Vegetation Greenness Changes and Land Surface Temperatures Monitoring in the Bandung City, West Java

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Abstract. Remote sensing can be used to examine the city of Bandung with variations in its topographical appearance. Apart from that, urban areas such as Bandung generally experience land cover transformation (vegetation and non-vegetation) as well as changes in land surface temperature. This research aims to: 1) Analyse vegetation greenness in the Bandung City, 2) Analyse land surface temperature in the Bandung City, and 3) Analyse the correlation between vegetation greenness changes with dynamics of land surface temperature in the Bandung City. The method used is information extraction through remote sensing imagery to obtain changes of vegetation greenness and dynamics of land surface temperature, as well as field measurements. This research use Landsat 5 and Landsat 8 to get a value of built-up index and vegetation greenness. The results of this research are the identification of the spectral character of vegetation greenness, as well as their influence on land surface temperatures in the Bandung Basin. Types of vegetated land use, including rice fields, parks and plantations, have lower temperatures than settlements, roads, empty land and cemeteries. Positive values in the regression results indicate a correlation between the NDVI and LST variables.

1 Introduction

Water, soil, and vegetation are three main objects with specific spectral responses that can identified directly using remote sensing satellite images [1]. The transfer of energy and materials between land and atmosphere whitin terrestrial ecosystems cannot be separated from the role of vegetation. So, when ecological and environmental changes occur, vegetation can be an indicator [2]. Geographic location and type of vegetation influence the connection between vegetation and climate phenomena. Vegetation dynamics such as the conversion of vegetated land to non-vegetated land can be caused by human activities, urban expansion and deforestation [3][4]. Vegetation dynamics and their relationship to the expansion of urban areas generally occur in large cities such as Bandung City.

Southern part of Bandung City is relatively flat, while in the northern region it is hilly. As the provincial capital, Bandung is experiencing significant population growth. The greater

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the population, the greater the opportunity for expansion of urban areas, which then causes vegetation areas to become built-up land. This change can then influence the increase in land surface temperature. Remote sensing can be used to examine the city of Bandung with variations in its topographical appearance. Apart from that, urban areas such as Bandung generally experience land cover transformation (vegetation and non-vegetation) as well as changes in land surface temperature.

Remote sensing with its spatial and temporal capabilities makes it possible to identify characteristics at different scales and at different times. The Normalized Difference Vegetation Index, has the advantage of being easy to use, facilitating high resolution, and can be used for images over long-time spans. In-depth analysis of vegetation condition and climate components reveals unique relationships to study [5]. Normalized Difference Vegetation Index (NDVI) is a generic algorithm that is quite widely used for calculating reflectance in the red band and near infrared band. The NDVI algorithm produces ground surface reflectance information such as biophysical and plant parameters. The advantage of vegetation indices using satellite imagery is that they cover a wide area so they are effective for monitoring vegetation dynamics on a global scale [2][6].

It is now common knowledge that the increase in temperature in recent decades is mainly caused by human activities. Analysis of changes in land surface temperature (LST) as well as increasing urbanization and land use changes can use remote sensing technology. This involves techniques for analysing spatial patterns and temporal changes in land surface temperature and land use by utilizing satellite imagery bands.This method has been applied in various fields such as forestry, agriculture, oceanography and regional planning [7][8]. Thermal sensors on remote sensing satellites can identify earth surface phenomena that are not directly visible, such as ground surface temperature. Remote sensing satellites record the earth's surface continuously over a certain time span, called temporal resolution. The availability of multi-temporal satellite imagery allows observations on the dynamics of the earth's surface including changes in temperature and vegetation land cover [9]. The analysis of vegetation greenness changes and dynamics of land surface temperature studied in the Bandung City because this city has a various land cover such as urban areas and natural areas. Based on the introduction, this research aims to: 1) Analyse vegetation greenness in the Bandung, 2) Analyse land surface temperature in the Bandung, and 3) Analyse the correlation between vegetation greenness changes with dynamics of land surface temperature in the Bandung City.

2 Study Area

Bandung city a metropolitan city located in centre area of West Java Province. The highest place in Bandung is Ledeng with elevation 892 meters and the lowest elevation is 666 meters in Rancanumpang. In terms of geographic position, Bandung has administrative boundaries with Bandung Regency, Cimahi City, and West Bandung Regency. The population of Bandung City in 2023 is 2,461,553 people, including of 1,239,053 men and 1,222,500 women. Bandung City's population growth per year is 0.35 percent.

