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Impacts of Land Cover Changes on Land Surface Temperature Using Landsat Imagery with the Supervised Classification Method

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Abstract – Land cover changes affecting the area's ecology align with the development and increase in urbanization. Tarogong Kidul Subdistrict, Garut Regency, experienced changes in the land cover which changed the soil surface temperature. This study aims to determine the relationship between changes in land cover and land surface temperature. This study used Landsat 8 Surface Reflectance Tier 1 satellite imagery to extract information on the Normalized Difference Vegetation Index and process ground surface temperatures for three periods, 2014, 2017, and 2020, and the guided classification method. Image collection and processing were carried out using Google Earth Engine and software. ArcGIS Pro. The distribution of land surface temperature was then correlated with changes in the NDVI (value of the land cover vegetation index) using simple linear regression analysis and spatial correlation. This study reveals that land cover change is closely related to an increase in soil surface temperature, as indicated by the rise in soil surface temperature in areas experiencing land use change. The results of the linear regression analysis (84.49%) showed that changes in land cover and the greenness index of vegetation were the most critical driving factors for changes in soil surface temperature.

Keywords: land cover, L.S.T., normalized difference vegetation index, supervised classification, Tarogong Kidul Sub-district, urbanization.

Introduction

Land cover changes result from increased population, facilities, and infrastructure development to support human activities (Duka *et al.*, 2020). Besides, infrastructure development and increased urbanization also cause land cover changes (Christian *et al.*, 2016). Land cover changes are caused by many factors that significantly change land surface temperature (Nadira *et al.*, 2019). In line with changes in surface temperature, there is an impact on the area's ecology, namely the decrease in the Normalized Difference Vegetation Index (NDVI) (Kayet *et al.*, 2016). Land cover is the physical appearance of the earth's surface (Sampurno & Thoriq, 2016).

Garut District is one of the districts with various land cover variations and a strategic location in West Java Province. Therefore, this district is used as a buffer for the capital city of West Java Province (Garut District B.P.S., 2017). Tarogong Kidul Sub-district, the capital of Garut District, has become the center of human activity. Thus, sub-districts experience changes in land cover adjusted to human activities in the area within a certain period (Ghani *et al.*, 2021).

Based on Garut Regency data for 2021, the total land cover in this district in 2018 reached 307,407 Ha, with details of 13.92% for paddy fields, 68.53% for non-rice areas, and 17.55% for non-agricultural land. However, in the 2014-2018 period, there was a change in land cover: paddy areas decreased by 1.84%, non-paddy fields increased by 1.68%, and non-agricultural land increased by 0.16%. Specifically, a decrease in paddy field cover of 12 hectares occurred in 2018.

The reduction in the paddy field cover area of 12 Ha is the conversion of vegetation land into built-up land, especially settlements, and public sports facilities. This statement is supported by the fact that the population of the Tarogong Kidul sub-district was issued by the Central Bureau of Statistics of Garut Regency in 2021, namely that there is a reasonably stable increase in population growth of 0.75% of people every year. The high population

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also aligns with the density of human activities on land cover (Ishad, 2018), affecting natural, human, and physical aspects (Jansen & Di Gregorio, 2001). Land cover changes are caused by development and increased urbanization, affecting the area's ecology, decreasing the NDVI, and increasing land surface temperature (Tursilowati, 2002; Wiweka, 2014).

The NDVI provides information on the greenness of plants. Referring to the Regulation of the Minister of Forestry Number P.12/Menhut-II/2012, the classification of the NDVI cover five classes. This study used NDVI to analyze changes in the land surface temperature of an area influenced by human activities such as converting vegetation land into settlements and expanding public sports facilities. Land surface temperature is above the ground surface with a distance tolerance of 2 meters (Sasmito & Suprayogi, 2018). The land surface temperature can be detected using remote sensing technology to analyze spatial data for a wide area (Roy *et al.*, 2014; Loveland and Irons, 2016).

Along with the development of remote sensing technology, the study of changes in land surface temperature can obtain accurate spatial data quickly. Image data collected in this study were processed using Google Earth Engine and ArcGIS Pro software. The satellite image data used is Landsat 8 Surface Reflectance Tier 1. This study aims to determine the relationship between changes in land cover and land surface temperature.

