The Impact of Global Climate Change to Climate Condition of Bengkulu Watershed, Indonesia

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Abstract. Global climate change that occurred in this century can affect the pattern of rain and increase in temperature on earth. This study aims to determine and analyze the increase in rainfall, air temperature, potential evapotranspiration and actual evapotranspiration in the Bengkulu watershed. For this reason, the regional rainfall is calculated using the Thiessen Polygon, the mean air temperature of the watershed based on the median elevation, potential evapotranspiration using the Thornthwaite Method and actual evapotranspiration using the basis of the difference in rainfall to potential evapotranspiration. The results showed that every year there was an increase in rainfall, air temperature, potential evapotranspiration and actual evapotranspiration in the Bengkulu Watershed. In the 2009-2013 period, the average annual rainfall of 3,581 mm increased to 3,641 mm in the 2014-2018 period. For air temperature, the average monthly air temperature in the Bengkulu Watershed for the 2009-2013 period was 25.8°C, while the air temperature in the 2014-2018 period was 26.1°C. This means that in a period of 5 years there is an increase in temperature of 0.3°C. Furthermore, due to the increase in air temperature, there was an increase in the average monthly potential evapotranspiration from the 2009-2013 period to the 2014-2018 period, namely from 1,493 mm to 1,537 mm, while for actual evapotranspiration there was an increase from 1,486 mm to 1,518 mm.

1 Introduction

According to United Nation Environmental Program (UNEP) experts, climate change is a major environmental problem of this century. Some indications of the impact of climate change are the increased air temperature and changing rainfall patterns [1]. As a result of changes in climate elements, the condition of water resources can change [2].

The amount of water on earth is constant, as is the amount of water that can be accommodated in a watershed. The existence of a phenomenon of shortage and excess of water in an area is only a matter of its unequal distribution, or because the phases of its form in the hydrological cycle are not balanced. Therefore, the problem in water management is that water can be sufficiently available where it is needed with good and sustainable quality [3-4].

In water management in a watershed, the concept of the hydrological cycle in its entirety must be understood to study rain as an input that falls on the surface of the watershed and returns to the sea again through various processes, stages and changes in form [5-6]. In this phenomenon the most important processes are rainfall, air temperature and evapotranspiration, which then affect surface runoff in the watershed.

Rainfall is an important aspect as a cause of runoff including floods, because rain is the main source of surface runoff [7-9]. The size of the rainfall and runoff and the distribution of runoff over time can also be used as the basis for the operation of water structures. Rain is water that falls to the earth's surface in the form of droplets due to the condensation of water vapor in the atmosphere. The factors that influence the distribution of rain are latitude, elevation, distance from water sources, location from mountains, wind direction and physical properties of air masses.

Air temperature is a measure of the heat of the earth's surface and the atmosphere due to solar radiation [10]. The factors that influence the difference in temperature from one place to another are the angle of incidence of sunlight, long exposure time, elevation and geographical conditions of the area. Air temperature greatly affects evapotranspiration, namely the process of water loss due to evaporation and transpiration.

Regarding evapotranspiration, there are two dimensions of evapotranspiration, namely potential evapotranspiration (Ep) and actual evapotranspiration (Ea). Potential evapotranspiration is the amount of water lost due to evapotranspiration if there is sufficient water available or in ideal conditions, while actual evapotranspiration is the actual evapotranspiration that occurs.

Astronomically, the Bengkulu watershed is located at coordinates 102°14'39 "- 102°35'00" East Longitude and 3°37'6 "- 3°50'33" South Latitude [11]. According to [12], the average annual rainfall in the Bengkulu watershed is around 3,118 mm/year, so that the

Bengkulu River, which is the main river of the Bengkulu Watershed, experiences two floods during the rainy season [13]. Because in the process of rainfall to flow in a watershed is influenced by the characteristics of the watershed climate, flood events can be analyzed through aspects of rainfall, air temperature and evapotranspiration in the watershed [14].

