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Climatology of Discomfort Index for Decade in Bandar Lampung, Indonesia

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Abstract

Climate change as certain phenomena has occurred globally and the impact feels by people especially for those who live on the island. Weather pattern shifting is one of the evidence of climate change impact, and many scientists are still trying to prove it. Weather affected by a combination of temperature, relativity humidity, etc. The fact that those parameters closely related to the need of health especially temperature and relative humidity and well-known thermal scale grouped in a range called discomfort index (DI). This study aims to analyze the outdoor condition in Bandar Lampung by figure out discomfort index. Weather parameter collected from secondary data of Teluk Betung weather station from 2007 – 2017 in three levels of high, average and low condition. In that period, temperature and humidity in Bandar Lampung relatively stable between 20-35°C and 50-100%. In general, the city encountered with varies conditions by high temperature above 29°C and high relative humidity more than 85%.
Meanwhile, DI changes from year to year are not significantly occurred that indicates in high temperature, average and low weather are everyone feels severe stress, more than 50% of people feel discomfort, and comfortable condition. Nevertheless, every year it already shows an uncomfortable situation especially in high temperature and even at an average temperature. Furthermore, the study needs to compare with other weather stations in Bandar Lampung.

Keywords: climate change, temperature, relativity humidity, discomfort index

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1. Introduction

Climate variability brings changes in climate component and effects to environment and society. Some of the climate components are temperature, precipitation, humidity and wind speed. Since the 19th century, temperature has been quantifying in term of comfort condition [1]. The finding of how much environment comfort can be adopted into indoor called effective temperature by Thom [2]. It is approached with an easy linear formula that depends on air temperature (dry-bulb temperature) and the wet-bulb temperature. Those conditions become well-known as temperature humidity index (THI), thermal scale grouped in a range called discomfort index (DI), simple measurement of

outdoor condition as Stathopoulou et al stated [3]. Temperature can be derived from both observation and satellite data.

Many types of research had analyzed how much temperature could indicate those conditions. Several cities had represented the condition such as Greece for 2000 [3]. The DI estimation and observation from 6-9 January 2000 reach 21 – 28°C, and in 2008-2009, DI showed differences in climate between the north, center, and south of Greece and specifically at the local level, it was shown to evaluate climate differences in urban areas as well as rural [4]. In three city of Egypt: South Alexandria, Cairo, and Aswan city, although they were not reached extreme climate conditions, the climate in the north was milder than the climate in the south for 2011 [5]; This study found that less than 50% of the population experienced a sense of discomfort from November to April when the discomfort indices ranged from 22 to 24. But more than 50% of the population suffered from discomfort when the indices ranged from 24 to 29 from April to October. The discomfort indices greater than 30 or 32 (indicating 100% of the population feeling discomfort or the condition of a medical emergency, respectively) were not attained in Khartoum State Kenya for 1985 – 2015 [6]. Several studies also conducted in Sudan city (Africa) for 2013 [7], in a tropical country such as Gujarat city (India) for 1993 – 2013 [8] and Assam city (India) for 2003 – 2014 [9].

Mohan mentioned [10] climate, represented by temperature, intend to the need for health, tourism, and energy resource management. In the health field specifically, temperature and humidity closely related to mortality. The relationship showed by U-shaped which meant the relationship between them was a quadratic function or not linear at the large outmost size in national data in America. Both effects on cardiovascular and influenza disease connected to mortalities as explained in [11]. Wentasari stated [12] that characteristics of the microclimate (temperature, humidity, and light intense) in Bandar Lampung influence sweet corn production in various types of the cropping system.

In general, there is three most used-simple approach to find out outdoor thermal comfort are Discomfort Index (DI), Temperature Humidity Index (THI) and Comfort Index (CI) [13]. This study objective is to analyze the change of temperature and humidity in Bandar Lampung parameter using DI.

2. Research and Method

2.1. Study area and data

Bandar Lampung is the capital city of Lampung Province, 5 ˚20' – 5˚30' S and 105˚28' – 105˚37' E located in South Island of Indonesia seen at Figure 1. This city covers 19.722 ha, with 979,287 populations, consist of 20 districts and 126 sub-districts (Figure 1). Land usage of settlement area reaches 37% of total area, green space area is 15% of total area and for the farming area is 19% of the total area. As a port city located on a bay-shaped coastal area, the high wave creates strong breeze but it could not entirely hit the coastal areas.