Materials and Methods

The study was conducted in the Tarogong Kidul Sub-district, Garut District. Based on the 2021 Garut District data, geographically, Tarogong Kidul Sub-district is located at 7°12'0"LS and 107°52'0"E. The border of this sub-district is Garut Kota Sub-district in the east, Bayongbong and Cilawu Sub-district in the south, Samarang Sub-district in the west, and Tarogong Kaler Sub-district in the north., Tarogong Kidul Sub-district, the capital of Garut District, has become the center of all community activities that lead to the development and increased urbanization. As mentioned in www.garutkab.go.id, Tarogong Kidul Sub-district experienced a land conversion in 2018 with a reduction of rice field areas of 12 hectares for the expansion of settlements and construction of public sports facilities. The administrative map of the study area can be seen in Figure 1.

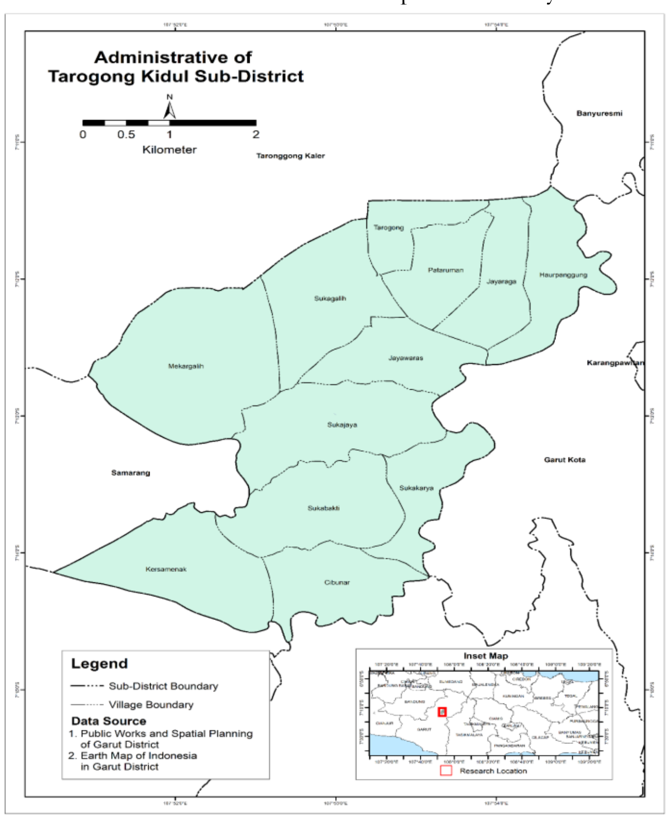

Figure 1. Administrative Map of the Research Area

This study used land cover changes, the Normalized Difference Vegetation Index, and land surface temperature variables. The variables, data collection, and the source of data are listed in Table 1. This study used

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both primary and secondary data. The primary data were daily temperature data for a certain period obtained using a digital anemometer and brief interviews about the land surface temperature of the land around Tarogong Kidul Sub-district residents. Then, the secondary data were Landsat 8 Surface Reflectance Tier 1 satellite imagery obtained from Google Earth Engine software for three periods of 2014, 2017, and 2020. Landsat 8 Surface Reflectance Tier 1 satellite image data are presented in Figure 2.

Table 1. Data Collection

Variable	Data	Source of Data
Land Cover Change	Landsat Image Data in 2014, 2017, and 2020	Landsat 8 Surface Reflectance Tier 1 Satellite
Normalized Difference Vegetation Index	Vegetation Index Value	Band 4 and Band 5 of Landsat 8 Surface Reflectance Tier 1 Satellite
Land Surface Temperature	NDVI data and temperature value in Celsius (°C)	Primary Data Collection Survey in the Field