2 Methodology

This study is based on secondary data, namely monthly rainfall and air temperature data in the Bengkulu watershed in 2009-2018 which were obtained from the Bengkulu Climatology Station BMKG. For rain, the rainfall data used is monthly rainfall data at six rain stations around the Bengkulu watershed area which is then processed into regional average monthly rainfall data using the Thiessen Polygon method. The rain gauge used is the Observatory (Obs) gauge, while the location of rainfall station used in this study is shown in Figure 1 and Table 1 and the percentage of the Thiessen Polygon area to the sub-watershed is shown in Table 2.

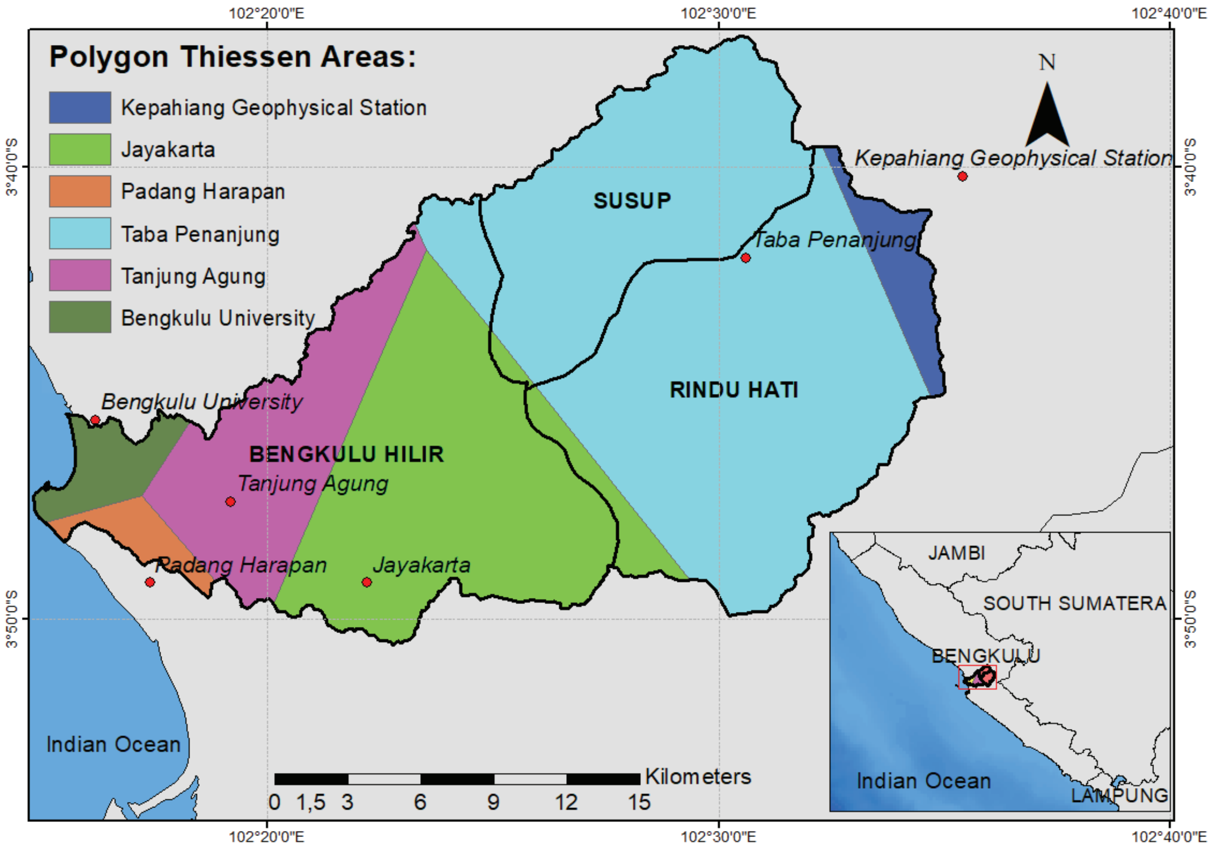

Fig. 1. Location of rainfall station [15].

Tabel 1. Location and elevation of rainfall station.

