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Research article

The Effect of Vegetation Density on Land Surface Temperature in Klojen District

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Abstract.

Due to its increased population, the Klojen District has become the center of government and economy in Malang City. Overpopulation has caused an increase in land conversion and a decrease in vegetation area, resulting in the Urban Heat Island effect or increased land surface temperature (LST) in urban areas. This study aimed to determine the effect of the normalized difference vegetation index (NDVI) on LST in the Klojen District. The data were processed by interpreting Landsat 8 satellite imagery using NDVI and LST analyses in 2018 and 2020, and the two variables were tested for linear regression. The regression test results showed that the NDVI and LST in 2018 and 2020 had a negative correlation. The data indicated that as vegetation density increased, the LST decreased, and vice-versa. According to the NDVI-LST coefficient of determination value, the correlation in 2020 was higher than in 2018, indicating that the NDVI-LST correlation became stronger every year with a coefficient of determination value between 0.67 and 0.81.

Keywords: vegetation density, land surface temperature, NDVI

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1. Introduction

Located in East Java Province, Malang City has a population of 843,810 people in 2020. According to the BPS of Malang City, the city's population has grown by 0.28 percent over the last 10 years (2010-2020) [1,2,3]. This increase affects the demand for land, resulting in a change in land usage. The impact is reduced green areas due to opening space and increased Urban Heat Island (UHI). UHI is a condition in which urban areas show higher surface temperatures than the surrounding areas [4]. UHI contributed to climate change in the atmosphere and surface of urban areas and affected human welfare, urban air pollution, energy management, and urban planning [4,16]. The high level of UHI in urban areas is caused by increased greenhouse gas emissions. Greenhouse gas emissions are caused by fossil fuel combustion and the lack of green open areas.

Klojen District, with an area of 883 ha, is the center of government and economic activity. Based on previous research data, the green areas open space in Klojen District is 31 ha of 2212 ha total Green Open Space of Malang City or the Green Open Space in Klojen District received only a 1.4 % of the 19.9% Green Open Space area in Malang City [5,19]. This area is under the basic regulation of Law No. 26 of 2007, requiring that at least 30% of the city's area be given access to green open space. According to Law No. 26 of 2007 on Spatial Planning and Minister of Public Works Regulation No. 05/PRT/M/2008 on the Provision and Utilization of Green Open Space in Urban Areas, Green Open Space is defined as an enlarged or clustered area with a more open use, where plants grow, both naturally occurring and artificially cultivated [5,18]. Vegetation in urban areas must be maintained to provide comfort and pleasant land use and maintain the surface temperature stable in Klojen District.

Vegetation density is one of the primary indications of surface temperature. A low index of surface temperature indicates a high vegetation density, and likewise. Analysis of the vegetation index can be identified using remote sensing [6,7,10]. This study used the Normalized Difference Vegetation Index (NDVI) to determine the distribution of vegetation density in Klojen District. The range of NDVI values is between -1 to 1. The +1 value indicates that the area has a high concentration of green vegetation, whereas the -1 value showed that the area has a very low concentration of green vegetation and nearly no vegetation and is frequently referred to as a non-vegetated area [8,9]. Measuring the Land Surface Temperature (LST) using Landsat 8 OLI/TIRS satellite imagery can be used to determine the high and low surface temperatures.

The purpose of this study was to determine the effect of NDVI and LST in Klojen District. The results of this study are expected to show the achievements of the application of green areas in the development of the Malang city center area – namely, Klojen District – in 2 years. This research is expected to help the government in planning urban area development more carefully. Also, with a good understanding of the variations in the relationship between NDVI and LST, it can be served as a reference for future related studies.

2. Method

Forests can influence the microclimate around them by reducing the land surface temperature, making cities with high forest cover feel colder [10,17]. Correlation analysis is performed to find out the impact of vegetation on urban temperature changes. Correlational research aims to determine the relationship between one variable and variation

in one or more other variables [5,11]. The research was conducted in Klojen District, Malang City with coordinates 7°57'01.2" - 7°59'56.1" S and 112°36'47.7" - 112°38'22" E.

