RESEARCH ARTICLE

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Tracing Global Warming Path in Local Scale: Greenhouse Gas Emission or Land Use Changes?

Tumiar Katarina Manik and Paul Benyamin Timotiwu

ABSTRACT

Increasing mean atmospheric temperature is considered as an indicator of global warming and eventually climate change. Source of increasing atmospheric temperature is the accumulation of greenhouse gases. However, these emissions will affect atmosphere temperatures in a global scale and in long term. In smaller scale -both in spatial and time- land surface condition is probably the dominant factor compared to greenhouse gases emission. This paper attempted to analyze those two factors in local air temperature rise, using Bandar Lampung City, Indonesia as the study area. The results showed that N_20 was the greenhouse gas that have closest connections to local air maximum temperature compared to CH_4 and CO_2. Related to different local surface condition, it was clear that business area of Bandar Lampung was the hottest local maximum temperature with maximum temperature difference 1.5 ºC. It is convinced that greenhouse gases emission is the source of global temperature rising, however, understanding how local surface condition affected the air temperature would motivate public and local government to maintain vegetation area in a city.

Keywords: Emission, Global Scale, Greenhouse, Land Surface, Temperature.

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T. K. Manik*
The University of Lampung, Indonesia.
(e-mail: tumiar.katarina@fp.unila.ac.id)
P. B. Timotiwu
The University of Lampung, Indonesia.
(e-mail: paul.timotiwu@fp.unila.ac.id)

****Corresponding Author***

I. Introduction

The increasing global atmospheric mean temperature is the global warming indicator that led to climate change. Global warming or climate change caused increasing sea surface temperature, melting the glaciers and ice sheets, expanding water bodies and worldwide sea levels rise [1]. Climate scientists believe that increasing temperature caused by cumulative increase in global concentration of greenhouse gas in the atmosphere.

United States as a big country emit greenhouse gases mostly from transportation (in 2019 this was 29 percent of all greenhouse gas emissions), electricity (25%), industry (23%), commercial and residential (13%), Agriculture (10%), land use and forestry (12%). In Indonesia, emissions from transportation reached up to 30% from CO_2 total emission, most of it from land transportation including public transportation which contributed up to 88% from transportation emissions. Numbers of private cars and motorcycle increased rapidly in Indonesia; this was proved from domestic cars selling which increased more than 200% the last 15 years and predicted continue to grow [2]. Therefore, alternative transportation mode that emit less CO_2 should get attention in mitigating the climate change impacts.

Global warming does not necessarily mean that average air temperature rises in every single location across the globe all the time. Global warming due to intensification of greenhouse gases emissions affected long-term climate change from 100 to 1000 years, while phenomena such as El Nino and La Nina cause the main short time climate change [3]. There has been much research on El Nino Southern (ENSO) impact on global rainfall including Indonesia rainfall pattern. Longer dry season in Indonesia observed during El Nino occurrence, while La Nina marked longer rain season [4]. El Nino and La Nina started with changing temperature on sea surface, therefore, surface temperature certainly an indicator of climate change in local scale.

There were many studies of temperature rising in recent years and in the future. In India mean annual temperatures over the last 111 years was increased by 0.46 ºC; observed 24.23 ºC in 1901 to 24.69 ºC in 2012. Compared to global scale, combined surface temperatures over land and sea have been increased about 0.79 ºC from similar period (1990 to 2010). If the increase continued, globally averaged surface temperature of the 21st century is expected to rise between 1.1ºC up to 6.4 ºC [5]. As an archipelago country air temperature in Indonesia observed in different places. In Pagai strait West Region of Sumatra the sea surface temperature rises 3.5 ºC in last five years and it considered caused by IOD (Indian Ocean Dipole) [6]. From 162 climate stations in Indonesia most of the stations 67% showed that annual mean maximum temperature rises and 86% for the minimum temperature, the region averaged temperature showed increase of 0.18 ºC to 0.3 ºC per decade. It strongly related to El Nino and La Nina events [7].

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Greenhouse gas emission to upper layer of atmosphere is not observed or measured locally; there were some local stations that set up in big cities. In Indonesia, however, Global Atmosphere Watch (GAW) station at Bukit Kototabang, Agam, West Sumatra is one of global atmospheric monitoring station in Indonesia that could globally represent the atmospheric condition over Indonesia. Besides climate change did not happen instantly, rarely are greenhouse gasses emissions data distributed to public; those might the reasons that public do not aware of how much their activities contributed to global warming and eventually to climate change. Land use changes are more factual for public understanding and could be more correlated to temperature increases in local scale.