2.2. Methods

Two indicators for discomfort index are temperature and relative humidity (RH) by using secondary data from *WunderGround* (https://www.wunderground.com) for Teluk Betung weather Station (Figure 1). It derived from Personal Weather Stations, COOPs (Cooperative Observer Network), airport and weather balloon.

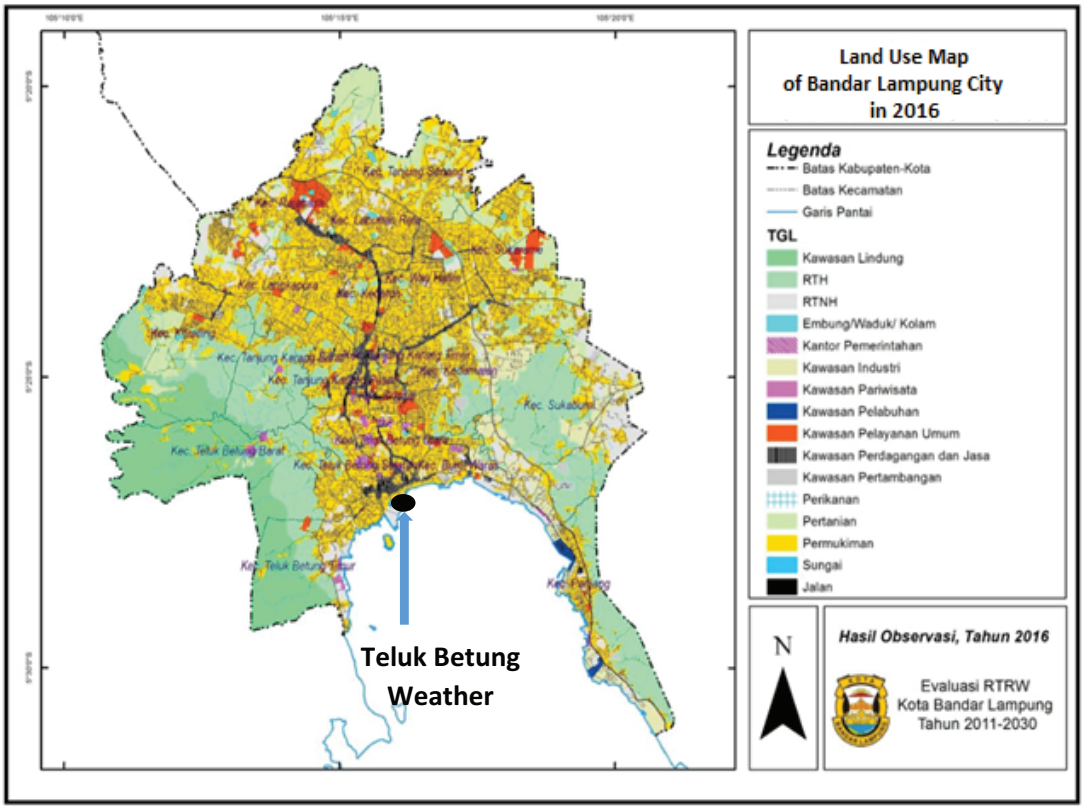

Figure 1: Bandar Lampung City (Source: Medium Term Regional Government Work Plan of Bandar Lampung 2011-2030, 2016).

The data provided in three ranges: high, average and low temperature and humidity from January 2007 to December 2017 (only available in December 2012). Several data in January 2007 and December 2017 as shown in Figure 2. The average temperature of high, average and low reach 31.98°C, 27.64°C and 23.11°C.

