IOP Conference Series: Earth and Environmental Science

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To cite this article: R R Darettamarlan *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **936** 012037

Correlation analysis of *Land Surface Temperature (LST)* measurement using *DJI Mavic Enterprise Dual Thermal* and *Landsat 8 Satellite Imagery* (case study: Surabaya City)

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Abstract. Landsat 8 Satellite Imagery (Landsat Data Continuity Mission, LDCM) is a satellite product made by Orbital Science Corporation, which launched with The Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) instruments as the latest features. One of the Thermal Infrared Sensor (TIRS) instruments is called Band 10, that provide temperature information on the earth's surface. As many research conduct the temperature comparison between satellite imagery analysis and land cover temperature has been come with positive correlation for both of the variable. As to prove the temperature relationship, it is necessary to validate the actual temperature values on the earth's surface by conduct the temperature survey in the area using the temperature measurement tools. One of the tools is DJI Mavic Enterprise Dual Thermal camera as the camera that capable to take samples data of particular objects categories that included urban areas, waters, vegetation, open land, settlements, and industrial factories. Using the satellite imagery's temperature data and the land cover temperature data survey, comparing and accuration assessment are needed to see how close the value of both variable. The data processing carried out that both of the data have a positive correlation as the relationship, which have a Pearson correlation value of 0.892 and sig. (2-tailed) at the number 0.000000068. This correlation value showed that the relationship between both data is acceptable as the both data can represent each other to conduct any research. However, as the satellite imagery contains 29,85% of cloud cover, the temperature obtained lower in the Landsat 8 satellite image rather than the actual temperature on the earth's surface.

Key Words : DJI Mavic Enterprise Dual Thermal, Land Surface Temperature (LST), Satellite Imagery, Landsat 8, Pearson Correlation, Temperature Comparison.

1. Introduction

Landsat 8 (Landsat Data Continuity Mission, LDCM) satellite imagery created by the Orbital Science Corporation and launched by an Atlas-V rocket from Vandenberg Air Force Base, California, on February 11, 2013, as a follow-up mission to the first Landsat 1 has been an earth observation satellite since 1972 (Landsat 1) by bringing the latest features, namely the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) instruments. One of the Thermal Infrared Sensor (TIRS) instruments carried is in Band 10 with a wavelength of 10.6 – 11.19 and a spatial resolution of 100 m which can represent thermal mapping [1]. Band 10 spatially can provide more detailed information on sea surface temperature or land surface temperature [2].

According to Utomo et al. (2017), the suitability of thermal mapping using Landsat 8 Satellite Imagery has a positive relationship with land cover class. The highest surface temperature is in the built-up land class, and the lowest temperature is in the agricultural class [3]. As surface temperature is influenced by biological, physical, and chemical processes based on the effects of ecosystem function, thus the difference land condition will have various temperature [13]. Green space or tree species has a range of temperature that impact the surrounding of human living environment. And also the urban area or human-dominated area will have a relative temperature difference than the green area [13].

To prove the theory, it is necessary to validate the temperature in the field using the DJI Mavic Enterprise Dual Thermal camera, a 3-axis gimbal camera with a 4K sensor for capturing light, and a FLIR Lepton thermal micro-camera for thermal imaging. Validation is done by referring to the different categories of the objects in urban areas, waters, vegetation, open land, settlements, and industrial factories to see the biological, physical, and chemical effect that happened. The validation process needs to do in areas that still have all the required categories. Surabaya City is an urban area suitable as a study area because it still has the required object categories and has a higher temperature than other cities [4]. It can be seen the difference in temperature between existing object categories.

