ISSN 2354-9114 (online), ISSN 0024-9521 (print)
Indonesian Journal of Geography Vol 54, No 2 (2022): 280—289
DOI: 10.22146/ijg.73460 website: https://jurnal.ugm.ac.id/ijg


INDONESIAN JOURNAL OF GEOGRAPHY

RESEARCH ARTICLE

# 30-Year Spatial-Temporal Analysis of Air Surface Temperature as Climate Change Mitigation

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**Received:** 2022-03-13
**Accepted:** 2022-08-03

**Keywords:**
land cover change;
land surface temperature;
air surface temperature;
model spatial;
mitigate of climate change

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**Abstract.** Natural and anthropogenic factors, such as volcanic eruptions and land use, are indirect causes of changes in the micro-scale climate. Over the past 30 years, climate change has been detected with increased air surface temperature (AST) above 30.0$^0$C, a phenomenon of Urban Heat Island. Therefore, this study aimed to create a spatial model to see changes in AST in Bandar Lampung City from1990 to 2020. The spatial and temporal analysis uses Landsat data to produce land surface temperature (LST) and AST models. The results showed a temperature rise in the LST area, which tends to be the northern part of Bandar Lampung City, by 25.0$^o$C and above for 30 years. Compare LST and AST from two stations between 30 years is 5.0$^0$C. In 1990, the LST concentrated on the spatial distribution of the AST model with a temperature above 30.0$^0$C, while in 2020, it diffused to the northern part of Bandar Lampung City. The results concluded that the air temperature in the city has warmed up to 0.46$^O$C (+1$^0$C), which is in line with the findings of IPPC and various world cities. It is also in occurrence with the UHI phenomenon since 2014 that climate change is part of climate change mitigation.



## 1. Introduction

Changes in surface coverage and landscape patterns caused by rapid urbanization increase land Surface Temperature (LST). Land-cover change is one of the most visible outcomes of ecosystem modification, which significantly impacts the local, regional, and global environment (Xiao & Weng, 2007). According to Dong et al. (2013), changes in land cover impact two aspects, natural variations of the earth system and human activities. It is caused by human activities such as converting vacant and vegetated lands into impermeable areas comprising buildings of varying heights and densities (Adulkongkaew et al., 2020; Wang et al., 2020). Preliminary studies stated higher temperatures in the central urban location and non-vegetated areas (Oke, 1987; Streutker, 2002; Dorigon & Amorim, 2019). According, previous study stated that Land cover change will impact higher temperatures in non-vegetated areas.

The Fifth Assessment Report released by the UN Intergovernmental Panel on Climate Change (IPCC) indicated an increase in global mean temperature by 1-2$^0$C at the end of this century (Wibowo & Salleh, 2018). The report further confirmed that 2016 was the warmest year on record, with a global mean temperature of 1.1$^0$C above the pre-industrial period, which was 0.06$^0$C higher than the previous record set in 2015 (WMO, 2017). Over the past few decades, climatic elements such as temperature and precipitation have recorded significant changes (Mukhtar et al., 2021). Samson and Olorunnimbe (2011) stated that climate change poses increasing challenges for cities, placing tremendous stress and impacts on multiple social and biophysical systems, including urban infrastructure, water, and energy demand. Impacts of climate change have been widely discussed, with only a few kinds of study revealing its effect on temperature (Harmantyo, 2008). Based on previous study stated that climate changed with indication as increased temperature between 1-2$^0$C caused impact on environrmnrt and effect on human.

The variation of activities dynamically changes land cover, creating variations in LST with the highest increase in developing areas. The LST impacts the thermal comfort of human activity, specifically when it reaches more than 30$^0$C in tropical climates (Ichinose et al., 2008; Srivanit and Hokao, 2013, Wibowo et al., 2017). The land cover changes were primarily observed in developed areas with temperatures above 30$^0$C, such as Seoul (Kim and Baik 2005), Singapore (Wong and Yu 2005), Tokyo (Suzuki 2008), Wuhan (Li and Yu 2008), and Hong Kong (Memon et al. 2009), Jakarta, Bandung, Semarang, and Surabaya (Tursilowati et al. 2012). Changes to land cover led to extreme temperature and precipitation index trends in Padang (Hermon, 2014). The increase in LST is an indication of the UHI phenomenon, which has occurred in several major cities in Indonesia, such as Bandung (Ningrum & Narulita, 2018), Surabaya (Sobirin & Fatimah, 2015), Tangerang (Wibowo et al., 2016), and Jakarta (Fitriani et al., 2019). Therefore, the UHI phenomenon regarding LST and Air Surface Temperature (AST) was generally influenced by anthropogenic factors, such as human activities (Fabrizy et al., 2010; Priyankara et al., 2019) and the development of urban areas due to overcrowding (Wibowo et al., 2020; Zhang et al., 2018).

Bathiany et al. (2018) used 30-year data to detect climate change by examining the monthly temperature anomalies, where each value represents the deviation associated with global warming. Meanwhile, Olsson et al. (2015) conducted study to reveal the underlying change in patterns, using a period above 30 years. The Climatological Practice Guide (WMO, 2018), Technical Regulations (WMO, 2011), and a book on CLIMAT TEMP reporting (WMO, 2009) recommend a 30-year reference period of available data standardized to detect the typical climate change. The Seventeenth World Meteorological Congress (WMO, 2017) defined a climatological standard using the last 30-year period divided into 10 years each (Nazarudin, 2021). For example, Makassar City, studied from 1972 to 2002, had a positive trendline with an average increase in temperature at 0.018$^0$C/year and 0.082$^0$C/year every January and June (Aldrian et al., 2011). Furthermore, in South Sumatra Province, the temperature increase was between 0.4 to 0.6$^0$C, while at Malang Raya, its range was 0.7 to 0.8$^0$C (Ruminta et al., 2018). The remaining sections of this study detected climate change using a 30-year timeframe.