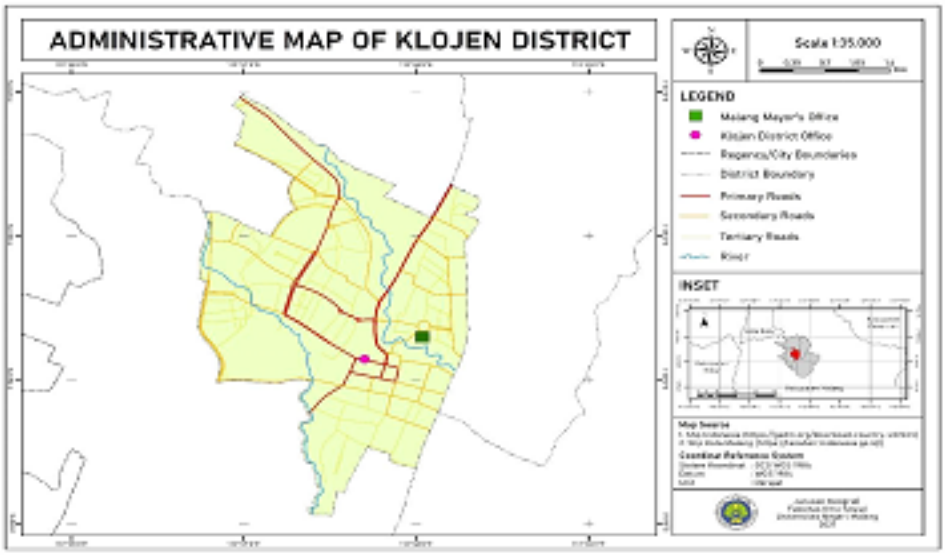

Figure 1: Administrative Map of Klojen District, Malang City.

This study used Landsat-8 OLI/TIRS images recorded in September 2018 and 2020, and that has been adjusted for radiometric and geometric errors. A two-year difference is used to measure the effect of vegetation density on temperature. Image data is used to obtain information about vegetation density and surface temperature through NDVI and LST processing methods with ArcGIS software. Correlations between NDVI and LST were determined using linear regression statistical tests in RStudio, with LST served as the dependent variable and NDVI served as the independent variable.

The NDVI is used to assess urban vegetation quantitatively. The NDVI is a normalized indicator that enables the detection and quantification of vegetation by comparing the difference between the near-infrared (NIR) and red (R) bands of the electromagnetic spectrum. The index ranges between -1 and 1 (surface totally covered by vegetation), and the median value represents places with little or no plant cover, such as bodies of water, sand, or snow. The following formula calculates the application of the NDVI model.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

Where:

NIR = Near Infrared Reflectance (Band 5)

RED = Red Channel Reflectance (Band 4)

The result will produce an NDVI used to identify the vegetation index map from the resulting color. Further, the land surface temperature map is identified using an image

interpretation technique that calculates color variations and the maximum and minimum values of the LST.

3. Results and Discussion

3.1. Analysis of Vegetation Density

The processing results using the NDVI technique obtained the vegetation density value in Klojen District, Malang City as shown in the following Figure 2.

