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# Analysis of the Impact of Residential Land Development on LST in Semarang City

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**Abstract.** All activities, including the economy, government, and other supporting activities, are centered on urban areas. Human activities have both positive and harmful impacts on the urban itself. One of the impacts is the development of built-up land, which will impact temperature changes. Within eight years, 500 ha of irregular settlements have emerged. This research, therefore, aims to analyze the level of built-up land (NDBI), vegetation density (NDVI), and surface temperature level (LST), which then built-up land and vegetation density to LST would be correlated. The method used in this study was descriptive, describing vegetation density, built-up area, and surface temperature, as well as the correlation between built-up area and vegetation density on LST, conducted descriptively. The findings revealed that while built-up land was directly proportional to changes in LST, vegetation density had an inverse relationship with those changes. In other words, the higher the available vegetation density, the lower the surface temperature. Indirectly, vegetation density has numerous benefits, one of which can affect temperature, especially in urban areas. Additionally, the relationship in built-up land was directly proportional to LST, where the higher the built-up area, the higher the LST. In this situation, many built-up areas use materials to store heat and cover the ground surface, especially in urban areas.

**Keywords:** Anthropogenic activity · NDBI · NDVI · LST

## 1 Introduction

The urban area serves as the center or core of many human activities. However, human activities ultimately indicate a demand for more land, reducing the area covered by vegetation now (Zhang et al., 2010). Increased infrastructure development and other activities in urban areas can also lead to urban development in various socio-economic activities. Nevertheless, rapid development, particularly in urban areas, has negative impacts, including deteriorating environmental quality and rising temperatures due to many uncontrolled urban activities, which raise the temperature in urban areas and their surroundings (Kurniati & Nitivattananon, 2015). In terms of urban development, it can be seen from the increase in population density, increasingly dense layers of buildings,

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and population growth, particularly the construction of higher settlements and complete infrastructure. Urban also offers supporting facilities for urban socio-economic activities. Efficiency gains can be achieved with compaction events in urban areas; although there is a correlation between the impact of high-temperature events in urban areas and greater compaction, it should be noted that the city is covered in urban heat-absorbing materials, making it warmer than the interior (Sharifi & Lehmann, 2015).

Contrarily, development is a form of economic activity that generates goods and services related to buildings used as places for other activities (Haryanto et al., 2019). Urbanization, transportation, industry, and housing are the main activities that may be related to surface temperature (LST). Additionally, anthropogenic activity is anticipated to increase LST, while a decrease in anthropogenic activity may decrease surface temperature (Hadibasyir et al., 2020). Furthermore, as more people live in and around urban areas, there will be greater demand for built-up areas. This situation affects surface temperature and land availability for the construction of settlements and other infrastructure in urban areas (Fikriyah et al., 2022). In this sense, current research on international relations goes beyond the state's role to include individuals' influence on the global society.

Environmental concerns are one of them; they require both domestic and international attention from the international community. Furthermore, since each nation is accountable for environmental protection, environmental issues should not be centered on mapping developed or developing countries (Herfana & Rijal, 2022). Specifically, Semarang City is the capital city of Central Java, in particular having an essential role in terms of accessibility, such as sea, land, and air transportation networks, as well as airports, which are potential transportation links in the Central Java regions. Semarang City can be categorized into a large city group with various functions and roles, namely as a point of government, trade, services, education, industry, and a transit city for transportation and tourist transit. Due to the attractiveness of urban areas, land has changed from being green to being built-up, and land development in urban areas, particularly in Semarang City, is also happening very quickly. Table 1 displays changes to residential land in the city.

Based on Table 1, there was a change in residential land of more than 400 ha in arranged settlements, while there was a change in the land of more than 500 ha in unarranged settlements. Here, land use results from all forms of human intervention or activity, from simple to technological. Moreover, using natural resources aims to meet needs, both materially and spiritually, or both. Since almost all human activities are related to land use, with human activity increasing rapidly, land as a resource is becoming scarce. Furthermore, decisions to change land use patterns can provide significant advantages and disadvantages from an economic and environmental perspective (Nuraeni et al., 2017). Particularly, the livelihoods of Semarang City residents are remarkably diverse, consisting of traders, government employees, factory workers, and farmers. Aside from being a trading city, Semarang City is a tourism service city. Therefore, Semarang City will continue to grow by providing facilities and improving infrastructure to support development.

