LOCAL CLIMATE ZONE (LCZ) IN BANDAR LAMPUNG CITY

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Abstract. The rapid growth of the population in Bandar Lampung has led to a change in the land's usage from vegetation to built-up land. In the end, less vegetation will be present, which also results in higher temperatures in urban. This study intends to identify the state of the city's building density, vegetation density, land surface temperature, and Local Climate Zone (LCZ) in Bandar Lampung. Local Climate Zone (LCZ) maps can provide information on the physical structure of urban planning based on building density, and vegetation density, and are useful in the mitigation and public monitoring of increasing urban temperatures. The data was collected using images from Landsat 8 OLI/TIRS and high-resolution satellite imagery from Maxar Technologies downloaded using Google Earth Pro. Additionally, a field survey was used to measure the air temperature. The LCZ Generator WUDAPT is used to process LCZ data. The findings revealed that Bandar Lampung was dominated by medium-density buildings in the city's canter and medium-density vegetation in its western. The highest LST in residential areas is 35°C, while forest areas have the lowest LST at 15,68°C. There are 14 LCZ classifications, covering seven building types and seven land cover types. The dense tree zone has the highest vegetation density, the open low-rise zone has the highest land surface temperature, and the compact low-rise zone has the highest building density.

Keywords: *Bandar Lampung, Building Density, Vegetation Density, Local Climate Zone, Land Surface Temperature*

1 INTRODUCTION

A local Climate Zone (LCZ) is a climate-based classification system that considers the similarity of land cover, surface structure, building construction materials, and human activities over a horizontal range of 100 meters to several kilometers (Stewart & Oke, 2012). The LCZ map could show information on the urban structure, showing that as urban growth increases, so do the city's temperature and the density of buildings, while vegetation density decreases (Pradhesta et. al., 2012). Local Climate Zone (LCZ) represents a simple composition of buildings, roads, plants, soil, rocks, and water, each uniformly organized into 17 classification classes with different microclimate conditions in various zones related to air temperature (Stewart & Oke, 2012).

One way to find out is to use which use image modification techniques like the Normalized Difference Vegetation Index (NDVI) to acquire the vegetation density index and the Normalized Difference Built-up Index (NDBI) to obtain the building density index (Wass & Nababan, 2010; Kaya, 2011). Based on Hidayati et al. (2018), a high Normalized Difference Built-up Index (NDBI) value indicates a high surface temperature as well.

Due to Bandar Lampung's excellent accessibility as a gateway from Java Island to Sumatra Island (RPIJM for Human Settlements of Bandar Lampung in 2012-2016), it grew to the third-most-developed city on Sumatra Island between 2000 and 2015 (Mardiansjah & Paramita, 2019) and during the previous ten years, its population has increased by 75% (BPS Lampung, 2021). As the population grows, so does the need for residential land (Astuti & Fitria, 2021). The conversion of 304.21 hectares of Bandar Lampung's vegetative land to built-up land in 2012 serves as evidence of this (Ikhsanuddin, 2015)

The massive land conversion has led to an increase in urban temperatures (Zhang et al., 2010). Bandar Lampung's air temperature has consistently increased between 1976 and 2010, with an average increase for the minimum temperature of 0.7°C and the highest temperature of 0.32°C (Manik & Syarifah, 2013). Another study states that the air temperature in Bandar Lampung has increased by about 1 ° C every year from 2011 to 2019 (Gitawardani, 2019).

Seeing the ever-increasing trend of urban temperature in Bandar Lampung City, it is necessary to have special research in the field of urban climate to identify LCZ by paying attention to building density, vegetation density, and urban temperature. LCZ is considered an effective method in the study of urban structure and climate on a local scale. This is because the LCZ classification is believed to be better able to explain variations in urban landscapes and built-up areas (Aslam and Irfan, 2022). Moreover, LCZ helps mitigate and public monitoring of increasing urban temperatures, climate modeling, weather forecasting, and urban temperature analysis (Stewart & Oke, 2012). That's because LCZ can explain information about the physical structure of city planning (Pradhesta et. al., 2012).