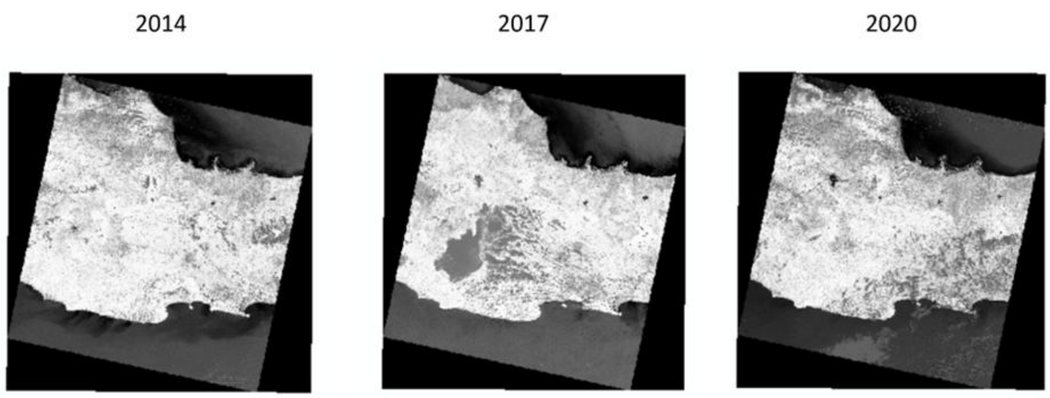

Figure 2. Landsat 8 Surface Reflectance Tier 1 Satellite Images in 2014, 2017, and 2020

This study used different sampling techniques to determine the number of sample points for land cover accuracy testing and surface temperature data. Based on Fitzpatrick-Lins in 1980 (Hernina & Wicaksono, 2016), the sampling technique for testing land cover accuracy used the following formula:

$$N = \frac{Z^2\,(p)(q)}{E^2} \tag{1}$$

N = Number of sample points
p = Expected map accuracy
q = 100-p
Z = 2 (from the normal standard deviation of 1.96 for a two-tailed confidence level of 95%)
E = Tolerate error

$$N = \frac{2^2\,(90)(10)}{5^2} \tag{2}$$

Based on the calculation above results, the number of sample points obtained is 144. The sample points were randomly distributed according to the land cover classification. A map of land cover sample points is presented in Figure 3. There are 144 sample points scattered according to the type of land cover. Tarogong Kidul District has a heterogeneous land cover. Settlements dominate the north and northeast sides, while the west and southwest areas are dominated by agricultural land cover and rice fields, but there are also settlements.

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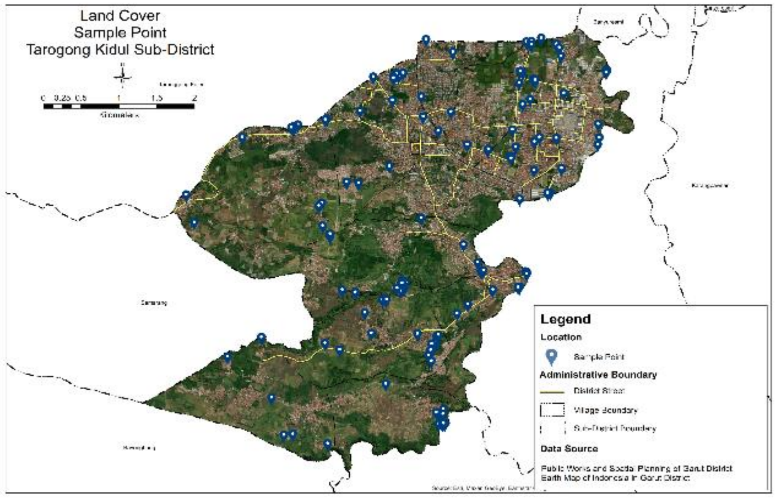

Figure 3. Land Cover Sample Point Map

We determined the number of sample points for surface temperature data collection using a different sampling technique from the land cover accuracy test. According to Sari (2019), simple random sampling can be done by selecting samples randomly from a small segment of individuals or members of the entire population so that all parts of the region have equal probability as samples. A map of land cover sample points can be seen in Figure 4. This study used Landsat 8 Surface Reflectance Tier 1 satellite imagery using Google Earth Engine software to obtain the NDVI value through the supervised classification method.

