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Research article

Spatial Analysis of Temperature Changes in Batu City Due to Land Conversion in 2015-2020

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Abstract.
Batu City has positioned itself as a center for organic agriculture based on international tourism, and, consistent with its vision in the Batu City Regional Spatial Plan for 2010-2030, the city will become a City of Tourism and Agropolitanism in East Java. From 2015 to 2020, Batu City increasingly developed, especially its tourism sector. The increased number of Batu City tourism sites indirectly illustrated changes in land use. The availability of relatively fixed land is not directly proportional to the high demand for land use and the decreasing vegetation cover. This has led to changes in land use and temperature. This research on temperature changes due to land conversion was carried out in Batu City, East Java. The research design employed Landsat 8 OLI/TIRS image processing using land surface temperature, the normalized difference vegetation index (NDVI), and the normalized difference built-up index (NDBI). The results showed a relationship between land conversion and temperature changes in Batu City, where there was a change in the land surface temperature interval in 2015-2020. Temperature changes were caused by conversion of forest into agricultural land and built-up land. Vegetated land areas were also converted, so land with dense and moderately dense vegetation decreased. The dense vegetation decreased from 3,757 hectares to 3,437 hectares, while the moderately dense vegetation decreased from 7,867 hectares to 7,531 hectares. Conversely, the sparsely vegetated land increased from 7,463 hectares to 8,117 hectares.

Keywords: land surface temperature, land conversion, Batu City

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1. Introduction

Batu City designs its area as a center for organic agriculture based on international tourism. The development of Batu City focuses on the tourism and agriculture sectors consistent with its vision in the Batu City Regional Spatial Plan for 2010-2030—the city will become a City of Tourism and Agropolitan in East Java. The new brand image of Batu City as a resort city is increasingly strengthening the tourism development, especially for Tourism Objects and Attractions *(Objek dan Daya Tarik Wisata – ODTW),* to advance the city. Various tourism developments and their supporting facilities have reduced green land, ultimately increasing surface temperature.

The 2010-2030Batu City Regional Spatial Plan divides the regional construction and development into three, namely the City Territory Section (Bagian Wilayah Kota – BWK) I, II, and III. BWK I covers Batu District as the main area for government activities, modern trade, service activities, tourism activities, accommodation supporting services, and secondary education. BWK II covers Junrejo District as the main area for urban settlements, city and region-scale health services, higher education, and the supporting area for government and private offices. BWK III covers Bumiaji District as the main area for agropolitan development, natural and environmental tourism development, and agro-tourism activities.

In 2015-2020, Batu City developed rapidly, especially in the tourism sector. As recorded by the Central Bureau of Statistics of Batu City, Batu's tourist objects had increased from 25 in 2018 to 30 in 2020. This increase reflects land conversion indirectly. Land conversion is influenced by three interconnected things: human, activity, and location [1]. There has been concern about one type of land conversion—conversion from dry fields and apple orchards into built-up land. The Department of Agriculture and Forestry of Batu City confirmed that the agricultural land in Batu City shrunk by 5-10% every year.

However, facts depict that many land uses are not following the Batu City Regional Spatial Plans. In Bumiaji District, areas in Mount Arjuno and Panderman that are supposed to be designated for Forests and Green Open Spaces have become agricultural and residential areas. Additionally, the ratio of green open space per unit area did not meet the Minimum Service Standards (MSS) with only 0.08% compared to the MSS target of 25% according to the Batu City Medium Term Development Plan (Rencana Pembangunan Jangka Menengah Daerah – RPJMD) for 2012-2017. It happens because many green open spaces have been converted into residential areas and other productive lands.

The availability of relatively fixed land is not proportional to the high demand for land use and the decreasing vegetation cover; it leads to land use and temperature changes. The increasingly dense built-up area and lack of open space affect the land surface cover material, causing the increased surface temperature of the area. It is correlated with the increasing land conversion as the built-up land without considering its proportionality to open space. The soil in built-up land tends to absorb and retain heat, further encouraging temperature changes.

2. Method

2.1. Study Site and Methods

This research was conducted in Batu City, East Java, using Landsat 8 OLI/ TIRS image processing with Land Surface Temperature (LST), Normalized Difference Vegetation Index (NDVI), and Normalized Difference Built-up Index (NDBI) methods. The city was selected because of its significant changes in land use with the moor soil type and rice fields in the last five years (The Department of Agriculture and Forestry, Strategic Plans of Batu City for 2017-2022). This research had two variables: the independent variable (land conversion) and the dependent variable (temperature changes).