2. Methodology

2.1. Research Location

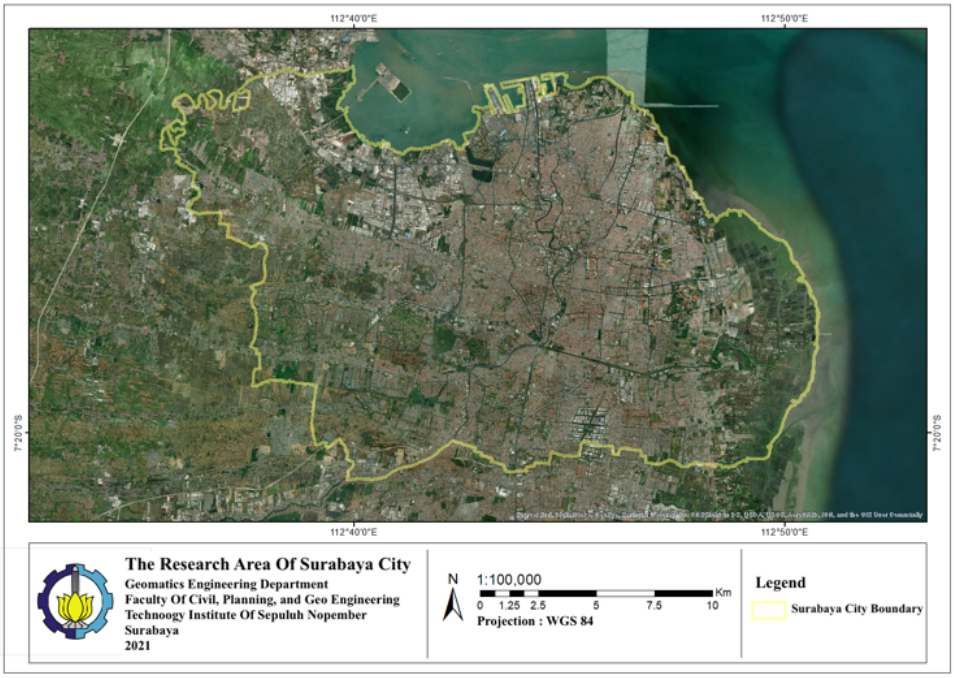

Figure 1. The study area (Source : Landsat 8 Satellite Imagery)

The research located in Surabaya City at coordinates 07°11′00″ – 07°21′00″ South Latitude and 112°36′00″–112°54′00″ East Longitude. The boundaries are in northern and eastern is the Madura Strait, in the south bordering is Gresik Regency, and in the west is bordered by Sidoarjo Regency [5]. The area of Surabaya City is recorded at 33,206.30 hectares [6].

2.2. Data

The data that used in this study are spatial data, consisting of location data for the distribution of object categories that allow flights to be carried out using the DJI Mavic Enterprise Dual

Thermal, Landsat 8 Satellite Imagery data on March 12, 2021, and vector data for the Surabaya City Administrative Boundary in the form of .shp which can be downloaded on the official inageoportal page https://tanahair.indonesia.go.id/portal-web/inageoportal/.

2.3. Method

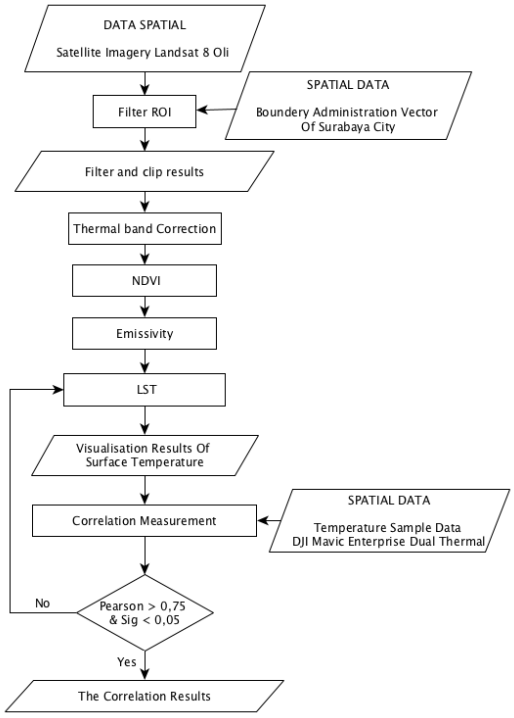

Figure 2. Data processing flowchart

2.3.1. Selecting The Survey Area

Survey area selected as the difference of temperature that based on the biological, physical, and chemical processes [13]. Surabaya City as the second biggest city in Indonesia dominated by urban area because of the human activities [14]. Thus, the Surabaya City doesn't have the equal amounts of green spaces that will be balanced the temperature by reduce the amount of carbon [15]. By the reason, the survey area contains urban areas as physical environment process, waters as biological and chemical process; vegetation as biological and chemical process; open land as biological, chemical, and physical process; settlements as physical process; and also industrial factories as chemical and physical process to see the difference temperature effect between each biological process, physical process, chemical processes.