The geological features and soil in the Bandung area were shaped during Quaternary period, with alluvial soil layers formed by eruption from Tangkuban Perahu. In the Central and Western parts, andosol types are distributed. Bandung has a humid and cool mountain climate, with an average temperature of 23.5°C [10].

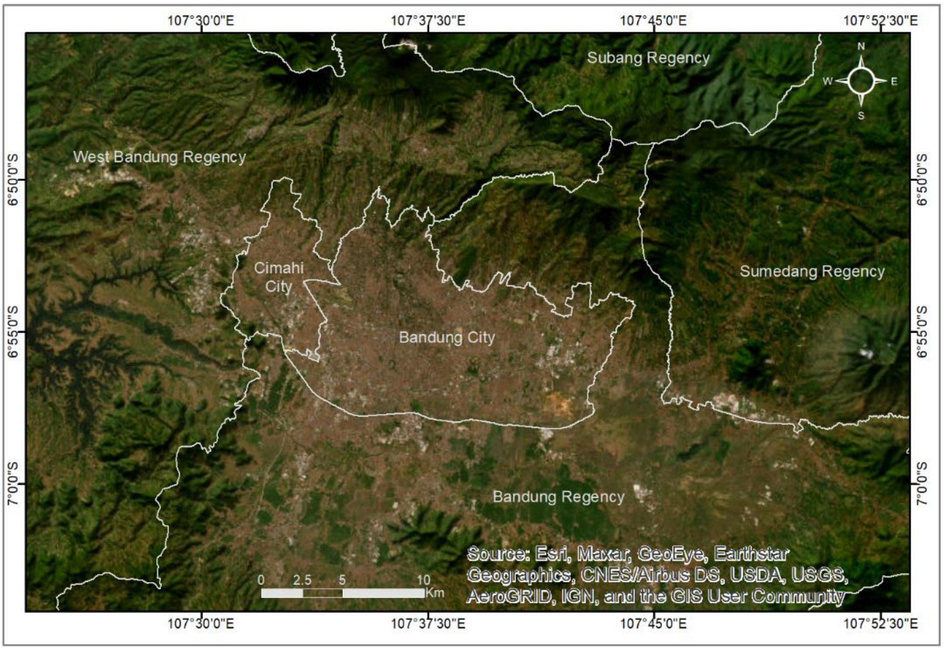

Fig. 1. Bandung City location

3 Methods

3.1 Processing of Normalized Difference Vegetation Index

Remote sensing satellites record the earth's surface with various types of sensors. Remote sensing satellite sensors capture the spectral reflection of objects. Chlorophyll in leaves causes very high reflectance in the green wavelength spectrum, and much energy is absorbed in the blue and red wavelength spectrum. In addition, healthy vegetation reflects near infrared rays so its reflectance value is very high. The algorithm used to quantify vegetation reflectance is the Normalized Difference Vegetation Index (NDVI). The NDVI results have a value of -1 to 1, this value represents low and high greenness of vegetation [1] [11].

$$NDVI=(NIR-Red)/(NIR+Red) \quad (1)$$

The Normalized Difference Vegetation Index formula or algorithm involves the spectral channels most closely related to vegetation (red and near infrared). The mathematical equation used is, comparing the difference and dividing the digital pixel values in the infrared band and red band. This research uses Landsat 8 images recorded in 2014 and 2023, so to obtain NDVI values the bands used are band 5 (near infrared) and band 4 (red band).

3.2 Land Surface Temperature Measurement

Understanding the surface energy balance and the exchange of heat energy between the earth's surface and the atmosphere cannot be separated from the role of the Land Surface Temperature (LST) parameter. LST can be termed the surface temperature of the top layer of the earth observed via remote sensing satellites. The top layer of the earth also includes grass, leaves, snow, ice, and forest canopy [12]. Satellites that are capable of recording the thermal spectral reflection of the earth's surface are satellites with sensors such as Landsat 8. LST processing using Landsat 8 images not only considers emissivity, but also uses greenness of vegetation parameters through the normalized difference vegetation index algorithm. This is because there are differences in emissivity values in dense vegetation areas (0.99) and sparse vegetation areas (built-up land with an emissivity value of 0.97) [8][13]. This research uses the land surface temperature calculation method to obtain temperature values for various land covers in the city of Bandung and its surroundings. The formula used is:

$$LST=T\_B/(\llbracket 1+(\lambda \times T \rrbracket\_B/\rho) \ln \varepsilon) \quad (2)$$