Table 1: Total Area (Ha) of Batu City's Land Use from 2015 to 2019.

No.	Land Use	2015	2016	2017	2018	2019
A.	**Protected Forest Area**					
1.	Protected Forest	2945	2943	2943	2943	2935
2.	Conservation Forest	-	-	-	-	-
B.	**Cultivation Area**					
1.	Production Forest Area	3550	3550	3535	3535	3520
2.	Community Forest Area	-	-	-	-	-
3.	Agricultural Area					
	1) Wetland Agriculture	2350	2350	2215	2215	2060
	2) Dryland Agriculture	5725	5710	5680	5680	5540
4.	Plantation Area	3295	3295	3205	3205	3112
5.	Industrial Area	78	78	91	91	95
6.	Residential Area	1632	1649	1907	1907	2314

Source: Central Bureau of Statistics [2]

The secondary data used were the satellite image data of Landsat 8 Operational Land Imager and Thermal Infrared Sensor (OLI/TIRS) of the 2015 and 2020 and Batu City shapefile further processed through ArcGIS software. Landsat 8 OLI/TIRS satellite image data were downloaded through the United States Geological Survey (USGS) website with archival data on paths 118 and row 65. The secondary data for Landsat 8 OLI/TIRS satellite image with a data span of five years (2015-2020) were selected due to the significant development during the last five years that has increased land conversion.

According to the Department of Agriculture and Forestry of Batu City, agricultural land in the city shrinks by 5-10% every year. The rapid development of the service and tourism industries in Batu City has significantly increased land conversion (The Department of Agriculture and Forestry, Strategic Plans of Batu City for 2017-2022). The temperature change index, vegetation density, and built-up land can be identified based on the Landsat 8 OLI/TIRS satellite image specification. The surface temperature distribution or LST can be determined using thermal channels in band 10 and band 11.

TABLE 2: Specification of Landsat 8 OLI/TIRS Satellite Image.

Band Numer	**Wave Length (μm)**	**Resolution**
Band 1 (Ultra Blue)	0.43 – 0.45	30
Band 2 (Blue)	0.45 – 0.51	30
Band 3 (Green)	0.53 – 0.59	30
Band 4 (Red)	0.64 – 0.67	30
Band 5 (Near Infrared)	0.85 – 0.88	30
Band 6 (Shortwave Infrared 1)	1.57 – 1.65	30
Band 7 (Shortwave Infrared 2)	2.11 – 2.29	30
Band 8 (Panchromatic)	0.50 – 0.68	15
Band 9 (Cirrus)	1.36 – 1.38	30
Band 10 (Thermal Infrared 1)	10.60 – 11.19	30
Band 11 (Thermal Infrared 2)	11.50 – 12.51	30

Source: U.S. Geological Survey (USGS)

2.2. Data Processing and Analysis

The data in this research were analyzed using a spatial descriptive analysis method. The method explained the spatial distribution of land cover and surface temperature extraction results from Normalized Difference Vegetation Index (NDVI), Top of Atmosphere (ToA), Brightness Temperature, Land Surface Temperature (LST), and Normalized Difference Built-Up Index (NDBI).

1. *Land Surface Temperature (LST)*

The distribution of Land Surface Temperature (LST) is identified using band 10 and band 11. The LST calculation begins with converting the pixel value in the Digital Number (DN) to the ToA Spectral Radiance (SR) value, followed by calculating the ToA Brightness Temperature. Mathematically, the conversion of SR and the calculation of ToA Brightness Temperature can be seen in the following equations, respectively:

$$L\lambda = ML \times Qcal + AL \text{ ....}(1)$$

$$T = \frac{K2}{ln(\frac{K1}{L\lambda} + 1)} \text{ ....}(2)$$

Where:

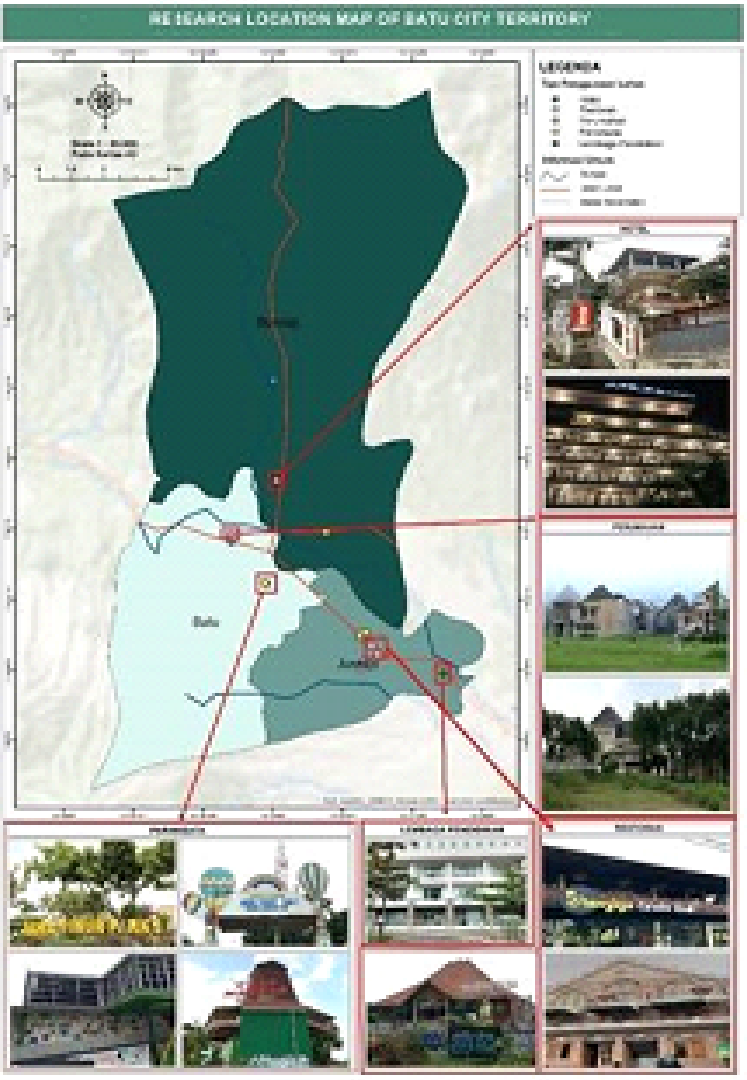

Figure 1: Map of the Study Site Source: Author (2021).

Lλ = ToA spectral radiance (W/(m2 * sr * μm))

M_L = Band-specific multiplicative rescaling factor from the metadata

Qcal = Quantized and calibrated standard product pixel values (DN)

A_L = Band-specific additive rescaling factor from the metadata

T = ToA brightness temperature (K)

K2 = Band specific thermal conversion constant from the metadata [2]

K1 = Band specific thermal conversion constant from the metadata [1]

The LST calculation uses the land surface temperature algorithm with a conversion factor to Celcius (Sobrino et al., 2004).

$$LST = \frac{T}{1+(w*Tp)\times ln(e)} - 273,15 \qquad (3)$$

Where:

LST = Land Surface Temperature (°C),

w = Wavelength of emitted radiance (11.5 μm)

p = h * c / σ (1,438 * 10-2 mK)

h = Planck's constant (6.626 *10-34 Js),

c = Light speed (2.998 * 10^8 m/s) and

σ = Boltzmann constant (1.38 * 10^{-23} J/K)).

e = Land surface emissivity of 0.937 [3]

1. *Normalized Difference Vegetation Index (NDVI)*

NDVI values range from -1 to 1. The greater the NDVI value, the higher the vegetation density level. The NDVI calculation begins with converting the DN value to the reflectance value or radiometric correction to obtain the emission or wave reflectance value used for the NDVI calculation. The NDVI conversion and calculation can be seen in the following equations.

$$\rho\lambda' = M\rho * Qcal + Ap \text{..................}(4)$$

$$NDVI = \frac{pNIR - pRED}{pNIR + pRed} \text{..............................}(5)$$

Where:

ρλ' = ToA Planetary Spectral Reflectance

Mρ = Band-specific multiplicative scaling factor from the metadata

Aρ = Band-specific additive scaling factor from the metadata

pNIR = NIR Near-Infrared band reflectance

pRED = RED band reflectance

2.2.1. Normalized Difference Built-up Index (NDBI)

The built-up land index can be detected using the Normalized Difference Built-up Index (NDBI) algorithm, which is very sensitive to built-up land and open land. The NDBI algorithm was chosen because this formula is the most widely used in assessing the built-up land index [4]. The NDBI calculation begins with converting the DN value to the reflectance value, followed by calculating the built-up area index using the given below equations.

$$\rho\lambda' = M\rho * Qcal + A\rho \text{.................}(6)$$

$$NDBI = \frac{pSWIR - pNIR}{pSWIR + pNIR} \qquad (7)$$

Where:

SWIR = Shortwave infrared band reflectance

NIR = Near-infrared band reflectance

3. Results and Discussion

3.1. Analysis of Land Surface Temperature (LST)

Land Surface Temperature (LST) is controlled by surface energy balance, atmospheric state, and surface and subsurface thermal properties. LST processing is carried out using the Landsat 8 OLI/TIRS satellite image data of Batu City in 2015 and 2020 captured on the thermal band. The heat emission of the land surface was captured by satellite image sensors in the infrared thermal spectrum range of band 10 and band 11, which can be used to identify the distribution of Land Surface Temperature (LST). The data of Batu City's Landsat 8 OLI/TIRS in 2015 processed into LST were then classified into five numerical interval values with the lowest interval at 9-15 and the highest interval at 25-33. Based on 2015 LST data results, the highest interval range visualized in red color forms a clustered or concentrated pattern at a higher temperature than the surrounding area.

LST with the highest interval values centrally clustered in Batu District, most of Junrejo District, and some areas of Bumiaji District. Meanwhile, the lowest interval values visualized in green were primarily found in the northern part of Bumiaji District, with highland typography showing a lower temperature distribution. Furthermore, the data of Batu City's Landsat 8 OLI/TIRS in 2020 processed into LST were classified into five numerical interval values, with the lowest interval at 12-17 and the highest interval at 25-32. Visually, Batu City's LST data in 2015 and 2020 did not significantly change, except for the change in surface temperature distribution at several regional locations. The highest interval range visualized in red is centrally clustered in Batu District, most of Junrejo District, and a small part of Bumiaji District. Visually, the northern part of Bumiaji District in 2015 had higher intervals than in 2020.

Based on the 2015 and 2020 data processing results, the highest LST distribution was found in Junrejo District despite spreading out due to the absence of LST distribution with the lowest interval in the area. Junrejo district is the smallest area in Batu City, with an area of 2,565.02 hectares. However, rice field conversion can very likely occur in Junrejo District; the development of the tourism sector is accelerating the rice field conversion in this district. 16 hectares of rice field had been converted into an amusement park (Jatim Park 3) in 2016 in Beiji Village, Junrejo District. It was exacerbated by the construction of Campus 3 UIN Malang, covering 100 hectares in Tlekung Village, Junrejo District [5].

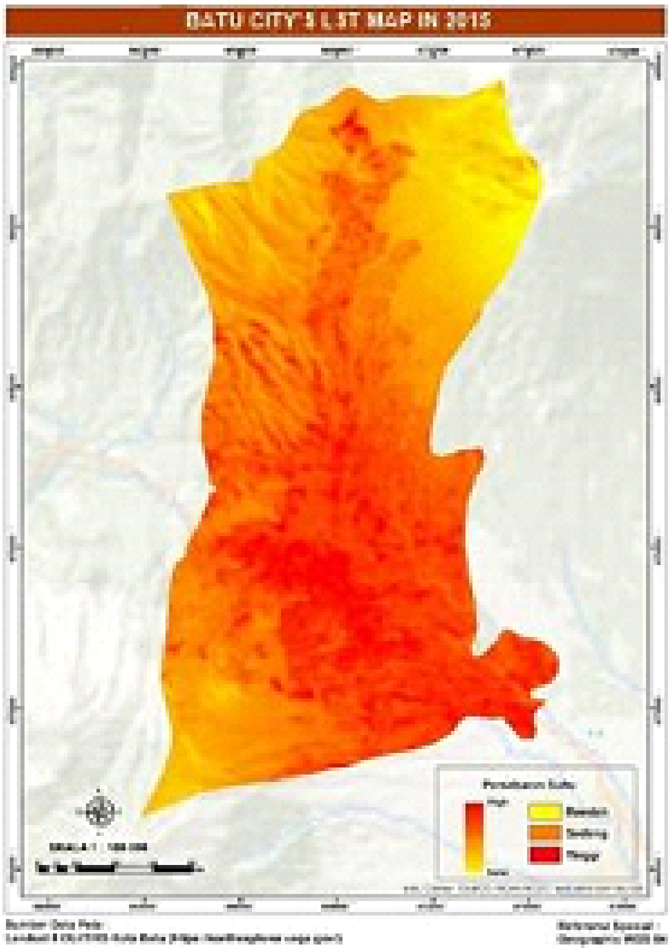

Figure 2: Batu City's LST Map in 2015. Source : Author (2021).

