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Identification of temperature and rainfall pattern in Bandar Lampung and the 2020 -2049 projection

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Abstract. Climate change is a global phenomenon that is increasingly needed to be discussed. In local scale climate change is expressed often as climate phenomenon such as El-Nino South Oscillation (ENSO), Madden Julian Oscillation (MJO) and Dipole Mode Index (DMI). This condition caused many problems at the local scale especially in urban areas. Major hydrometeorological disasters such as floods and droughts impacted community daily life. Therefore, to deal with those hydrometeorological disasters, cities need to develop mitigation mechanisms based on data and information of future weather conditions. The objection of this study was to analyse historical climatic conditions of Bandar Lampung, Indonesia, and project the future climate up period of 2020-2049 using CMIP5 Representative Concentrations Pathways (RCP) 4.5 and RCP 8.5 models. Observed data was obtained from BMKG (Indonesian Agency for Meteorology, Climatology and Geophysics) stations while projected data obtained from BMKG Climate Change Centre. The results showed there were downward tendency of rainfall both in historical data and the projection and for most of the season except for dry periods; while temperature showed upward tendency consistently. Mitigation actions with reducing greenhouse gas concentrations have impact more on temperature trend than on rainfall distribution.

1. Introduction

Climate change is a global phenomenon caused by warming in the global climate system as results of increasing greenhouse gases concentration in the atmosphere. Climate change marked with an increase in global air and sea surface temperature, usually land are warming faster than oceans [1]. Global temperature has increased 0.2°C per decade during the last 30 years and the rate of change per year is greater when the El-Nino phenomenon occurs [2]. Over the next two decades, global temperature increase is projected to be between 0.3°C-0.7°C [3]. In addition, temperature in Lampung has changed due to changes in land use structures. In general, temperatures have increased for downtown areas, oil palm plantations and open areas in coastal areas; the projected temperature rise can be or the temperature is projected to rise to 4°C for these areas. Meanwhile, for rice fields the temperature is relatively stable and constant [4].

Changes in air temperature lead to several changes in other climate elements such as changes in rainfall distributions and seasonal patterns in one region. Changes in both rainfall and temperature can directly have impact on agriculture production [5], especially in crop and yield production [6]. Impact of climate

change on agriculture production has been a serious concern [7].The most risk in agriculture sector related to climate change in Indonesia is decreased harvested area and rice production [8].

Indonesian is a region which could severely affected by climate change. The phenomenon of global climate change affects areas of Indonesia that are especially sensitive to climate variability, such as El-Nino South Oscillation (ENSO), Madden Julian Oscillation (MJO) and Dipole Mode Index (DMI)**.** If that high sensitivity area combined with low adaptability, then those areas become vulnerable to climate change. Urban areas referred as one of vulnerable area since they are usually located close to coastal areas, have poor drainage systems and occupied by dense population. Urban areas problems included lack of clean drink water, flooding and rob from sea level rise. In facing those possible conditions, urban areas need environmental management strategies based on valid data and sound climate change analysis. One of the information needed is a historical study of the climate in the area and its future projections to determine adaptation and mitigation actions.

This study in general is a study of air temperature and rainfall trend, while indication of climate change was analyzed with time series methods. Time series could provide information on trends, cycles or shifts pattern around the long-term average. The study continued with climate projection as an effort to obtain description of the future climate in response to changes in greenhouse gases composition in the atmosphere. Several simulation models are available up to year 2100 projection. The projection results depend on the assumed global development scheme. Intergovernmental Panel on Climate Change (IPCC) issued some new scenarios, called Representative Concentration Pathways (RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5). Four Representative Concentrations Pathways (RCP) scenarios illustrate the range of greenhouse gas radiation strengths in 2100, from 2.6 to 8.5 W m^{-2}. The lowest level scenario, the middle level is a stable scenario Representative Concentrations Pathways (RCP) 4.5, and the highest or a scenario without mitigation efforts is Representative Concentrations Pathways (RCP) 8.5 [9]. This type of analysis have been done in India and found that the temperature increased by 2 ° C to 4.8 ° C, using RCP 2.6 and RCP 8.5, respectively, while rainfall was projected to increase by 6%, 10%, 9% and 14%, using RCPs of 2.6, 4.5, 6.0, and 8.5, respectively [10].