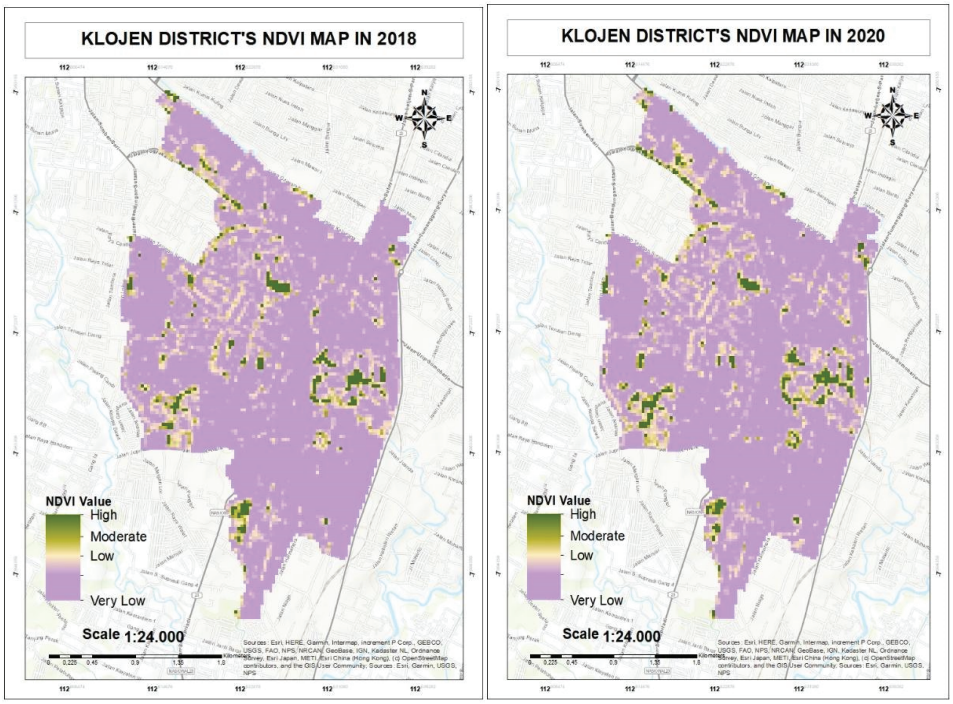

Figure 2: NDVI of Klojen District in 2018 (left) and 2020 (right).

The NDVI results will produce a value of -1 to 1 [7,11]. According to the Regulation of the Minister of Forestry of the Republic of Indonesia No. P.32 of 2009, NDVI values are classified as shown in the following Table 1.

TABLE 1: NDVI Classification.

Classification	NDVI	Greenery Level
1	-1 s/d -0.03	Non-vegetated land
2	-0.03 s/d 0.15	Very Low
3	0.15 s/d 0.25	Low
4	0.25 s/d 0.35	Moderate
5	0.36 s/d 1.00	High

Source: Minister of Forestry Regulation 2009

Field observations at some vegetation and non-vegetation collection points were used to validate, including Malabar City Forest Park, Kediri Street Urban Forest, Boulevard Park, Trunojoyo Park, Tugu Square, Green River Nirwana Residence, Bondowoso Street, Malang City Square, Ijen Block A Intersection, Padjajaran Street, and Malang City Market.

Table 2: NDVI of Klojen District in 2018 & 2020

Classification	NDVI	Greenery Level	Area (Ha)	
			2018	2020
2	-0.003 s/d 0.15	Very Low	582,63	563,87
3	0.15 s/d 0.25	Low	226,14	236,08
4	0.25 s/d 0.35	Moderate	49,92	56,67
5	0.36 s/d 1.00	High	10,53	13,25

Source: NDVI processing results in Klojen District

Based on the Table 2, it was found that the vegetation density of Klojen District was divided into four classes, namely very low, low, moderate, and high density. Very low vegetation density or class 2 is spread in almost all sub-districts, with an area of 582.63 Ha (2018) and 563.87 Ha (2020), including the residential area, markets, and roads. As shown in Figure 3, the NDVI value reflects a very low greenery classification because of the vegetation at the side of a road or yard with very few distances. Then the class 3 or low green density areas are spread out in Oro – Oro Ombo, Bareng, Klojen, and Kidul Dalem villages with an area of 226.14 Ha (2018) and 236.08 Ha (2020). Most of the locations with the class 3 density are residential are and main roads with sparse vegetation distance, such as on Batok Street, Oro-Oro Ombo Subdistrict (Figure 4).

Vegetation with densities of class 4 and 5 is scattered in several green areas of Malang City. The most extensive Green Open Space in Malang City has an area of 10.53 hectares in 2018 and increased in 2020 with 13.25 hectares. The increase in land area is a result of the vegetation's health. Vegetation that is actively photosynthesizing absorbs most of the sun's red waves and reflects the higher near-infrared waves [12,14]. Based on field interpretation and image interpretation, the land use in class 4 and 5 are recognized as urban parks and urban forest parks with relatively large plants, grassy fields, and annual plants.

3.2. Analysis of Land Surface Temperature

Klojen District has an area of 8.83 km^2. Most of the land is used as residential areas, markets, and Green Open Spaces. Green Open Space in this area has an area of 0.4%

Figure 3: Vegetation on the side of Market Street, Malang City).