Furthermore, the availability of remote sensing technology is an object research activity in areas that are not in direct contact with the object. This definition is an ideal

**Table 1.** Land use change (Rahmah et al., 2019)

| Land Use | 2010 | 2014 | 2018 |
|---|---|---|---|
| Airport | 189.99 | 207.82 | 254.54 |
| Forest | 2372.50 | 2147.34 | 2072.92 |
| Industry | 1676.85 | 1830.26 | 1991.27 |
| Service | 609.66 | 699.34 | 759.43 |
| Grave | 119.81 | 119.81 | 119.81 |
| Empty land | 620.53 | 2989.21 | 2972.27 |
| Harbor | 310.17 | 310.22 | 310.22 |
| Office and trade | 485.44 | 490.99 | 508.71 |
| Plantation | 8439.00 | 5685.79 | 5545.70 |
| Arranged settlement | 2144.94 | 2349.02 | 2587.05 |
| Unarranged settlement | 14578.43 | 14883.04 | 15117.03 |
| Rice field | 4250.05 | 4423.31 | 4106.53 |
| Station | 19.54 | 19.40 | 19.40 |
| Pond | 3275.41 | 2936.69 | 2736.25 |
| Total | 39092.23 | 39092.23 | 39092.23 |

definition of observation activities in a certain area. In fact, field data is always needed to validate data obtained from remote sensing but can control a wide range in a relatively brief time (Hadibasyir et al., 2012). In this case, Semarang City is a metropolitan city, the capital city of Central Java Province, which has adequate facilities, such as ports, education, health, shopping, business districts, and others. There, the increasingly rapid conversion of non-built-up land to built-up land because of increased development in Semarang City will trigger an increase in surface temperature warming. By utilizing remote sensing technology in the form of Landsat 8 OLI/TIRS imagery on the recording date of June 25, 2019, this research was conducted to analyze the level of built-up land, vegetation density, and surface temperature level, and the relationship between vegetation density (NDVI) on surface temperature (LST) and built-up land (NDBI) on surface temperature (LST) in Semarang City.

## 2 Method

### 2.1 Research Location

Figure 1 depicts the research location in Semarang City, the capital of Central Java. It is strategically located on the economical transportation route of Java Island and is located between 6°50′ to 7°10′ South Latitude and between 109°35′ to 110°50′ East Latitude. Administratively, Semarang City consists of 16 sub-districts and 177 villages, and the total area of Semarang City is 373.70 $km^2$ or 37,366.836 Ha.

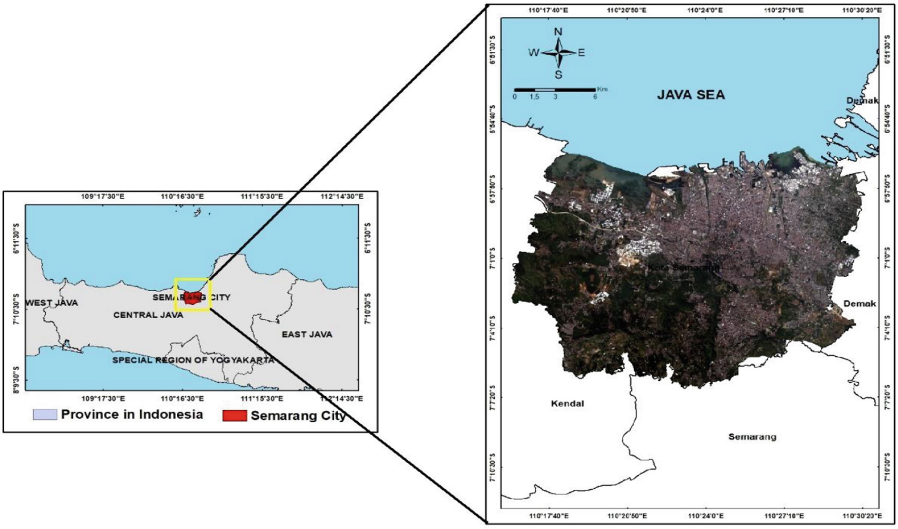


**Fig. 1.** Map of research location

Semarang City is bordered by the Java Sea to the north, Demak Regency to the east, Kendal Regency to the west, and Semarang Regency to the south. Its strategic location has triggered Semarang City to become the foundation for increasing the development of Central Java.