The objection of this study was to analyse historical climatic conditions of Bandar Lampung, Indonesia, and project the future climate up period of 2020-2049 using CMIP5 RCP 4.5 and RCP 8.5. RCP 4.5 and RCP 8.5 used to compare between projection scenarios that use mitigation scenarios and those that do not for Bandar Lampung area. The results could be used as bases of mitigation and adaptation strategies.

2. Methods

This study processed secondary temperature and rainfall data, obtained from the BMKG (Indonesian Agency for Meteorology, Climatology and Geophysics) Pesawaran Lampung, Indonesia. Data was available from 1976 to 2019.

Projections of temperature and rainfall used the GCM-CMIP5 output model with RCP 4.5 and 8.5 scenarios. The data was obtained from the BMKG Climate Change Centre. The data was available in grid form, completed with metafile attributes and was stored in a file with a special netCDF format. Prior to use, the projection data must be corrected with observational data to reduce any bias.

The difference between RCP 4.5 and RCP 8.5 are based on the mitigation scenario used. The RCP 4.5 scenario referred to a scenario of increasing greenhouse gases compensated with a mitigation scenario of reducing greenhouse gas concentrations; whereas the RCP 8.5 scenario based on a scenario of increasing greenhouse gases without a mitigation scenario of reducing greenhouse gas concentrations [12].
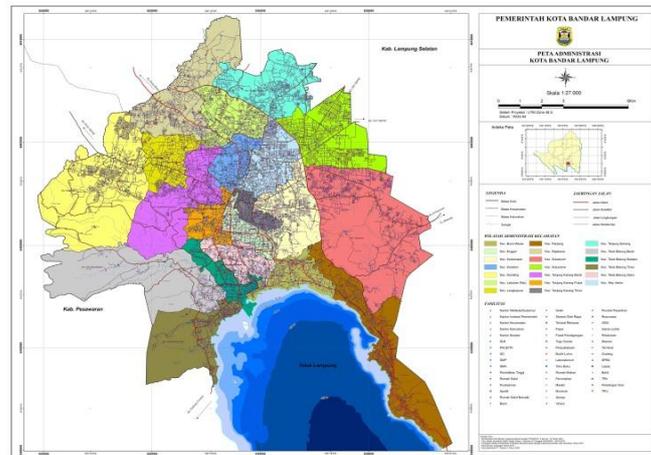
Figure 1. Research location in Bandar Lampung, Indonesia
(5°39' S, 105°.26' E and 113 m asl)

2.1. Method of collecting data

Data from RCP 4.5 and RCP 8.5 scenario models that have been extracted need to be corrected so that the model data has the same values and changes as the observed data. Data correction was done by calculating the difference between the observed data and the model data. The requirement for data correction is that the model data and observational data must have the same period. The calculation of data correction can be done with the following formula [13].

$$CH_{Model\_kor} = CH_{Mod} \times \frac{\overline{CHobs}}{\overline{CHmod}} \qquad (1)$$

$CH_{Model\ kor}$	= Corrected model of monthly rainfall
CH_{Mod}	= Rainfall model before corrected
$CHobs$	= Average baseline period of rainfall observational data
$CHmod$	= Average baseline period of rainfall data model

$$T_{Model\_kor} = T_{Mod} + (\overline{T}_{obs} - \overline{T}_{Mod}) \qquad (2)$$

$T_{Model\ kor}$	= Corrected model of monthly temperature
T_{Mod}	= Temperature model before corrected
$Tobs$	= Average baseline period of temperature observational data
$Tmod$	= Average baseline period of temperature data model

The projection process started with qualitatively matched baseline data with observational data. The appropriate model could be indicated from the uniformity of the baseline model pattern with the composite pattern of observation data. The next step was the validation process; starting with projecting the data using the selected model with the historical data period 1976-2019 and the period 2020-2049 as the predicted results. Validation was done by measuring the level of correlation between predicted and predictors, a model with a strong correlation would be selected.