The limitation of the temperature study regarding spatial and temporal data is due to the distribution of the Landsat thermal band with only one-time departure data. Berg and Kucharik (2021) studied the relationship between temperature using AST and LST and found that LST fit with a parabolic (R2) distribution of 0,7. Wibowo et al. (2017) examined the relationship between LST and AST using RMSE and obtained a minor error. The results stated that LST from satellite thermal can be used to compete with AST. Fauzan et al. (2022) used LST to estimate the spatial cover of Landsat data to answer the limitation of the spatial distribution climate station.

Climate change terms globally and local area or Local Climate Zone as spatial urban area or city. This was carried out to determine climate change in Bandar Lampung City, located on Sumatera and near Java Island. It is the fifth most populous city on Sumatra Island after Medan, Palembang, Pekanbaru, and Batam, which comprises 2,279,894, 1,662,893, 1,149,359, and 1,107,551 people, respectively. The city is a strategic area because it is a transit of economic activities between Sumatra and Java Islands, making it profitable as a center of trade industry and tourism (BPS Bandar Lampung City, 2020). The study on climate change due to mitigation were conducted globally, but there are still limitations in its empirical and modeling temperature with remote sensing. The 30 years study is significant for determining the characteristics and behavior of AST and the impact of solar heating on the land surface.

## 2. Methods

### Study Area

Bandar Lampung City is the capital of Lampung Province (Figure 1) and the center of social, political, educational, cultural, and economic activities. It is located strategically

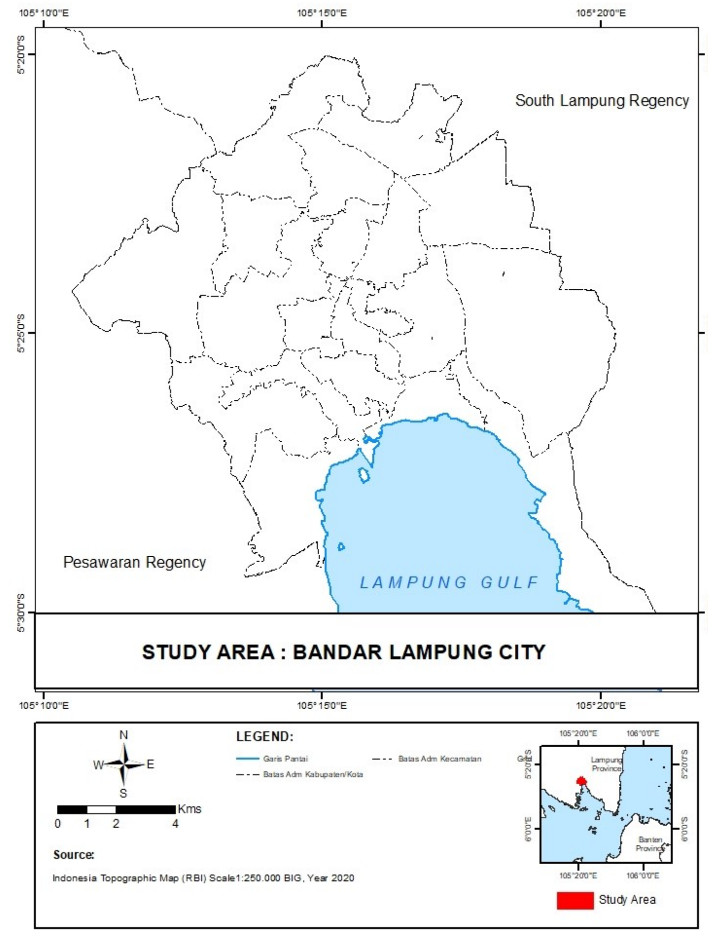


Figure 1. Study Area

because it is a transit route for economic activities between the islands of Sumatra and Java, making it profitable for the growth and development of trade, industry, and tourism. This city's Spatial Planning Regulation (RTRW) from 2011 to 2030 explained that the existing potential and development trends were due to its strategic location, natural potential, population, and supporting areas. The city can be developed as a growth center for Southern Sumatra and a national production commodity (sippa.ciptakarya.pu.go.id). This condition led to a population increase of 1.71% from 2018 to 2019 (BPS Bandar Lampung City, 2020).

## Method

This study used Landsat 5, 7, and 8 to collect this temporal chosen time with the lowes cloud covered. AST from Station Indonesian Agency for Meteorological, Climatological, and Geophysics. Google Earth Data and AST from the field survey is shown in Table 1. Geographic Information System (GIS) used tools from NDVI (Normalized Difference Vegetation Index) and LST. NDVI determined the vegetation density classification based on remote sensing data, NIR is the Near Infrared band, and R is the Red band.

The following is the formula for NDVI, the proportion of vegetation:

$$NDVI = (NIR - R)/(NIR + R) \qquad (1)$$

LST analysis was used to determine the classification of LST based on remote sensing data and interpreted to obtain temperature differences. The digital numbers (DN) value is converted to spectral radians using the following Equation (2), where M_L represents the band-specific multiplicative rescaling factor, Q_cal is the Band 10 image, and A_L is the band-specific additive rescaling factor:

$$L\lambda = M\_L * Q\_cal + A\_L \qquad (2)$$

After converting the DN to reflection, the TIRS band data is changed from spectral radiance to brightness temperature (BT) using the thermal constants provided in the metadata file:

$$BT = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda}+1\right)} - 273.15 \qquad (3)$$

K_1 and K_2 stand for the band-specific thermal conversion constants from the metadata using the Google Earth Engine application (GEE apps).