## 2.2 Tools and Materials

(a) Research Tools; One laptop device consisting of software for data entry, data processing, and data output (Envi 5.3, Microsoft Excel, and Arcgis 10.3). (b) Research Materials; Landsat imagery 8 OLI/TIRS path 120, row 64, on the recording date of June 25,2019. Data on Shapefile of Semarang City Administrative Boundary and Shapefile of Indonesian Province Administrative Boundary.

## 2.3 Research Data

The research used secondary data to obtain Landsat 8 OLI/TIRS satellite imagery through www.earthexplorer.usgs.gov, with acquisitions on June 25, 2019, in Semarang City. In addition, the fishnet technique was employed as a sampling point for image transformation, built-up area (NDBI), and vegetation density (NDVI) on surface temperature (LST) in Semarang City.

## 2.4 Research Object

Built-up land (NDBI), vegetation density (NDVI), and surface temperature (LST) in Semarang City served as the study's research objects. In this study, sampling was carried out by purposive sampling using the criteria of built-up land, vegetation density, and

**Table 2.** Interpretation of the correlation coefficient (Sugiyono, 2012)

| | |
|---|---|
| 0.00–0.199 | Very low |
| 0.20–0.399 | Low |
| 0.40–0.599 | Medium |
| 0.60–0.799 | Strong |
| 0.80–1.000 | Very strong |

**Table 3.** Coefficient of determination or R-Square (Chin, 1998)

| | |
|---|---|
| 0.19 | Weak |
| 0.33 | Medium |
| 0.67 | Strong |

surface temperature. The Central Limit Theorem, stating that a sample size of at least 30 samples is required to produce a standard curve, was employed to determine the sample size for this research. Since the number of objects for this study was unknown, the Central Limit Theorem was used to calculate the sample size. Therefore, in this study, a minimum of 30 samples was determined to obtain a normal curve.

### 2.5 Correlation Coefficient and Coefficient of Determination

The strength of the relationship between the independent variable (X) and the dependent variable is shown by the correlation coefficient (R) (Y). R-values vary from 0 to 1, with closer values of 1 indicating a greater relationship between the variables and closer values of 0 denoting a weaker relationship. Tables 2 and 3 contain guidelines for interpreting the correlation coefficient, according to (Sugiyono, 2012).

### 2.6 Image Transformation

**Vegetation Density Index (NDVI)**

Vegetation density (NDVI) was known by calculating data from near-infrared calculations using red, representing the greenness of the plants that underlie the local vegetation calcification. The NDVI value was calculated as the reflectance ratio of the red (R) band and the infrared (NIR) band. NDVI values range from -1 to 1 (Danoedoro, 2012). Then, further processing was carried out until the last stage, i.e., the vegetation density index, with the equation and classification of vegetation density values as seen in Table 4.

$$\mathrm{NDVI} = \left(\frac{NIR - RED}{NIR + RED}\right) \tag{1}$$

Description:

NDVI = Normalized Difference Vegetation Index

**Table 4.** Vegetation density classification (NDVI) (Sunaryo & Iqmi, 2015)

| Classification | Vegetation Density Level |
|---|---|
| Cloud and Water | -2.00–0.00 |
| Non-Vegetation | 0.00–0.21 |
| Un Tight | 0.21–0.42 |
| Tight Enough | 0.42–0.63 |
| Tight | 0.63–0.85 |

NIR = Near Infrared Band
RED = Red Band

Furthermore, the Pv value can be estimated using the previously obtained NDVI value; the NDVImin value is the NDVI value of vacant land (0.2); NDVImax is the NDVI value of an area with full vegetation capacity (0.5), with the following formula.

$$\mathrm{Pv} = \left(\frac{NDVI - NDVImin}{NDVImax + NDVImin}\right) \tag{2}$$

Description:

Pv = Proportion of vegetation
NDVI = NDVI previously obtained
NDVImin = NDVI value for vacant land (0.2)
NDVImax = NDVI value for full vegetation (0.5)

Then, the Emissivity Extraction value can be estimated using the Pv value obtained previously with the following formula (Sobrino et al., 2004).