On smaller scale (City) land use considered as the possible caused of air temperature increase. Land use change is a process in which human activities transform natural landscape to fulfil human needs, this could be reflected in different ways, for example, deforestation is the major cause of land use change. In many developing countries like Indonesia urbanization created rapid land use change. Upper Citarum Watershed is an upstream area of big city in Indonesia, the rapid land use change observed with this data: from 1997 to 2014 forest decreased by 41 % while agriculture area increased by 8 %, building area increased by 65%, bare land 56% and bushes decreased by 14% and so water body by 12% [8].

In the study area, rapid land use changes have also been investigated and reported. Forest in Way Betung watershed was decline, from 16.72% in year 1991 to 9.66% in 1999 and 7.17% in 2006. Those changes happened due to development of mixed farm and settlement area [9]. Other investigation in Way Pengubuan watershed area showed that forest area decreased from 0.93% to 0.83% during 2014 to 2017 while settlement area increased from 10.58% to 12.83% and mixed dry land farming from 10.35% to 33.42%. In the capital city Bandar Lampung on the east side of the city, in 2001, the open area (no vegetation, possibly housing or building) 68.3%, and in 2016 increased to 80.6% [10]. Urban area where vegetation has been replaced by concrete and asphalt has higher air temperatures since the excess heat from the buildings, transportation, industrial and residential area trapped the heat [11]. To study relation man made surface and surface temperature, [12] conducted research at an urban public open space in Beijing city. The results showed that at 20 m and 50 m above land surface, paved area has a significant positive correlation with air temperature while tree area has a significant negative correlation.

Land use change plays a critical role in regulating the climate system by changing the Earth's surface radiation balance through changing surface albedo and radiation emission. Growing urban populations and urban expansion, with increasing built-up areas and human activities, significantly modified the underlying surface properties and energy balance, and eventually the urban climate. The consequence of land use changes correlated to presence or absence vegetation on land's energy balance is complicated because it can modulate fast biophysical processes in several ways. The leading processes is the incoming radiation energy in a vegetated area is converted into latent heat during the day and the sensible heat flux is lower compared to. built-up area covered by asphalt or concrete. In addition, the greater vegetation reflection reduces the radiant absorption of the surface [13]. Research in lower foothills of the Sierra Nevada Mountains, California, USA covered with oak savanna and grassland conditions, proved that changes in land cover have a marked impact on the air temperature of a landscape. It was observed that the potential air temperature over the oak savanna was 0.58 ºC warmer than the air above an annual grassland, 2 km away. [14].

This paper attempted to compare how sensitive is air temperature to increasing greenhouse gas emission compared to land cover. The method is by using statistical analysis to investigate whether the relation of greenhouse emission or area land cover that show closer relationship to changing climate data (air temperature) in city level. The study also conducted by comparing land use difference and qualitatively correlated it to air temperature. In general, there were 4 land surface categories in Bandar Lampung: business area, housing area, suburb area and vegetation area. We hypothesized that the air temperature over those area would be different and vegetation presence would cool the air.

II. Materials And Methods

A. Greenhouse Data Sources

Greenhouse data was downloaded from the Global GAW station at Bukit Kototabang, the station is located on Sumatra, Indonesia (0° 12' 07" S-100° 19' 05" E, situated in the equatorial zone at an altitude of 864.5 m a.s.l., and 40 km off the western coastline. The temperature varies from 16 to 25 °C with only slight annual variation and the relative humidity is usually higher than 80%. Greenhouse emission data could be downloaded from ESRL/NOAA Global Monitoring Division [14]

B. Climate Data Sources

Global climate data was obtained from the Climatic Research Unit at the University of East Anglia [15]. Local climate data obtained from NASA Data Access Viewer Local land covers [16].

Bandar Lampung land cover area and daily maximum and minimum temperature were obtained from Marksim DSSAT weather file generator [17]. Spots places in Bandar Lampung (5.45 ºS, 105.27 ºE) that represented the land cover and temperature data were presented in Table I and Fig. 1.