Planck's constant (h), Wavelength of emitted radiance (λ), velocity of light, and Boltzmann's constant (σ) used as parameters in LST formula. In general, land surface temperature processing consists of several stages. The initial stage is radiometric correction and geometric correction, then calculation of Top of Atmosphere Radiance and Reflectance. After that, the brightness temperature and NDVI values are calculated to obtain the proportion of vegetation and emissivity values. After obtaining the emissivity, the land surface temperature value is measured for each pixel.

3.3 Relation Between Normalized Difference Vegetation Index (NDVI) and Land Surface Temperature (LST)

Urban areas like Bandung City, dominated by concrete and asphalt surfaces, typically exhibit higher Land Surface Temperature (LST) compared to low-density residential zones with greater green space. The connection between LST and various land cover types is often examined by analysing LST alongside spectral indices that represent different types of land cover [12]. Different types of land cover between urban and non-urban areas can be represented by vegetation index values.

The relation between Land Surface Temperature alongside with the the Normalized Difference Vegetation Index (NDVI) can be affected by the current season in one year [14]. Other researchers have carried out a correlation analysis of the two algorithms in the 4 seasons area in 2007 and concluded that a positive correlation occurs in winter. Meanwhile, negative relation between NDVI and LST occurs in other seasons. This research is in tropical areas which only have 2 seasons, the imagery used is Landsat 8 with recordings in the same season but in different years (2014 and 2023). This is to obtain a more representative correlation without potential interference due to seasonal differences when recording by remote sensing satellites.

The correlation between LST and NDVI values was analysed using the linear regression method. This method requires LST and NDVI data based on samples observed in image processing results and during field observations. The samples were then made into a scatter plot and the R2 value was calculated. These values are then analysed to see the correlation between LST and NDVI.

4 Results and Discussion

Visible and invisible phenomena can record by remote sensing satellite system. An example of visible object recorded by a remote sensing satellite sensor is a type of land cover. Meanwhile, invisible objects whose spectral responses can be recorded by satellite sensors are leaf chlorophyll in vegetation. The greenness of vegetation can mainly be observed in the near infrared band with high digital values characteristic for green and very dense vegetation objects [15]. Temperature is also an invisible object that can be recorded by remote sensing satellites via thermal infrared sensors. These two types of objects, although invisible, can be studied using remote sensing technology for various fields of study such as land use change, regional development, environmental studies and vegetation studies. This research uses

Landsat images of 8 areas of Bandung City in 2014 and 2023. The parameters studied are the Normalized Differenced Vegetation Index which represents the dynamics of green vegetation, and the Land Surface Temperature value which represents the temperature dynamics in Bandung City and its surroundings. The results of this research are explained in the following points

4.1. Vegetation Greenness in Bandung City 2014-2023

Bandung City has a flat topography area and surrounded by a lot of mountain (Mount Tangkuban Parahu, Mount Burangrang, Mount Manglayang, and Mount Malabar). Bandung City has a various land cover type with dynamic changes over time span. Because of its various topography phenomenon, Bandung City interesting to studied in term of vegetation greenness changes and land surface temperature. From 2014 to 2023, Bandung City developed related to increasing population and expansion of a built-up area.

Land use changes affect surface temperature dynamics in urban zones, while evapotranspiration in vegetation cools the earth's surface temperature. Changes in LST along with changes in land use and vegetation dynamics can be monitored with the help of NDVI [16]. The results of the land cover type survey are then processed to obtain an estimated range of NDVI values. Based on calculations, the land cover with the highest NDVI is plantations, meanwhile the lowest is settlements.