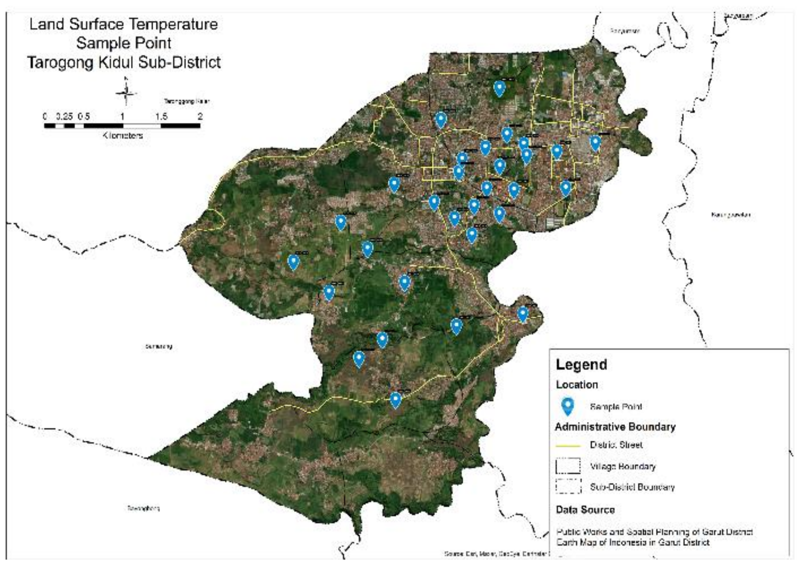

Figure 4. Land Surface Temperature Sample Point Map

Landsat imagery was computationally processed to perform radiometric corrections and band stacking. The greenness index requires Band 4 and Band 5. Next, we achieved guided classification, layout, and reclassification methods with ArcGIS Pro software. The land cover reclassification conforms to the Regulation of the Minister of Forestry of the Republic of Indonesia Number P.12/Menhut-II/2012 using five classes for the classification of the greenness index of vegetation, as shown in Table 2. After that, an accuracy test was carried out with a field survey.

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$$N = \frac{NIR-Red}{NIR+Red} \tag{3}$$

NIR = Band 5
Red = Band 4

Table 2. Classification of Normalized Difference Vegetation Index (NDVI) Values based on the Regulation of the Minister of Forestry Number P.12/Menhut-II/2012

Value	Class
- 1 < NDVI < - 0.03	No Vegetation
- 0.03 < NDVI < 0.15	Low Vegetation
0.15 < NDVI < 0.25	Sparse Vegetation
0.25 < NDVI < 0.35	Medium Vegetation
0.35 < NDVI	Dense Vegetation

After getting the NDVI value is processed to get the land surface temperature (L.S.T.) score. The L.S.T. values include the soil surface temperature's minimum, maximum, average, and standard deviation values. This process is carried out with the same treatment for each period.

$$LST = \frac{TB}{\{1+[\left(\frac{\lambda.TB}{c^2}\right)\ln\in\lambda\}} \tag{4}$$

TB = Temperature Brightness (°C)
λ = Central Wavelength of emitted radiance
$c^2 = h\,\frac{c}{s} = 1{,}4388.10^2\ mK = 14{,}388\mu mK$

Based on primary data from the field, the daily temperature data were processed using Excel Worksheet software. Daily temperature data were sorted by sampling time, and then a schema or graph was made to see the distribution of land surface temperatures. The resulting schema or diagram was then correlated with the vegetation index and land cover changes.

Data were analyzed using a simple linear regression method to obtain the relationship between land cover changes and their impact on the decrease in vegetation index and land surface temperature. The analytical approach used descriptive analysis through the map of the results of previous data processing. Then a simple linear regression analysis was carried out between land cover changes and land surface temperature. The simple linear regression results are associated with a decrease in the vegetation index value. Thus, the relationship between changes in land cover and the surface temperature will be seen.