$$\epsilon\mathrm{TM6} = 0.004\ \mathrm{Pv} + 0.986 \tag{3}$$

**Land Surface Temperature (LST)**

Land Surface Temperature was calculated using the Land Surface Temperature (LST) algorithm (Subiyanto & Amarrohman, 2018 in Fadlin et al., 2020). LST extraction was carried out using the formula (Deilami et al., 2016). Ts is LST (K); Tb is BT (K); λ is the wavelength of emitted radiance; α is 14388 µmK; ε is the surface emissivity.

$$\mathrm{Ts} = \left(\frac{Tb}{1 + [\lambda x Tb/\alpha) In\varepsilon]}\right) \tag{4}$$

Description:

Ts = Land Surface Temperature (Kelvin)
Tb = Brightness Temperature (Kelvin)
λ = The Wavelength of Emitted Radiance (10.8 µm)
$\alpha$ = 1.4388 µmK

**Table 5.** Classification of surface temperature value (LST)

| Range (°C) | Classification |
|---|---|
| 19.26–23.05 | Very Low |
| 23.05–26.84 | Low |
| 26.84–30.63 | Medium |
| 30.63–34.42 | High |
| 34.42–38.21 | Very High |

$\varepsilon$ = Surface Emissivity

To obtain the temperature value in Celsius units, the LST conversion process from Kelvin to Celsius could be carried out using an equation (Avdan & Jovanovska, 2016). The surface temperature class was determined based on the range of values in Table 5.

$$T2 = T - 273.15 \tag{5}$$

Description:

T = Temperature (Kelvin)
T2 = Temperature (Celsius)

**Normalized Difference Built-up Index (NDBI)**
Normalized Difference Built-up Index or built-up area is an algorithm to report or prove the density of built-up land. This algorithm is most commonly used to evaluate the index of built-up land by mass (Bashit et al., 2020). Meanwhile, determining the classification of built-up land (NDBI) can be seen in Table 6.

$$\text{NDBI} = \frac{(SWIR - NIR)}{(SWIR + NIR)} \tag{6}$$

Description:

SWIR = Short Wave Infrared
NIR = Near Infrared

# 3 Results and Discussion

## 3.1 Image Results of Vegetation Density, Built-Up Land, and LST

The results of image transformation of built-up land (NDBI), vegetation density (NDVI), and surface temperature (LST) processing utilizing Landsat 8 OLI/TIRS imagery can be seen in Fig. 2, Fig. 3, and Fig. 4.

Two classifications were generated based on the built-up land map in Fig. 2. Among them is the classification of non-built-up land, characterized by a pink color, while dark

**Table 6.** Built-up land value classification (NDBI) (Bashit et al., 2020)

| Number | NDBI | Classification |
|---|---|---|
| 1 | -1 s/d 0 | Non-Building |
| 2 | 0 s/d 0.1 | Sparse Built-up |
| 3 | 0.1 s/d 0.2 | Danse Built-up Area |
| 4 | 0.2 s/d 0.3 | Very Dense Building |