3. Result and Discussion

3.1. Annual Data Series Analysis and Projections

Time series of rainfall data of Bandar Lampung in 1976-2019 and its projection in 2020-2049 were presented in Figure 1 and 2. Observed rainfall for the period 1976-2019 showed a decrease with a trend of 14.581 mm per year. These results were linear with the results of the two scenario data which showed a decline for the 2020-2049 periods with a trend of 3.4702 mm from the RCP 4.5 scenario and 1.945 mm from the RCP 8.5 scenario.
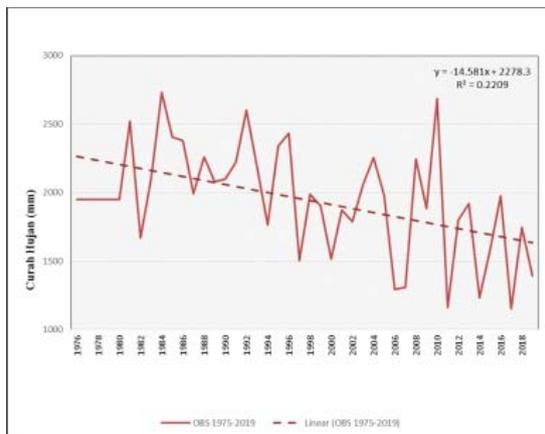
Figure 2. Observed Rainfall of Bandar Lampung in 1976-2019
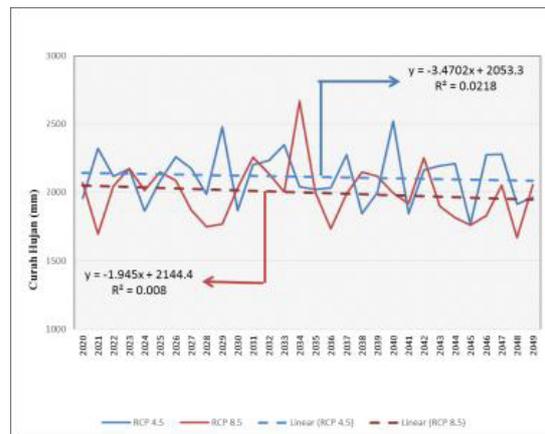
Figure 3. Projected Rainfall of Bandar Lampung in 2020-2049

Observation temperature of Bandar Lampung in 1976-2019 and its projecting for 2020-2049 period was presented in Figure 3 and 4.
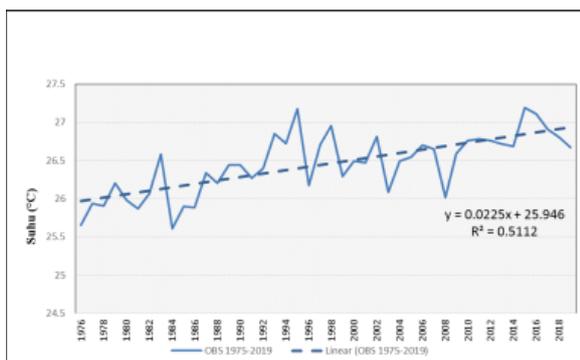
Figure 4. Observed temperature of Bandar Lampung in 1976-2019
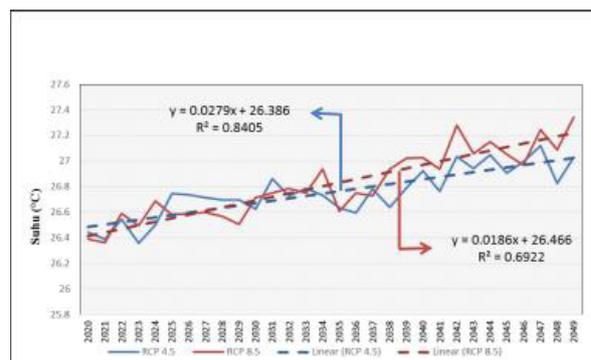
Figure 5. Projected temperature of Bandar Lampung in 2020-2049

Results of the rainfall trend showed a decrease for all observed years including the projection data which showed linear results with the observed data. A significant decrease occurred during the observation period, while the scenario data showed a decrease in rainfall but not as big as the trend of the observation data. RCP 4.5 showed a decrease of 3, 4702 mm per year while RCP 8.5 showed a decrease of 1,945 mm per year. Scenario results were not too significant compared to the observed data because they are only figures and have not been added to the variability and phenomena that usually occur in annual movements.

Result of RCP 4.5 was higher than RCP 8.5 for Bandar Lampung because it was only studied for a small area (one city), it was not researched for a wider area so the results may differ from the theory of research for the whole world.