Rainfall Station	South Latitude	East Longitude	Elevation (m)
Bengkulu University	3°45'36"	102°16'12"	29
Tanjung Agung	3°47'32"	102°19'13"	20
Padang Harapan	3°49'18"	102°17'11"	30
Jayakarta	3°49'12"	102°22'12"	39
Taba Penanjung	3°42'00"	102°30'36"	149
Kepahiang Geophysic Station	3°40'11"	102°35'20"	517

Source : [15]

Table 2. Percentage of Thiessen Polygon area to area of sub-watersheds in Bengkulu Watershed.

Rainfall Station	Sub Watershed (%)		
	Rindu Hati	Susup	Bengkulu Hilir
Bengkulu University	0	0	6.64
Tanjung Agung	0	0	29.40
Padang Harapan	0	0	4.16
Jayakarta	5.46	1.47	54.90
Taba Penanjung	86.06	98.53	4.90
Kepahiang Geophysic Station	8.47	0	

Source : [15]

Monthly air temperature determination is based on air temperature data from the nearest station as a reference and is calculated using the Mock method. Determination of the air temperature in the area using the median elevation

Potential evapotranspiration is calculated using the Thornthwaite equation, while actual evapotranspiration is determined based on the amount of rain and potential evapotranspiration. In the wet month (rainfall > potential evapotranspiration), the actual evapotranspiration is assumed to be equivalent to the potential evapotranspiration, while in the dry month (rainfall < potential evapotranspiration), the actual evapotranspiration is determined by increasing the amount of rainfall that occurs with changes in soil moisture storage which is deficit.

3 Results and discussion

3.1 Rainfall

The pattern of annual rainfall during 2009 to 2018 in the three sub-watersheds in the Bengkulu watershed can be shown in Table 3 and Figure 2.Based on Table 3 and Figure 2, it can be seen that every year the average annual rainfall in the Bengkulu watershed has increased.