Results

Analysis of Land Cover

Referring to the theory of Fitzpatrick-Lins (1980), the resulting land cover map is followed by an accuracy test with a total accuracy of 86.80%. There are a total of 125 correct points in the 144 samples tested. Six land cover classifications were obtained: shrubs, settlements, irrigated rice fields, rainfed rice fields, shrubs, and rivers. Thus, the land cover is declared valid and accurate. The land cover map is presented in Figure 5.

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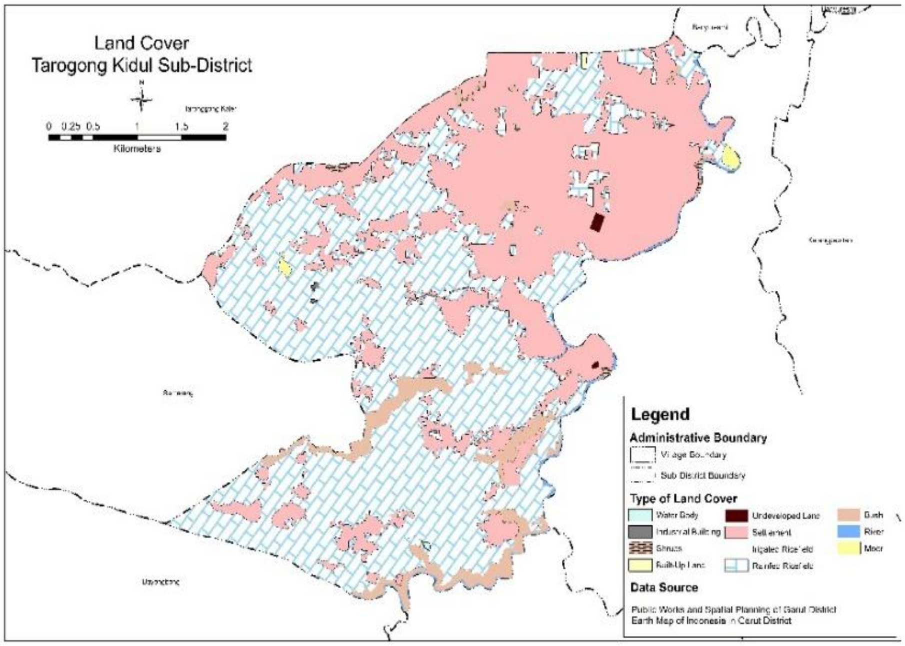

Figure 5. Land Cover Map

Analysis of Land Cover and Normalized Difference Vegetation Index

Data processing used the supervised classification method and produced a land cover map with six classifications, including built-up land (buildings, shop buildings, and settlements), vacant land, water bodies (ponds), and vegetation (irrigated rice fields). Regarding NDVI, based on the Regulation of the Minister of Environment and Forestry No. 12 of 2012, land cover refers to the suitability of the physical material of the earth's surface (Shidiq *et al.*, 2020). For example, vegetation land areas captured by the sensor show a decreasing maximum NDVI value. The results of the NDVI value can be seen in Table 3.