Batu District also showed the highest LST, following Junrejo District. Batu District is the center of the city with the densest population. This fact is inversely proportional to the availability of existing land and the high number of built-up land since most of the tourism and supporting facilities, such as hotels, homestays, and restaurants, are located in the district. Meanwhile, in Bumiaji District, the highest LST was only slightly identified in the southern region. The lowest LST in Bumiaji District was dominantly found in the northern part. The low LST in the north and southwest of Batu City correlated with the condition of the area, which is mostly forests. The LST becomes one of the significant factors influencing changes in air temperature. In other words, the increased surface temperature correlates with and becomes part of changes in air temperature.

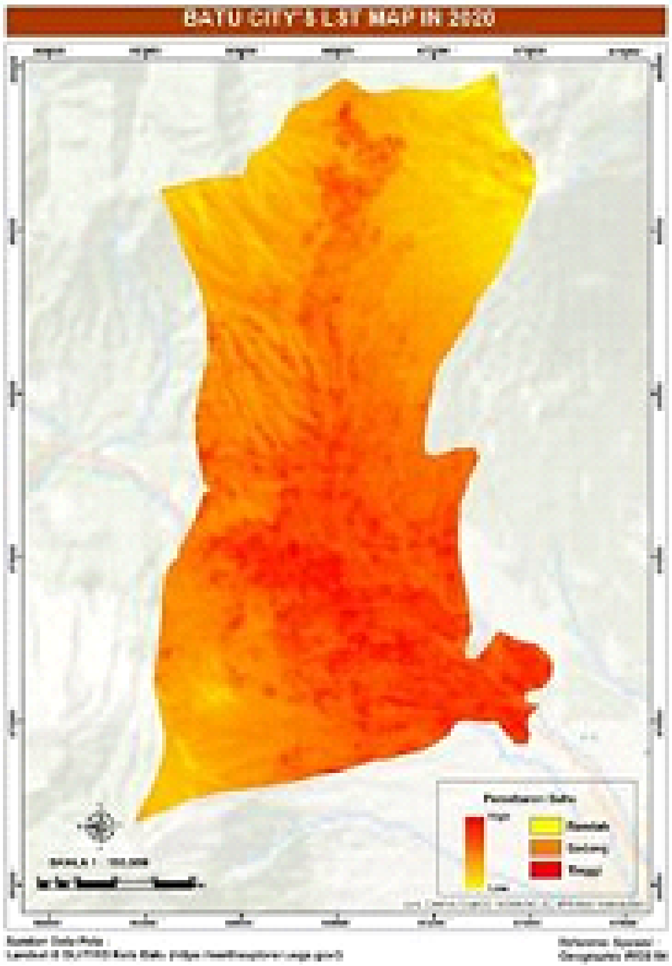

Figure 3: Batu City's LST Map in 2020. Source : Author (2021) .

3.2. Analysis of Normalized Difference Vegetation Index (NDVI)

Normalized Difference Vegetation Index (NDVI) represents the greenery or photosynthetic activity of vegetation. NDVI is based on the observation that different surfaces reflect different types of light waves. This research used data taken from Landsat 8 OLI/TIRS satellite images in 2015 and 2020. The results of the NDVI data processing depict Batu City's vegetation density in maps in Figures 4 and 5.

The maps below show that most Batu City areas are still densely vegetated, but most of the land in the northern part of Batu District has shallow vegetation. Similarly, most of the Junrejo District area also has shallow vegetation. However, if compared to 2020, the vegetation density in Batu City has slightly changed. As shown in the map, several areas have experienced a decrease in vegetation density, such as Bumiaji District. The vegetation in Bumiaji District has significantly decreased due to the forest conversion into agricultural areas.