2 MATERIALS AND METHODOLOGY

2.1 Location and Data

Bandar Lampung City is in Lampung Province and is the provincial capital. The city of Bandar Lampung is also the canter of government, political, social, educational, and cultural activities, as well as the canter of economic activity in Lampung Province. The city of Bandar Lampung is included in a strategic area because it is a gateway and transit area between the islands of Sumatra and Java. And also, is one of 18 cities in Indonesia that is included as a Metropolitan City. Bandar Lampung City is located at 5°20'-5°30'LS and 105°28' - 105°37' east longitude. The total area of Bandar Lampung City is 197.22 square kilometres which are divided into 20 sub-districts and 126 urban villages.

The data used in this study were primary and secondary (Table 3-1). Field surveys are one way to gather primary data that will be utilized to validate the air temperature data with the processed Landsat 8 OLI/TIRS satellite imagery. The field survey was carried out by plotting sample points that were afterward visited directly. The sample points consist of 100 points spread throughout the research area. From 9:00 a.m. until 15:00 WIB, temperature measurements were made three times every five minutes at each sample point under normal conditions (no rain) using a digital instrument, namely the K-Thermometer. It is assumed that within six hours the temperature is peak temperature (Wibowo et al., 2020).

Normalized Difference Built-up Index (NDBI), Normalized Difference Vegetation Index (NDVI), and Land Surface Temperature (LST) data were obtained from Landsat 8 OLI/TIRS path 123 rows 64 data in 2021 with a cloud cover limit of 20%. Meanwhile, LCZ data was obtained from high-resolution satellite imagery from Maxar Technologies in July 2021 and downloaded using Google Earth Pro. The secondary data collected from this study are the city's administrative boundaries obtained from the RBI Map of Bandar Lampung City on a scale of 1:50,000 from the Geospatial Information Agency.

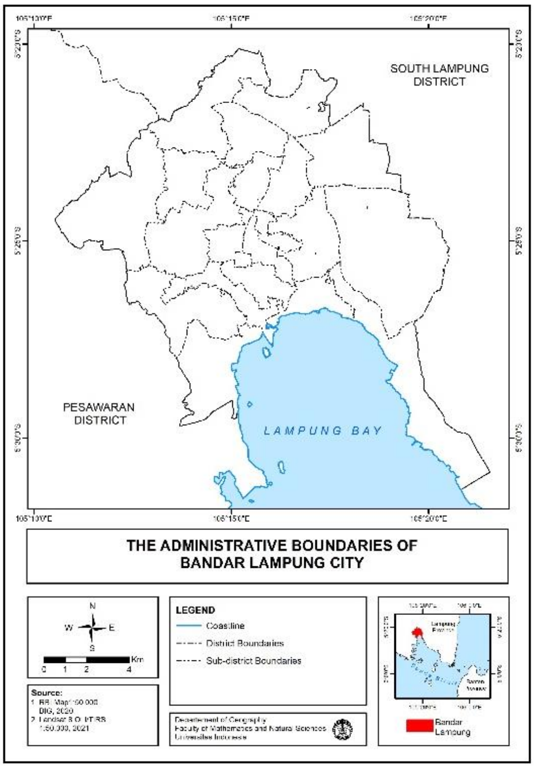

Figure 2-1: Bandar Lampung Administrations Map

Table 3-1. Type and Source of Data

Data	Data Type	Data Source
The boundary of Region Administration	Secondary	RBI Map Bandar Lampung City, 1: 50.000, Geospatial Information Agency.
Normalized Difference Vegetation Index (NDVI)	Primary	Landsat 8 OLI/TIRS imagery 1: 50.000 path 123 rows 64, 2021, USGS.
Normalized Difference Built-up Index (NDBI)		
Land Surface Temperature (LST)		
Local Climate Zone (LCZ)		Google Earth Imagery (July 2021)
Air Surface Temperature (AST)		Field Survey.

