Spatial Analysis of the Effect of Urbanization on Changes in Land Cover and Distribution of Surface Temperature in Madiun City in 2015 and 2020

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Abstract. Changes in land cover affect the increasing surface temperatures. Built-up land ensued by regional development is the cause of increasing surface temperatures in urban and triggering climate change. One of the reasons is urbanization which leads land cover to change, thus the population density in Madiun City also increases. This research takes a case study in Madiun city referring to several objectives, namely, understanding the effect of urbanization on changes in the land cover of Madiun; analyzing the effect of the changes on the surface temperature distribution that occurred in Madiun in 2015 and 2020. The research method used Landsat 8 Operational Land Imager (OLI) imagery with a remote sensing data approach through several extraction processes, including the use of supervised classification), Normalized Difference Vegetation Index (NDVI), and Land Surface Temperature (LST). The results showed that Madiun experienced significant changes in land cover due to population growth including urbanization which had an impact on the distribution of surface temperatures following changes in land cover. The change in land cover altered by 3% to 6% for each land cover in Madiun City. The distribution of surface temperatures in Madiun was dominated by warmer surface temperatures. The distribution of surface temperature in Madiun City was not well distributed and experienced significant changes due to the changes in land cover in Madiun.

Keywords: Madiun city · urbanization · land cover · surface temperature

1 Introduction

Accurate information on land cover is an important factor in understanding a phenomenon in an area, based on data needed for various studies, and a basis for a land management plan (Kosasih et al., 2019). One of the main factors influencing the rising surface temperature in cities is that changes in land use distort Green Open Space (GOS), which has decreased. Green open space serves as a natural cooling system to maintain a balance of humidity and surface temperature (Sari et al., 2018). Changes in land cover are modified by the interference of human activities to improve the quality

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of life. Factors affecting are not only human activity, but also the environment, sensors, and recording time (Rahman, 2018a).

As a result of the rapid growth of development in urban areas degrades the quality of land and the environment. It also affects the air temperature in an area, especially urban areas, thus triggering urbanization caused by uneven development between rural and urban areas (Harahap, 2013). Urbanization induces residents to move to urban areas because only several cities can accommodate the increasing population. The percentage of population density will continue to rise due to aggravated urbanization.

One of the areas of change in land cover in Madiun is the increasing number of residents who alter land from vegetated land into residential areas or industrial areas (Duka et al., 2020). The higher population density influences changes in the residential areas which are significantly denser so the vegetation area decreases and alters changes in surface temperature in Madiun (Aditiyanti et al., 2013). Agricultural land or vegetated land has changed into built-up land not only in residential areas. Also, road construction has affected the rising surface temperatures. Location, season, and land area are factors that depend on the rising surface temperature in a city (Fawzi & Iswari, 2019).

Madiun population from 2015 to 2016 experienced a growth of 0.35%. The total population of Madiun in 2016 was approximately 175, 607 people, consisting of 84,897 males and 90,710 females. Madiun has a population density of 5,873 (people/km^2) with a population growth rate of around 1.29%, which is governed by the uneven distribution of population (Anonim, 2017). Population growth in the City of Madiun continues to increase yearly, suggesting that Madiun is experiencing an area expansion due to limited territory. Madiun has encountered many changes and developments in land use, which have resulted in declining green open space. The government uses any land in Madiun as a shopping or housing site to improve the city's economic state. Therefore, research is necessary to examine the effect of urbanization on changes in land cover and the distribution of surface temperature in Madiun. Thus, this can be implemented as an overview for future regional development can maintain the quality of green open spaces, as it is the most important factor in the adequate and inadequate quality of an environment. Human activities, such as the construction of settlements, plantations, agriculture, industry, and so on are elements that modify changes in the distribution of surface temperature in the region (Delarizka et al., 2016).

Relatively vegetated areas are more likely to have cold surface temperatures so the distribution or contribution of air temperature is cooler. Meanwhile, the built-up area has a relatively warm surface temperature so that the distribution or contribution of air temperature is warmer. In other words, surface temperature and air temperature are connected (Fawzi & Iswari, 2019). The high and low land surface temperatures are influenced by land cover due to a growing population (Ekawati, 2020). This research entails shortcomings, in which the analysis for the surface temperature accuracy test does not conduct field validation due to the limitations of soil temperature measuring instruments, so the s analysis of surface temperature only refers to the results of image interpretation using the extracted thermal bands.