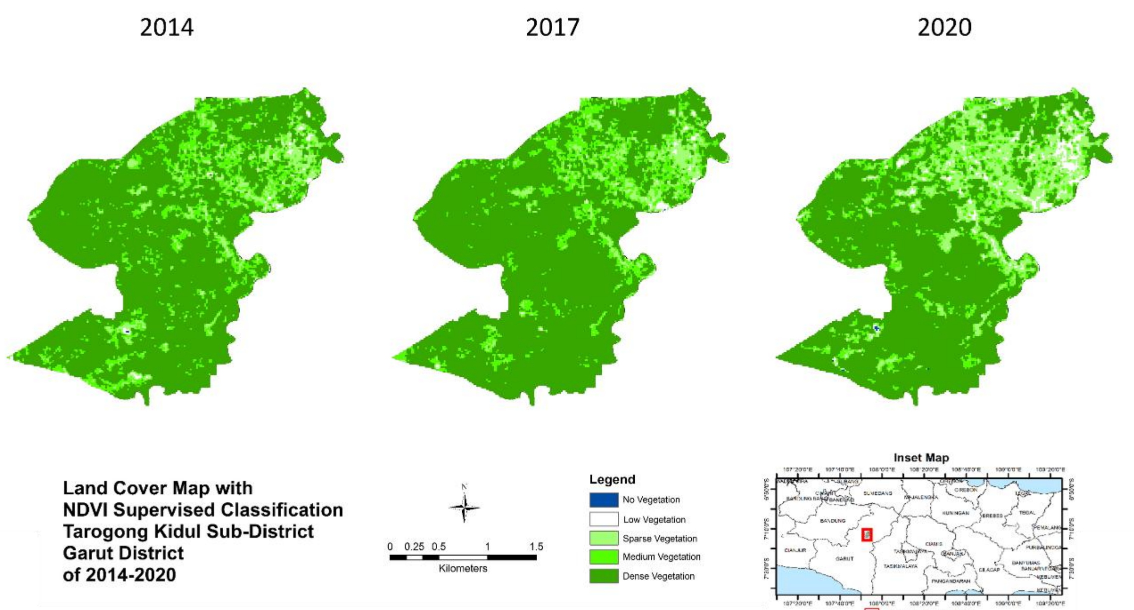

Figure 6. Land Cover Map with Vegetation Index of 2014, 2017, and 2020

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Table 3. Normalized Difference Vegetation Index

Year	NDVI Minimum	NDVI Maximum
2014	-0.0588877	0.953271
2017	-0.024565	0.876393
2020	-0.0289444	0.824831

Based on Figure 6, the normalized difference in the vegetation index in all classes experienced various changes. In 2017 it increased, but it decreased in 2020. The decline in the NDVI value impacts the reduced green vegetation due to the conversion of land to built-up land.

Analysis of Land Surface Temperature

Continuing the NDVI data, a map of the distribution of land surface temperatures in Tarogong Kidul Sub-district, Garut District, was produced. The class classification was used according to the range of land surface temperatures. The results of the land surface temperature values can be seen in Table 4.

Table 4. Land Surface Temperature Value

Year	L.S.T. Minimum	L.S.T. Maximum	Average L.S.T.	Standard Deviation
2014	22.6346	32.2709	24.31903146559176	0.953271
2017	22.9122	32.9606	24.49933516059751	0.876393
2020	23.4081	32.5283	23.3770140449608	0.824831

Based on Figure 7, in 2014, the dominance of surface temperatures was in the temperature range of <24°C. Besides, in 2017 the dominant surface temperature was still in the temperature range <24°C, but many areas had experienced a temperature range of 24 - 26°C. Then, in 2020, there was a significant change in surface temperature compared to the two previous periods, namely in the 24 - 26°C with the highest temperature of > 32°C in the northeastern region of Tarogong Kidul Sub-district, Garut District.