2.2 Methods

The calculation of the built-up land index (NDBI) uses band 6 (SWIR1) and band 5 (NIR) from Landsat 8 OLI/TIRS to produce an index of -1 to 1. The calculation process is carried out on ArcMap 10.7 software using the raster calculator tool with the following formula:

$$NDBI = \frac{SWIR1 - NIR}{SWIR1 + NIR}$$

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

Data processing to obtain land surface temperature using Google Earth Engine uses the 2021 Landsat 8 OLI/TIRS imagery which has a maximum cloud cover of 20%. It consists of three stages, including processing digital numbers into spectral radiance values, then converting them into temperature data in Kelvin units, and finally converting them into Celsius units.

Air Surface Temperature (AST) data processing is statistical processing, which is a simple linear regression test to validate and determine its relationship with LST. Before performing a linear regression test on LST and AST variables, it is necessary to test the classical assumptions first.

The LCZ data processing begins with the creation of a Region of Interest (ROI) through digitizing on Google Earth with imagery in July 2021. This study only identified 14 LCZ classifications with a total of ROI 157 polygons (Table 3-2). The next step is to submit to the portal WUDAPT LCZ Generator (https://lcz-generator.rub.de/ta_submission) to generate an LCZ map.

Table 3-2. Amount of ROI for LCZ

LCZ Classification	Amount of ROI (polygon)
Compact Highrise	0
Compact Midrise	10
Compact Low-rise	21
Open Highrise	0
Open Midrise	8
Open Low-rise	8
Lightweight Low-rise	21
Large Low-rise	0
Sparsely Built	3
Heavy Industry	7
Dense Tree	16
Scattered Tree	15
Bush, Scrub	9
Low Plants	11
Bare Rock or Paved	6
Bare Soil or Sand	13
Water	9
Total	**157**

The results of the LCZ map need an accuracy test, which consists of calculating the overall accuracy and Kappa HAT. The accuracy test is carried out automatically on the LCZ Generator by comparing the results of the Bandar Lampung City LCZ map with the existing conditions based on the data held by WUDAPT. The classification results are said to be good if the accuracy value is 80% compared to the existing field conditions (Anderson et al., 1976).

The analysis process in this study has three methods, including spatial, descriptive, and statistical analysis. The spatial analysis used is the method of overlapping to determine the characteristics and spatial patterns of LCZ. Descriptive analysis is used to explain the conditions of vegetation density, building density, and LST that are formed in Bandar Lampung City. Statistical analysis is needed to determine the level of representation and the relationship between LST as the independent variable and AST as the dependent variable. A regression test with a simple linear regression method was used to see the level and the relationship with the prerequisites that the AST and LST data met the classical assumption test, which are the normality test, heteroscedasticity test, and non-autocorrelation test.

3 RESULTS AND DISCUSSION

The building density index in Bandar Lampung City ranges from -0.69 to 0.48. The most dominating classification is medium building density with a percentage of 43.1%. While the classification with the smallest area is a low building density of 6.9%. The high building density is spread throughout the area and tends to be concentrated in the central and southern areas. Non-built areas can be assumed as vegetated areas in the West and Southeast, where the area is forest and hills with slopes >45% and an elevation of 100-500 meters above sea level so it is not suitable to be a built-up area.

Land use in non-building areas is forest, rice fields, and ponds. Areas of low building density and medium building density are settlements, public service facilities, and general trade. The difference is the width of the road. Almost the entire high-rise building density area is used for general trade.