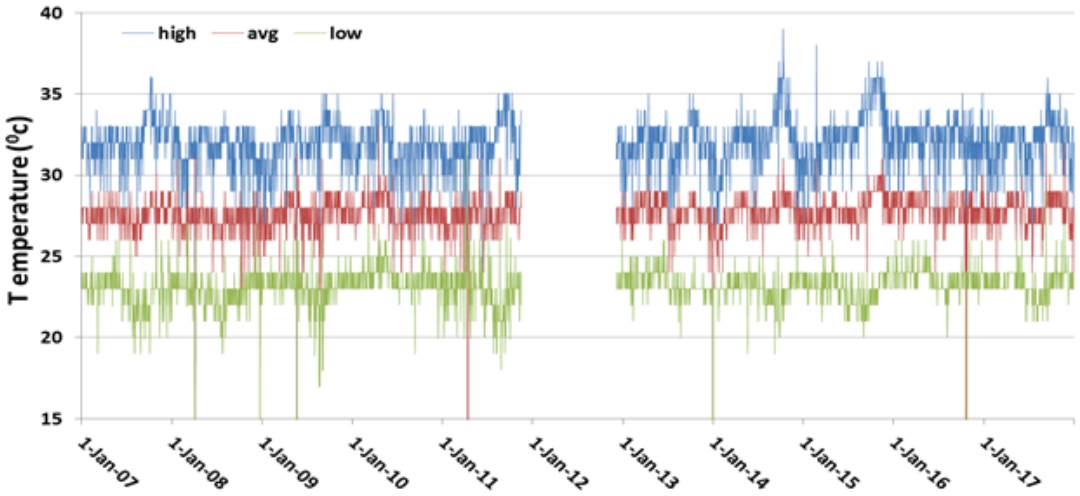

Figure 2: Temperature in January 2007 to December 2017.

Relative humidity in decade shown in Figure 2, whereas average RH in high, average and low reach 92.10%, 76.03%, and 53.60%. It is shown in Figure 3 below.

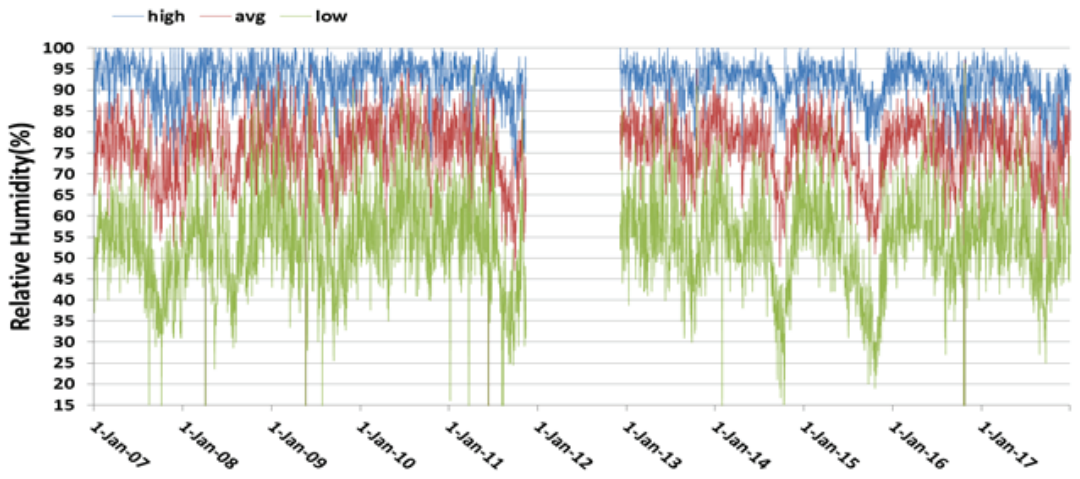

Figure 3: Relative Humidity in January 2007 to December 2017.

3. Discomfort Index in the Hot and Humid Climate Region

Tom in 1959 [2] formulated the Discomfort Index (DI) which affected by the dry bulb air temperature (Td) and relative humidity (RH) as linear and equation as follow:

$$DI = Td - 0,055\,(1 - 0,01\,RH)\,x(Td - 14,5) \quad (1)$$

Where Td is air dry bulb temperature in degree Celcius, and RH is relative humidity in percentage. Each range of DI indicates several conditions as Table 1 shown below.

TABLE 1: Classification of discomfort index values [1].