Figure 4: Vegetation on the side of Batok Street, Malang City.

or 22,075,000 m^2 of the total area of Klojen District. The surface temperature results of the Landsat 8 Satellite Imagery processing represent the monthly surface temperature of Klojen District as shown in the following Figure 6.

Figure 6 showed the classification of the lowest and highest temperatures for 2018 and 2020 using data from various land surfaces. The low temperatures ranged between

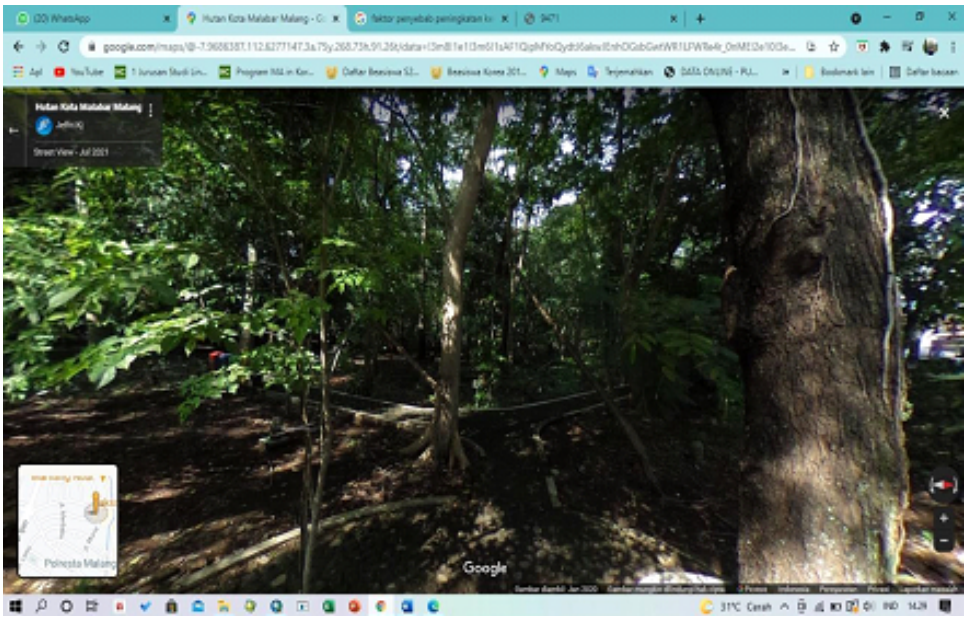

Figure 5: Malabar City Forest Park, Malang City.

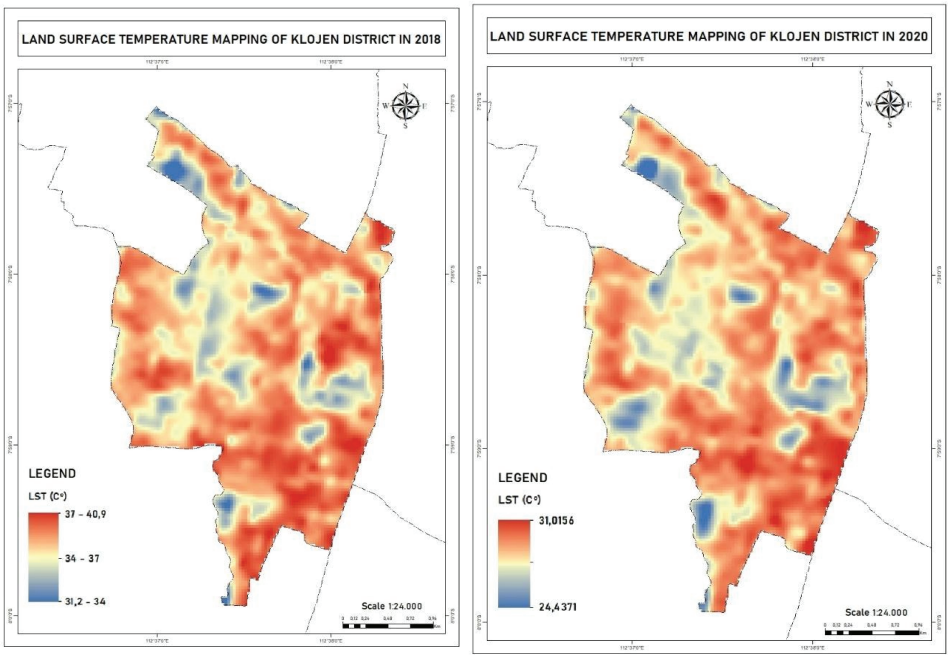

Figure 6: The LST of Klojen District in 2018 (left) and 2020 (right).