Table 3-2. Building Density

Building Density	Area (Ha)	Percentage (%)
High	1.495	8,5
Medium	7.611	43,1
Low	1.203	6,9
Non-Building	7.208	41,5

Source: Data Processing

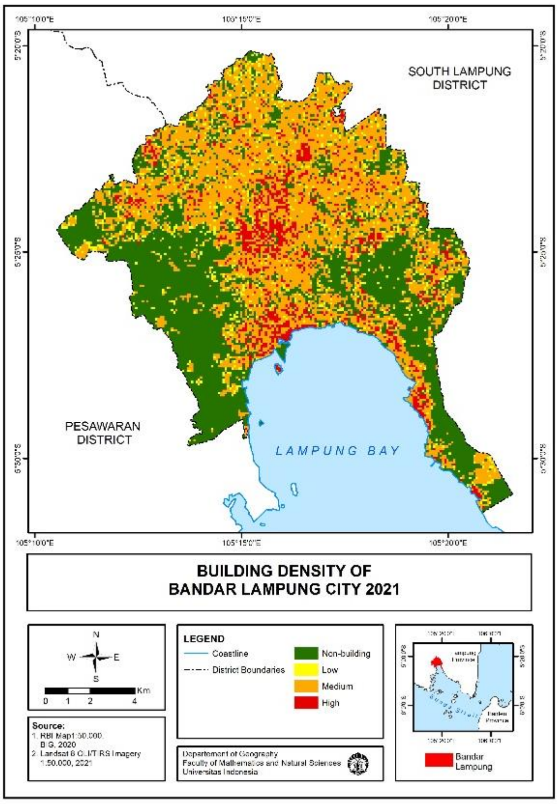

Figure 3-1: Building Density Map of Bandar Lampung

The vegetation density index in Bandar Lampung City ranges from -0.09 to 0.55. Areas of medium vegetation density are in the western and south-eastern areas of Bandar Lampung City which are represented by 4,576 grids or 12.5%. Then the area of low vegetation density tends to spread to all areas, represented by 4,862 grids or 14.8%. The non-vegetated area or it can be assumed as an area with built-up land is in the middle with a linear pattern from North to South, but in the centre of the city tends to be denser, the area is represented by 72.6%.

Land use in areas of low to medium vegetation density are forests covered with shrubs and large trees. While in non-vegetation, the land use is very diverse residential buildings, public trade, non-agricultural industry, government buildings, and public facilities.

Table 3-3. Vegetation Density

Vegetation Density	Area (Ha)	Percentage (%)
Non-vegetation	12.721	72,6
Low	2.601	14,8
Medium	2.195	12,5

Source: Data Processing

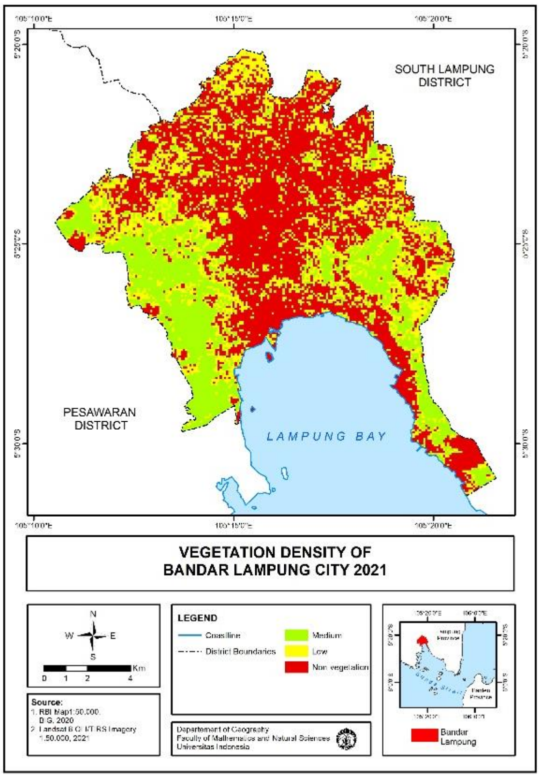

Figure 3-2: Vegetation Density Map of Bandar Lampung

The lowest LST value is in Bandar Lampung City at 15.68°C and the highest at 35°C. Thus, no area in Bandar Lampung was found to have an extremely high LST classification (LST value >35°C). The LST value is related to the vegetation and building density index values. High LST values are in areas with high building density and vice versa (directly proportional).