The temperature in Bandar Lampung city showed an increase in temperature with a trend of 0.0225 ° C per year. The trend of the increase in temperature is linear with the results of the two scenarios used. The scenario data for the 2020-2049 RCP 4.5 periods showed an increase of 0.0279 ° C per year. Meanwhile, based on the RCP 8.5 scenario, it showed an increase with a trend of 0.0186 ° C per year. The results of temperature trend indicated an increase in temperature for all observed periods of the year. The upward trend was not much different between the observed data and the scenario data.

3.2. Seasonal Data Series Analysis and Projections

The analysis continued with divide the months in one year into three 'seasons' which are DJF (December January February), MAM (March, April and May), JJA (June, July and August) and SON (September, October and November). These divisions was attended to find what is the trend in rain season DJF, in transitional season to dry season MAM, in dry season JJA and in transitional season to rainfall season SON.

3.2.1. Rainfall. Observed rainfall in terms of seasonal DJF, MAM, JJA and SON for the data 1976-2019 and the projection on period 2020-2049 presented in Figures 5 to 12.

Trend of seasonal rainfall and its projection was presented in Table 1 and 2. Historical seasonal data from 1976-2019 showed a downward trend in rainfall for all periods of the month except for the JJA season. The scenario results showed that for RC 4.5 there were decreases for all months except the SON period while RCP 8.5 results showed that there were decreases in rainfall for the DJF and SON periods and increases in rainfall during the MAM and JJA periods. MAM and JJA are seasonal transition periods for Bandar Lampung, allowing for high fluctuations in that period. The trend of increase and decrease in rainfall per year is greater for RCP 8.5 scenario results for all the periods studied.
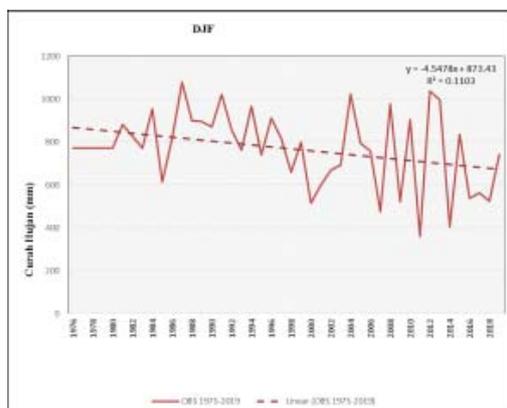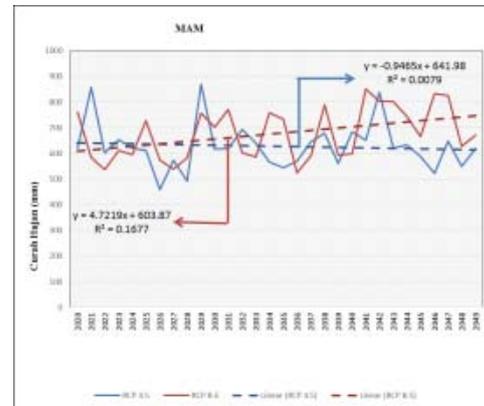