31.2 and 34 degrees Celsius, while high temperatures ranged between 37 and 40.9 degrees Celsius in 2018. Then, in 2020 the low temperature is at 24.4 ℃, and the high temperature is at 31 ℃. The distribution pattern of soil surface temperature in the two years is identical, but the temperature ranges are significantly different. The surface temperature is one of the components that significantly affect air temperature changes. Therefore, the surface temperature increases as a result of frequent variations in the weather.

3.3. Analysis of the Effect of Vegetation Density on Surface Temperature

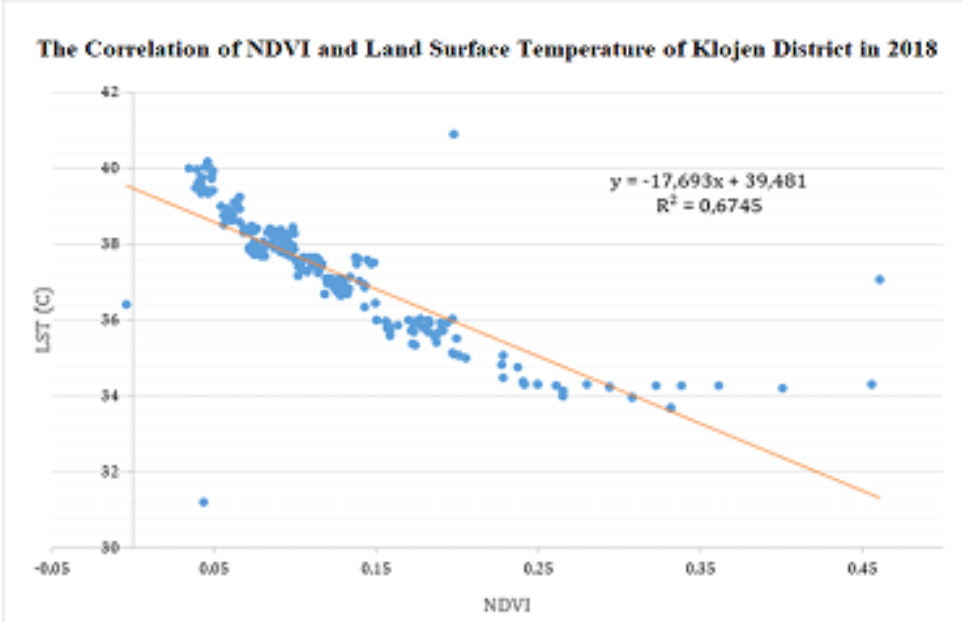

Figure 7: Scatterplot of NDVI and Surface Temperature (LST) in 2018.

The relationship between vegetation density and surface temperature was measured using a linear regression statistical analysis test for the two variables. The significant correlation between vegetation density and surface temperature demonstrates the interaction between environmental and climate conditions [8,9]. Figure 7 showed that the scatterplot between the NDVI and the surface temperature (LST) has a negative correlation of -17.69. A negative correlation indicates that the lower the degree of vegetation density, the higher the surface temperature value. It is showed by the low NDVI with a range of -0.003 – 0.15 (very low vegetation) having an LST of 36°C – 40°C. However, the obtained results are complicated in that the highest value of NDVI (0.46) indicates a high level of vegetation at a surface temperature of 36°C – 38°C, while the minimum value of NDVI (0.017) indicates a very low level of vegetation at the lowest surface temperature of 30°C – 32°C. According to a previous study, land cover features might affect the complex relationship between vegetation density and surface temperature, resulting in massive error differences in LST extraction from Landsat 8 OLI/TIRS satellite images, especially in urban areas [13,14]. The effect of the NDVI on LST is indicated from the coefficient of determination of 0.6745. This value stated that the vegetation density has a surface temperature variance of 67.45%.