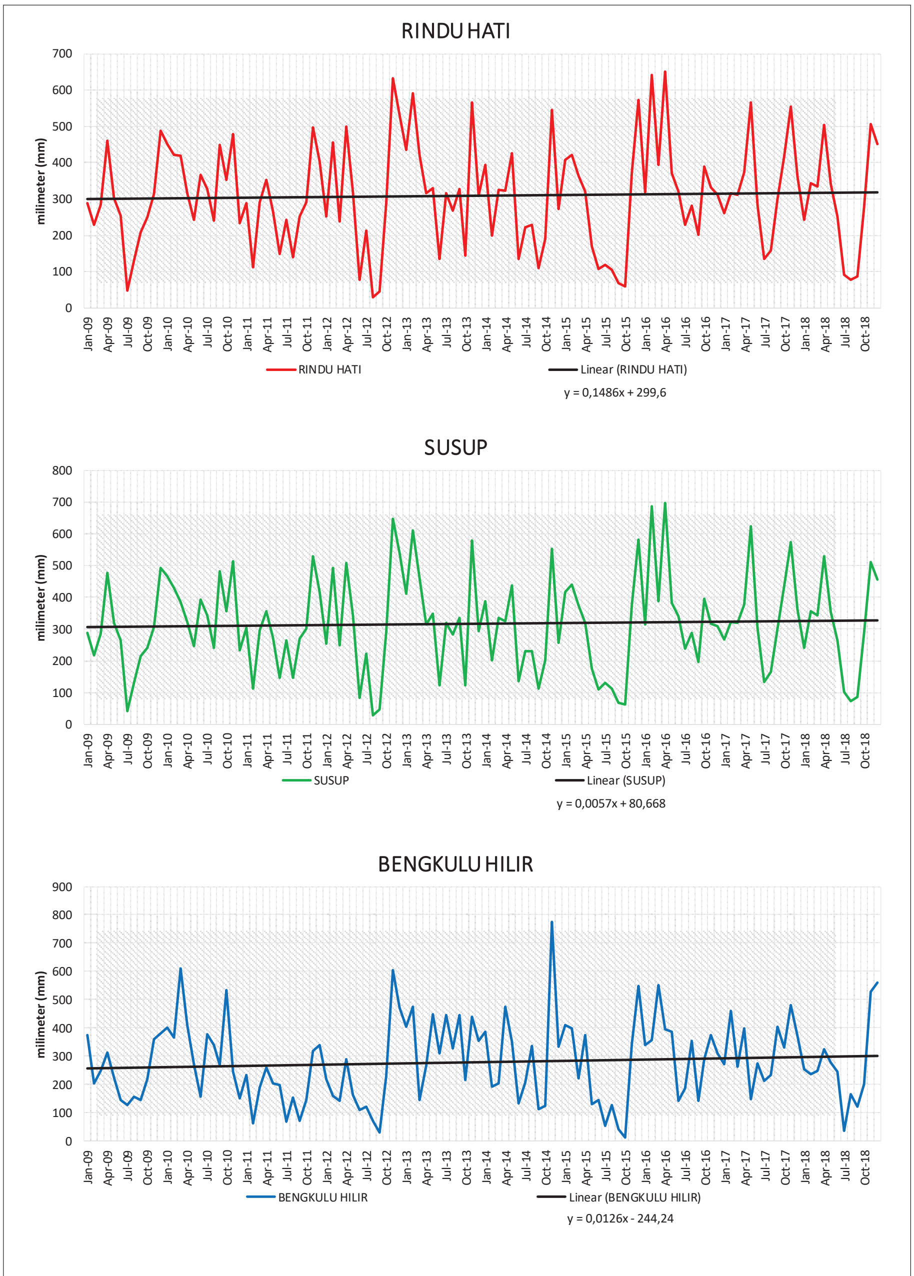

Fig. 2. Monthly rainfall 2009-2018 [15].

In the 2009-2013 period, Susup Sub-watershed had the highest average annual rainfall of 3,801 mm, while Bengkulu Hilir Sub-watershed had the lowest average annual rainfall of 3,225 mm. In the 2014-2018 period, the Susup Sub-watershed also had the highest average annual rainfall of 3,780 mm, while the Bengkulu Hilir Sub-watershed also had the lowest average annual rainfall of 3,455 mm. Observing the average rainfall per period, in the 2009-2013 period the average annual rainfall of 3,581 mm increased to 3,641 mm in the 2014-2018 period.

Table 3. Annual rainfall for the 2009-2013 and 2014-2018 periods.

Periods	Annual Rainfall in Sub-watershed (mm)		
	Rindu Hati	Susup	Bengkulu Hilir
Period 1			
2009	3,256	3,277	2,891
2010	4,304	4,409	4,123
2011	3,282	3,416	2,240
2012	3,582	3,706	2,598
2013	4,160	4,195	4,272
Average	3,717	3,801	3,225
Period 2			
2014	3,370	3,406	3,622
2015	3,088	3,164	2,798
2016	4,441	4,548	3,823
2017	4,037	4,181	3,845
2018	3,510	3,602	3,189
Average	3,689	3,780	3,455

Source : [15]

3.2 Air temperature

Looking at Figure 3, every year the average monthly air temperature in the Bengkulu Watershed has increased. Because it has the highest median elevation value, the average monthly air temperature in the Rindu Hati Sub-watershed is the lowest, while the highest average air temperature is found in the Bengkulu Hilir Sub-watershed (Table 4). Based on Table 4, it can also be seen that the average monthly air temperature in the Bengkulu Watershed for the 2009-2013 period was 25.8^{o}C, while the air temperature in the 2014-2018 period was 26.1^{o}C. This means that in a period of 5 years in the Bengkulu Watershed there is an increase in temperature of 0.3^{o}C.

Table 4. Average monthly air temperatures for the 2009-2013 and 2014-2018 periods.

Periods	Average Monthly Air Temperature (^{o}C)		
	Rindu Hati	Susup	Bengkulu Hilir
Period 1			
2009	25.1	25.7	26.4
2010	25.3	26.0	26.6
2011	25.1	25.7	26.4
2012	25.3	25.9	26.6
2013	25.3	25.9	26.5
Average	25.2	25.8	26.5
Period 2			
2014	25.3	25.9	26.6
2015	25.5	26.2	26.8
2016	25.7	26.3	26.9
2017	25.4	26.0	26.7
2018	25.4	26.0	26.7
Average	25.5	26.1	26.7

Source : [15]