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TABLE I: SPOTS AREA IN BANDAR LAMPUNG USED FOR THIS STUDY

No	Location	Latitude	Longitude	Land cover type
1	Teluk	-5.4483	105.3105	Business area
2	Panjang	-5.4686	105.3197	Port area
3	Pahoman	-5.4285	105.2736	Old residential
4	Kartini	-5.4145	105.2551	Business area
5	Diponegoro	-5.4293	105.2603	Business area
6	Teuku Umar	-5.3959	105.2615	Business area/campuses
7	Way Halim	-5.3942	105.2750	Residential area
8	Sukarno Hatta	-5.4198	105.2954	Highway and industrial
9	Univ Lampung	-5.3641	105.2428	Main university
10	Sukabumi	-5.4001	105.2940	New residential area
11	Natar	-5.2659	105.2428	Suburb area
12	Padang Cermin	-5.6042	105.1142	Suburb area coastline
13	Kalianda	-5.7359	105.5935	Peripheral area
14	Kemiling	-5.4037	105.2019	Suburb area
15	Pesawaran	-5.49	105.08	Suburb area

Source: Marksim DSSAT weather file generator.

III. DATA ANALYSIS

A. Effect of Greenhouse Gasses on Future Temperatures

Data analysis for this study had been done following multiple regression on this paper [18]

Three major greenhouse gasses (CO_2, CH_4 and N_2O) were analyzed to find which of those gas has a significant correlation to maximum temperature using multiple regression analysis in R program. There was more than one variable that might had correlations to maximum temperature, however, dropping some from the model found that model quality did not decrease. R provides a function that will automate the procedure of trying different combinations of variables to find a good compromise of model simplicity and R2 (coefficient correlation). This trade-off is formalized by the Akaike information criterion (AIC)-it can be informally thought of as the quality of the model with a penalty for the number of variables in the model.

C. Evaluating Land Cover Effect on Local Temperature

Land cover of Bandar Lampung and surrounded area were classified as some criteria; and climate data for each type of land cover was analyzed in simple statistic, then the main climate: data maximum and minimum temperature were plotted as a map to observe whether the climate data showed some relation with classified land cover.