Table 1 Minimum and maximum NDVI values per land cover

NDVI		Land Cover
Min	Max	
0,1334	0,4296	Asphalt Road
0,4745	0,6372	Empty land/field
0,3357	0,5342	Cemetery
0,4901	0,7098	Plantation
0,0837	0,5867	Settlement
0,2336	0,6470	Ricefield
0,2599	0,6220	Park

In 2014, Bandung dominated by NDVI more than 0.6 especially in the mountainous area in the north side of Bandung City. Lower NDVI values appear in the middle of Bandung Basin which is a centre of human activity with a dense built area. The NDVI transformation also processed in 2023. From Figure 2, it is shown that a NDVI value tend to decreased symbolized with light magenta color dominantly in center parts of Bandung City. It is assumed that Bandung area in 2023 has more built area than in 2014 so the NDVI values is lower. The expansion of the built-up zones, influenced by many factors, one of which is population growth and urban area expansion in the city of Bandung. Based on the results of NDVI processing 2014-2023, it can be seen that built-up areas with low NDVI (symbolized in red) values appear to be expanding towards the west (Cimahi City), south and east (Bandung Regency). This is different from the mountainous areas in Bandung City which experienced a decrease in NDVI values, but most likely there are still areas with green vegetation.

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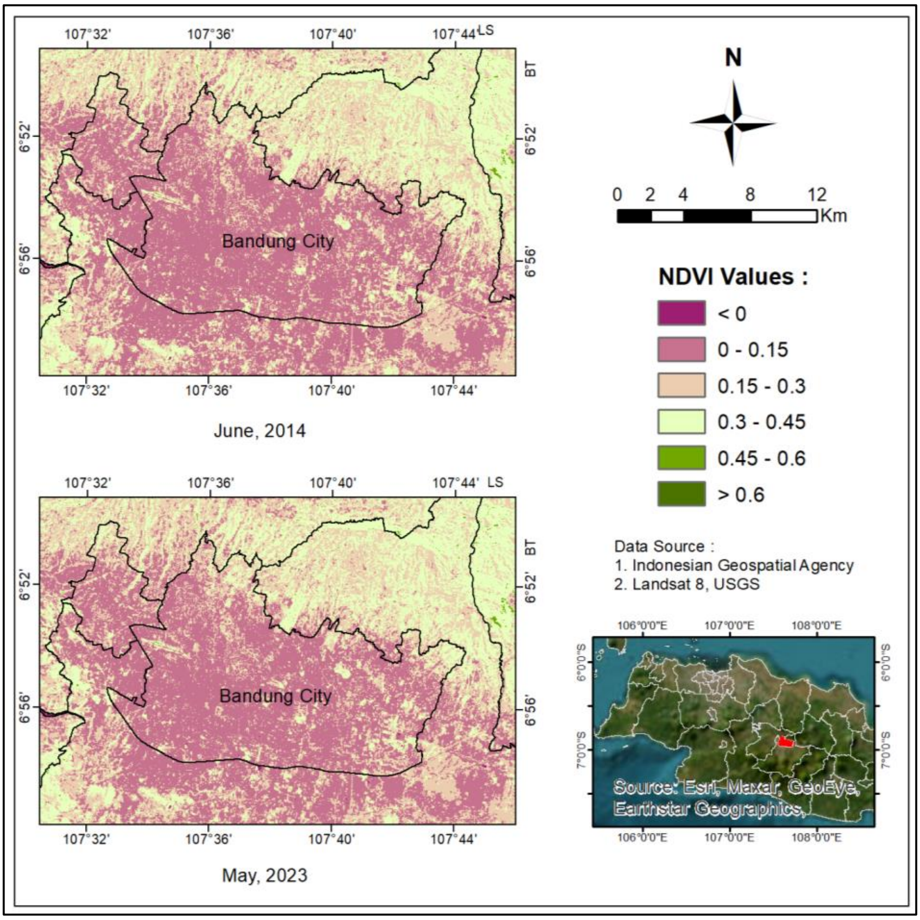

Fig. 2. NDVI changes in Bandung City

4.2. Land Surface Temperature in Bandung City 2014-2023

Only certain remote sensing satellites are equipped to detect the thermal spectral response of objects on earth surface. Landsat is a series of satellites that have been in orbit since 1972, the newest series are Landsat 8 and 9. The Landsat 8 satellite carries sensors capable of recording spectral reflections in 11 bands, two of which are Thermal Infrared Sensors. The Thermal Infrared Band is a breakthrough that allowing for observations and research in various studies such as climate phenomena and global warming. This research utilizes the Landsat 8 thermal infrared band to extract land surface temperature values of Bandung City in the period 2014 and 2023.