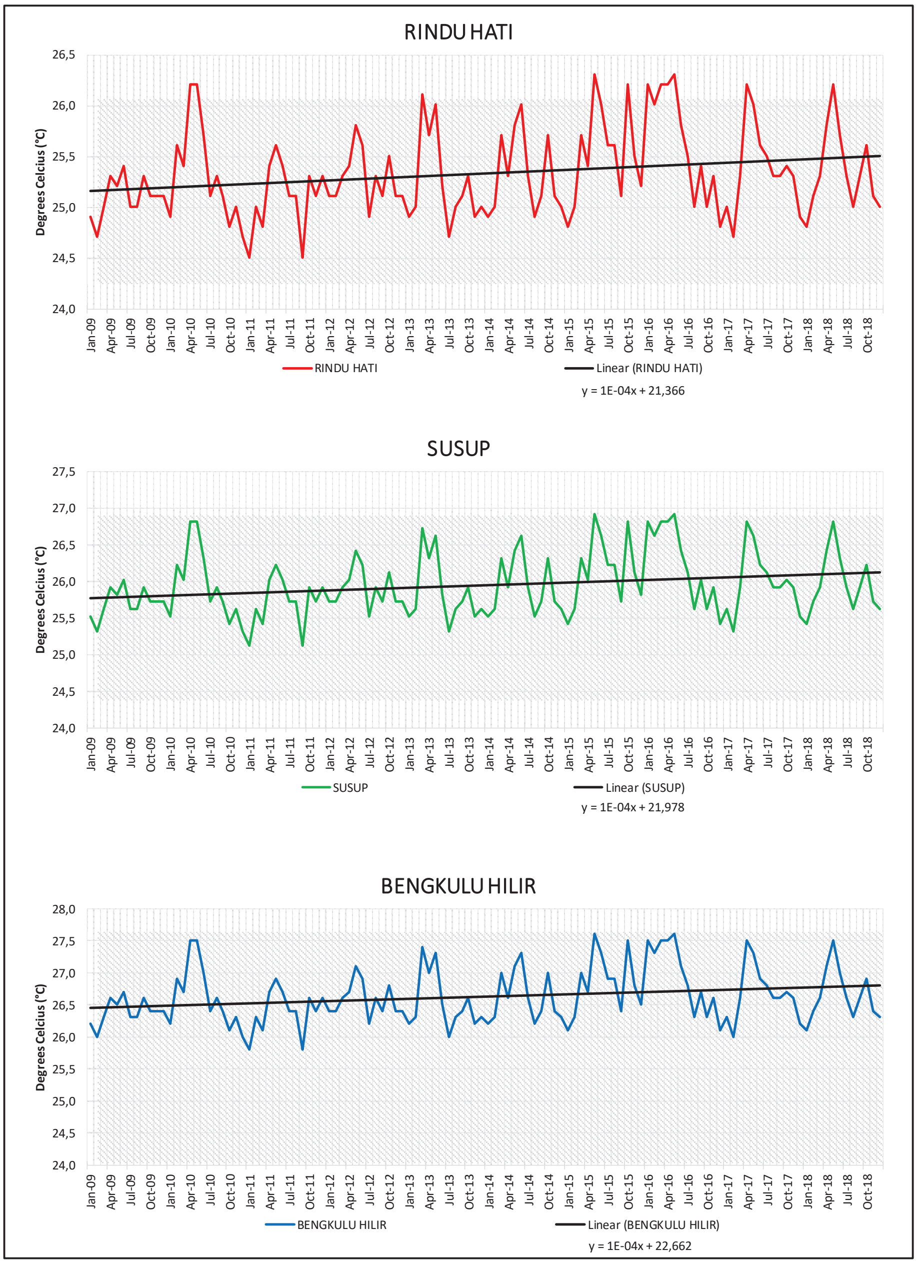

Fig. 3. Monthly air temperature in 2009-2018 [15].

3.3 Evapotranspiration

In general, each year the potential and actual monthly evapotranspiration in the Bengkulu Watershed also increases (Figure 4). However, at some point in time the opposite may also have happened. For example, the actual evapotranspiration in September 2012 decreased, but in October 2015 only the Bengkulu Hilir Sub-watershed experienced a decline. This phenomenon can occur due to the effect of low rainfall of less than 50 mm, whereas for October 2015 only actual evapotranspiration in Bengkulu Hilir Sub-watershed decreased because the rainfall in October 2015 in Bengkulu Hilir sub-watershed was only 12 mm.