The Air Surface Temperature Model (M-AST) used a simple linear regression to obtain LST from the image processing and AST from field survey measurements. The simple linear regression formula is determined using the following Equation: = (4), where Y and X are the dependent and independent variables, a is constant (value of Y when X = 0), and b is the regression coefficient (positive or negative effect). The M-AST map is then developed using the ArcGIS 10.3 raster calculator model before testing the M-AST for accuracy. The Root Mean Square Error (RMSE) method is a statistical calculation used in study to test the accuracy of the data between the M-AST value and AST. The air temperature for 30 years is compared with Urban Heat Island phenomena in Bandar Lampung City to determine climate change.

## 3. Results and Discussion

### Spatial-Temporal Vegetation Coverage

Figure 1 shows the distribution of spatial-temporal vegetation with none, low, moderate, and high coverage from 1990 to 2020. The vegetation-covered categories are deficient, while the non-vegetation is increasingly widespread. Furthermore, from 1990 to 2020, the vegetation cover area with moderate and high coverage decreased. Figure 2 explains the increasing trend of land cover with no vegetation in the northern part of Bandar Lampung City. In the north-South cross-section, the coverage decreased to the north with the index value less than 0.3 in 2020, compared to 1990, which was mostly 0.4, as illustrated in Figure 3.

From 1990 to 2020, shallow and no vegetation density became widespread. On the other hand, those in the moderate and high coverage decreased in 2020. Table 2 shows that Bandar Lampung City had moderate vegetation density with the most expansive height in 1990, compared to 2005 and 2020. Approximately 53.63% of the city in 1990 consisted of medium to high-density vegetation, while in 2005, it reduced to 42.41%. Conversely, in 2020 the area with moderate to high vegetation density decreased by 35.03%. In 2020, moderate vegetation was the lowest with 2,518.37 ha, followed by the broadest non-rotating land of 2,072.35 Ha compared to 1990 and 2005.

The result showed that the landcover change during 30 years period increased without vegetation coverage or building and reduced from 33.54% in 1990 to 14.03% in 2020. This is in accordance with the preliminary studies by

Table 1. Data Used

| Data | | | |
|---|---|---|---|
| | Landsat 5 (1990) | Landsat 7 (2005) | Landsat 8 (2020) |
| Landsat | 14 June | 11 March | 03 August |
| *Path* 123 dan *Row* 64 | 16 July | 06 November | 06 October |
| | 07 December | 08 December | 25 December |
| Administration Map | Indonesian Agency of Geospatial Data | | |
| Air Surface Temperature | Data Acquisition (Field survey) | | |
| Air Surface Temperature | Meteorology Station | Climatology Station | |
| | Raden Inten II (30 years) | Pesawaran (25 years) | |
| | Indonesian Agency for Meteorological, Climatological and Geophysics | | |
| Land Cover Existing | Survey and Google Earth Data | | |

Sources: Data Collecting

Xiao & Weng (2007), Dong et al. (2013), Adulkongkaew et al. (2020), and Wang et al. (2020). In 2003, Jakarta City had a vegetation coverage of 30%, which is a 70% decrease from its value in 1940, due to the impact on temperature rise to 32.00$^0$C (Wibowo, 2005). The land cover changed in the city, hence, it will impact higher temperatures in non-vegetated areas.

### Spatial-Temporal Land Surface Temperature

In 1990, 2005, and 2020, LST >25.0$^0$C expanded further northwards, as shown in Figure 4. LST tended to be distributed from the centre to the southern and northern city of Bandar Lampung at a temperature >25.0$^0$C in 1990 and 2005, as indicated in Figure 4. In North and south transverse cross-sections from 1990 to 2020, the changes generally increase towards the north (Figure 5). Figure 5 further showed that the profile cross-section of the southern part of City (A) did not experience a significant increase in LST, as opposed to City (B), at a temperature of 27.2$^0$C.

The period 1990-2020 explained that LST increased and decreased at temperatures >25.0$^0$C and <20$^0$C, respectively. In 1990, 65.29% or 11,723.92 ha of Bandar Lampung City had LST with temperature <25.00C, where at >25.0$^0$C, it covered 6.76% or 1,214.53 ha. Furthermore, the value