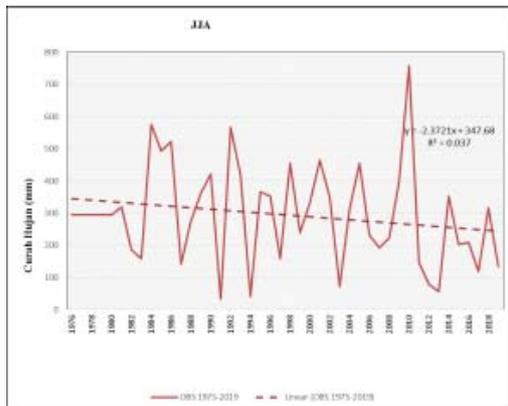**Figure 6.** Observed rainfall of Bandar Lampung in December, January and February
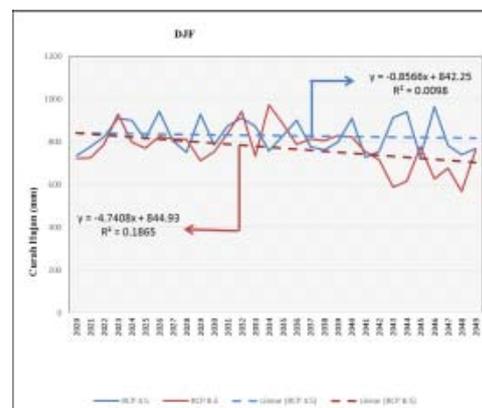
Figure 7. Projected rainfall of Bandar Lampung in December, January and February
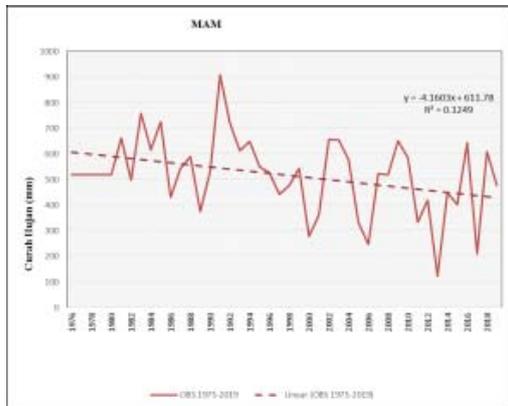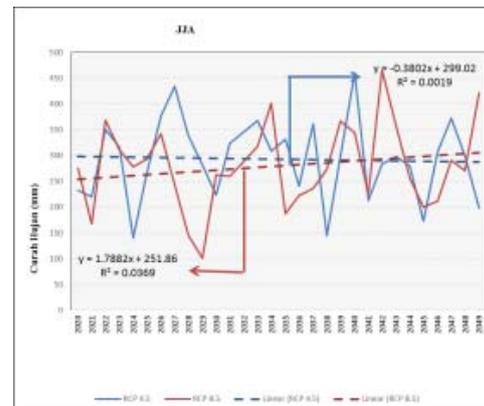
Figure 8. Observed rainfall of Bandar Lampung in March, April and May
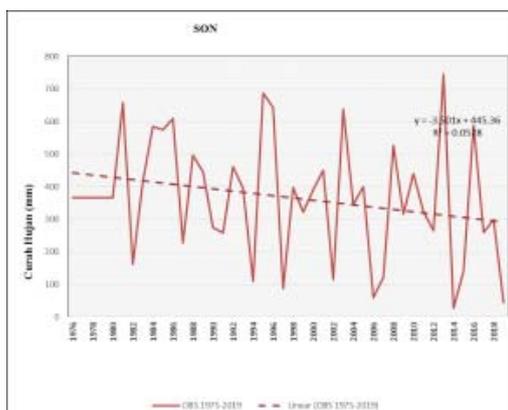

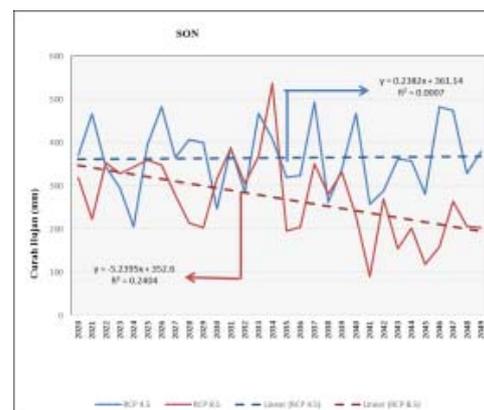**Figure 9.** Projected rainfall of Bandar Lampung in March, April and May

Figure 10. Observed rainfall of Bandar Lampung in June, July and August

Figure 11. Projected rainfall of Bandar Lampung in June, July and August

Figure 12. Observed rainfall of Bandar Lampung in September, October and November

**Figure 13.** Projected rainfall of Bandar Lampung in September, October and November

Table 1. 1976-2019 Rainfall Seasonal Rainfall Trend

Periods	DJF	MAM	JJA	SON
1976-2019	-4.5478	-4.1603	2.3721	-3.501

Table 2. Projection of Seasonal Rainfall Trend

| Scenarios	DJF	MAM	JJA	SON
RCP 4.5	-0.8566	-0.9465	-0.3802	0.2382
RCP 8.5	-4.7408	4.7219	1.7882	-5.2395