There are 405 grids, non-built areas with medium vegetation density, located in the western and south-eastern regions of Bandar Lampung and represent areas with very low LST. Low LST in the West and Southeast experience the same thing. With non-built land and medium to low vegetation density, 4,175 or 22.9 % of the land area is in low LST areas. The LST classification is then distributed throughout practically all of Bandar Lampung, with a total grid of 13,475 or 74.9 %, and is cantered in the city to the north, west, and east. High LST areas are areas with built-up land and medium and high building density.

The simple linear regression test was used to determine the strength of the relationship between the LST (Landsat 8 OLI/TIRS imagery) and AST (field survey). The result from this test is an equation Y = 0.6835x + 4.7981 with a correlation coefficient of 0.604 which belongs to the category of strong correlation. So, it is concluded that the LST data is quite representative of the actual conditions in the field.

Table 3-4. Land Surface Temperature

LST	Area (Ha)	Percentage (%)
Very Low	373	2,1
Low	4.003	22,9
Medium	13.122	74,9
High	19	0,1

Source: Data Processing

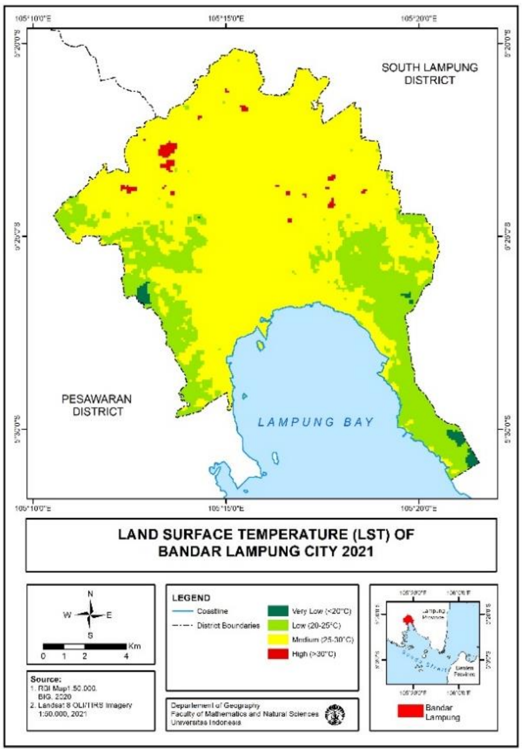

Figure 3-3: LST Map of Bandar Lampung

The overall accuracy value for the resulting LCZ map is 88.4% or has an error of 11.6%, where this value meets the requirements and can be said to be good because the accuracy value is 80%. When viewed from the Kappa HAT coefficient, the LCZ map has a Kappa HAT value of 0.82, which means the level of accuracy and interpretation is high.

Referring to the definition of the Local Climate Zone classification, it is known that the density of buildings and vegetation is closely related to the determination of the LCZ classification class. In particular, the building density for the building type and the vegetation density for the land cover type. Where the building type LCZ is divided into compact, open, and sparse zones. The compact zone is a zone with tight and not spaced building arrangements, the open zones is a zone with an open building structure and are spaced between buildings, while the sparse zone is a zone where the building structure is spread out and the distance between buildings is far apart.

Likewise, vegetation density influences the classification of the Local Climate Zone (LCZ), especially on the type of land cover. Where the distance and height of vegetation are divided into several classifications such as dense tree for tall vegetation that gathers in one area and scattered tree for medium-tall vegetation, but the pattern is scattered.

The results of data processing led to the identification of 14 of the 17 LCZ classifications in Bandar Lampung, which included 7 different types of buildings (compact midrise, compact low-rise, open midrise, open low-rise, large low-rise, sparsely built, and heavy industry) and 7 types of land cover (dense tree, scattered tree, bush/ scrub, bare paved, bare soil, low plants, and water). Meanwhile, the LCZ with the smallest area is the bare paved/rock LCZ, which only represents 10 grids or 0.06 % of the total area (Table 3-4).