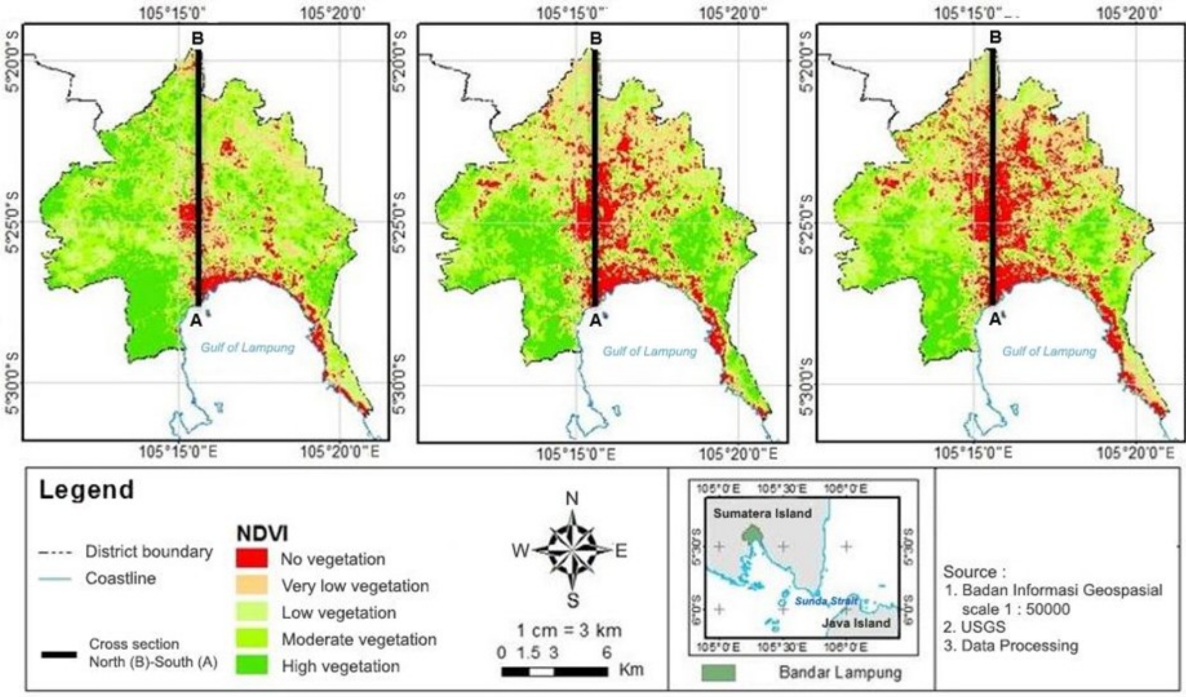


Figure 2. Map of Vegetation Coverage 1990-2005-2020 at Bandar Lampung City

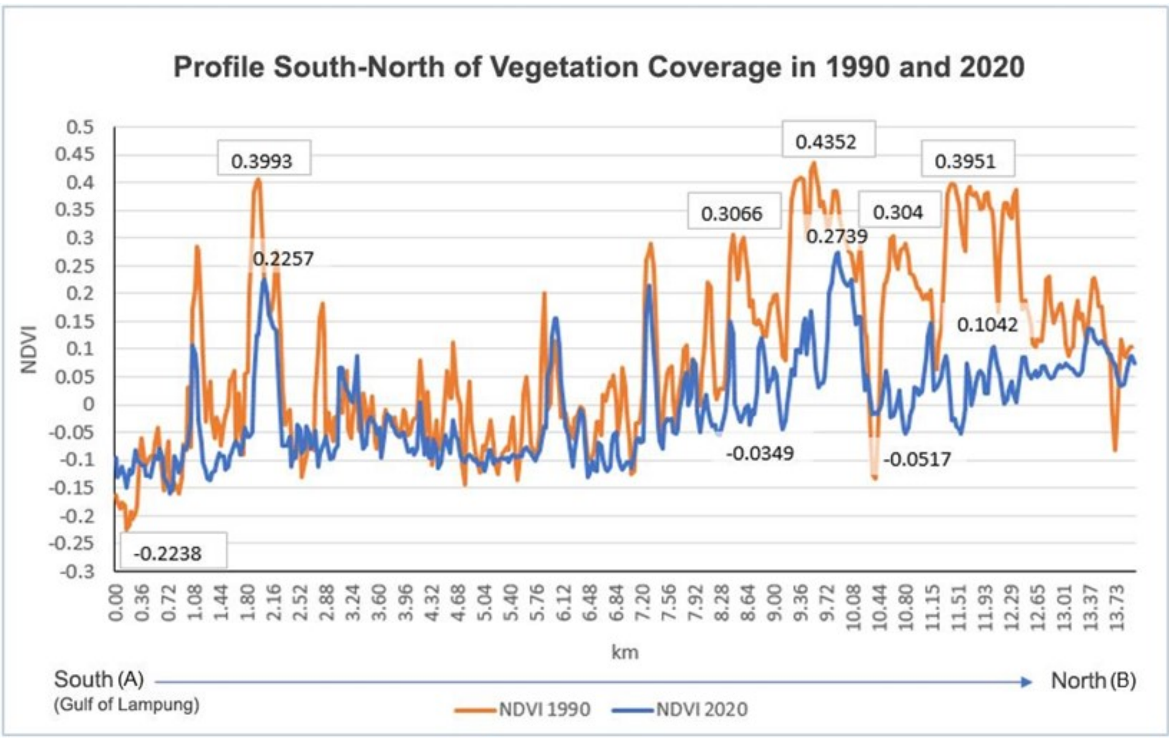


Figure 3. Profile South-Nort of Vegetation Coverage in 1990 and 2020

increased by 45.26% between 2005 and 2020, as illustrated in Table 3.

The result showed that the landcover changed (30 years) from 6.76% in 1990 to 45.26% in 2020 with a temperature >25.0$^0$C. The result is similar to the previous study that land cover changed impact on increasing a higher temperature as temporal and extension of the covered area. The studies by Oke (1987), Streutker (2002), and Dorigon & Amorim (2019) defined the higher temperatures of the central urban area. Studies in Indonesia, Jakarta (Wibowo, A. 2005), Makassar City (Aldrian et al., 2011), Sumatera Selatan Province and Malang Raya (Ruminta et al., 2018) concluded that there was an increased temperature for 30 years due to decreased vegetated area. LST will affect environments, specifically AST, regarding each urban heat signature of land cover types.