3.2.2. *Temperature.* Observed temperature in seasonal DJF, MAM, JJA and SON for the data 1976-2019 and the projection on period 2020-2049 presented in Figures 13 to 20.
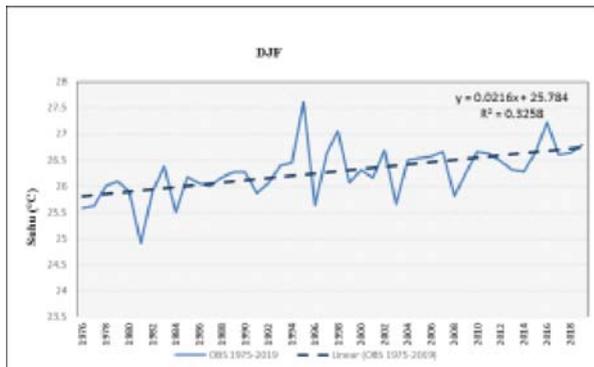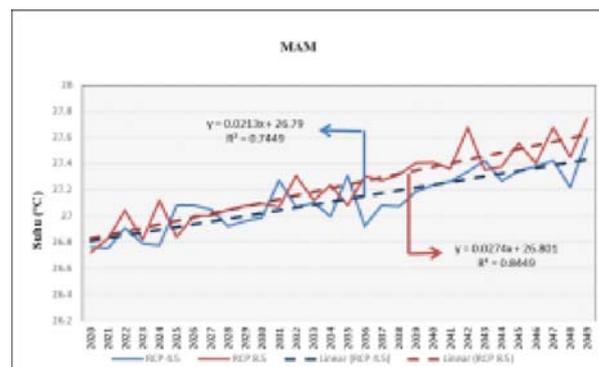

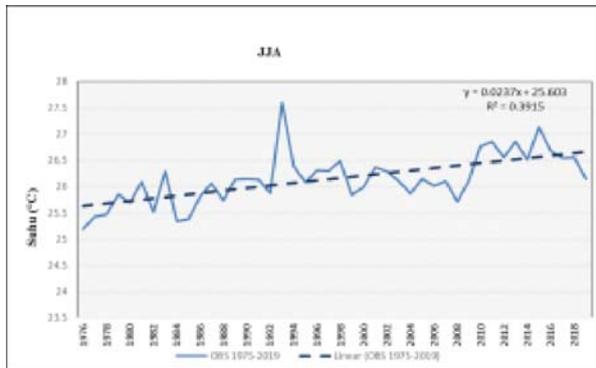**Figure 14.** Observed temperature of Bandar Lampung in December, January and February
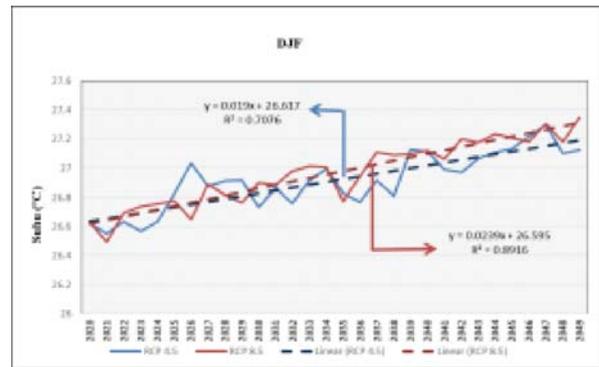
Figure 15. Projected temperature of Bandar Lampung in December, January and February
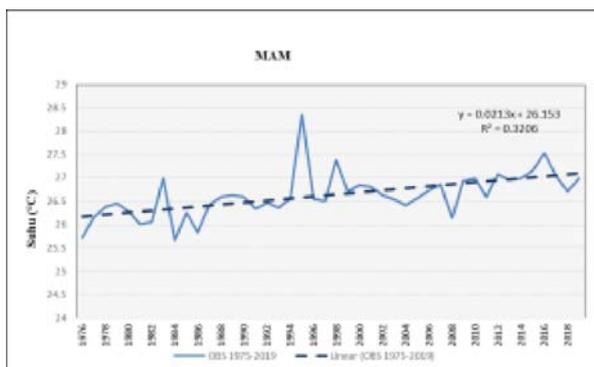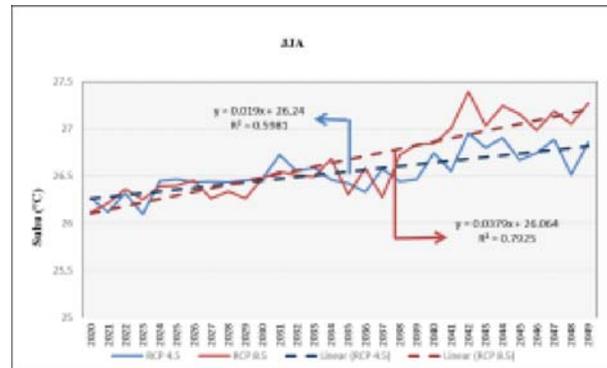