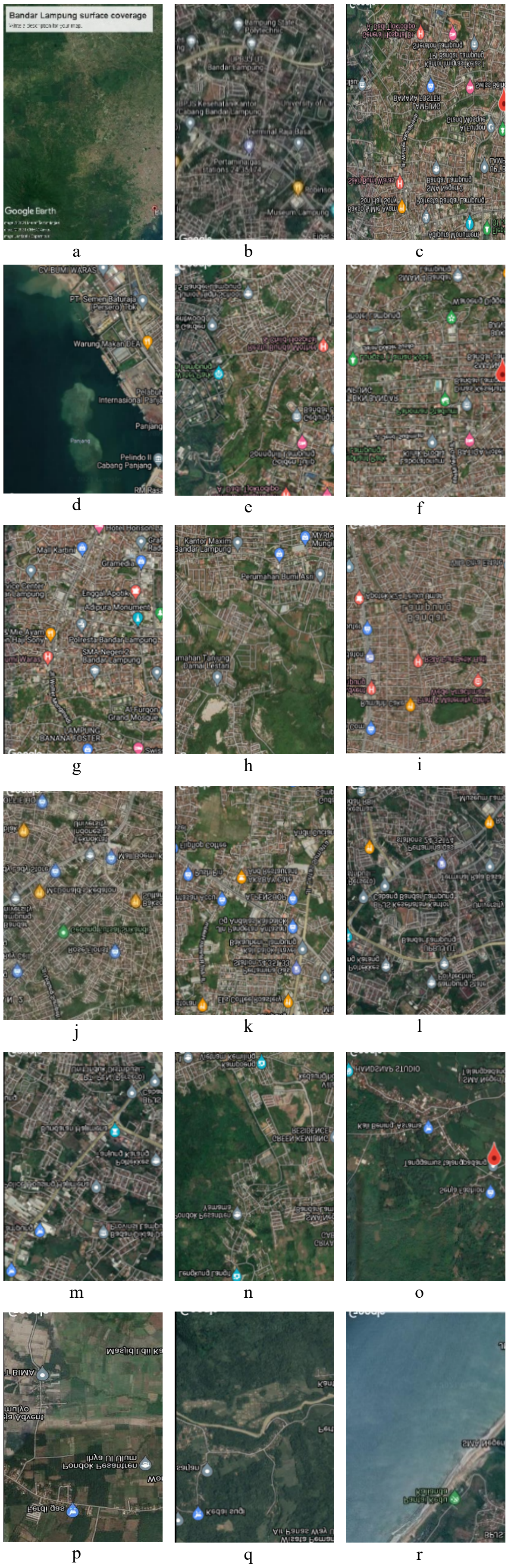


Fig. 1. Land cover of spot areas which represented Bandar Lampung. (a) Bandar Lampung surrounding (b) Bandar Lampung, (c) Diponegoro, (d) Panjang Port, (e) Teluk Betung, (f) Pahoman, (g) Sudirman, (h) Sukarno Hatta, (i) Teuku Umar, (j) Way Halim, (k) Sukabumi, (l) University Lampung, (m) Polinela, (n) Kemiling, (o) Talang Padang, (p) Natar, (q) Padang Cermin, (r) Kalianda.

III. Results And Discussions

After some processes to find combinations of variables resulted in good compromise of model simplicity with lowest AIC then the results were presented in Fig 2. The results showed that N_2O was the greenhouse gas that showed some impact on maximum temperature compared to CO_2 or CH_4.

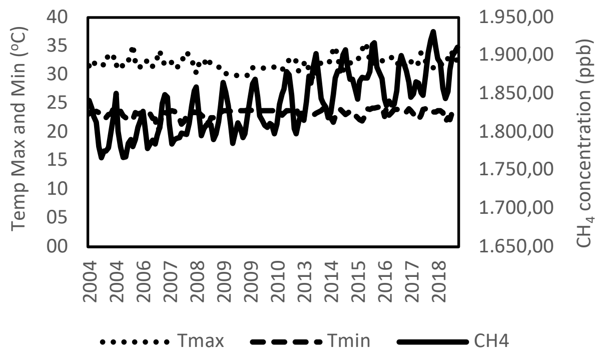
```
Step:  AIC=-14.06
Tmax ~ N2O + Rainfall

           Df Sum of Sq    RSS     AIC
<none>                  60.315 -14.056
- Rainfall  1     2.805 63.119 -12.511
- N2O       1    32.788 93.103  17.806
> summary(climate_step1)

Call:
lm(formula = Tmax ~ N2O + Rainfall, data = climate_train)

Residuals:
     Min       1Q   Median       3Q      Max
-1.50297 -0.68824  0.08359  0.50216  2.77323

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 160.26680   20.13205   7.961 1.42e-11 ***
N2O          -0.39961    0.06258  -6.385 1.29e-08 ***
Rainfall     -0.11997    0.06424  -1.867   0.0657 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.8968 on 75 degrees of freedom
Multiple R-squared:  0.3524,    Adjusted R-squared:  0.3352
F-statistic: 20.41 on 2 and 75 DF,  p-value: 8.374e-08
```

Fig. 2. Statistical analysis using R in finding the most significant gas emission related to maximum temperature.

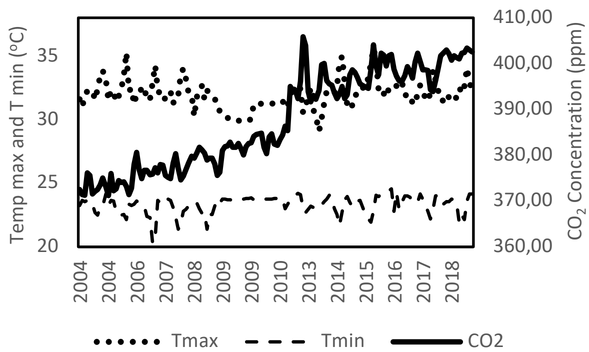
Additional information for these results could be seen in Fig. 3; when plotted, N_2O had a constant rising and less deviation compared to CO_2 or CH_4. Even though all gasses showed increasing trend in 14 years, Methane emission were highly fluctuated, while CO_2 and N_2O least fluctuated, also Methane increasing rate was smaller compared to CO_2 and N_2O. However, those increasing trends of greenhouse gasses did not reflect in increasing air temperature both in maximum and minimum air temperature. The rising trend of the gasses was obvious; however, the air temperature rising trend was moving on its average.

Fig. 4 revealed that no specific correlation could be find between the greenhouse gasses emission and air temperature pattern; just one possible correlation (on the red circles) between the N_2O emission and average air temperature. Bandar Lampung surrounds by arable cropping lands, some agricultural activities still exist in the city. On this type of land use N_2O emissions are directly associated with the fertilizers input. For example, China has significantly increased N_2O emission because of fertilizers using of fertilizers. The emission ranged about 191.1-334.7 mg N_2O-N m^{-2} and 176.5-393.0 mg N_2O-N m^{-2} [19].