### Spatial-Temporal of Model Air Surface Temperature

The station climatology or meteorology has few locations and a minimal area to cover one of the stats. This study uses AST distribution in a simple model of AST generated from LST to validate the distribution of AST in Bandar Lampung City based on two station observation points, namely Radin Inten II and Lampung Climatology. Due to the lack of sample points where only two temperature observation points were used in this study, the difference between LST and AST was considered the same in all points of the Lampung region in the same year.

Table 4 explains calculations performed to determine the average difference between LST data and AST from Raden Inten II and Pesawaran, which act as Meteorology and Climatology Stations. The result showed that the average delta change between 1990 and 2020 was 5.02$^0$C and 4.54$^0$C. The LST is the average maximum temperature of three years in 1990, 2005, and 2020, estimated with AST model M-AST.

The average delta temperature added to LST using the mathematical model of M-AST 0C= LST 0C+ 5.0$^0$C was based on Fauzan et al. (2021). Table 5 shows the ground and AST, with a difference of approximately 0.3$^0$C. The RMSE test was carried out on the M-AST in 2020 to determine the accuracy and correctness of the modeling data from field measurements. The trendline results were calculated with y = 0.057x-1.0719, where R2 equals 0.1036 obtained an error r of 0.05 in the model of air surface. This means that the most significant possible deviation value is 0.05 from LST to AST in the field, as shown in Figure 5.

Figure 6 explains that in 1990, very few areas with temperatures above 30.00C were south of Bandar Lampung City. However, its development in 2005 with a temperature >30.0$^0$C continued expanding to the north until 2020. Based on Table 6, the area Model of AST with temperature <25.0$^0$C declined in 1990 and increased to>30.0$^0$C. Result of a model of AST with temperature <25.0$^0$C is 1,960.98 ha or 10.91% in 2020 and 6,282.21 ha or 34.93% in 1990. Table 7 showed

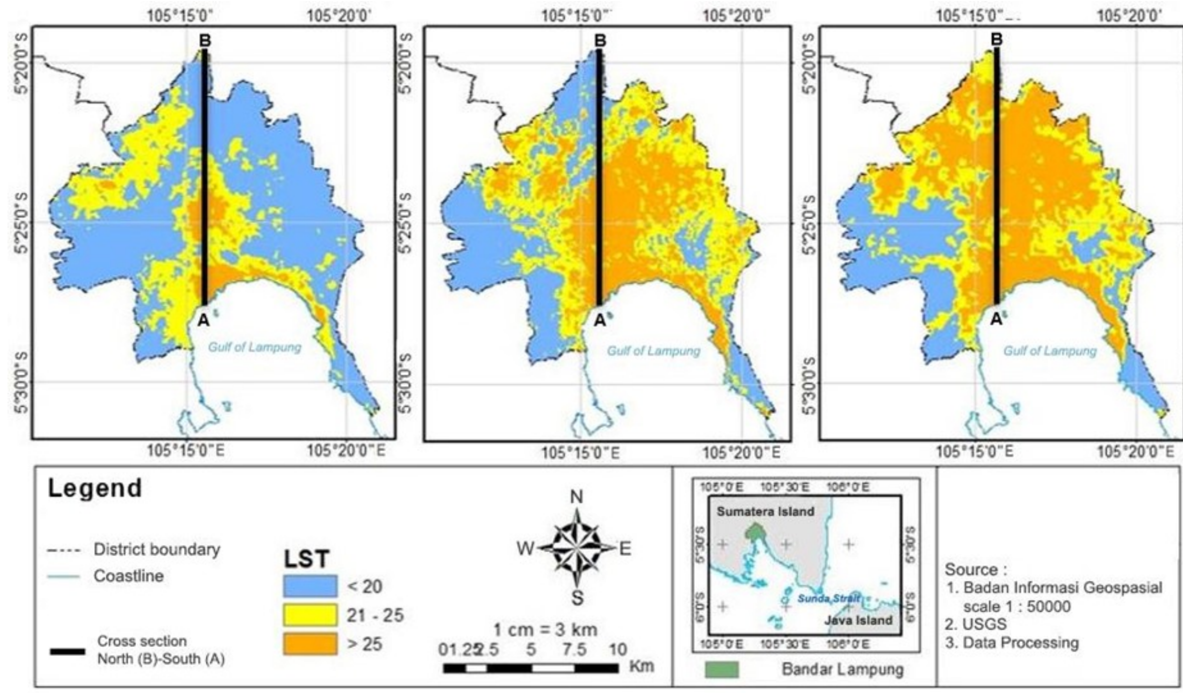


Figure 4. Map of Land Surface Temperature 1990 and 2020 at Bandar Lampung City

Table 2. Area of Vegetation Coverage in Bandar Lampung City years 1990, 2005 and 2020

| Vegetation density | 1990 | | 2005 | | 2020 | |
|---|---|---|---|---|---|---|
| | Area (Ha) | (%) | Area (Ha) | (%) | Area (Ha) | (%) |
| no vegetation | 1,246.25 | 6.94 | 2,592.53 | 14.44 | 3,318.60 | 18.49 |
| Very Low Vegetation | 2,561.16 | 14.27 | 3,575.05 | 19.92 | 4,263.30 | 23.75 |
| Low Vegetation | 4,514.74 | 25.15 | 4,168.98 | 23.23 | 4,079.47 | 22.73 |
| Moderate Vegetation | 5,401.37 | 30.09 | 4,056.75 | 22.60 | 3,769.54 | 21.00 |
| High Vegetation | 4,226.06 | 23.54 | 3,554,.1 | 19.81 | 2,518.37 | 14.03 |