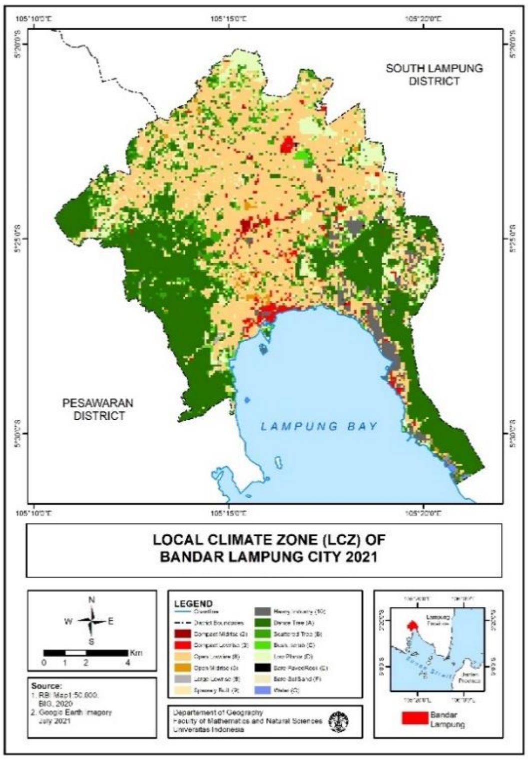

Figure 3-4: LCZ Map of Bandar Lampung

The LCZ compact midrise is characterized by buildings with dense construction, 3 to 5 floors high, made of concrete, brick, and glass, and with little vegetation and an asphalt-covered landscape. According to overlapping analysis, compact midrise has a high to medium building density, LST ranges from 25 to 30° C., and general trade is the dominant land use. The low-rise compact LCZ which has nearly identical characteristics to the midrise compact (different levels of building height) shares the same height and building density.

The characteristics of the open midrise zone or half-height building with an open layout are low to medium building density, low vegetation density, and medium LST. This LCZ is dominated by public service facilities and housing. Furthermore, open low-rise LCZ has characteristics that are almost similar to open midrise, but land use is more dominated by villages and housing.

LCZ's large low-rise is the smallest zone identified in Bandar Lampung for the type of building. The characteristics of this zone are medium building density, low to medium vegetation density and LST ranges from 25 - 30°C. The same characteristics were also identified in the sparsely built LCZ, where the only difference was the land use. The last type of LCZ building is a heavy industry that has medium to high building density, low vegetation, and non-vegetation density, and medium to low LST. The heavy industry zone tends to cluster in the southern part of Bandar Lampung City which is classified as a non-agricultural industrial area.

The LCZ dense tree has the characteristics of medium vegetation density, non-building, and low to very low LST. LCZ's dense tree is abundant in forests and some urban parks. Furthermore, the characteristics of an LCZ scattered tree are almost the same as a dense tree, but the difference is in the type and pattern of vegetation distribution. The scattered tree features random and spreading patterns, as well as a distance between vegetation and smaller vegetation types.

The LCZ bush or scrub is a zone with the least amount of vegetation cover in Bandar Lampung compared to other vegetation land cover zones. The characteristics of this zone are non-built with low to moderate vegetation and LST density. In contrast to the low plants' zone which is dominated by agriculture (rice fields) and city parks with natural grass, the scrub is dominated by urban parks and a little forest on the land use of LCZ bush. The low plants' zone has the same characteristics as the LCZ bush that is the scrub.

The bare paved or rock LCZ is an asphalt-covered zone with asphalt with no or little vegetation around it. Even though it is open land, the LST in this zone is in the range of 25-30°C. It is influenced by asphalt or paving, which can absorb more sunlight. The next open land zone is LCZ bare soil or sand, but the characteristics are different where bare soil or sand has a lower LST due to the higher vegetation density of this zone than bare paved or rock LCZ.

