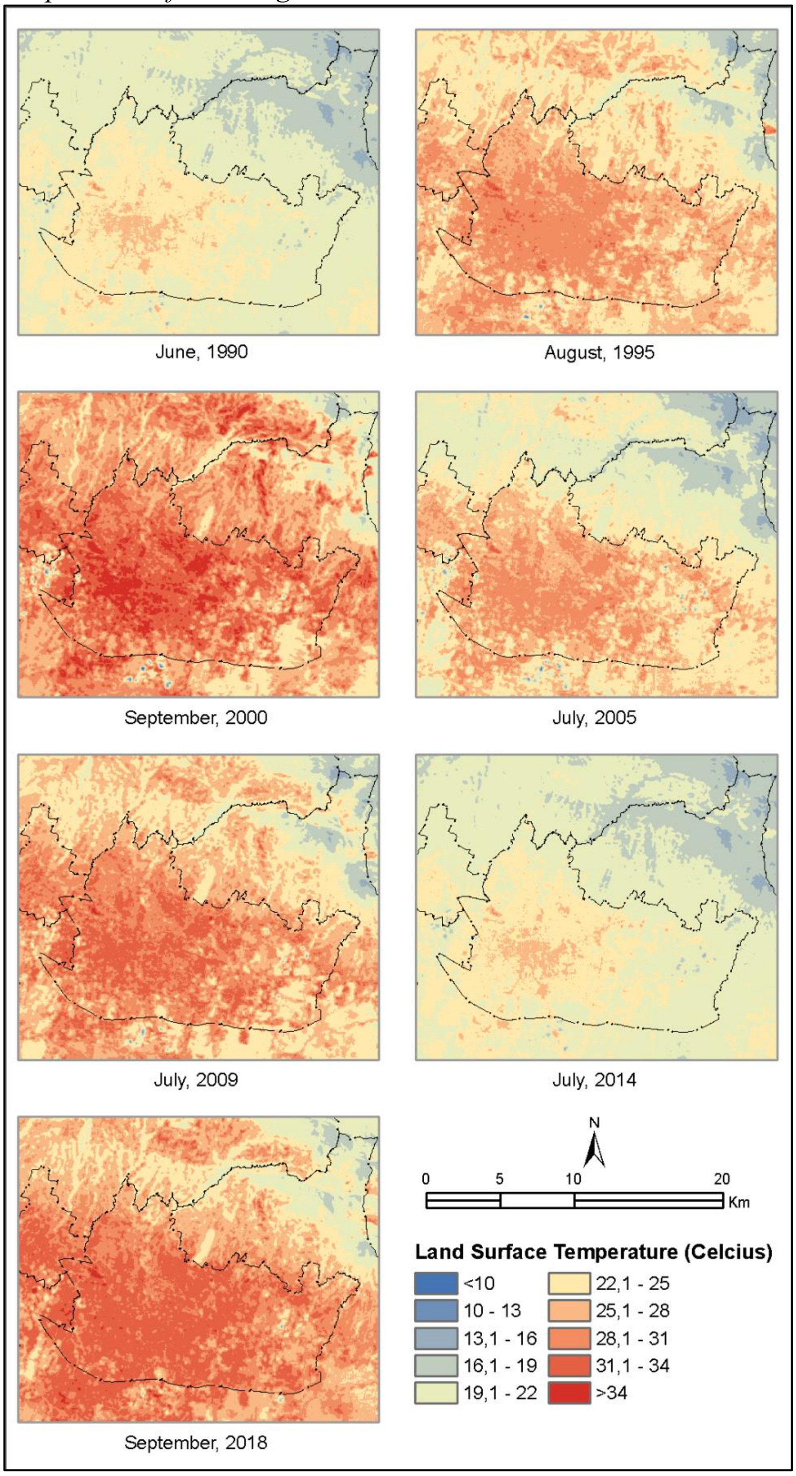

Figure 2. Land Surface Temperature of Bandung Basin 1990-2018

Extraction of land surface temperature (LST) using Landsat 5 and Landsat 8 imagery with a period of 1990 until 2018 showing temperature variations in the Bandung Basin (presented in Figure 2). In the central part of the Bandung Basin the value of LST increased at 1990 until 1995, but decreased in 2005 (25.1-28^{0}C), increased again in 2009 (up to above 31^{0}C), dropped dramatically in 2014 (19-25^{0}C) and increased again in 2018 (above 28^{0}C). Whereas in the northern part of the Bandung Basin, the value of LST tends to be lower, which is below 20^{0}C, even in 1990 it had a temperature of 10-13^{0}C.