Sources: Data Processing, 2021

Table 3. Temporal changed Land Surface Temperature in Bandar Lampung City

| LST ($^0$C) | Area | Area | Area | Area | Area | Area |
|---|---|---|---|---|---|---|
| LST ($^0$C) | 1990 | 1990 | 2005 | 2005 | 2020 | 2020 |
| LST ($^0$C) | Ha | % | Ha | % | Ha | % |
| <20.0 | 11,731.65 | 65.25 | 6,289.40 | 34.98 | 4,900.95 | 27.26 |
| 20.0-25.0 | 5,024.99 | 27.95 | 5,939.00 | 33.04 | 4,942.79 | 27.49 |
| >25.0 | 1,222.26 | 6.8 | 5,750.50 | 31.98 | 8,135.16 | 45.25 |

Source: Data Processing, 2021

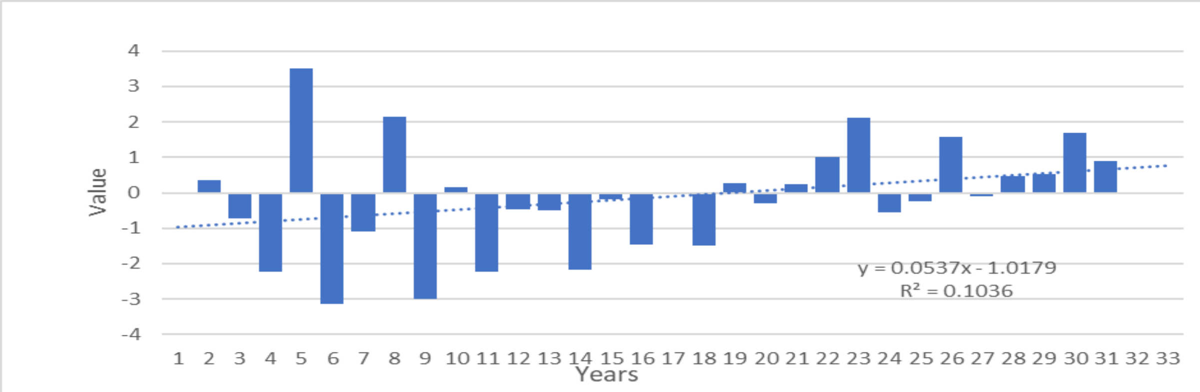


Figure 5. Trendline Value 30 years Model AST validated with AST Radin Inten 2

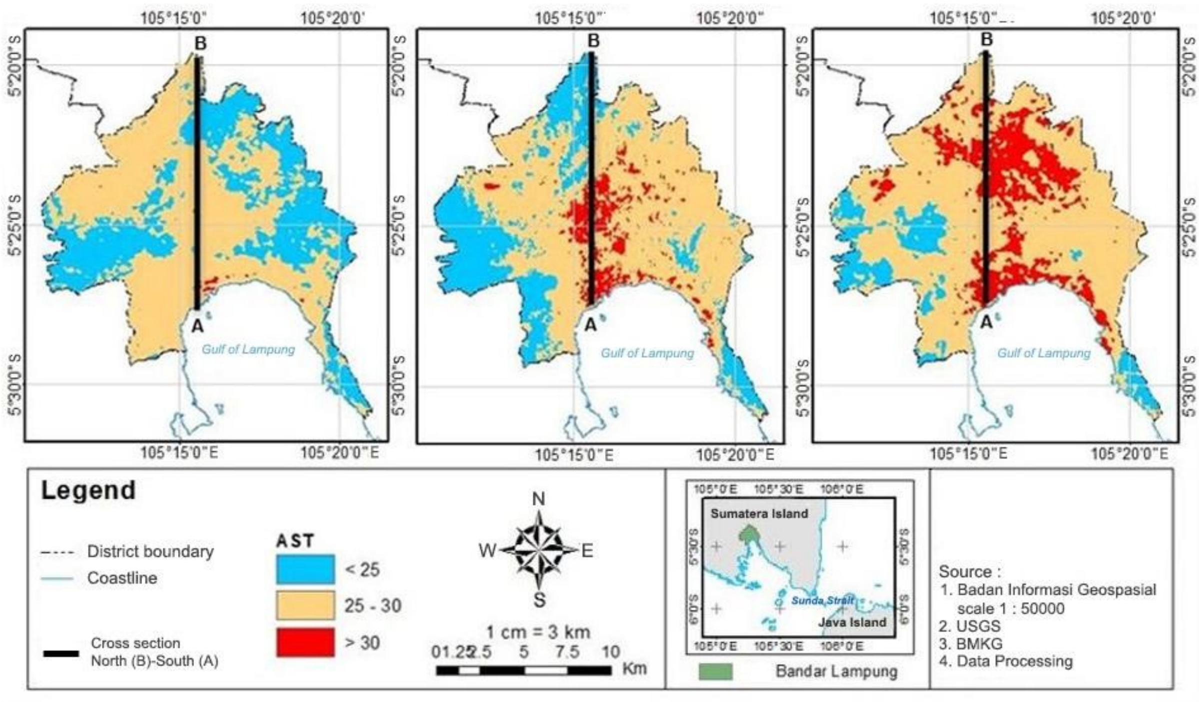


Figure 6. Map the Distribution Model of AST in 1990, 2005 and 2020

that AST area with temperature <25.0$^0$C decreased by 4,319.43 ha or 24.02% from 1990 to 2020. MAST with temperature >30$^0$C from 1990 has 1,281.91 ha or 7.13%, which expanded in 2020 to 3,245.08 ha or 18.05%. This means that for 30 years, only a temperature range of 1 to 5$^0$C was added.