2.3.2. Temperature Sample Data Collection and Processing with DJI Mavic Enterprise Dual Thermal.

The survey using the DJI Mavic Enterprise Dual Thermal was on March 23, 2021, to March 31, 2021 (9 Days) with a span of 30 minutes from 09.45 WIB to 10.15 WIB as followed the time the Landsat 8 satellite passed through the equator or (Local Time on Descending). Node - LTDN) [7]. The DJI Mavic Enterprise Dual Thermal is used in conditions where no calibration has been done due to the absence of a special study related to the calibration tool.

At the time of taking temperature sample data, a minimum distance of 100 m between sample objects is required in order to be able to adjust the pixel size on the Landsat 8 satellite imaginary, which will be used for the results of calculating the average temperature.

A sampling of data is done by flying the DJI Mavic Enterprise Dual Thermal and seeing the temperature at the desired points with a minimum of 20 points per object. After all the temperature sample data are collected, the average calculation for each object is carried out.

2.3.3. Land Surface Temperature (LST) with Landsat 8 Satellite Imaginary Processing.
Land Surface Temperature (LST) data processing carried out from image data that has been adjusted to the region of interest in the form of .shp, which uses the thermal band from the Landsat 8 satellite and is translated into a value in degrees Celsius using the following equations :

1. Change the Digital Number in Landsat 8 to Top Of Atmosphere (TOA) Radiance [8].

$$L_\lambda = M_L Q_{cal} + A_L \quad (1)$$

Information :
L_λ : Top Of Atmosphere (TOA) Radiance
M_L : RADIANCE_MULT_BAND_10
Q_{cal} : Digital Number
A_L : RADIANCE_ADD_BAND_10

2. Change the value of Top Of Atmosphere (TOA) Radiance to Top Of Atmosphere (TOA) Brightness Temperature [8].

$$T_B = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda}+1\right)} \quad (2)$$

Information :
T_B : TOA Brightness Temperature (Kelvin)
K_1 : 774,8853 $^{W}/_{m^2 srad\ \mu m}$
K_2 : 1321,0789 $^{W}/_{m^2 srad\ \mu m}$

3. Calculating the value of the Normalized Difference Vegetation Index (NDVI), which is the amount of the greenness of the vegetation from digital signal processing of brightness value data for several channels of sensor data on satellites [8].

$$NDVI = \frac{(NIR-Red)}{(NIR+Red)} \quad (3)$$

Information :
NIR : Near Infrared Band
Red : Red Infrared Band

4. Extraction of emissivity values using the Normalized Difference Vegetation Index (NDVI) value reduces errors in the estimation of ground surface temperature in

satellite imagery [12]. The requirements for categorizing NDVI values are as follows [9]:

- $NDVI < NDVI_s(0,2),\ \varepsilon_s = 0,97$
  If the NDVI pixel value is less than 0.2, then this condition is considered that the data consists of bare ground so that it has an emissivity value of 0.97.
- $NDVI < NDVI_V(0,5),\ \varepsilon_V = 0,99$
  If the NDVI pixel value is higher than 0.5, then this condition is considered that the data consists of dense vegetation so that it has an emissivity value of 0.99.
- $0,2 \leq NDVI \leq 0,5$
  If the NDVI pixel value has more than 0.2 and less than 0.5, it is assumed that the data consists of a mixture of bare soil and dense vegetation. So it have to calculate the Proportion of Vegetation before having the emissivity value with the equation:

$$PV = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2 \quad (4)$$

Information :
PV : Proportion of Vegetation with range of value 0 - 1
NDVI : Nilai NDVI in each pixel
$NDVI_{min}$: Nilai NDVI minimum
$NDVI_{max}$: Nilai NDVI maximum