Increased LST is influenced by various causes, such as population growth which then raises the need for land for shelter and activities. So that the land with low temperature is converted into a built-up area that has a higher temperature because it tends to absorb sunlight radiation.

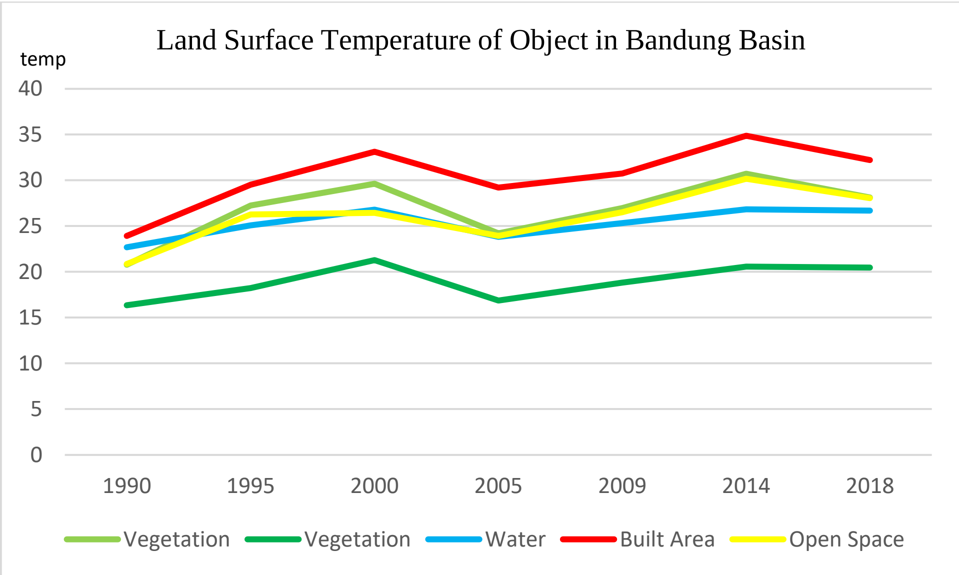

Figure 3. Land Surface Temperature of several Land Cover in Bandung Basin 1990-2018

To observe LST changes in Bandung Basin, samples were taken on various types of land cover : Vegetation on flat areas, Vegetation on steep areas and high altitude, Water, Built-up Area, and Open Area. Figure 3 shows the temperature change trend from 1990 until 2018. Based on the type of land cover, the object that has the lowest LST is Vegetation on steep and high altitude areas. Whereas the one with the highest LST is the built-up area. In general, it can be concluded that there was an increase in temperature in various land cover from 1990-2018, despite the temperature decline in 2005 which could be caused by climatic conditions during image recording or other factors.

4.3. Vegetation Index of Bandung Basin 1990-2018

The NDVI transformation have a value between -1 and 1. Figure 4 shows the NDVI values in Bandung Basin from 1990 until 2018. The northern part of Bandung Basin has vegetation values above 0.4 and looks most green in 1990. Whereas in the central part of Bandung Basin, NDVI continues to decrease, it can be seen that over time more areas have NDVI values less than 0.2. This can be caused by changes in vegetation to non-vegetation area (built-up area).

