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

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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 N2O was the greenhouse gas that have closest connections to local air maximum temperature compared to CH4 and CO2. 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 °C. 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.

I. INTRODUCTION

The increasing global atmospheric mean temperature is the global warming indicator that led to climate change. Global warming or climate change cause 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 increases 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 CO2 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 CO2 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 °C; observed 24.23 °C in 1901 to 24.69 °C in 2012. Compared to global scale, combined surface temperatures over land and sea have been increased about 0.79 °C from similar period (1990 to 2010). If the increase continued, globally averaged surface temperature of the 21st century is expected to rise between 1.1°C up to 6.4 °C [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 °C 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 °C to 0.3 °C per decade. It strongly related to El Nino and La Nina events [7].

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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 °C 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 station, 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 °S, 105.27 °E) that represented the land cover and temperature data were presented in Table I and Fig. 1.
TABLE I: SLOTS 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   | Area/campuses           |
| 7  | Way Halim | -5.3942   | 105.2750   | Residential area         |
| 8  | Sukarno Hatta | -5.4198    | 105.2954   | Highway and industrial area |
| 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 (CO₂, CH₂, and N₂O) were analyzed to find which of those gases has a significant correlation to maximum temperature using multiple regression analysis in R program. There was more than one variable that might have 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 surrounding area was 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 N2O was the greenhouse gas that showed some impact on maximum temperature compared to CO2 or CH4.

Additional information for these results could be seen in Fig. 3; when plotted, N2O had a constant rising and less deviation compared to CO2 or CH4. Even though all gasses showed increasing trend in 14 years, Methane emission were highly fluctuated, while CO2 and N2O least fluctuated, also Methane increasing rate was smaller compared to CO2 and N2O. 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 temperature pattern; just one possible correlation (on the red circles) between the N2O 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 N2O emissions are directly associated with the fertilizers input. For example, China has significantly increased N2O emission because of fertilizers using of fertilizers. The emission ranged about 191.1-334.7 mg N2O-N m⁻² and 176.5-393.0 mg N2O-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 regional 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).
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 °C and on the central city, business area and coastal area has reached 40 °C. 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 °C | Tmin °C | Tavg °C |
|----|--------------|----------|-----------|---------|---------|---------|
| 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 | Polinema     | -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   |
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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