### Mitigation of Climate Changed based on 30 years Spatial-Temporal of Urban Heat Island

The study analyzed the changes in temperature from 1990 to 2020 to determine their effect on global warming from previous studies conducted by WM0 (2011), Olson et al. (2015), and Bathiany et al. (2018). It also examined climatology for 10 years based on Nazarudin's (2021) analysis. This study regarding mitigation of climate change in urban areas or city morphology referred to the global temperature that experienced a positive trend of 0.85$^0$C from 1880 to 2012, and 0.05$^0$C per decade from 1998 to 2012 (IPCC AR5, 2014). The result showed that climate change in Bandar Lampung City from the perspective of air temperature was due to a rise of 0.47$^0$C, thereby leading to a positive trend of Urban Heat Island AST at a warming rate of 0.23$^o$C from 1990 to 2020. Based on the AST models in

Table 4. Delta Comparative between AST dan LST from 1990 until 2020

| Year | Meteorology Station Radin Inten II | Meteorology Station Radin Inten II | Delta 1 | Climatology Station Pesawaran | Climatology Station Pesawaran | Delta 2 ($^0C$) | Delta Avg. ($^0C$) |
|---|---|---|---|---|---|---|---|
| Year | AST ($^0C$) | LST($^0C$) | Delta 1 | AST ($^0C$) | LST ($^0C$) | | |
| 1990 | 26.31 | 21.29 | 5.02 | | 20.90 | | 4.80 |
| 1991 | 26.30 | 21.69 | 4.61 | | 22.51 | | 4.61 |
| 1992 | 26.22 | 20.51 | 5.72 | | 20.09 | | 5.72 |
| 1993 | 26.86 | 19.62 | 7.25 | | 21.02 | | 7.25 |
| 1994 | 26.74 | 25.24 | 1.50 | | 24.98 | | 1.50 |
| 1995 | 26.42 | 18.27 | 8.15 | | 17.85 | | 8.15 |
| 1996 | 26.37 | 20.45 | 5.92 | 26.55 | 21.07 | 5.48 | 5.70 |
| 1997 | 26.72 | 24.02 | 2.70 | 26.87 | 24.25 | 2.62 | 2.66 |
| 1998 | 26.95 | 18.92 | 8.03 | 26.91 | 19.39 | 7.52 | 7.78 |
| 1999 | 26.28 | 21.36 | 4.92 | 26.21 | 20.82 | 5.39 | 5,.5 |
| 2000 | 26.49 | 19.15 | 7.34 | 26.38 | 20.57 | 5.81 | 6.58 |
| 2001 | 26.50 | 21.13 | 5.37 | 26.59 | 19.79 | 6.80 | 6.08 |
| 2002 | 26.97 | 21.38 | 5.60 | 26.88 | 22.32 | 4.56 | 5.08 |
| 2003 | 26.60 | 19.53 | 7.07 | 26.70 | 20.50 | 6.20 | 6.64 |
| 2004 | 26.65 | 21.70 | 4.95 | 26.88 | 21.62 | 5.27 | 5.11 |
| 2005 | 26.61 | 21.40 | 5.21 | 26.86 | 21.09 | 5.76 | 4.78 |
| 2006 | 26.50 | 21.76 | 4.74 | 26.79 | 21.27 | 5.52 | 5.13 |
| 2007 | 26.67 | 20.34 | 6.33 | 26.82 | 22.13 | 4,69 | 5.51 |
| 2008 | 26.38 | 21.66 | 4.72 | 26.38 | 19.46 | 6.92 | 5.82 |
| 2009 | 26.76 | 21.62 | 5.14 | 26.92 | 22.23 | 4.69 | 4.91 |
| 2010 | 26.69 | 21.98 | 4.71 | 26.74 | 21.48 | 5.26 | 4.99 |
| 2011 | 26.80 | 22.87 | 3.93 | 26.87 | 22.85 | 4.01 | 3.97 |
| 2012 | 26.83 | 23.00 | 3.83 | 26.99 | 22.06 | 4.93 | 4.38 |
| 2013 | 26.68 | 20.47 | 6.20 | 26.93 | 21.54 | 5.39 | 5.80 |
| 2014 | 27.09 | 20.91 | 6.18 | 26.72 | 20.07 | 6.65 | 6.42 |
| 2015 | 27.29 | 23.82 | 3.47 | 27.03 | 23.13 | 3.90 | 3.69 |
| 2016 | 27.18 | 22.11 | 5.08 | 27.13 | 20.69 | 6.44 | 5.76 |
| 2017 | 26.91 | 22.28 | 4.63 | 26.79 | 20.34 | 6.45 | 5.54 |
| 2018 | 26.86 | 22.34 | 4.52 | 26.80 | 23.31 | 3.49 | 4.00 |
| 2019 | 27.22 | 23.95 | 3.28 | 27.26 | 23.37 | 3.89 | 3.59 |
| 2020 | 26.98 | 22.94 | 4.04 | 27.04 | 22.00 | 5.04 | 4.54 |

Average of Delta Avg. 5.00

(Source: Data Analysis, 2021)