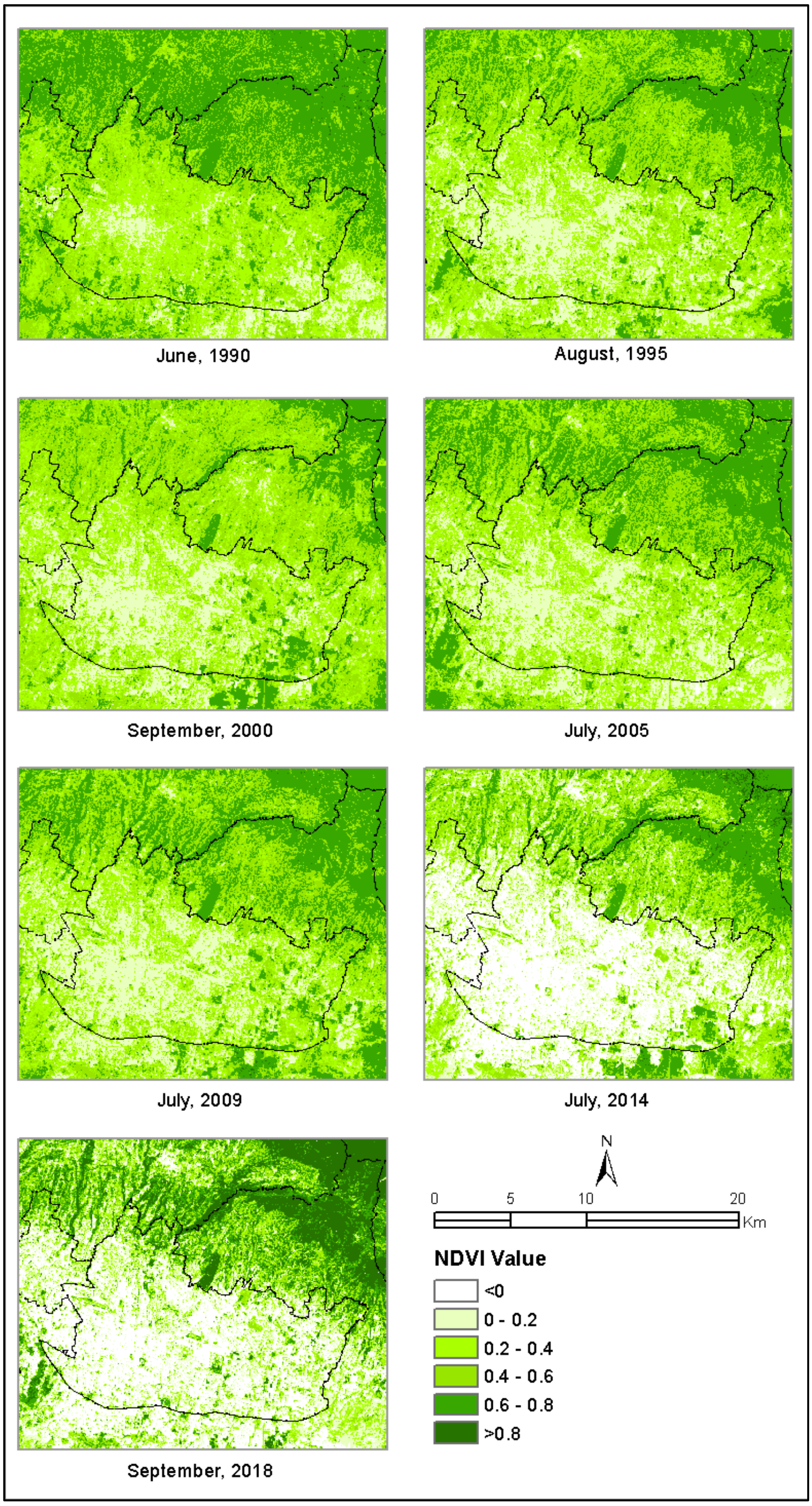

Figure 4. Normalized Difference Vegetation Index of Bandung Basin 1990-2018

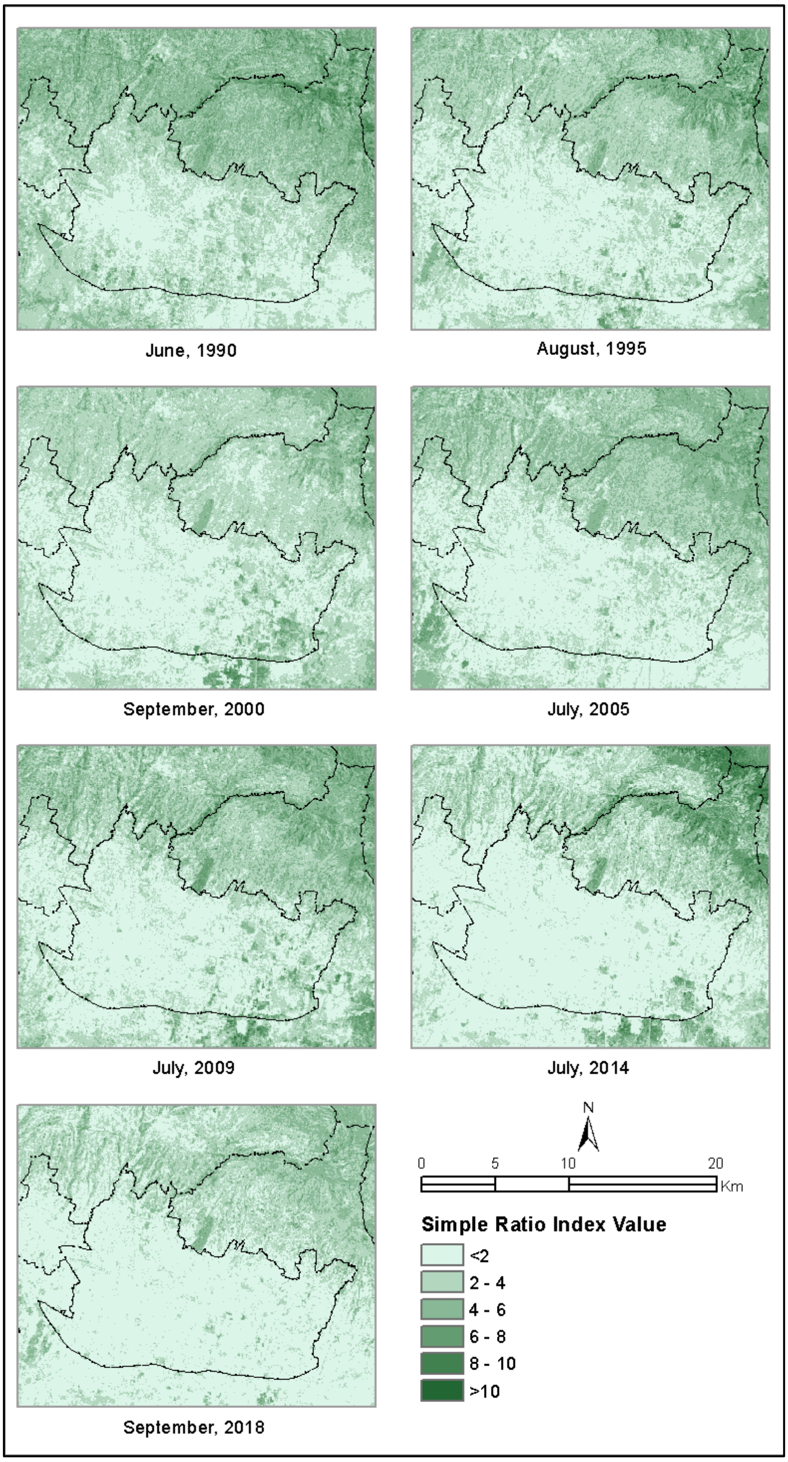

Figure 5. Simple Ratio Index of Bandung Basin 1990-2018

The higher value of Simple Ratio Index (SRI) indicate the greener vegetation. Not much different from the NDVI transformation results, Figure 5 shows that the value of SRI in the north area of Bandung Basin tends to be stable with a value above 4. While in the central part of Bandung Basin the SRI value continues to decrease. It can be seen that there are fewer areas with a value SRI that more than 4 in 2018. So it can be concluded that over time, more less green vegetation in Bandung Basin.