Image composites with the best band combinations were carried out for land cover classification. In visual observation of land cover objects, we employed Landsat 8 OLI imagery (Sampurno & Thoriq, 2016). Remote sensing in identifying land cover and

surface temperature distribution allows for the analysis of large areas, is relatively inexpensive, and is flexible in time to produce fairly accurate spatial data in a relatively short time (S. Nugroho et al., 2016). Landsat 8 imagery is expected to interpret changes in land cover and estimate land surface temperature in Madiun. Temperature information was recorded by digital number satellite imagery so it should be converted to spectral radial so that gradations of surface temperature analysis are attained (Iswari et al., 2016). The purpose of this study was to analyze the effect of urbanization on changes in land cover and surface temperature distribution that occurred in Madiun in 2015 and 2020. This research was conducted because of the need to review the management of land development in Madiun for better sustainability of land quality in Madiun. As a result of uneven land cover changes, the distribution of surface temperatures in Madiun follows the suit. This research shows a classification of changes in land cover and the distribution of surface temperature that influences both.

2 Method

2.1 Research Sites

Madiun has a total area of around 33.23 km^2 and comprises three subdistricts, namely Taman Subdistrict, Manguharjo Subdistrict, and Kartoharjo Subdistrict with a total of 27 urban villages (Fig. 1). Madiun consists of a tropical climate with temperatures of 20 °C–35 °C and an average rainfall of 2000 m^3/year. The pattern of land use in Madiun is dominated by settlements and paddy fields. It is an urban area vastly occupied by trade and services, education, offices, and settlements. The following is an administrative map of Madiun City.

2.2 Research Data

The data in this study are primary data gathered directly and secondary data obtained indirectly. Primary data are in the form of Landsat 8 OLI image data in 2015 and 2020 from the United States Geological Survey (USGS) EarthExplorer (usgs.gov), while secondary data are in the form of Indonesia topographic maps of the Madiun City taken from the Ina-Geoportal web (Indonesia Geospatial Portal). Table 1 is a table of research data and their sources.

2.3 Data Analysis

This study applied a geographic analysis method, namely spatial analysis. The spatial analysis studies and identifies changes in land cover and land surface temperature distribution in Madiun. Data analysis processing employed a qualitative and quantitative GIS approach with qualitative and quantitative descriptive analysis, which refers to the spatial pattern (Fikriyah et al., 2022). The spatial pattern considers the temperature distribution of the land cover types that occur. Several stages were carried out in this study, as described in Fig. 2.

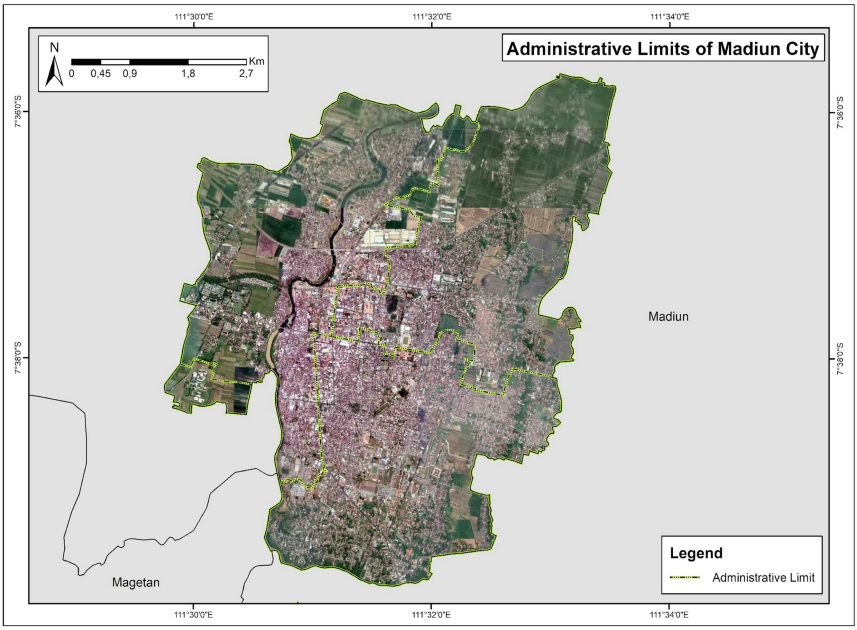

Fig. 1. Research Site Map

Table 1. Research Data

Data	Source
Data on Land Cover types in 2015 and 2020	Landsat 8 image OLI
Surface Temperature Distribution data for 2015 and 2020	Landsat 8 image OLI
Digital Map of Indonesia topographic maps	Ina-Geoportal