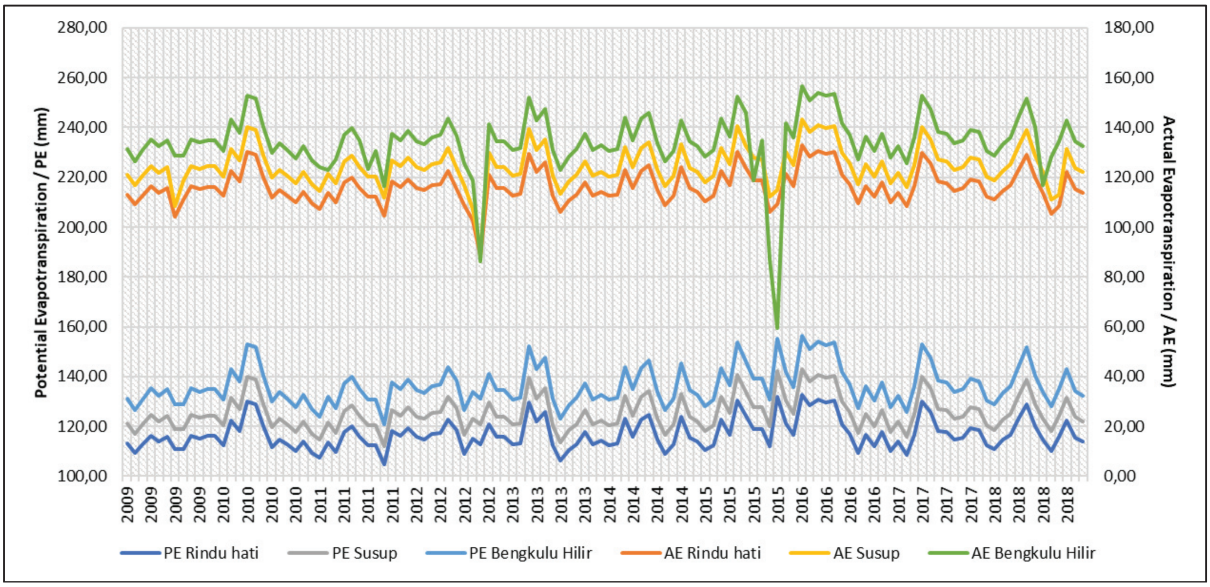

Fig. 4. Monthly potential and actual evapotranspiration in 2009-2018 [15].

The average potential and actual evapotranspiration in each sub-watershed are different due to the difference between the average potential and actual evapotranspiration in each of these sub-watersheds. The difference that occurs shows that the rainfall in that month is smaller than the potential evapotranspiration in the sub-watershed.

In the period 2009-2013, Rindu Hati Sub-watershed and Susup Sub-watershed experienced differences in the average potential evapotranspiration and actual evapotranspiration from June to September, while for Bengkulu Hilir Sub-watershed it occurred from February to March and June to September (Figure 5). In the 2014-2018 period, the difference between potential evapotranspiration and actual evapotranspiration in Rindu Hati and Susup Sub-watersheds occurred from June to October, while in Bengkulu Hilir Sub-watershed it occurred from May to October (Figure 6).