The plot distribution pattern in 2020 is generally similar to 2018, with the minimum ESG value occurring in the low NDVI ranged (0–0.05), and increasing fluctuations in

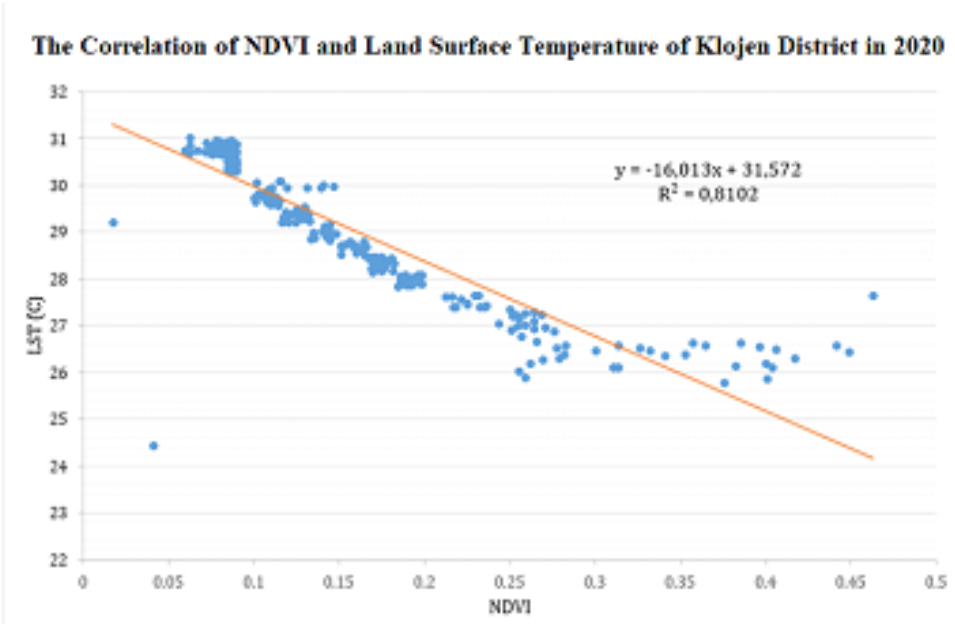

Figure 8: Scatterplot of NDVI and Surface Temperature (LST) in 2020.

the LST value occurring in the high NDVI ranged (0.33–0.46). Figure 8 showed a linear relationship between NDVI and LST with a correlation value of -16.013, resulting in a negative correlation. It showed that the optimum distribution of LST values in the range (30°C – 31°C) is in the NDVI value in the range of 0.05 – 0.1 (very low vegetation). The NDVI has an effect on LST of 0.81 or 81 %, indicating that vegetation density may accommodate the difference in land surface temperature.

Table 3: NDVI and LST in Klojen District.

Year	$NDVI_{min}$	$NDVI_{max}$	LST_{min}	LST_{max}	R	R^2
2018	-0,0036	0,4603	31,21°C	40,90°C	0,821..	0,6745
2020	0,0174	0,4628	24,43°C	31,01°C	0,900..	0,8102

Source: Data processing

The correlation in 2020 is higher than in 2018 based on the NDVI-LST coefficient of determination. It showed that the NDVI-LST correlation is increasing every year. Table 3 showed an increase in the NDVI value, indicating a significant increase in vegetation density. Large areas always increase the opportunities to develop solid LST-NDVI correlations in urban areas [15,16,17]. Table 3 also showed a decreasing change of surface temperature in 2020. The difference in surface temperature changes is significant that the 2018 minimum surface temperature is similar to the September 2020 maximum surface temperature [18]. Due to global climate change, the difference affects soil emissivity, atmospheric transmission, and the average atmospheric temperature at image capture.

4. Conclusions

The vegetation density in Klojen District is divided into four classes, namely very low, low, moderate, and high. A collection of different vegetation types will result in varying amounts of vegetation density depending on the land use in an area. The low temperature in Klojen District was at the interval of 31.2 - 34 C, and the high temperature was at the interval of 37 - 40.90C in 2018. Then, in 2020 the low temperature was at 24.4 C, and the high temperature was at 310C. Based on the coefficient of determination of NDVI-LST, the correlation in 2020 is higher than in 2018, showed that the NDVI-LST relationship is increasing every year. It is followed by the increase in vegetation density in Klojen District.

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