2.4 Identification of Urban Development

Identification of urban development was carried out utilizing a literature study; collecting the necessary information and data from relevant sources as analysis material. The data used are in the form of population data and population density from secondary sources, such as Statistics Indonesia (known as BPS).

2.5 Land Cover Classification

Classification of land cover with supervised classification, taking into account the appearance of Landsat imagery based on the classification of 37 land covers according to the Indonesian National Standard (SNI) in 2010. The land cover classification functions to group phenomena based on certain criteria. Classification of land cover using multispectral classification with supervised classification methods. The available classification

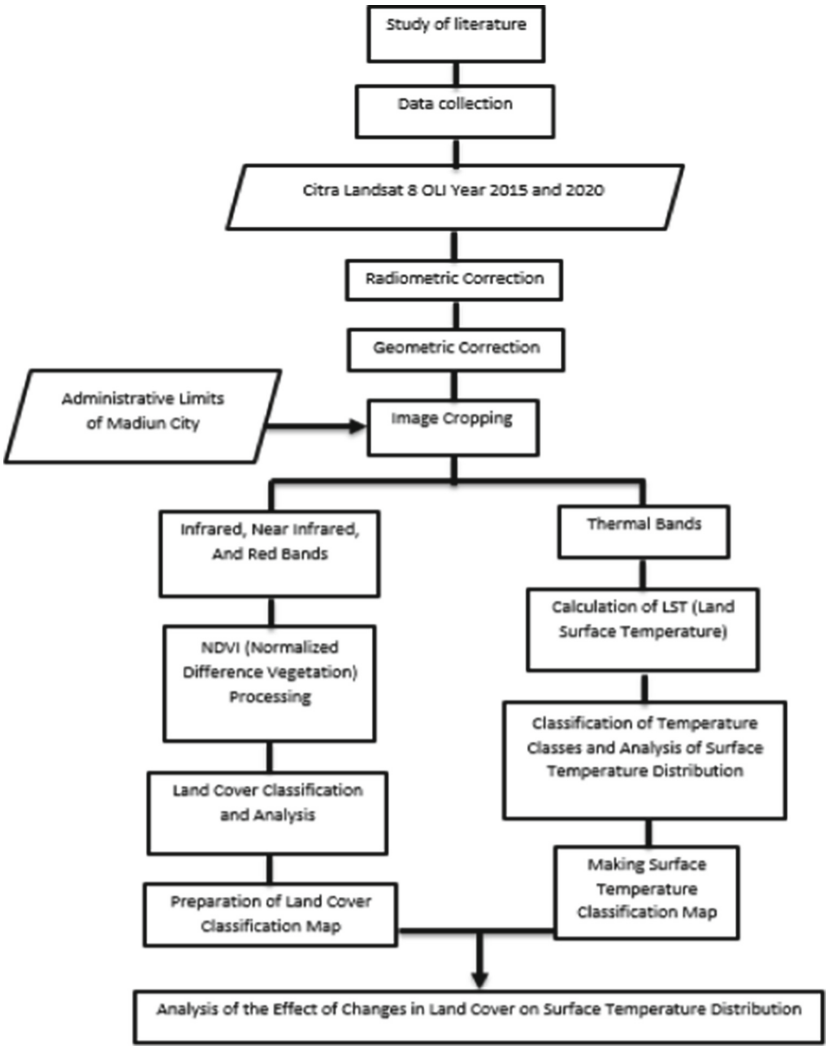

Fig. 2. Research Flowchart

method in this study selected the Spectral Angle Mapping algorithm. The sampling of 30 points was conducted randomly, spreading over the Madiun through the Stratified Random Sampling method (Harjadi, 2010). Furthermore, a percentage value of 100% was obtained from the results of the research accuracy test by considering the results of image interpretation classification and observation results using the Error Matrix or Confusion Matrix method.