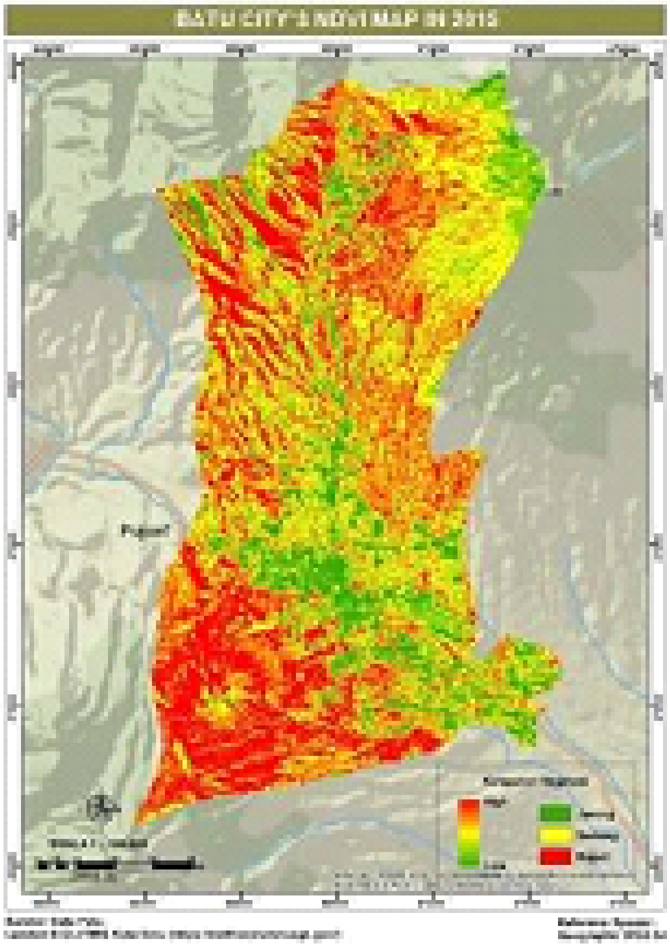

Figure 4: Batu City's NDVI Map in 2015. Source : Author(2021).

The vegetation density in Junrejo and Batu Districts in 2020 has significantly decreased compared to 2015. It happens due to the increasing land conversion into residential areas in Junrejo District, and residential and tourist sites in Batu District, considering that Batu District is the center of government and economic activities in Batu City. In general, the vegetation in Batu City has changed a lot. As seen in the figures above, the areas with moderately dense vegetation are expanding, and dense vegetation areas are narrowing.

The figure above showed a decrease in land with dense vegetation and moderately dense vegetation. The land with dense vegetation decreased from 3,757 hectares to 3,437 hectares, while that with moderately dense vegetation decreased from 7,867 hectares to 7,531 hectares. Differently, the sparsely vegetated land area increased from 7,463 hectares to 8,117 hectares. Batu City's land conversion may be caused by the growing density and the development of facilities and infrastructure [6]. Batu City's density maps in 2015 and 2020 showed that the areas with no vegetation and low vegetation appear to be expanding in Batu and Junrejo District.

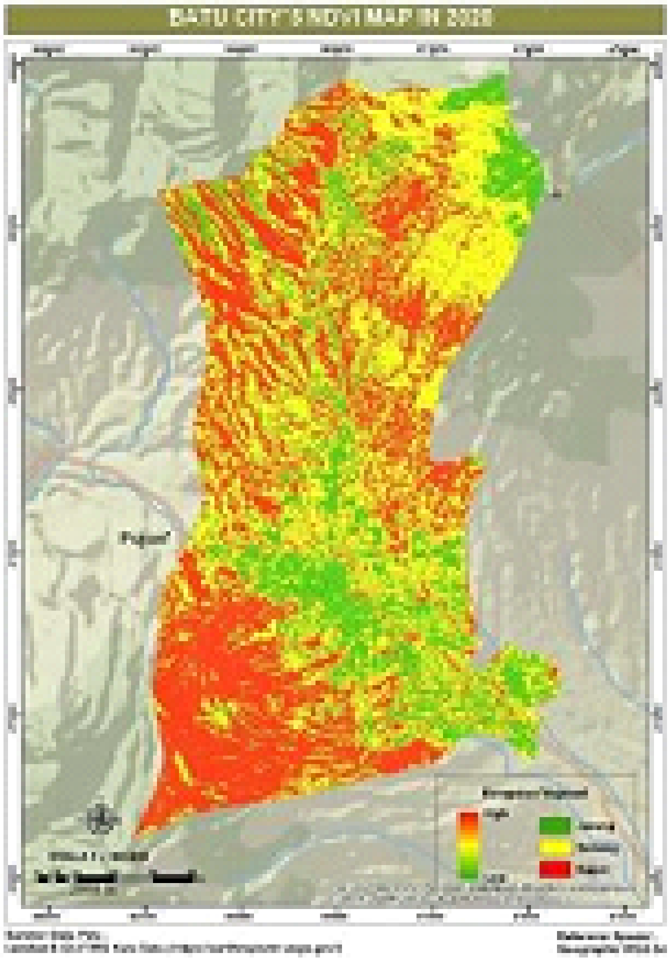

Figure 5: Batu City's NDVI Map in 2020. Source : Author (2021).