DI range (˚C)	Discomfort conditions
DI < 21	No discomfort
21 ≤ DI < 24	Less than 50% of people feel discomfort
24 ≤ DI < 27	More than 50% of people feel discomfort
27 ≤ DI < 29	Most of the population feel discomfort
29 ≤ DI < 32	Everyone feels severe stress
DI ≥ 32	Medical emergency

Thom's discomfort index ranges temperatures 21˚C - 31˚C for discomfort condition. It seems to be more suitable for mild altitude countries with cold climate. Still, ambient thermal comfort standard is not present in Indonesia at the moment. The usage of Thom's DI in a similar tropical country like Malaysia has been used to determine various building layout [14]. Accordingly, by using this Thom's index, it is hoped that an initial and simple measurement of thermal comfort condition in Bandar Lampung can also be determined.

4. Result and Discussion

Climate changes have affected the weather of Bandar Lampung City in 10 years span resulting on a higher average of discomfort days for its people. The result of Discomfort Index (DI) of Bandar Lampung 2007-2017 could be found in

From the DI pattern in Figure 4, it could be identified that since 2014, there were some changes on the daily DI pattern. At 2007-2013, the gap of high, average, and low indexes was relatively close which indicated a stable weather condition. Whereas at 2014 and 2015, the gap between the indexes was widened, at 2014 the high DI was the highest, while the low DI was getting lower, the patterns were indicating that the weather was shifting into an extreme condition.

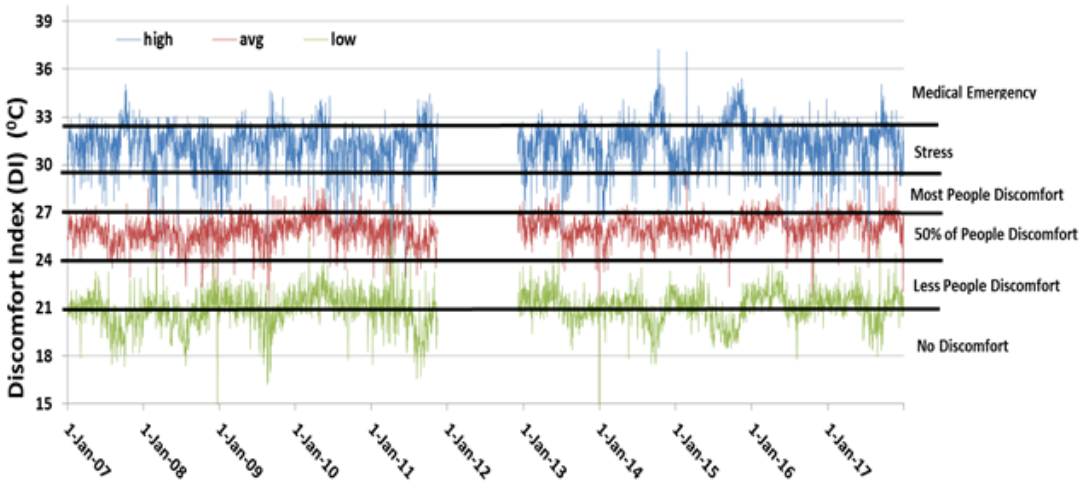

Figure 4: Discomfort Index (DI) of Bandar Lampung City in 2007-2017 (Generated from: Author's research result).

It was also showed that in 2007-2017, Teluk Betung Bandar Lampung's weather was relatively stable. The highest temperature, as well as the temperature range between high and low temperature in a day, could be found in 2014 and 2015 when Indonesia was affected by El-Nino phenomenon [15]. The highest DI of Bandar Lampung was 37,25°C and the highest temperature range in a day was 18.22°C both happened in 2014. In 2016, the weather was calmer but it was getting up a little in 2017.

But, in term of Discomfort Index, the weather trend in Bandar Lampung was alarming. The figure indicated that in 10 years span in Bandar Lampung, in its average temperature and humidity at least more than 50∧% people feel discomfort already. In its high temperature and humidity (blue dots), the figure showed the domination of stress and medical emergency level of discomfort index. Only on low temperature and humidity (grey dots), people could felt no discomfort. The data of classification of DI Values in Bandar Lampung provided in Table 2 for high temperature and humidity. It showed a slightly increase of "severe stress" condition ($29 \leq DI < 32$) annually.

For average Temperature and Humidity, level of daily frequency found lower than high ones. The dominant DI condition was "more than 50% of people feel discomfort" as shown in Table 3.