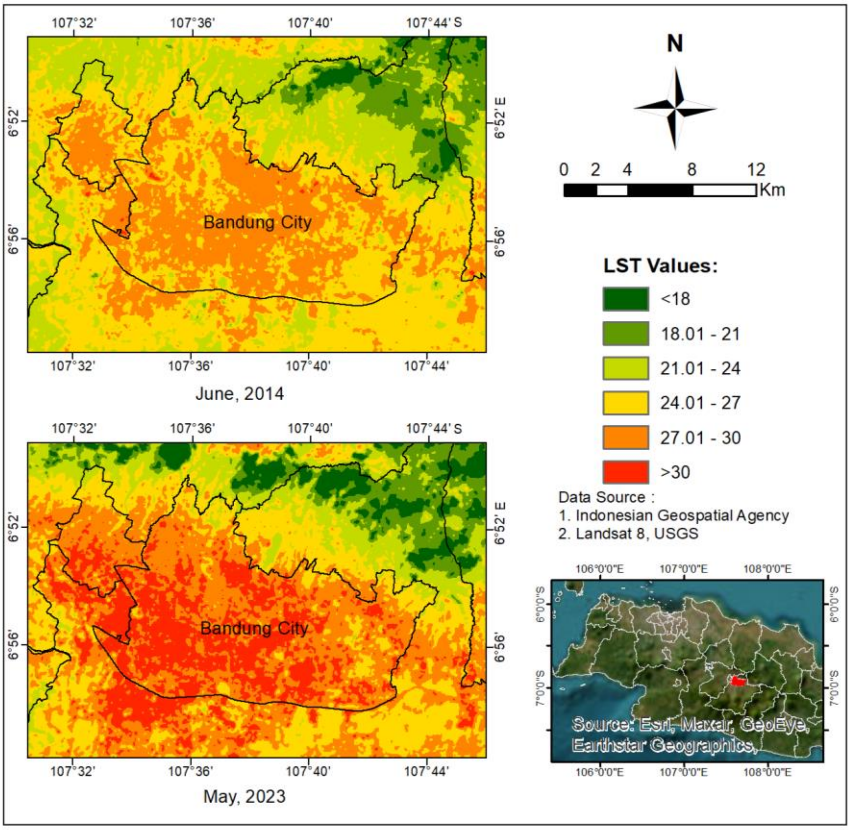

Fig. 3. LST changes in Bandung City (2014-2023)

Figure 3 shows the dynamics of land surface temperature in Bandung City from 2014 to 2023. Landsat 8 thermal infrared band processing produces land surface temperature values. The land surface temperature value per pixel is then classified into 6 (in degrees Celsius): below 18, 18.01 to 21, 21.01 to 24, 24.01 to 27, 27.01 to 30, and above 30. In a period of 9 years, the difference in land surface temperature quite significant in Bandung. In 2014, the city of Bandung was dominated by temperature classes of 24.01 – 27°C and 27.01 – 30 °C. Meanwhile, in 2023 the temperature is likely to increase to 27.01 – 30 and above 30 °C. The hilly and mountainous northern side of Bandung City tends to have lower temperatures, but in this area, it can be seen that there are more areas with temperatures of 24.01 – 27 °C in 2023 compared to 2014. Changes in temperature can be caused by the conversion of natural land (forests, grasslands) to man-made land (settlements, tourism areas, industrial area, etc.). This is in accordance with the concept which states that temperatures in built-up areas tend to be higher than in vegetated areas.

4.3. Relation between vegetation greenness (NDVI) and land surface temperature in Bandung City

Research on land surface temperature always involves vegetation index as the dominant factor in the derivation process. This is related to the emissivity of the soil surface, the value of which is different between vegetated land and no-vegetated land. As previously explained, LST and NDVI are affected by seasonal changes. So, for multi-temporal research it is best to use images recorded in the same season. In tropical environments, the LST and NDVI correlation is commonly negative, which is also influenced by changes in land cover over time. Apart from spatial and temporal changes, the seasonal variation of NDVI and LST relationships is a very important study in each type of land cover [17].

Vegetation index used as an parameter for measuring vegetation greenness in satellite data by utilizing red and near infrared band. The outputs of NDVI and LST are visualized and analysed to identify the relationship between two parameters. Field surveys were carried out to obtain actual temperature data in the research area as well as observations of an actual land cover in Bandung City. Samples were taken from 78 points spread across Bandung City, West Bandung Regency and Cimahi City. The field survey was carried out in July involving 4 surveyors. The data taken during the survey are coordinates, temperature measurement, type of land cover, building density, presence and type of vegetation.