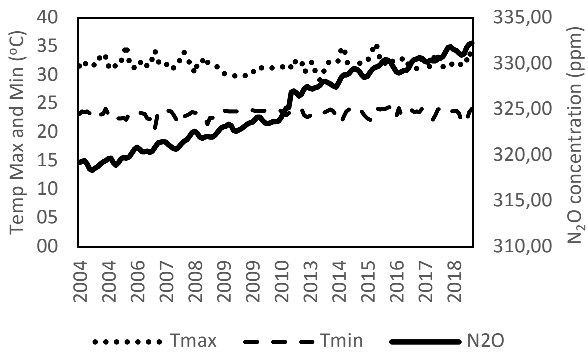
Results of Fig. 4. could imply that direct correlation between greenhouse gasses emissions and rising local air temperature was weak and unclear, however, those were not profs that global warming did not happen in Bandar Lampung, since increasing temperature is not the only indicator of global warming. Global warming indicators differ on a scale: local, regional, or global. At reginal and global scale explicit models and climate change scenarios represent levels of global mean temperature rising. In agriculture, changes in average length of crops growing seasons that eventually change crop yields are significant indicators [20]. Climate has varied scales, operating at multi-millennial, millennial, century, decadal, and interannual scales, and controlled by independent physical mechanisms. At the global scale, the global warming caused by accumulation of greenhouse gasses due to anthropogenic activities that affects the net solar radiation. At regional scale, El-Niño/La Niña cycle affects Southeast Asia Climate, and the Pacific Decadal Oscillation (PDO) affects the west coast of North America. These shorter cycles result from mechanisms internal to earth, that involve ocean circulation and temperature. At the smaller scale or local scale, the land cover plays an important role. Climate at any scale is the cumulative expression of all mechanisms operating together. Therefore, this study continued with investigating the local land cover of Bandar Lampung City (Fig. 4) and the observed weather data (Table II).



a.



b.



c.

Fig. 3. Plots of main greenhouse gases (a) CH_4, (b) CO_2, and (c) N_2O related to maximum and minimum temperature in Bandar Lampung.

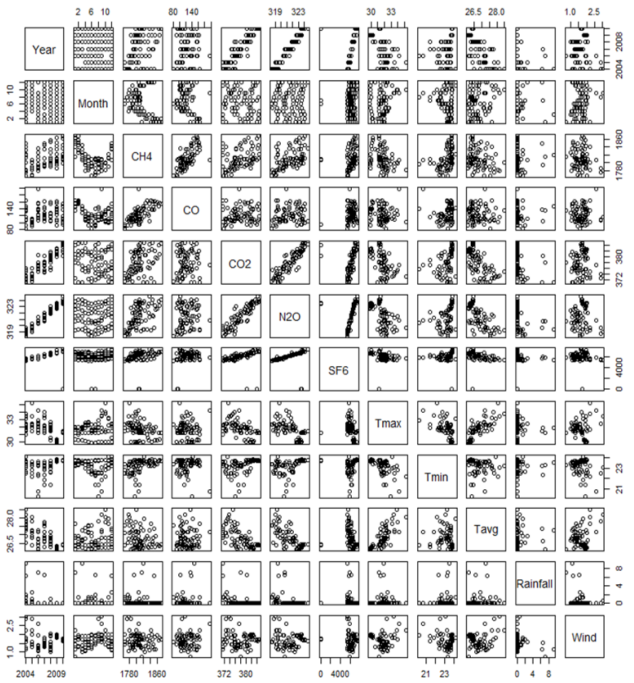


Fig. 4. Multi correlation data of greenhouse gasses and climate data.

From Table II and Fig. 5, it could be seen there were four temperature clusters.

First, areas with maximum temperature above 40 ºC including Teluk, Panjang, Pahoman, and Diponegoro which are central of the city and business area and Padang Cermin and Kalianda were with higher temperature since those are coastline area. Second, area with maximum temperature 40 ºC including Kartini, Teuku Umar, Way Halim, Sukarno Hatta, Sukabumi which are crowded residential area and next, area with slight lower than 40 ºC: Natar, Polinela, Universitas Lampung and Talang Padang could be included in this area. Those are the area which still have some vegetation cover and followed with Kemiling and Talang Padang. Kemiling is some sort of water conservation area for Bandar Lampung city while Talang Padang is an area of paddy field. Then the last category was area with maximum temperature significantly lower, around 37 ºC: Pesawaran and Gunung Putri. Pesawaran is a green area while Gunung Putri is forest area. These patterns were similar for minimum temperature and average temperature.