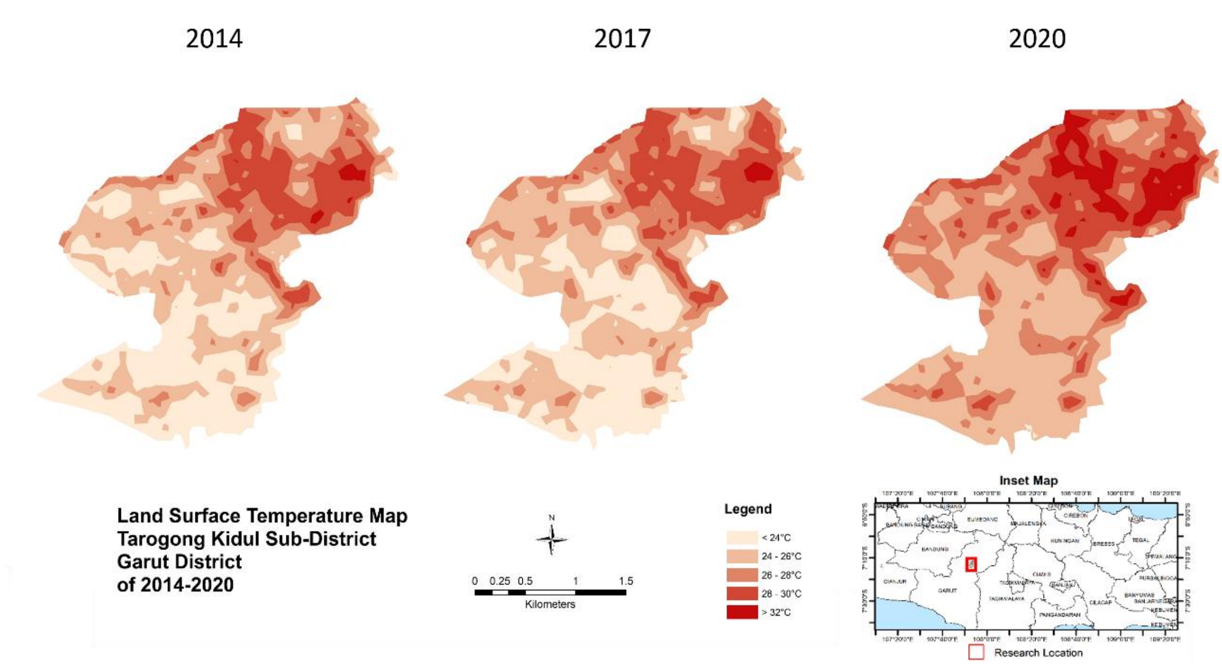

Figure 7. Land Surface Temperature Map of 2014, 2017, and 2020

The graph forms a relatively similar pattern based on the daily temperature graph from the primary data processing results in Figure 8. The daily temperature pattern shows the daily temperature data has less volatile cycles. Thus, an increase in surface temperature will be felt after a certain period (Sugianto *et al.*, 2023). The

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observations of several residents support these results: in 2014 and 2020, the rise in ground surface temperature was more significant compared to 2014 to 2017 or 2017 to 2020. This meaningful comparison is since the period between 2014 and 2020 is longer than other periods, so temperature changes are also more noticeable.

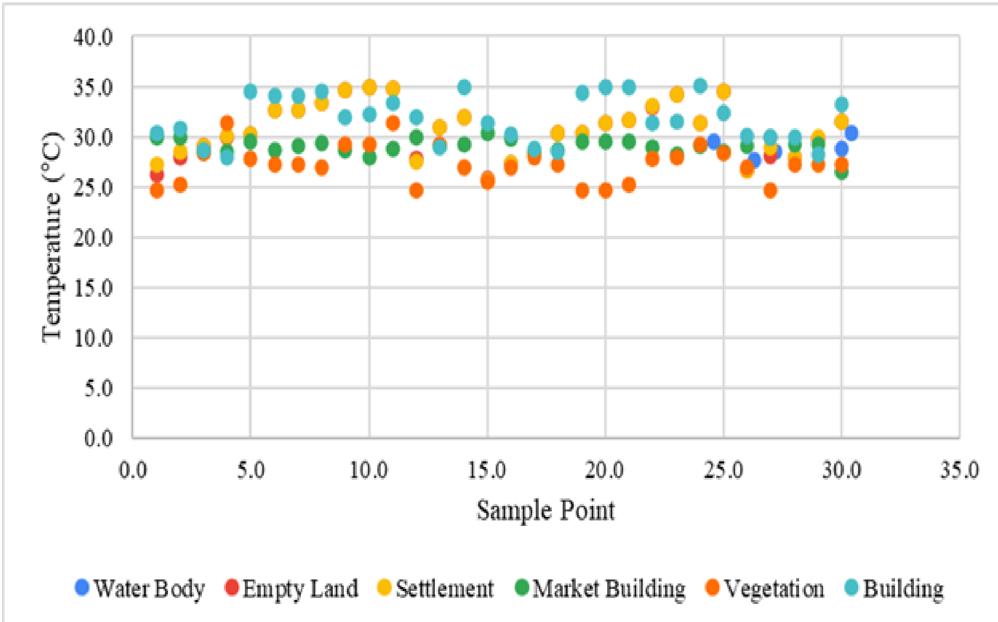

Figure 8. Graph of Land Surface Temperature Distribution in terms of Functional Analysis Unit (Data 17-18 May 2022, Tarogong Kidul Sub-district, Garut District)

Based on the scatter plot graph, the settlement land cover class has the highest temperature, and the vegetation class has the lowest temperature. However, based on the land cover type, building land cover has moderately fluctuating land surface temperatures, which tend to increase compared to other land covers. The results of a simple linear regression method between land surface temperature and land cover evidence this increase in temperature.