$$\text{Accuracy} = \frac{30}{30} \times 100\% = 100\% \quad (1)$$

2.6 Surface Temperature Extraction

Landsat satellite image data generates a land surface temperature. It cannot directly convert the digital number but should undergo several conservation stages to achieve the actual surface temperature value. TOA (Top of Atmosphere) correction is an image correction by performing radiometric calibration (Kalinda et al., 2018).

$$TOA = ML * Qkal + AL \tag{2}$$

The Brightness Temperature (BT) value is obtained from the conversion of the digital number into radiance, which is the TOA value reflected from a pure surface object from reflection producing a radiance value on the sensor (Ibrahim et al., 2016).

$$\mathrm{BT} = \frac{K2}{1n(\frac{k1}{L\lambda} + 1)} \tag{3}$$

Normalized Difference Vegetation Index (NDVI) is to determine the green value or vegetation density from digital signal processing of brightness value data. The NDVI value is the calculation of Near Infrared with Red reflected by vegetation and a comparison of Near Infrared and Red data can be conducted (Philiani, 2018).

$$NDVI = Float(\mathrm{Ba}nd5 - Band4)/Float(\mathrm{B}and5 + \mathrm{Band4}) \tag{4}$$

The emissivity (ε) is the radiation surface compared to a dark object at an identical temperature (Ibrahim et al., 2016).

$$\varepsilon = 0.004\ Pv + 0.986 \tag{5}$$

The LST value is influenced by the wavelength which is very sensitive to surface temperature, namely the thermal infrared (Nugroho & Domiri, 2017).

$$LST = \mathrm{BT}/(1 + (0.00115 * BT/1.4388) * Ln(\varepsilon)) \tag{6}$$

3 Results and Discussion

3.1 Identification of Urban Development

The increasing development growth every year in Madiun thanks to population growth. The effect of population growth and population density also has an impact on changes in land cover in urban areas. As a result of population growth, the environment is required to meet the criteria for developing residential areas (Haryana et al., 2013). This growth will result in contracted vegetated land such as agricultural land and plantations in Madiun, which in consequence bring an impact on changes in land cover. Table 2 is a table of the Population Density of Madiun by Subdistrict.

Table 2 shows that the population in Madiun is mostly located in Taman Subdistrict at 42.88%, while the Manguharjo subdistrict has only 29.60% and the Kartoharjo

Table 2. Population Density of Madiun City in 2020 (Statistics Indonesia of Madiun City, 2021)

Subdistrict	Percentage of Total Population	Population Density (people per km^2)
Manguharjo	29.60	5,755
Taman	42.88	6,717
Kartoharjo	27.51	5,004
Total	**100.00**	**5,873**

subdistrict at 27.51%. As a result of the continuous and uncontrolled progress of development, it transformed the development of residential areas that should have brought related studies so that future problems can be avoided, such as the loss of vegetation which will later affect the distribution of land surface temperatures in the Madiun City area (Arsandrie, 2018).

Urban development in Madiun is based on the urbanization process with the influx of outsiders into the city. The increase in population also led to high demand for facilities and infrastructure services. The rising demand for land will pressure the space in restricted urban areas.

3.2 Land Cover Classification

There are three classes in classifying land cover change in Madiun in 2015 and 2020, namely vegetation, vacant land, and built-up land. After processing the classification, the results were obtained from the two comparisons in 2015 and 2020. Land cover changes in Madiun obtained from 2015 and 2020 showed varied changes in each different class. The utilization of Landsat 8 imagery with a spatial resolution of 30 m could only identify cover information, and only detect types of vegetation or non-vegetation land cover. As a consequence, it could not determine a density or vegetation function (Sumaryana et al., 2022). Table 3 is a comparison table of changes in the land cover in Madiun.

Vegetation land cover has changed in the area from 6.67 km^2 in 2015 to 7.49 km^2 in 2020, the vegetation area of Madiun City has changed by around 3% from 2015 to 2020 where the area has increased. The vacant land cover experienced a significant transformation wherein in 2015 the area of vacant land cover was around 6.02 km^2 and decreased in 2020 by approximately 6%, namely 4.31 km^2. Changes in built-up land cover increased by 3% from 2015 to 2020, around 21.90 km^2 and around 22.78 km^2,

Table 3. Comparison of Land Cover Changes

Land Cover	Area 2015 (km^2)	Area 2020 (km^2)	Difference Change	Percentages
Vegetation	6.67	7.49	0.82	3
Vacant land	21.90	22.78	0.88	3
Built-up land	6.02	4.31	1.71	6

respectively. The following is a map of the land cover change in Madiun in 2015 and 2020 (Fig. 3).