If it meets the 3rd requirement, it must calculate the Proportion of Vegetation, then the calculation of the emissivity value becomes:

$$LSE = m \times PV + n \quad (5)$$

With,

$$m = \varepsilon_V - \varepsilon_s - (1 - \varepsilon_s)F_{\varepsilon V} \quad (6)$$

$$n = \varepsilon_s + (1 - \varepsilon_s)F_{\varepsilon V} \quad (7)$$

Information :
m : Standard deviation of surface emissivity (0,004)
n : The subtract value of vegetation emissivity and 'm' value (0,986)
ε_V : Vegetation emissivity (0,99)
ε_s : Soil emissivity (0,97)
F : Different geometric distribution form factors (0,55)

5. The conversion value of Brightness Temperature to be Land Surface Temperature (LST) value [8].

$$T_s = \frac{T_B}{1 + [(\lambda \times T_{B/\alpha}) \ln \varepsilon}} \quad (8)$$

Information :
T_s : Land Surface Temperature (LST) (Kelvin)
T_B : TOA Brightness Temperature (Kelvin)
λ : Wave length emitted radiance equal ($11,5 \times 10^{-6}$)
α : $1,438 \times 10^{-2}$ mk
ε : Emisivitas permukaan atau Land Surface Emissivity

6. The conversion value from Land Surface Temperature (LST) in Kelvin to Celcius [8].

$$T_c = T_k - 273,15 \quad (9)$$

Information :
T_c : Land Surface Temperature (LST) in Celcius.
T_k : Land Surface Temperature (LST) in Kelvin.

2.3.4. The Pearson Correlation calculation.

By using image data from aerial photography using the DJI Mavic Enterprise Dual Thermal and the results of Land Surface Temperature (LST) processing on Landsat 8 images, ground truth validation is done using Pearson Correlation as a calculation to measure the linear relationship strength between two variables in the interval or ratio data. The calculation is done in the application SPSS Statistics.

The equation of Pearson Correlation is [11] :

$$r = \frac{\Sigma(X-\bar{X})(Y-\bar{Y})}{\sqrt{(\Sigma(X-\bar{X})^2)(\Sigma(Y-\bar{Y})^2)}} \quad (10)$$

According to Sarwono (2009) the interval of relationship strength group is as follows [10]:

Table 1.
The interval of relationship strength group (Sarwono, 2009)

The Coefficient Values	**The Relationship Strength**
0,00	No Correlation
0,00 - 0,25	Weak Correlation
0,25 - 0,50	Enough Correlation
0,50 – 0,75	Strength Correlation
0,75 - 0,99	Very Strength Correlation
1,00	Perfect Correlation

3. Results and Discussion

3.1. Sample Temperature from DJI Mavic Enterprise Dual Thermal survey.

The sample temperature survey with DJI Mavic Enterprise Dual Thermal survey was executed in 37 points which located in figure 3 :

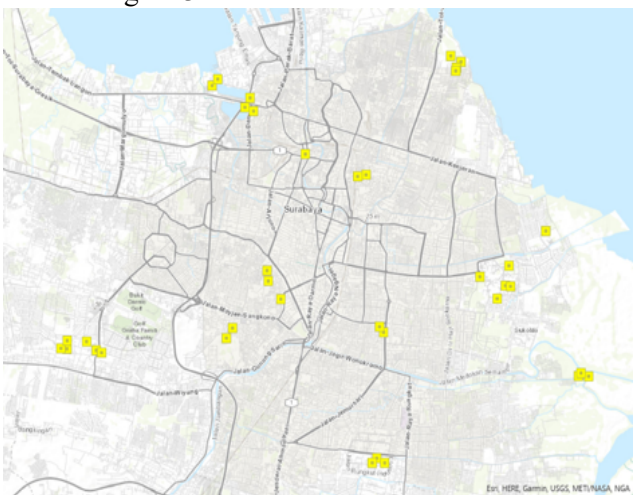

Figure 3. The location of sample temperature using *DJI Mavic Enterprise Dual Thermal.*

However, 5 sample points are not used due to lack of sampling points; objects are not homogeneous; differences in object conditions; differences in coordinates; and objects taken do not match any existing categories.

The 32 points used as temperature sample points are grouped into five categories of objects: waters, vegetation, open land, factories, and settlement. The majority of temperatures conduct from the lowest temperature being the category of waters objects, followed by vegetation objects, open land objects, factory objects, and settlement objects for the highest temperature.