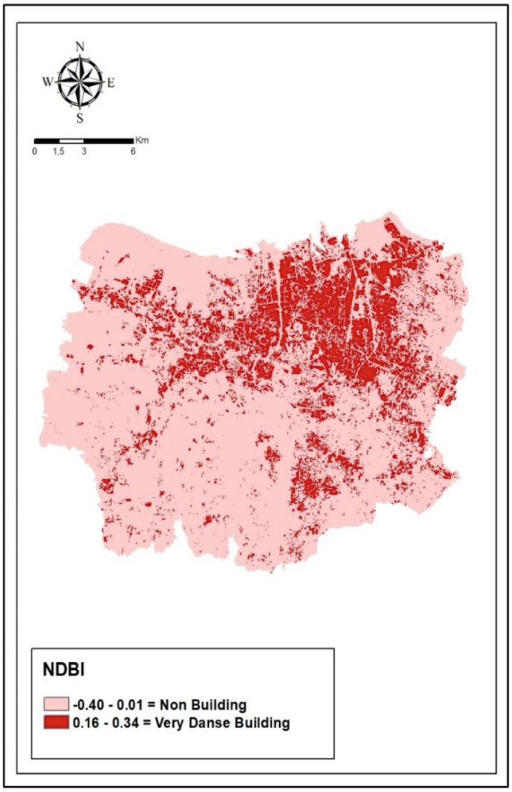


**Fig. 2.** Built-up land (NDBI)

red marks dense built-up land. Areas with high building density are spread across almost all of Semarang City and dominate urban areas. Urban areas have a high built-up land value since they are the center of all anthropogenic activities. Then, the part of the low value of built-up land is marked in pink, which has a high potential as a place for further development of built-up land. It will happen if the population increases, indicating a demand for built-up land, which triggers the shift of agricultural land into built-up land; it would be the start of urban development (Subiyanto & Amarrohman, 2018). As illustrated in Fig. 3, the vegetation density is impacted by the expansion of the built-up area.

In Semarang City, vegetation density values ranged from -0.65 to the highest value of 0.85. Values for vegetation density varied from -1 (negative) to 1 (positive); when the value of vegetation density (NDVI) is above 1 (positive), it indicates that the vegetation in the area is both dense and healthy (Prahasta, 2008; Lillesand & Kiefer, 1997). According to the visualization of the vegetation density map, colored green from light to dark, the lower the density value, the lighter the green color of the vegetation density. However, the darker the color of the green, the denser the area's vegetation. The dense vegetation density in Semarang City was located outside the center of anthropogenic activities, to be precise, in the south and west. It occurred due to the lack of or not being touched by human intervention activities in the area. In contrast, it is seen that the vegetation density level in urban areas with different anthropogenic activities is denoted with a slightly dark green color, with a value range of 0 to 0.21, falling under the non-vegetated classification.

In this case, the decline in vegetation density in urban areas was caused by an indicator of the need for built-up land as one of the developments for the city. Indirectly, vegetation

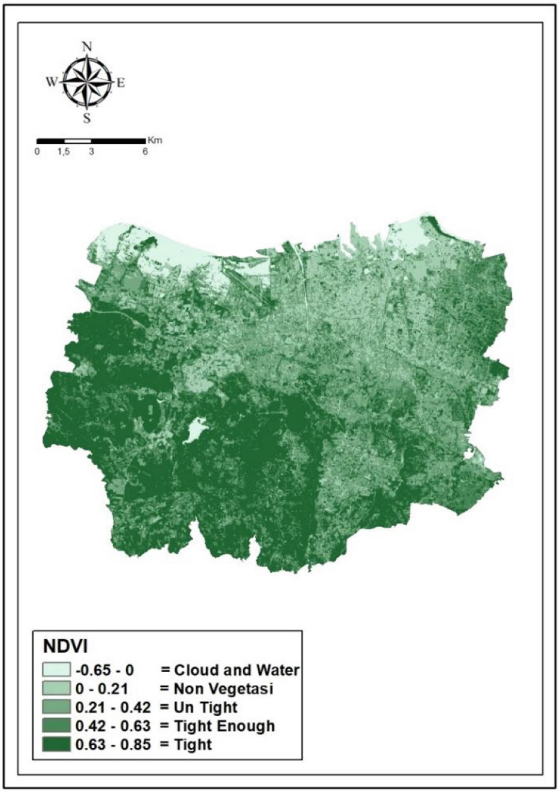


**Fig. 3.** Vegetation density (NDVI)

density has various benefits, one of which can affect the temperature in urban areas and their surroundings (Nowak et al., 1998). The high and low surface temperatures affected by the existence of built-up land also have an impact on reduced vegetation density, triggering high and low surface temperatures. Surface temperature levels can be observed in Fig. 4.

The surface temperature levels obtained into the five surface temperature class classifications revealed that the smallest value ranged from 19.26 to the largest, 38.21, with classification classes from very low to very high. Seen on the visual surface temperature level (LST) map marked in yellow to reddish-orange, various LST levels can be observed from the visual map and color as a sign of high or low surface temperature in the area. The southern part of Semarang City is still dominated by bright yellow and solid yellow surface temperatures. It can be seen again in Fig. 3 that the vegetation density in the area was still dominated by the level of vegetation density, which was quite dense and dense. The surface temperature at the center of anthropogenic activity is also marked with a reddish-orange color.