The land cover that dominates the land cover change map in Madiun City is built-up land cover in red, given the majority of the Madiun map is covered in red. This suggests that Madiun is dominated by high settlement distribution and density compared to vegetation land cover. The results of land cover classification through field validation of sampling or random sample points in each land cover class have an accuracy value of 100%. Image interpretation validation and field validation were carried out with a total of 30 sample points and all sample data were correct based on the classification results with actual conditions. Changes in land cover are determined by the interference

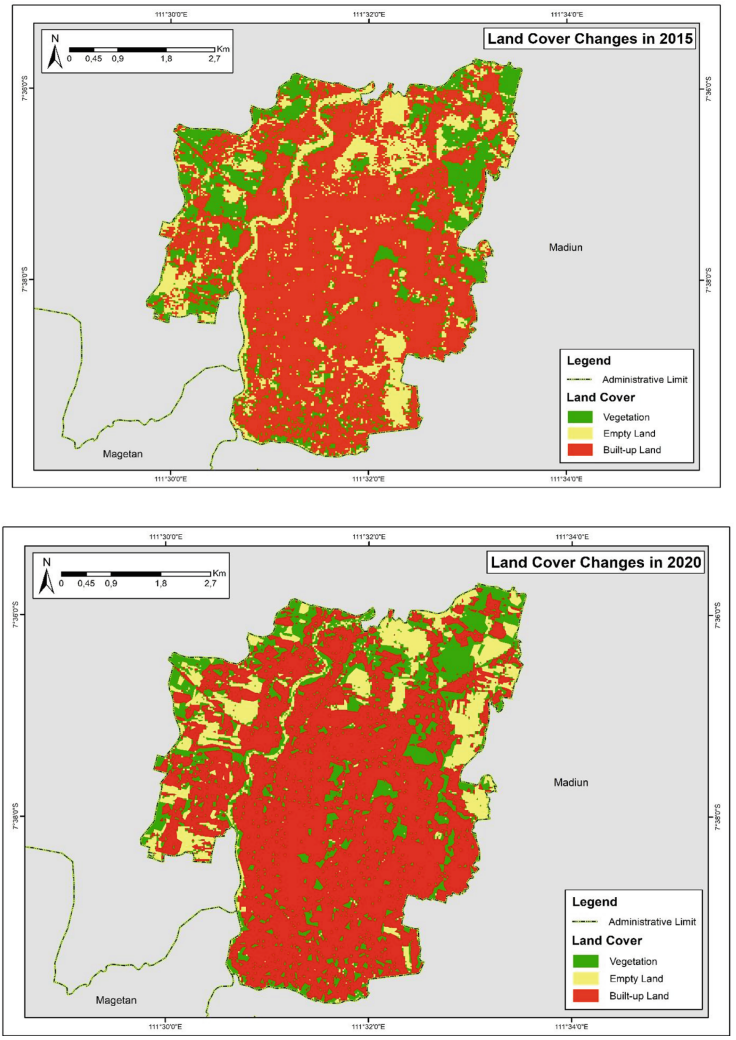

Fig. 3. Map of Land Cover Change

of human activities to improve the quality of life. Not only do human activity factors influence land cover changes, but also the environment, sensors, and recording (Rahman, 2018a).

Very significant land changes can be noticed in built-up land and vegetated land which reduce highly vegetated land in Madiun. Changes in an area are not only precipitated by land convection, such as forests or mixed gardens, however, but they may also occur due to shifting vegetation patterns so that the area is unstable and decreases yearly. The change in land cover in the Madiun area is altered by the increasing number of residents who converted the land from vegetated land into housing purposes (Duka et al., 2020).