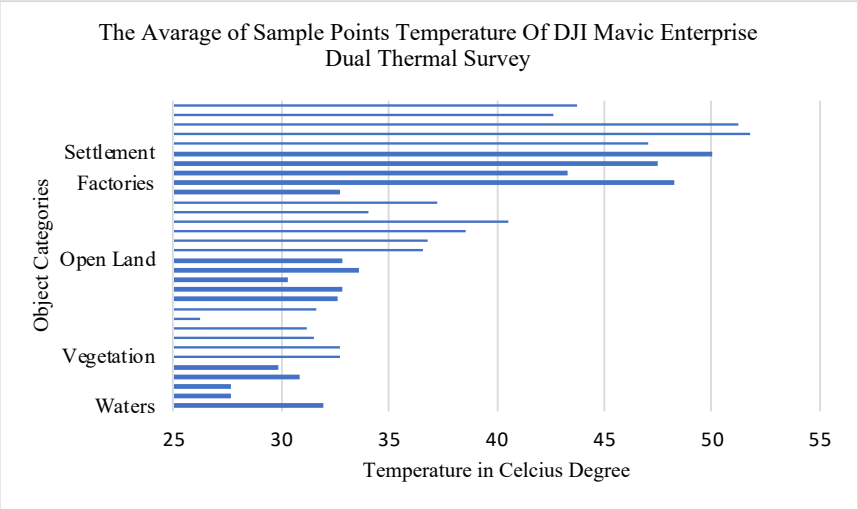

Figure 4. The average of sample points temperature in Surabaya City using *DJI Mavic Enterprise Dual Thermal.*

The temperature average in each object categories are :

Tabel 2.
The temperature average of temperature survey using *DJI Mavic Enterprise Dual Thermal.*

Object Categories	**The Temperature Avarage (℃)**
Waters	29,623
Vegetation	31,30833333
Open Land	35,88166667
Factories	46,35833333
Settlement	47,7375

3.2. Land Surface Temperature (LST) processing.

Land Surface Temperature (LST) data processing was carried out on satellite imagery on March 12, 2021, with a cloud cover of 29.85%. The satellite image was chosen because it is the closest to the time of the temperature sample survey in the Surabaya City using a DJI Mavic Enterprise Dual Thermal camera and has the minor cloud cover of all the closest imagery, so it is expected to represent the temperature in the city of Surabaya during the survey period.

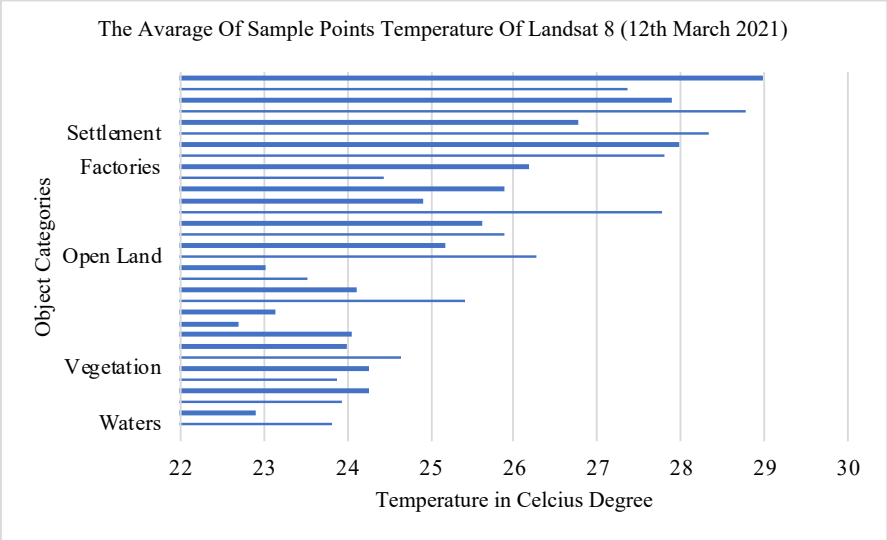

Figure 5. The temperature average of Landsat 8 Satellite Imagery at 12 March, 2021, in Surabaya City

The temperature average in each object categories are :

Tabel 3.
The temperature average of Land Surface Temperature processing from Landsat 8 Satellite Imagery

Object Categories	**The Temperature Avarage (°C)**
Waters	23,758
Vegetation	23,97888889
Open Land	25,44666667
Factories	27,32
Settlement	28,02333333

3.3. Correlation Measurement Between The Temperature Results of DJI Mavic Enterprise Dual Thermal survey and Land Surface Temperature (LST) processing.