Multi-temporal remote sensing imagery can analyse urban spatial information and thermal environment effectively. Correlation test results typically indicate a positive relation between LST and NDVI, meaning that as the land surface temperature increases, the vegetation level tends to decrease [18].

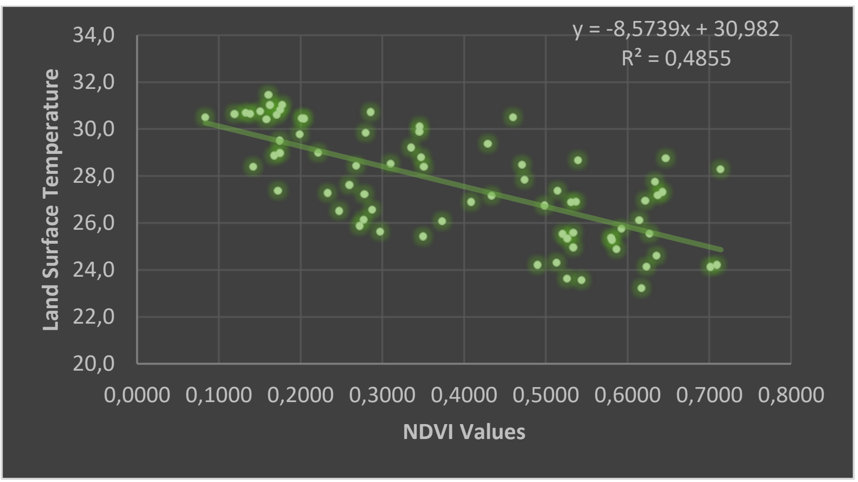

Fig. 4. Linear Regression of NDVI and LST in Bandung City.

Field survey results show that the highest LST values are for residential land use (31.4 ºC) and roads (30.8ºC). It was concluded that the built-up zones had the highest temperature value compared to all types of land use observed in this study. Overall, types of vegetated land use, including rice fields, parks and plantations, have lower temperatures than settlements, roads, empty land and cemeteries.

Linear regression is a data analysis technique used to model dependent and independent variables with a two-dimensional depiction. The variables used in this research are land surface temperature and normalized difference vegetation index. Linear regression models tend to be simple and easy to interpret, and can be created in software applications such as Microsoft Excel. This research assumes that green and dense vegetation areas will have high NDVI values, but low temperatures. In contrast to high LST values which are indicated as non-vegetation areas or built-up areas. Figure 4 shows the regression results with a proportion of 0.48. Positive values in the regression results indicate a correlation between the NDVI and LST variables.

5 Conclusion

Visible phenomena (type of land cover) and invisible (vegetation chlorophyll, temperature) phenomena can record by remote sensing satellite sensors. Although vegetation chlorophyll and land surface temperature are invisible, it can be studied using remote sensing technology for various fields such as land use change, regional development, environmental studies and vegetation studies. This research uses Landsat images of 8 areas of Bandung City in 2014 and 2023. Based on calculations, the land cover with the highest NDVI is plantations, while the lowest is settlements. it is shown that a NDVI value tend to decreased symbolized with light magenta colour dominantly in centre parts of Bandung City. It is assumed that Bandung area in 2023 has more built area than in 2014 so the NDVI values is lower. Built-up area had the highest temperature value compared to all land use variation observed in this research. Types of vegetated land use, including rice fields, parks and plantations, have lower temperatures than settlements, roads, empty land and cemeteries. Positive values in the regression results shows a relationship between NDVI and LST variables This research can be developed for spatial modelling of the correlation of green vegetation with land surface temperature. This research is expected to contribute to the application of remote sensing vegetation studies as and serve as a basis of policymaking regarding the conversion of natural land into urban areas, which can lead to an increase in surface temperatures.