For low Temperature and Humidity, the level of daily frequency found lower than the average ones. The dominant DI condition was "no discomfort" yet the number of occurrences daily slightly shifted toward "less than 50% of people feel discomfort" annually as shown in Table 4.

TABLE 2: Day Number of High Temperature and Humidity of Bandar Lampung on DI Condition in 2007-2017.

DI Condition	Day Number											Total	%
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
No discomfort	-	-	-	1	-	-	-	-	-	-	-	1	0.03
Less than 50% of people feel discomfort	-	1	-	1	2	-	-	-	-	1	-	5	0.14
More than 50% of people feel discomfort	-	9	4	7	3	-	6	5	1	2	4	40	1.11
Most of population feel discomfort	16	27	22	25	31	2	27	28	20	19	24	242	6.70
Everyone feels severe stress	236	250	240	248	202	21	240	203	193	227	267	2322	64.25
Medical emergency	112	78	97	85	76	4	92	129	151	115	70	1004	27.78
Total day Observed Day	364	365	363	367	314	27	365	365	365	364	365	3614	100%

Based on Table 2, it was identified that when the temperature and humidity are high, in 1.004 days of 10 years, the DI in Bandar Lampung City already reached ”medical emergency” status, and in 2.322 days of 10 years in ”severe stress” status. This status depends on how long the high temperature lasted on a day, could be a dangerous situation for people, especially the elders and children [16]. It could also affect the productivity of workers especially the ones that work outside. The average temperature and humidity DI also showed that the majority (91%) of the days of 10 years fell into the category “more than 50% of people feel discomfort”, indicated that in the most of times in a day, most people were feeling discomfort too. In low temperature and humidity periods, Figure 3 showed that on 50% of days in 10 years “fewer people feel discomfort.” Hence, it could be summarized from DI perspective that the weather condition in Bandar Lampung was not particularly comfortable for its people.

5. Conclusions

In 10 years periods for 2007 – 2017, temperature and humidity in Bandar Lampung relatively stable between 20-35°C and 50-100%. In general, the city encountered with

Table 3: DI Classification of Average Temperature and Humidity of Bandar Lampung City DI Condition in 2007-2017.

DI Condition	Day Number											Total	%
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
No discomfort	-	1		2	1	-	1	-	-	-	-	5	0.14
Less than 50% of people feel discomfort	6	16	13	4	16	-	5	5	2	4	4	75	2.07
More than 50% of people feel discomfort	351	338	329	306	279	25	330	347	343	305	343	3295	91.15
Most of population feel discomfort	7	10	21	55	14	2	29	13	19	55	18	239	6.61
Everyone feels severe stress	-	-	-	-	-	-	-	-	1		-	1	0.03
Medical emergency	-	-	-	-	-	-	-	-	-	-	-	0	0.00
Total day Observed Day	364	365	363	367	310	27	365	365	365	364	365	3615	100%

varies conditions by high temperature above 29˚C and high relative humidity more than 85%. Meanwhile, by the Discomfort Index, indicated in high, average and low temperature and humidity, there were varying results. At high temperature and humidity, most population felt severe stress. At average temperature and humidity, more than 50% of people feel discomfort. At low temperature and humidity the population felt no discomfort. Nevertheless, every year it already shows uncomfortable condition especially in high temperature and in average temperature.

This study still needs refinement using observation data at other monitoring stations in finding closely look in each region. For further research, there is a need to consider other weather parameters such as wind speed and the subjective perspective of thermal.

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Table 4: DI Classification of Low Temperature and Humidity of Bandar Lampung City DI Condition in 2007-2017.

DI Condition	Day Number											Total	%
	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
No discomfort	242	225	189	103	188	9	170	191	223	109	163	1815	50
Less than 50% of people feel discomfort	122	137	173	263	121	18	195	174	142	255	201	1800	50
More than 50% of people feel discomfort	-	3	-	1	3	-	-	-	-	-	1	0	0
Most of population feel discomfort	-	-	-	-	-	-	-	-	-	-	-	8	0
Everyone feels severe stress	-	-	-	-	-	-	-	-	-	-	-	1	0
Medical emergency	-	-	-	-	-	-	-	-	-	-	-	0	0
Total day Observed Day	364	365	362	367	314	27	365	365	365	364	365	3624	100%

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