In the results of Land Surface Temperature (LST) data processing on Landsat 8 Satellite Imagery on March 12, 2021, as the survey's closest time using a thermal camera, it produces a different temperature from the results of a direct survey in the field. Still, it has the order of object categories in the survey results with DJI Mavic Enterprise Dual Thermal. The temperature generated from the Landsat 8 Satellite Image has a lower value than the temperature in the survey results using the DJI Mavic Enterprise Dual Thermal due to many thin clouds and several thick clouds in the Landsat 8 image on March 12, 2021 [3].

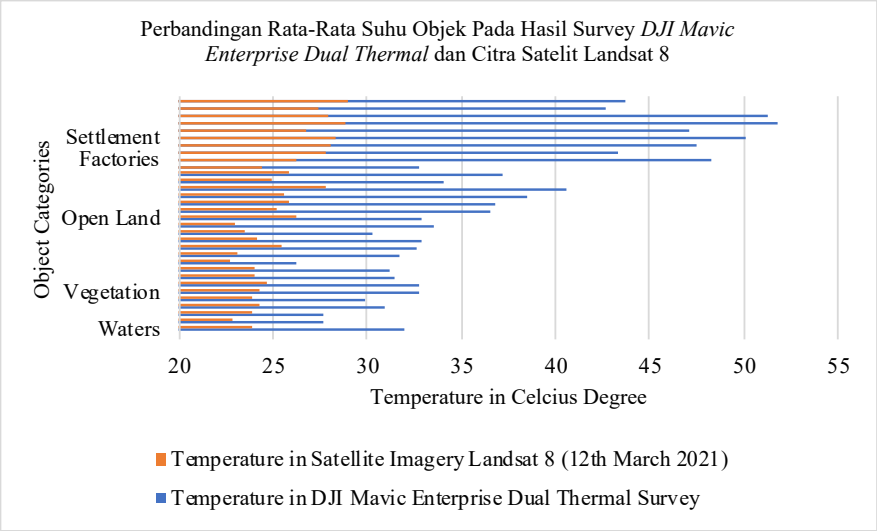

Figure 6. The sample temperature comparation between the results of *DJI Mavic Enterprise Dual Thermal survey and Land Surface Temperature (LST) processing.*

However, the correlation calculation results using the SPSS Statistic application show that the two data have a Pearson correlation of 0.892, that categorized in the relationship strength interval group as 'Very Strong Correlation' and Sig. (2-tailed) value is 0.000000068 that interpreted as the relationship contained in R is considered significant (accepted in a two-way relationship) because of the Sig. (2-tailed) value is smaller than 0.05 [11].

From the results obtained, it concluded that the correlation between the two data has a very strong positive correlation where there is an increased temperature of the survey results with the DJI Mavic Enterprise Dual Thermal, there will be an increased temperature in the results of data processing of Land Surface Temperature (LST) satellite imagery. Landsat 8 dated March 12, 2021, and the same will apply to data declines that occur.

4. Summary

The correlation between the temperature sample data from the survey using the DJI Mavic Enterprise Dual Thermal and the Land Surface Temperature (LST) data processing of the Landsat 8 satellite image on 12 March 2021 has a very strong positive correlation as the relationship between the two data. It proved by The Pearson Correlation value of 0.892 and sig. (2-tailed) at 0.000000068. As the data results, the actual temperature in Surabaya City and the Satellite Imagery of Landsat 8 match each other. However, to produce better data, it would be better if the field survey was carried out during the dry season to avoid unstable weather and could use images with areas clear of clouds.

Acknowledgments

The author thanks to Mr. Husnul Hidayat, S.T., M.T. and Mr. Mohammad Rohmaneo Darminto, S.T, M.Sc. as a supervisor for the author's final project.

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