Table 5. Validation model AST with AST from di Station Climatology and Meteorology

| Year | LST ($^0$C) | Average ($^0$C) | M-AST ($^0$C) | AST ($^0$C) | Validated Model-AST |
|---|---|---|---|---|---|
| 1990 | 21.29 | 5.00 | 26.29 | 26.31 | -0.02 |
| 1991 | 21.69 | 5.00 | 26.69 | 26.30 | 0.36 |
| 1992 | 20.51 | 5.00 | 25.51 | 26.22 | -0.72 |
| 1993 | 19.62 | 5.00 | 24.62 | 26.86 | -2.24 |
| 1994 | 25.24 | 5.00 | 30.24 | 26.74 | 3.50 |
| 1995 | 18.27 | 5.00 | 23.27 | 26.42 | -3.15 |
| 1996 | 20.45 | 5.00 | 25.45 | 26.55 | -1.10 |
| 1997 | 24.02 | 5.00 | 29.02 | 26.87 | 2.15 |
| 1998 | 18.92 | 5.00 | 23.92 | 26.91 | -2.99 |
| 1999 | 21.36 | 5.00 | 26.36 | 26.21 | 0.15 |
| 2000 | 19.15 | 5.00 | 24.15 | 26.38 | -2.23 |
| 2001 | 21.13 | 5.00 | 26.13 | 26.59 | -0.46 |
| 2002 | 21.38 | 5.00 | 26.38 | 26.88 | -0.50 |
| 2003 | 19.53 | 5.00 | 24.53 | 26.70 | -2.17 |
| 2004 | 21.70 | 5.00 | 26.70 | 26.88 | -0.18 |
| 2005 | 21.40 | 5.00 | 25.40 | 26.86 | -1.46 |
| 2006 | 21.76 | 5.00 | 26.76 | 26.79 | -0.03 |
| 2007 | 20.34 | 5.00 | 25.34 | 26.82 | -1.48 |
| 2008 | 21.66 | 5.00 | 26.66 | 26.38 | 0.28 |
| 2009 | 21.62 | 5.00 | 26.62 | 26.92 | -0.30 |
| 2010 | 21.98 | 5.00 | 26.98 | 26.74 | 0.24 |
| 2011 | 22.87 | 5.00 | 27.87 | 26.87 | 1.00 |
| 2012 | 23.00 | 5.00 | 28.00 | 26.99 | 2.11 |
| 2013 | 20.47 | 5.00 | 25.47 | 26.93 | -0.54 |
| 2014 | 20.91 | 5.00 | 25.91 | 26.72 | -0.24 |
| 2015 | 23.82 | 5.00 | 28.82 | 27.03 | 1.59 |
| 2016 | 22.11 | 5.00 | 27.11 | 27.13 | -0.09 |
| 2017 | 22.28 | 5.00 | 27.28 | 26.79 | 0.48 |
| 2018 | 22.34 | 5.00 | 27.34 | 26.80 | 0.54 |
| 2019 | 23.95 | 5.00 | 28.95 | 27.26 | 1.69 |
| 2020 | 22.94 | 5.00 | 27.94 | 27.04 | 0.90 |
| 30 years | +1.65 | | +1.65 | +0.73 | 0.01 |

Sources: Data analysis, 2021

Table 6. Model AST year 1990, 2005 and 2020 in Bandar Lampung City

| AST ($^0$C) | Area | | | | | |
|---|---|---|---|---|---|---|
| | 1990 | | 2005 | | 2020 | |
| | Ha | % | Ha | % | Ha | % |
| <25.0 | 6,282.21 | 34.93 | 4,776.47 | 26.57 | 1,960.93 | 10.91 |
| 25-30.0 | 11,637.50 | 64.74 | 11,861.23 | 65.97 | 12,713.70 | 70.71 |
| >30.0 | 59.19 | 0.33 | 1,341.20 | 7.46 | 3,304.27 | 18.38 |
| | 17,978.90 | 100.00 | 17,978.90 | 100.00 | 17,978.90 | 100.00 |

Source: Data analysis, 2021

Table 7. Changes area of AST in Bandar Lampung during the decade

| AST ($^0$C) | Area | | | | | |
|---|---|---|---|---|---|---|
| | 1990 – 2005 | | 2005 - 2020 | | 1990 -2020 | |
| | Δ (Ha) | % | Δ (Ha) | % | Δ (Ha) | % |
| <25 | -1,503.94 | -8.37 | -2,815.49 | -15.66 | -4,319.43 | -24.02 |
| 25-30 | 223.40 | 1.24 | 852.60 | 4.74 | 1,076.00 | 5.98 |
| >30 | 1,281.91 | 7.13 | 1,963.17 | 10.92 | 3,245.08 | 18.05 |

Source: Data analysis, 2021

the city, it was found to obtain a temperature of >30.0$^0$C in urban areas north-south according to the UHI profile, indicating its occurrence.

## 4. Conclusion

In conclusion, the LST increase indicated the occurrence of UHI phenomenon. Furthermore, the Raden Inten II Meteorological Station air temperature experienced a positive trend for 30 years, namely from 1990 to 2020 with an increase at a warming rate of 0.0218$^0$C per year, with a difference of 0.66$^0$C. The results showed an expansion of the LST area of temperature >25.00C in the northern part of Bandar Lampung City, compared to AST at 5.0$^0$C. The LST expansion impacts the spatial distribution of model AST with temperature >30.0$^0$C, which is concentrated in the center and northern part of the city at the beginning and of the timeframe. This study further concluded that the air temperature in the city has warmed up to 0.46$^0$C (+1$^0$C), which is in line with the findings of IPPC and various world cities. The temperature detections for 30 years occurred in accordance with the UHI phenomenon since 2014, indicating a part of climate change mitigation.

## Acknowledgement

This research supported Research Grant from the Faculty Mathematics and Natural Sciences of Universitas Indonesia year 2021 based on contract number: NKB-002/ UN2.F3/HKP.05.00/2021.

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