Analysis of the Relationship between Land Cover Changes and Land Surface Temperature

Descriptive analysis was carried out through data processing maps. The relationship between land cover changes and land surface temperature was analyzed using a simple linear regression method between land cover changes and land surface temperature in Tarogong Kidul Sub-district, Garut District. The results of data processing can be seen in Table 5.

Based on the data processing results using a simple linear regression method, the highest correlation with the equation of $y = 0.068x + 12{,}203$. The result shows a coefficient of determination of 0.8449, which means that the effect of the land cover building class on the average surface temperature reaches 84.49%.

Table 5. Results of Simple Linear Regression between Land Cover Changes and Land Surface Temperature

Land Coverage Type	Correlation Results of Land Surface Temperature	Source of Data
Land Cover Change	Landsat Image Data in 2014, 2017, and 2020	Landsat 8 Surface Reflectance Tier 1 Satellite
Normalized Difference Vegetation Index	Vegetation Index Value	Band 4 and Band 5 of Landsat 8 Surface Reflectance Tier 1 Satellite
Land Surface Temperature	NDVI data and temperature value in Celsius (°C)	Primary Data Collection Survey in the Field

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Discussion

Normalized Difference Vegetation Index values are presented in Table 3, and soil surface temperature values are shown in Table 4. The results of a simple linear regression test on all land cover classes to determine the relationship between land cover change and surface temperature showed the highest correlation with y = 0.068x + 12,203. This equation shows that the coefficient of determination reaches 0.8449, meaning that the effect of changes in land cover for building classes on ground surface temperature is 84.49%. In different years there was a correlation of 66.62% for data for 1997 and 2007 and 17.52% for data for 2007 and 2017. The difference in correlation values was due to the time difference between 1997-2017, with slight changes in land cover (Putra et al., 2018).

The correlation states the relationship between land cover and land surface temperature. The area's characteristics are similar to Tarogong Kidul District, Garut Regency. It was mentioned in previous research that Surakarta City had become one of the cities with the most extensive development in Central Java in the past few years, resulting in over-urbanization. This condition is similar to Garut Regency. However, as previously mentioned, temporal differences produce different results because this study used data for 1997-2017, where the significance of changes in land cover was not too different compared to the year above.

The data processing results show a relationship between the Normalized Difference in Vegetation Index and soil surface temperature. The decrease in the maximum value of the Normalized Difference Vegetation Index is in line with the increase in the minimum surface temperature value in each period. Vegetation density decreases every year, which also causes an increase in land surface temperatures due to reduced green vegetation in land cover (Duka et al., 2020).

In another previous study, in Gorontalo City, it was also stated that a decrease in the Normalization Difference Vegetation Index causes an increase in soil surface temperature. The rise in surface temperature is caused by reduced green vegetation in land cover. Thus, the Normalization Difference Vegetation Index affects land surface temperature, especially in areas that have experienced a conversion from vegetated land to built-up land.

Conclusion

Changes in land cover are indicated by a decrease in the Normalized Difference Vegetation Index from 2014 to 2020. A reduction in NDVI affects an increase in the minimum value of ground surface temperature from 2014 to 2015. An increase in soil surface temperature in 2017 was 0.2776°C, and from 2017 to 2020, of 0.7735°C. Based on daily temperature data, the built-up soil has a surface temperature that fluctuates and increases quite a bit. The results of simple linear regression tests for all land cover classes show a high correlation between land cover changes and surface temperature. The effect of changing the type of ground cover buildings on soil surface temperature is 84.49%. In addition, the Normalization Difference in Vegetation Index affects soil surface temperature, especially in areas experiencing conversion from vegetated land to built-up land.

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