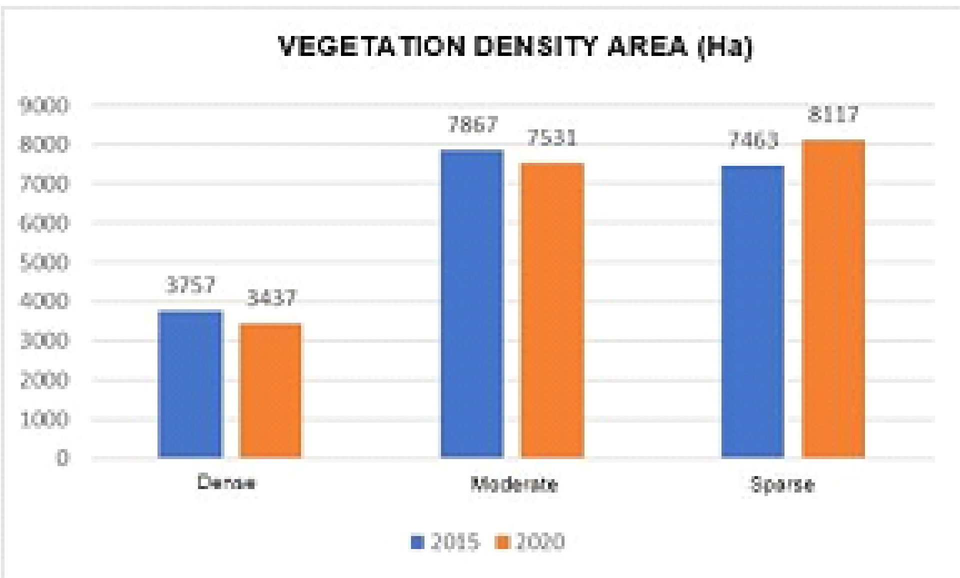

Figure 6: Graph of Batu City Vegetation Density Area in 2015 and 2020. Source: Author (2021)

3.3. Analysis of Normalized Difference Built-Up Index (NDBI)

Normalized Difference Built-up Index (NBDI) is a parameter used to identify the condition of built-up land in an area. The NBDI method uses the same data as LST and NDVI. NBDI is an algorithm showing the density of built-up land [7]. In the Landsat 8 data processing, the SWIR uses band 6, and the NIR uses band 5. The results of the data processing can be depicted in the following maps.

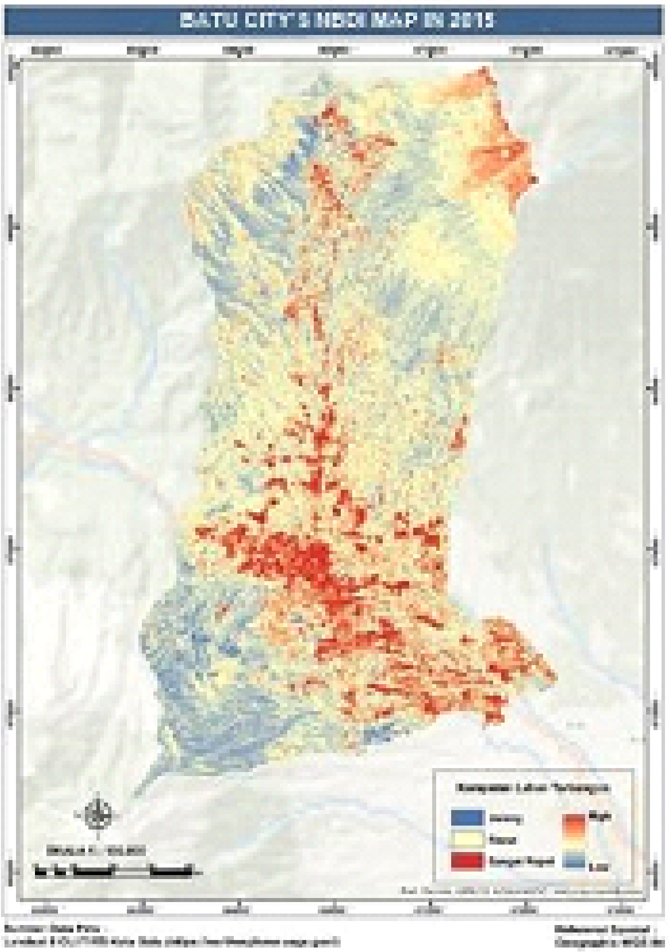

Figure 7: Batu City's NBDI Map in 2015. Source : Author (2021).