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References

1. P. H. Swain, S. M. Davis. *Remote Sensing the Quantitative Approach*. McGraw-Hill Inc, United States of America (1978)
2. H. Yu, Q. Yang, S. Jiang, B. Zhan, C. Zhan C. *Detection and Attribution of Vegetation Dynamics in the Yellow River Basin Based on Long-Term Kernel NDVI Data*. Remote Sensing, **16**, 1280 (2024)
3. W. Hua, H. Chen, L. Zhou, A. Xie, M. Qin, L. Li, H. Ma, Q. Huang, S. Sun S. *Observational Quantification of Climatic and Human Influences on Vegetation Greening in China*. Remote Sensing, **9**, 425 (2017)
4. Y. Lu, L. Zhang, X. Feng, Y. Zeng, B. Fu, X. Yao, J. Li, B. Wu. *Recent ecological transitions in China: greening, browning, and influential factor*s. Scientific Reports Subject Areas: Macroecology Sustainability Conservation Biology, **5**, 8732 (2015)
5. H. Zhang, L. Li, X. Zhao, F. Chen, J. Wei, Z. Feng, T. Hou, Y. Chen, W. Yue, H. Shang, S. Wang, M. Hu. *Changes in Vegetation NDVI and Its Response to Climate Change and Human Activities in the Ferghana Basin from 1982 to 2015*. Remote Sensing, **16**, 1296 (2024)
6. L. P. Cambrussi, M. J. Cargnin, M. Bianchini, M. Übel, N. C. Reginato, P. Spagnollo, S. B. Belo, V. Tebaldi, A. Neckel, L. S. Maculan, G. T. Cardoso, H. A. Kujawa. *Remote Sensing Applied to NDVI and LST in Urban Streets in Southern Brazil.* Journal of Civil Engineering and Architecture, **15**, 186-192 (2021)
7. G. Rees, L. Hebryn-Baidy, V. Belenok. *Temporal Variations in Land Surface Temperature within an Urban Ecosystem: A Comprehensive Assessment of Land Use and Land Cover Change in Kharkiv, Ukraine*. Remote Sensing, **16**, 1637 (2014)

8. S. Anbazhagan, C. R. Paramasivam. *Statistical Correlation between Land Surface Temperature (LST) and Vegetation Index (NDVI) using Multi-Temporal Landsat TM Data*. International Journal Advance Earth Science Engineering, **12**; 5(1):333–46 (2016)
9. S. Himayah. *Perubahan Temperatur Permukaan Lahan di Kota Bandung Tahun 2009-2018*. Jurnal Geografi Gea, **19**, 1 (2019)
10. Badan Pusat Statistik. *Kota Bandung dalam Angka*. Badan Pusat Statistik Kota Bandung (2023)
11. R. Houborg, M. C. Anderson, W.P. Kustas, F. Gao, M. Rodell. *Routine Mapping of Land-surface Carbon, Water and Energy Fluxes at Field to Regional Scales by Fusing Multi-scale and Multi-sensor Imagery*. Hydrology and Remote Sensing Laboratory, Maryland, USA (2011)
12. G. Mohiuddin, J. P. Mund. *Spatiotemporal Analysis of Land Surface Temperature in Response to Land Use and Land Cover Changes: A Remote Sensing Approach*. Remote Sensing **16**, 1286 (2024)
13. U. C. Nugroho, D. D. Domiri. I*dentification of Land Surface Temperature Distribution of Geogthermal Area in Ungaran Mount by Using Landsat 8 Imagery*. International Journal of Remote Sensing and Earth Sciences, **12** (2): 143 – 150 (2016)
14. D. Sun, M. Kafatos. *Note on the NDVI-LST relationship and the use of temperature-related drought indices over North America*. Geophysical Research Letters, **34**, L24406 (2007)
15. M. Ozyavuz. *Analysis of Changes in Vegetation Using Multitemporal Satellite Imagery, the Case of Tekirdagˇ Coastal Town*. Journal of Coastal Research, **26** (6) :1038-1046 (2010)
16. Z. Khan, A. Javed. *Correlation between land surface temperature (LST) and normalized difference vegetation index (NDVI) in Wardha Valley Coalfield, Maharashtra, Central India*. Nova Geodesia, **2** (3): 53 (2022)
17. S. Guha, H. Govil. *Land surface temperature and normalized difference vegetation index relationship: a seasonal study on a tropical city*. SN Applied Sciences **2**:1661 (2020)
18. O. Tulung, W. Wekua, C. Mongi. *Spatio Temporal Characteristics of LST to NDBI and NDVI in Lake Tondano Based on Landsat*. The International Conference on Natural Sciences, Mathematics, Application, and Technology (ICON-SMART) Proceedings Vol **I**, 46-55 (2021)