It is signified by the surface temperature level in anthropogenic activities, which had a high temperature compared to other areas. If the vegetation density level in the city

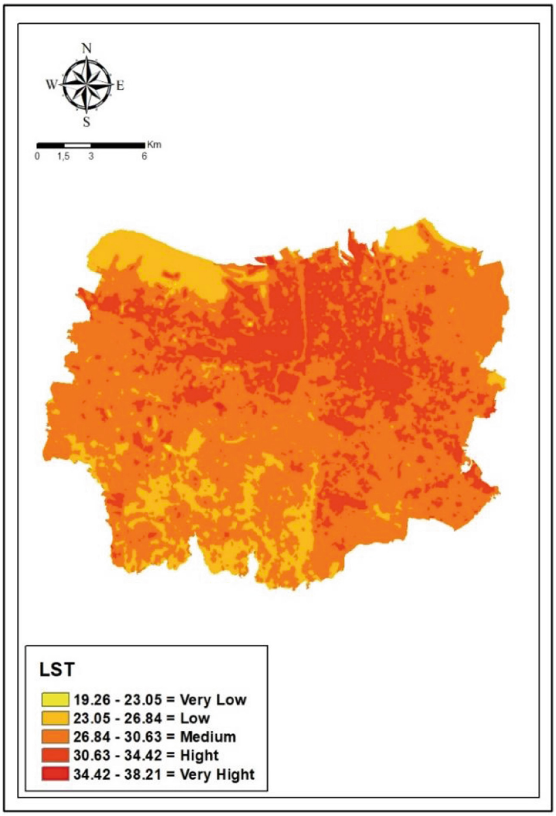


**Fig. 4.** Land surface temperature (LST)

center as an anthropogenic activity is looked at again, it was included in the non-vegetated class classification; it was due to environmental changes dominated by human activities, especially land use, and changes in land cover (Spencer, 1993). In areas of anthropogenic activity with a very densely built-up area, it can trigger increasing surface temperature in urban areas. It happens because much land is built using materials that store heat and cover various soil surfaces in urban areas (Yuan & Bauer, 2007). Therefore, the surface temperature in urban areas is higher than in undeveloped areas (Fatimah, 2012). Knowing the level of relationship from the results of the image transformation of vegetation density (NDVI) on surface temperature (LST) can be seen in Fig. 5 and Table 7.

### 3.2 Correlation Results Between Vegetation Density and LST

The equation between vegetation density (NDVI) and surface temperature (LST) is y = -5.5491x + 30.668, and the value of the constant a in the formula shown was 30.668. If the NDVI value is 0, the LST value equals this constant. Meanwhile, coefficient b had a value of -5.549, meaning that it had a negative impact on LST, or an increase in the NDVI value caused a decrease in the LST value. As seen in the linear pattern line down the graph of the relationship between NDVI and LST, the relationship between the two was directly proportional and negative.

Vegetation density and LST had a strong association. It can be seen from the R-value of 0.718, which belonged to the strong class, with the equation y = -5.5491x + 30.668. This equation denotes that vegetation density and LST had a negative relationship. In other words, the LST decreases as vegetation density increases. Furthermore, a coefficient of determination of 51.5% indicates that vegetation density impacted LST to the extent of 51.5%, with the remaining portion being influenced by factors not covered in this study.

In connection with that, areas with high vegetation density typically have cooler temperatures (Kayet et al., 2016) than regions with low vegetation density. It might

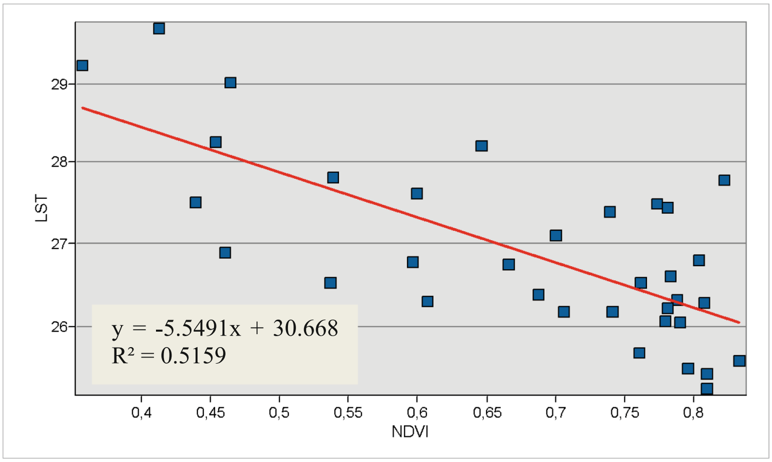


**Fig. 5.** Graph of relationship processing results between NDVI and ESG

**Table 7.** The relationship between NDVI and LST

| Regression Statistics | |
|---|---|
| R | 0.718 |
| R-Square | 0.515 |
| Adjusted R-Square | 0.500 |
| Standard Error | 0.769 |
| Observations | 34 |