4.4. Correlation between Land Surface Temperature and Vegetation Index of Bandung Basin 1990-2018

Table 1. Correlation between LST, NDVI, and SRI

Year	LST and SR	LST and NDVI
1990	0.3408	0.2852
1995	0.6349	0.3889
2000	0.3097	0.1222
2005	0.3562	0.2312
2009	0.4452	0.2655
2014	0.4894	0.1465
2018	0.6037	0.1864

Correlation of LST with NDVI and SRI that showed in Table 1 was analyzed by taking samples of several land cover type : Vegetation on flat areas, Vegetation on steep areas and high altitude, Water, Built-up Area, and Open Area. The results of the analysis show a better correlation value between LST and SRI than the correlation between LST and NDVI. The highest correlation value is in 2018 which is 0.6037. The correlation shows that when the LST value is high, the value SRI is low, and if the LST value is low then the SRI value is high. Based on this, it can be concluded that in order to maintain temperature stability in Bandung, the greenness of the vegetation needs to be maintained. The result of Bandung Basin SRI presented in Figure 6.

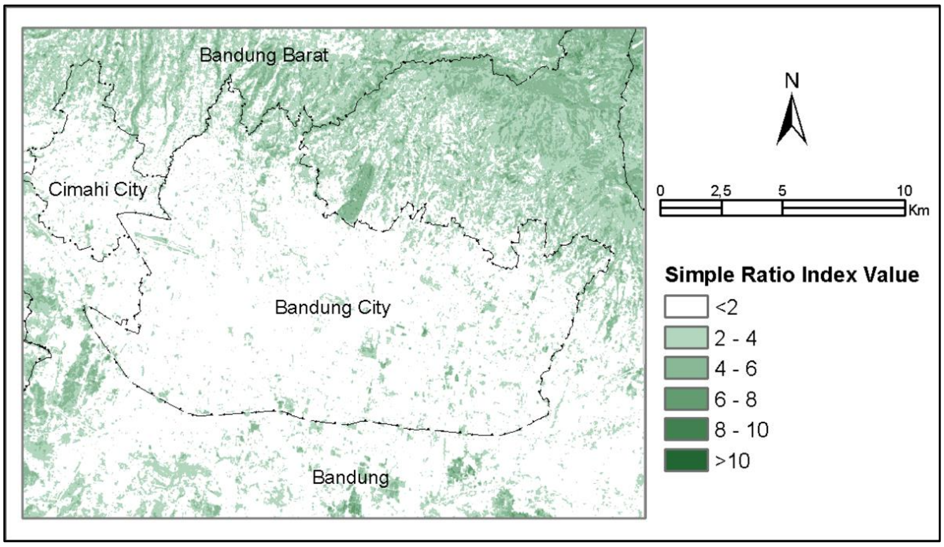

Figure 6. Simple Ratio Index of Bandung Basin, 2018

Efforts to maintain the greenness of vegetation can use the results of SRI in 2018 as a reference. Most of the city of Bandung is recommended to preseve its vegetation area so that there is no increase in LST, as well as the southern part of Bandung and the southern part of Cimahi City. Example of efforts to preserve the vegetation area is to maintain, manage and develop Green Open Space according to government regulations.

Unlike the case with the northern part of Bandung and West Bandung, the area that has a higher value of vegetation greeness than the central part of Bandung Basin (Kota Bandung). However, to prevent the occurrence of an increasing temperature in the future, preservation of vegetated areas can be done in Bandung Basin area.

5. Conclusion

In Bandung Basin, there is an increase in temperature in various land covers (Vegetation in flat areas, Vegetation in steep areas and high altitude, Water, Built-up area, and Open space area) from 1990-2018. Meanwhile, there is more less green vegetation in Bandung Basin from 1990-2018. The correlation shows that when the LST value is high, the value of green vegetation is low, and if the LST value is low then the green vegetation value is high. Most of the city of Bandung is recommended to preserve its vegetation area, as well as the southern part of Bandung and the southern part of Cimahi City. Example of efforts to preserve the vegetation area is to maintain, manage and develop Green Open Space according to government regulations. Based on this, it can be concluded that in order to maintain temperature stability in Bandung Basin, preservation of vegetated areas can be done in Bandung Basin area.

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