3.3 Analysis of Land Surface Temperature Distribution

The results of the Madiun LST extraction were obtained from the results of the NDVI index which observed a level of vegetation density in Madiun by considering the wavelength color of sunlight as observed from the near-infrared reflection results. In 2015, Madiun had the broadest NDVI class on non-vegetation land, which is around 11.79 km^2. Meanwhile, in 2020, the widest NDVI class was on a very low green level, which was around 14.81 km^2. Land cover emissivity values and Thermal channel wavelength values in the image are needed to determine a surface temperature distribution value (Rahman, 2018b). The level of vegetation density on the land surface can be performed by observing the wavelength color of visible sunlight and the results of near-infrared reflection (Zulkarnain, 2016). The following is the NDVI map of Madiun in 2015 and 2020 (Fig. 4).

It can be inferred that on the map of the NDVI or vegetation density index, there has been a change from 2015 to 2020. In 2015, the green value was rather high and extensive there was compared to 2020, in which almost no high green value. Subsequently, it was dominated by low green, very low green, and nonvegetation land. The vegetation density index in Madiun is rather tenuous or does not have a high density. Based on the comparison of the NDVI index map, we can see that the distribution and density of vegetation in Madiun City have decreased every year, which certainly influences the distribution and increase in the distribution of land surface temperature in urban areas. The following is the distribution of land surface temperature in Madiun in 2015 and 2020 (Fig. 5).

The distribution of land surface temperature in Madiun varies in the area for each class. In 2015, the highest temperature was in the 27 °C–30 °C category, which was an area of around 8.30 km^2. In 2020, the highest temperature was in the 24 °C–27 °C class, which was an area of around 9.71 km^2. The lowest temperature only reached coverage of 5.78 km^2 in 2015 and 5.69 km^2 in 2020. It can be inferred from the 2015 and 2020 maps that the dominant colors are yellow, orange, and red, which implies that the surface temperature in Madiun is relatively warmer than the land surface temperature. The following is a graph of the distribution area of land surface temperature in Madiun in 2015 and 2020 (Fig. 6).

The comparison of land surface temperature distribution in 2015 and 2020 is located in the area with the highest land surface temperature distribution, namely built-up land. Between 2015 and 2020, it had a relatively high land surface temperature class rather than a low surface temperature class. This is due to its land cover. There was a decrease and increase in the existing classification. It is affirmed that there was a change in