The LCZ water is a zone with a land cover of water bodies with various land uses, such as lakes, reservoirs, fishponds, and pools. Generally, there is vegetation in the form of grass or trees around the water zone, so the vegetation density in this zone is moderate, affecting the LST, which is characterized as low to moderate LST.

Table 3-5. Local Climate Zone in Bandar Lampung City

LCZ Classification	Area (Ha)	Percentage (%)
Compact midrise (2)	54,5	0.31
Compact low-rise (3)	415,3	2.37
Open midrise (5)	223,2	1.27
Open low-rise (6)	6.965,7	39.76
Large low-rise (8)	38,4	0.22
Sparsely built (9)	917,5	5.24
Heavy Industry (10)	764,4	4.36
Dense Tree (A)	5.323,4	30.39
Scattered Tree (B)	1.187,2	6.78
Bush, scrub (C)	349,4	1.99
Low plants (D)	1027,2	5.86
Bare paved, rock (E)	9,8	0.06
Bare soil, sand (F)	187,2	1.07
Water (G)	54	0.31

Source: Data Processing

However, if examined based on the LST value, an anomaly was found, which is the open low-rise zone in the west of Bandar Lampung has the characteristics of an open structure and lots of vegetation but has a high LST (30-35°C). This can happen because the zone is assumed to be a residential area with a high intensity of human activity and is also supported by many buildings with asbestos roofs which have more heat-absorbing characteristics than clay roofs.

The spatial pattern of the LCZ when viewed based on the road pattern (arterial roads, collector roads, local roads, and neighborhood roads), the building classification LCZ is closer to the arterial and collector roads, while the vegetation type LCZ is closer to the neighborhood road. The road density in the building LCZ is also higher than in the land cover type LCZ. Then from the morphological elements of building types (open, closed, and non-building) there are also similar characteristics, such as LCZ compact midrise and compact low-rise are in the closed type building, LCZ open midrise and open low-rise are in the open type building. and LCZ dense trees, scattered trees, bush/scrub, and low plants are in the non-built land type.

Table 3-6. Characteristics of LCZ in Bandar Lampung

LCZ Classification	Land Surface Temperature	Vegetation Density	Building Density	Imagery
Compact Midrise (2)	Medium	Non-Vegetation	High	
Compact Low-rise (3)	Medium	Non-Vegetation	High	
Open Midrise (5)	Medium	Low	Medium	
Open Low-rise (6)	High	Low	Medium	
Large Low-rise (8)	Medium	Non-Vegetation	Medium	
Sparsely Built (9)	Low	Low	Low	
Heavy Industry (10)	Medium	Non-Vegetation	Medium	
Scattered Tree (B)	Low	Medium	Non-Building	

				
Bush, scrub (C)	Medium	Medium	Low	
Low Plants (D)	Medium	Medium	Non-Building	
Bare Paved or Rock (E)	Medium	Non-Vegetation	Non-Building	
Bare Soil or Sand (F)	Medium	Low	Low	
Water (G)	Medium	Medium	Non-Building	

4 CONCLUSIONS

The city of Bandar Lampung is characterized by built-up land with medium density located in the city center or at an elevation of <7 to 500 meters above sea level. However, the western and eastern parts are dominated by low to medium-density vegetation or at an elevation of 100-500 meters above sea level with slopes of 15-45%. This also affects LST, the highest LST reported in residential areas at 35°C, and the lowest LST is at 15.68°C in forest areas.

The Local Climate Zone (LCZ) in Bandar Lampung has 14 classifications. The highest building density is in the low-rise compact LCZ in the Northeast with residential land use. The maximum vegetation density is in the LCZ dense tree with forest land use. The highest LST was discovered in the open low-rise zone with residential land use with relatively high human intensity.

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