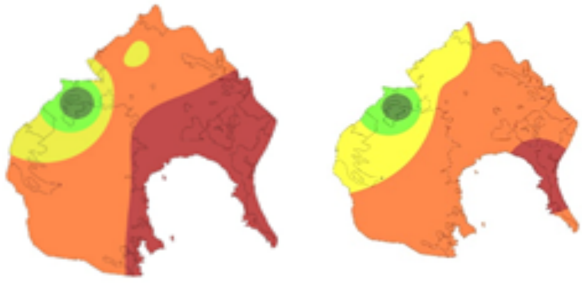
Urban areas are sources of anthropogenic heat since the energy balance in an urban area is disturbed. Effect of the urban climate on air temperatures is called urban heat island (UHI), which refers to the temperature difference between urban areas and surrounding cool rural areas. Usually, it pictured with that the center of city is the hottest area and surrounding by cooler vegetation area. Bandar Lampung temperature pattern was not centralized, the central city had the same temperature with the coastline area, while the cool area consistently occurs at the vegetation area.

The observed air temperatures varied significantly according to land cover types: air temperatures were higher in the built-up area and lower in the vegetated area. This has been reported by some studies [11], [13], [21]. The facts that greenhouse gasses are the source of global rising temperature is obvious and has become scientific belief. This paper did not aim to prove against those findings; but to support that temperature rising caused by different mechanisms on different scale. For small local scale, land cover especially dominated by built up and artificial surfaces, is the main factor that caused a place become hotter [13] and this could be worst when global temperature keep rising due to greenhouse gases emissions.

As a growing city, Bandar Lampung also experienced land use changes because the needs for housing, building, factories, and transportation facilities; and these problems happened in all big cities in the world. An observation in 2013 reported that the air temperature in agriculture area was 27-31 °C, the residential area and industrial area had a bit higher temperature (29-32 °C) and finally the central city, business area and coastal area had the highest temperature (32-34 °C) [22]. Compared to the recent condition on this study that the green area maximum air temperature has reached 37 ºC and on the central city, business area and coastal area has reached 40 ºC. These results should be a warning that the city green area or vegetation cover on its land has been decreased significantly.

TABLE II: DAILY CLIMATE DATA ON THE AREA THAT REPRESENTED BANDAR LAMPUNG

No	Location	Latitude	Longitude	Tmax ºC	Tmin ºC	Tavg ºC
1	Teluk	-5.4483	105.3105	40.3	15.3	27.78
2	Panjang	-5.4686	105.3197	40.2	15.2	27.67
3	Pahoman	-5.4285	105.2736	40.1	14.9	27.41
4	Kartini	-5.4145	105.2551	40	14.8	27.30
5	Diponegoro	-5.4293	105.2603	40.1	15	27.41
6	Teuku Umar	-5.3959	105.2615	40	14.8	27.26
7	Way Halim	-5.3942	105.2750	40	14.8	27.32
8	Sukarno Hatta	-5.4198	105.2954	40	14.7	27.37
9	Univ Lampung	-5.3641	105.2428	39.7	14.4	27.14
10	Sukabumi	-5.4001	105.2940	40	14.5	27.34
11	Natar	-5.2659	105.2428	39.9	14.6	27.33
12	Padang Cermin	-5.6042	105.1142	40.5	15.5	27.71
13	Kalianda	-5.7359	105.5935	40.7	15.5	28.00
14	Kemiling	-5.4037	105.2019	39.2	13.1	26.35
15	Polinela	-5.3583	105.2329	39.9	14.3	27.17
16	Talang Padang	-5.3638	104.7695	39.5	13.5	26.237
17	Pesawaran	-5.49	105.08	37.4	8.1	22.08
18	Gunung Putri	-5.026	104.48	37.2	8.2	23.09



a b

Fig. 5. Maximum (a) and minimum (b) surface air temperature above Bandar Lampung City.

IV. Conclusion

Factors associated with the rising air temperature should be investigated considering the spatial scale. On local or city level, land cover is the main factor. Since urbanization happen all over the world, places experienced rapid land cover changes; global warming should be mitigated through careful plans of cities development besides slower greenhouse gas emissions.

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