The two maps indicate that the density of buildings in Batu City centralizes in the middle of the region, mainly in Batu District. Batu District is the center of government and economic activities in Batu City, where various developments are carried out, such as constructing various public facilities and settlements for the residents. The strategic area is also one of the factors attracting the people to choose to settle there. Furthermore, most of the southeastern region of Batu City, namely Junrejo District, has a high building density. As shown in the map, almost all parts of Junrejo District have a fairly dense

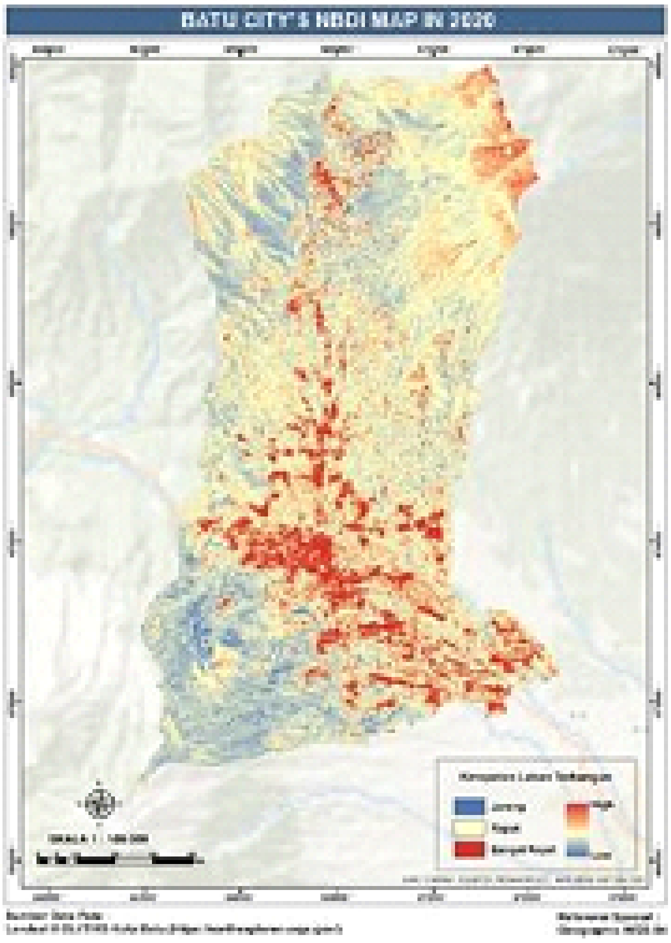

Figure 8: Batu City's NBDI Map in 2020. Source : Author (2021).

development. Junrejo District has its unique charm, attracting business people to make various investments in tourism and lodging sectors, such as hotels and villas.

Table 3: Batu City's Population in 2015-2020.

District	Year					
	2015	**2016**	**2017**	**2018**	**2019**	**2020**
Batu	86,401	94,132	94,966	95,852	96,699	96,921
Junrejo	49,985	50,079	50,617	51,186	51,734	55,105
Bumiaji	52,895	58,108	58,414	58,750	59,057	61,020
Batu City	**189,281**	**202,319**	**203,997**	**205,788**	**207,490**	**213,046**

Source: Central Bureau of Statistics [2]

The high population is also affecting the increase in built-up land in Batu City. As an example, Junrejo District had a total population of 55,105 people in 2020. This number is not proportional to the area, which is only 25.65 km2 or 12.88% of the total area of Batu City. It means that the population density of Junrejo District in 2020 reached

2,155 people/km2, higher than Batu and Bumiaji Districts. The continuously growing population of Batu City automatically also increases the need for settlement land.

The higher the population in an area, the higher the need for land, both for settlements and business places. The construction of villas, homestays, and tourist attractions in Junrejo District shows that the population has caused many developments in the district. Thus, the high population density and the vast developments to support various sectors, both the economic and tourism sectors in Junrejo District, lead to a high index of the evenly built-up area throughout its territory.

4. Conclusions

Based on the discussion above, it can be concluded that land conversion affects temperature changes in Batu City, proven by the difference in the Land Surface Temperature (LST) interval in Batu City in 2015 and 2020. Temperature changes are caused by forest conversion into agricultural land and built-up land and agricultural land conversion into non-agricultural land (built-up land). The attractiveness of Batu City as a resort city also affects the occurrence of land conversion in the region because the increasing need for land encourages forest conversion into tourist attractions, homestays, hotels, and so on. The demand for land continuously increases from year to year because the growing population encourages an increase in built-up land in Batu City, ultimately raising the temperature in Batu City from 2015 to 2020.

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