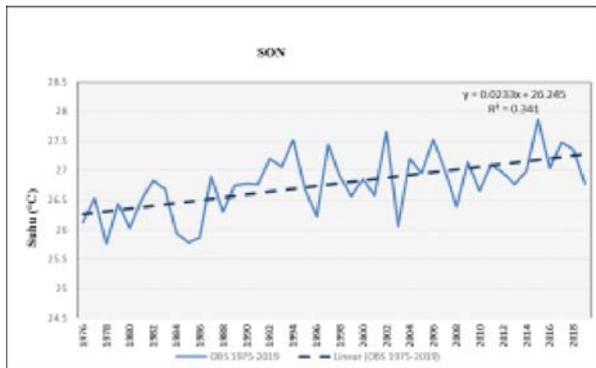**Figure 16.** Observed temperature of Bandar Lampung in March, April and May

Figure 17. Projected temperature of Bandar Lampung in March, April and May
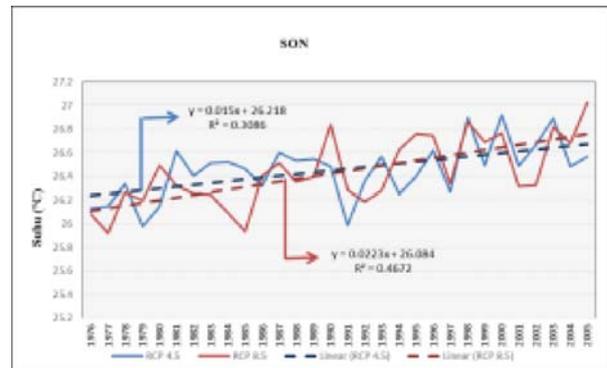
Figure 18. Observed temperature of Bandar Lampung in June, July and August

Figure 19. Projected temperature of Bandar Lampung in June, July and August

Figure 20. Observed temperature of Bandar Lampung in September, October and November

Figure 21. Projected temperature of Bandar Lampung in September, October and November

Trend of seasonal temperature and its projection was presented in Table 3 and 4. Historical seasonal data from 1976-2019 showed an upward trend in temperature for all periods of the month. The scenario results also showed an increase for the two scenarios. Temperature rise trend is greater for RCP 4.5. Movement of the temperature increase trend is greater in the RCP 8.5 scenario.

Table 3. 1976-2019 Seasonal Temperature Trend

Periods	DJF	MAM	JJA	SON
1976-2019	0.0216	0.0213	0.0237	0.0233

Table 4. Projection Seasonal Temperature Trend

Scenarios	DJF	MAM	JJA	SON
RCP 4.5	0.019	0.0213	0.019	0.015
RCP 8.5	0.0239	0.0274	0.0379	0.0223

The rainfall analysis indicated that in the future, based on the projection scenario used, there would be additional rainfall during the dry season and the intensity of rainfall could decrease in the rainy season. It seemed that water will be available all year and this might be appropriable for agriculture productions. However, with a constant upward tendency of temperature, agriculture activities need to be alarmed whether crops water need would be met since high temperature will increase the evapotranspiration rate [14]. High temperature could also ignite forest fire. The temperature increase will affect the sea surface temperature around Bandar Lampung. The existence of a constant increase in temperature will have an effect on the environment and changes in the pattern of human life such as increasing consumption of air conditioning so that the rate of temperature change increases

4. Conclusion
Rainfall analysis showed a downward tendency of rainfall both in historical data and the projection and for most of the season except for all dry periods, while temperature showed an upward tendency consistently. From the scenario, mitigation of reducing greenhouse gas concentrations did not have a consistent impact on rainfall but impacted on temperature trend. Rainfall distribution and temperature change would be two elements that are interrelated in future changes.

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