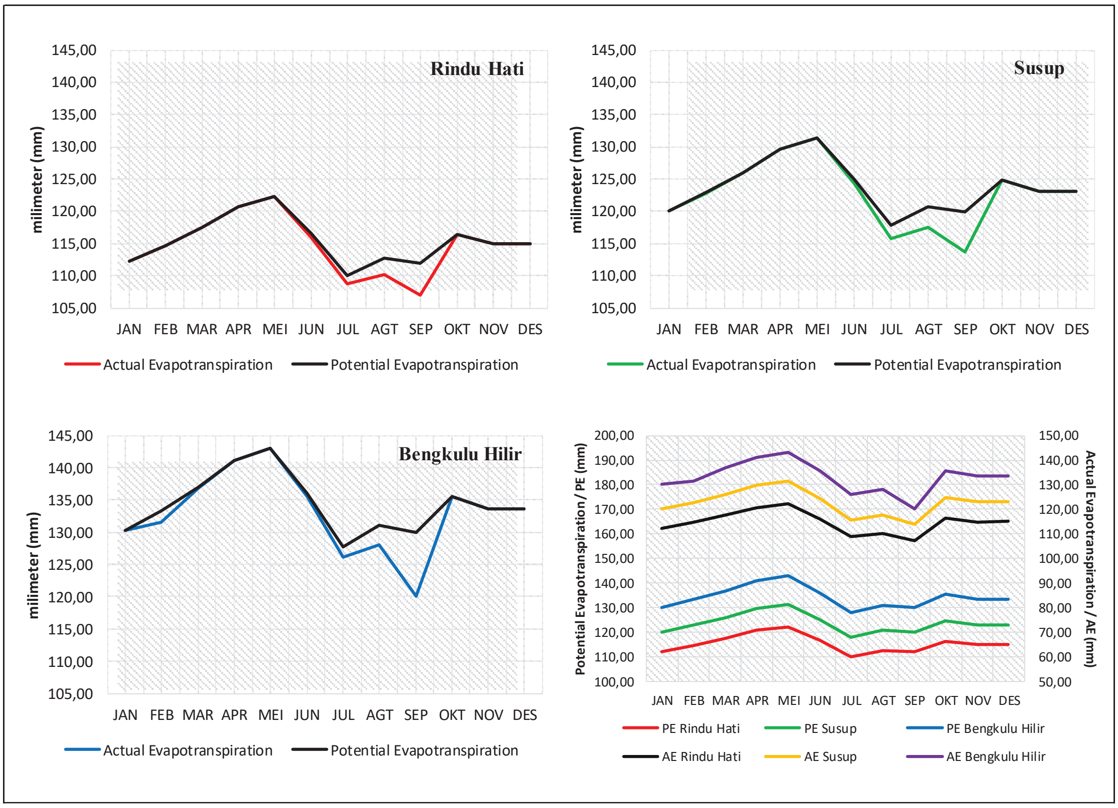

Fig. 5. Monthly potential and actual evapotranspiration in 2009-2013 [15].