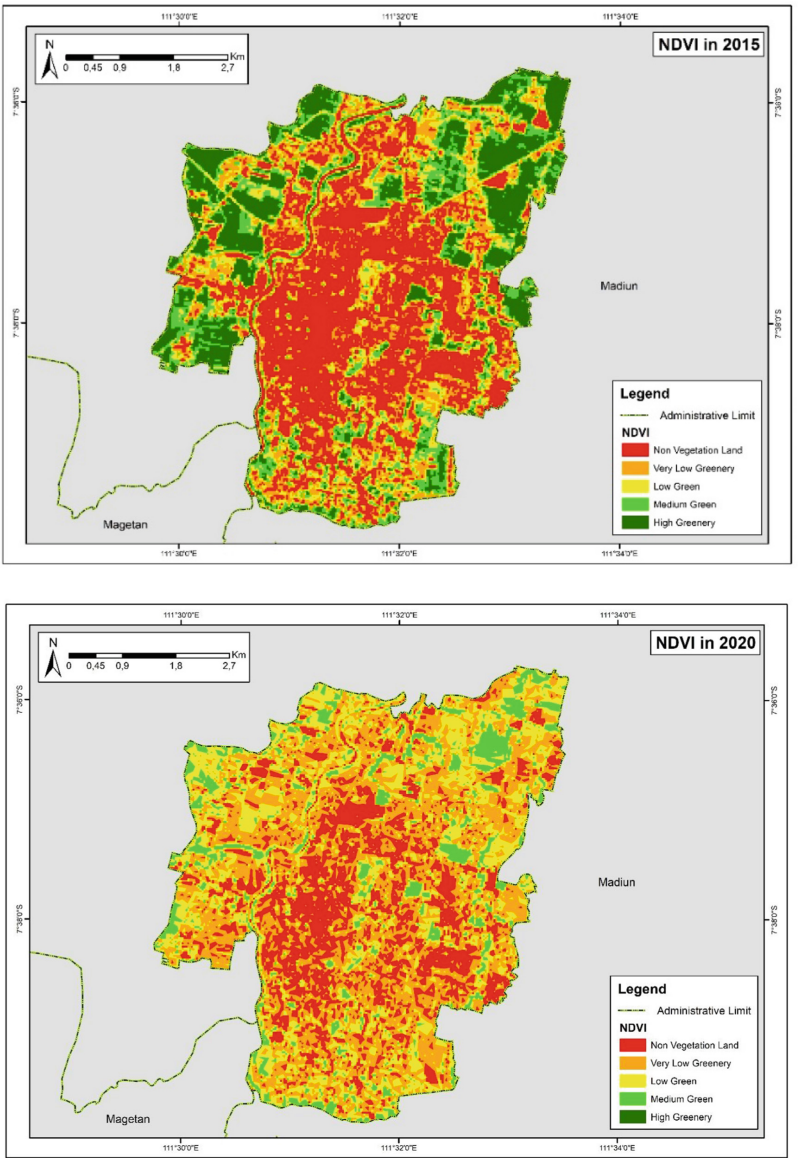

Fig. 4. Vegetation Density Map (NDVI)

land surface temperature. The pattern of distribution and changes in land cover affected land surface temperature in this study with the growth of the built-up area, as well as vacant land with a similar distribution of land surface temperature. Even, it contained an identical effect on the distribution of land surface temperature. Conversely, the effect of vegetation land cover could increase the surface temperature in this study. There was a decrease and increase in the classification results that imply there was a temperature

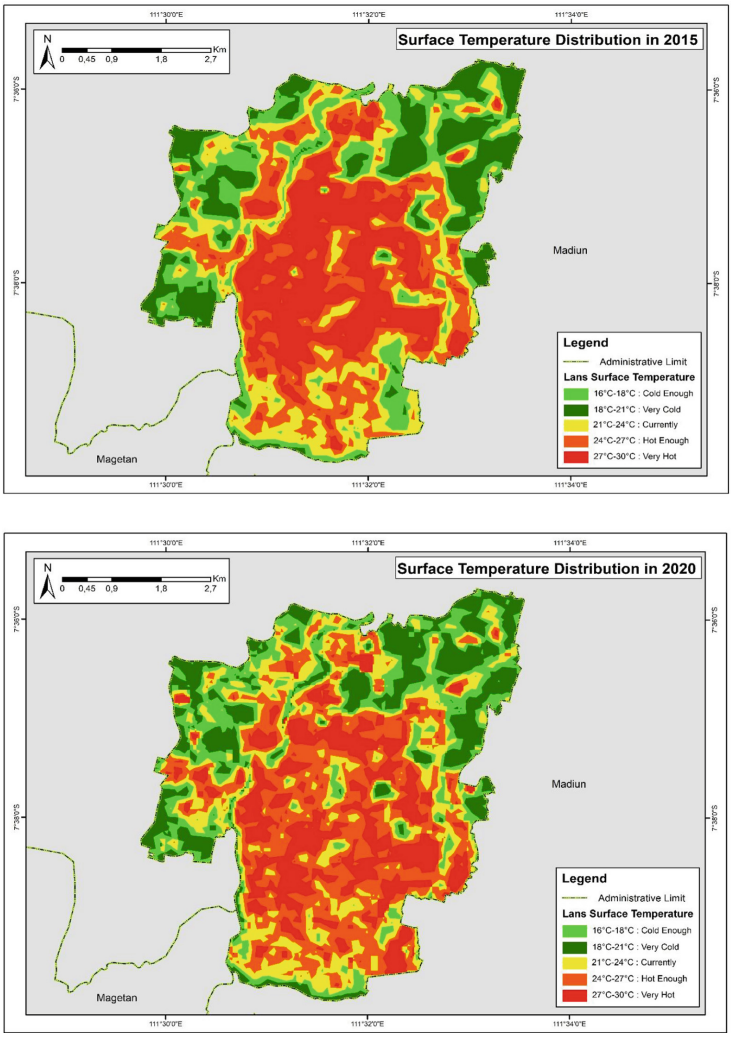

Fig. 5. Map of Land Surface Temperature Distribution

change. The temperature distribution in Madiun in 2015 and 2020 continued to change in line with changes in the land use (Prasasti et al., 2022).