result from the close relationship between areas with little vegetation and those with high building densities, which may impact temperature. The relationship between building density and temperature is explained in Fig. 6 and Table 8.

### 3.3 The Results of the Correlation Between Built-Up Land and LST

The equation between built-up land (NDBI) and surface temperature (LST) is $y = 10.746x + 28.081$. The value of the constant a in this equation was 28.081. It signifies that if the built-up land value (NDBI) is 0, the LST value equals this constant. Meanwhile, coefficient b had a value of 10.746, meaning it impacted LST positively, or the higher the NDBI value, the higher the LST value. In this case, the physical properties of the surface play an essential role in processes related to changes in surface temperature in the surrounding environment (Dousset & Gourmelon, 2003). It can be seen in the linear pattern extending upwards in the graph of the relationship between NDBI and LST, illustrating that the relationship between the two was directly proportional and positive.

An R-value of 0.197, included in the very low class, demonstrated a relationship between built-up land (NDBI) and surface temperature (LST), which was present. LST also had an NDBI coefficient of determination of 3.8%, placing it in the weak class. According to this determination value, only 3.8% of the relationship between surface

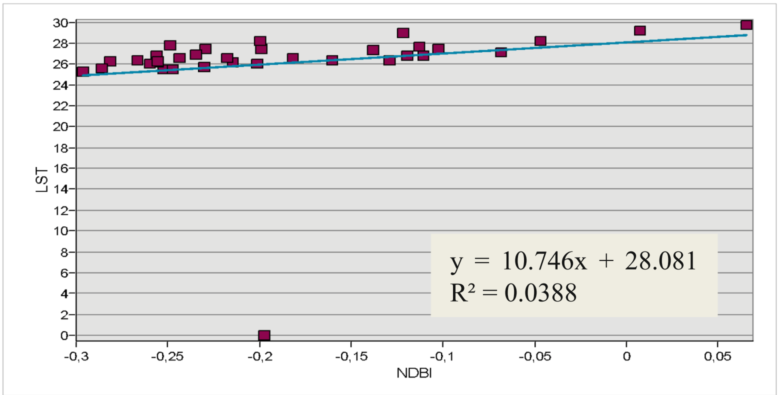


**Fig. 6.** Graph of relationship processing results between NDBI and LST

**Table 8.** The relationship between NDBI and LST

| Regression Statistics | |
|---|---|
| R | 0.197 |
| R-Square | 0.038 |
| Adjusted R-Square | 0.008 |
| Standard Error | 4.713 |
| Observations | 34 |

temperature and land use could be attributed to built-up land, with other factors accounting for the remaining 96.28%. From the level of built-up land relations to surface temperature, a decrease in vegetation density and an increase in building area can change surface temperature, causing problems such as changes in surface temperature (Sasky et al., 2017).

## 4 Conclusions

Semarang City has dense vegetation density, located on the city's outskirts, which is far from anthropogenic activities. However, the vegetation density at the center of anthropogenic activity is not included in the non-vegetation classification since it can be seen on the built-up area map (NDBI) of anthropogenic activity centers. One indication of the cause of reduced vegetation density in anthropogenic activity centers is that the level of built-up land in anthropogenic activity centers is very dense, triggering a spike in surface temperature levels into the very high-class classification. In addition, the relationship between vegetation density and surface temperature is negative. If anthropogenic activities have high vegetation density, the surface temperature level will be low, and vice versa. In fact, built-up land at the center of anthropogenic activities to support various socio-economic activities has a dense built-up level. It is also seen that the relationship between built-up land and surface temperature is positive, so dense built-up land for anthropogenic activities triggers high surface temperatures at the center of anthropogenic activities.

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