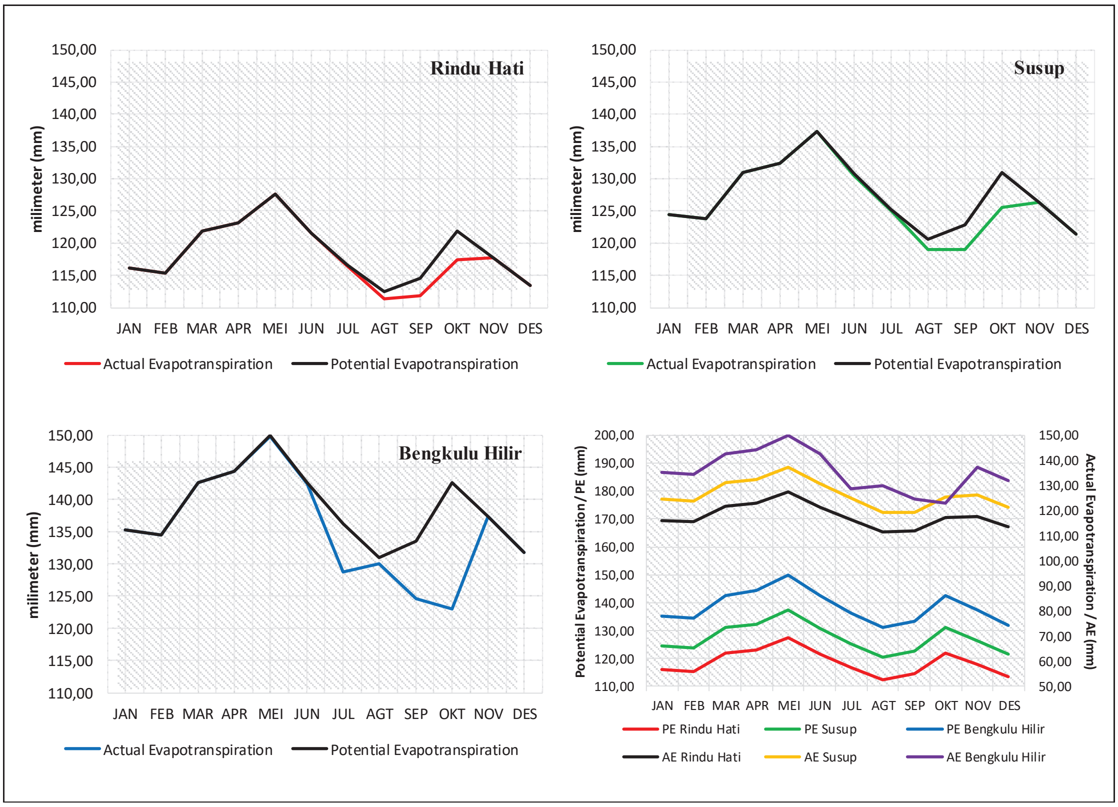

Fig. 6. Monthly potential and actual evapotranspiration in 2014-2018 [15].

On an annual basis, the average potential evapotranspiration in Rindu Hati Sub-watershed in the 2009-2013 period as well as the 2014-2018 period is the lowest. The highest average potential evapotranspiration occurs in Bengkulu Hilir Sub-watershed (Table 4). For actual evapotranspiration, the lowest average actual evapotranspiration also occurred in the Rindu Hati sub-watershed, while the highest actual evapotranspiration also occurred in Bengkulu Hilir Sub-watershed (Table 5). When viewed by time, there is a tendency for an increase in the average annual potential evapotranspiration from the 2009-2013 period to the 2014-2018 period throughout the watershed, from 1,493 mm to 1,537 mm. For actual evapotranspiration there is an increase from 1,486 mm to 1,518 mm.

Table 5. Annual potential pvapotranspiration in the Bengkulu Watershed.

Periods	Annual Potential Evapotranspiration in Sub-watershed (mm)		
	Rindu Hati	Susup	Bengkulu Hilir
Period 1			
2009	1,367	1,464	1,588
2010	1,405	1,507	1,639
2011	1,368	1,464	1,589
2012	1,395	1,496	1,625
2013	1,391	1,491	1,620
Average	1,385	1,481	1,612
Period 2			
2014	1,402	1,503	1,634
2015	1,437	1,543	1,681
2016	1,456	1,565	1,706
2017	1,411	1,514	1,647
2018	1,407	1,509	1,641
Average	1,422	1,527	1,662

Source : [15]

Table 5. Annual actual evapotranspiration in the Bengkulu Watershed.

Periods	Annual Actual Evapotranspiration in Sub-watershed (mm)		
	Rindu Hati	Susup	Bengkulu Hilir
Periods 1			
2009	1,360	1,454	1,588
2010	1,405	1,507	1,639
2011	1,368	1,464	1,569
2012	1,355	1,446	1,562
2013	1,391	1,491	1,620
Average	1,391	1,472	1,595
Period 2			
2014	1,402	1,501	1,631
2015	1,407	1,507	1,515
2016	1,456	1,565	1,706
2017	1,411	1,514	1,647
2018	1,394	1,491	1,624
Average	1,414	1,516	1,624

Source : [15]

4 Conclusion

1) Every year there is an increase in the average monthly rainfall in the Bengkulu Watershed. In the 2009-2013 period, the average annual rainfall of 3,581 mm increased to 3,641 mm in the 2014-2018 period.
2) Every year the average monthly air temperature in the Bengkulu Watershed has also increased. The average monthly air temperature in the Bengkulu watershed for the 2009-2013 period was 25.8°C, while the air temperature in the 2014-2018 period was 26.1°C. This means that in a period of 5 years in the Bengkulu Watershed there is an increase in temperature of 0.3°C.
3) Due to the increase in air temperature, there was an increase in the average annual potential evapotranspiration from the 2009-2013 period to the 2014-2018 period, namely from 1,493 mm to 1,537 mm, while for actual evapotranspiration there was an increase from 1,486 mm to 1,518 mm.

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