3.4 Analysis of the Relationship Between Changes in Land Cover and LST

Table 4 is a table of land cover classes based on the distribution of land surface temperatures in Madiun in 2015 and 2020.

The 2015 and 2020 land cover classification in Madiun indicates that land change occurred. This change affected the surface temperature distribution in Madiun on the land cover distribution pattern. The land cover area of the relatively dense built-up area had

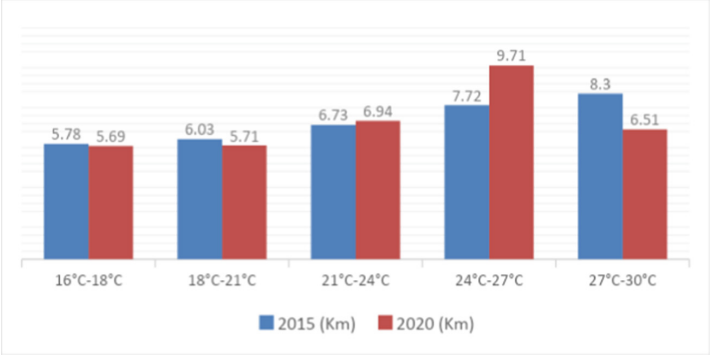

Fig. 6. Graph of Land Surface Temperature Distribution in 2015 and 2020

Table 4. Land Cover Based on Land Surface Temperature Distribution

Land Cover	**Temperature**	**Land Cover Area (km^2)**		**Surface Temperature Area (km^2)**	
		2015	**2020**	**2015**	**2020**
Vegetation	16 °C–21 °C	6.67	7.49	11.81	11.4
Vacant land	21 °C–30 °C	21.9	22.78	10.75	23.16
Built-up land	18 °C–24 °C	6.02	4.31	12.76	12.65

a higher surface temperature. The open land cover had a moderate land surface temperature distribution, and vacant land adjacent to vegetated land areas had a similar surface temperature, namely moderate to cold temperatures. If the vacant land cover is adjacent to the built-up land cover, it is more likely to have moderate to high temperatures. This denotes that each land cover influences the change in land surface temperature distribution or land cover, in which one follows the other. The vegetated land cover appears to have relatively low temperatures. This demonstrates that vegetation can maintain land surface temperature balance while the growth of built-up land triggers an increased surface temperature. Land cover affects the reflectivity of solar radiation in an area, while reflective solar radiation causes fluctuations in temperature values in an area (Sugini, 2014).

Based on the classification results and analysis of land surface temperature distribution in Madiun, the average low surface temperature values are vegetation land cover areas and high land surface temperature values are built-up land cover areas. Vegetated areas have cooler surface temperatures than built-up areas. This is thanks to the contribution of vegetated areas to colder air temperatures, and built-up land areas contribute to air warmer temperatures due to air mixed in the atmosphere (Fawzi & Iswari, 2019). This is modified by the energy from the reflection and the recording of the satellite sensor on built-up land areas, namely settlements compared to other land covers. The results of the analysis between the distribution of land surface temperature and land cover data for

2015 and 2020 suggest that there was a comparison of land surface temperature values for each class of land cover and showed an increase in land surface temperature in both years.

Comparison of the land surface temperature of each class of land cover is influenced by different physical properties on each surface, such as specific heat capacity and thermal conductivity (Adiningsih & Soenarmo, 1998). The land surface receives an equal amount of solar radiation energy. However, different heat capacities make the temperature outcomes also different. If the heat capacity is high, the resulting temperature is low. Meanwhile, the small heat capacity results in high-temperature results (Duka et al., 2020).

4 Conclusions

Urban development is deemed rather influential on changes in land cover. Development growth should adjust to the conditions of limited urban areas and consider environmental problems for the future. Madiun has experienced a significant change in land cover. As a comparison from 2015 to 2020, there has been a change in the area of around 3% to 6%. Changes in the distribution of land surface temperatures in Madiun in 2015 were hotter than in 2020. This is due to the changes in the distribution of land cover. Changes in the distribution of surface temperature essentially follow the pattern of changes in the distribution of land cover in the region. Each land cover influences the change in land surface temperature. Temperatures in vegetated areas tend to be lower or cooler, temperatures in open land areas are relatively moderate, and temperatures in built-up areas appear to be hotter or warmer.

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