LOOK ACADEMIC PUBLISHERS
OPEN ACCESS

INTERNATIONAL JOURNAL OF ENVIRONMENTAL & SCIENCE EDUCATION
e-ISSN: 1306-3065
2019, Vol. 14, No. 9, 583-590

Effects of Climate Change on the Potential of Evapotranspiration in the Singkoyo Watershed, Central Sulawesi, Indonesia

I. Wayan Sutapa [1*], I. Gede Tunas [1]

[1] *Faculty of Engineering, University of Tadulako, Palu, Central Sulawesi, INDONESIA*

* CORRESPONDENCE: wsutapa@yahoo.com

ABSTRACT

Rainfall and ET0 are the two main factors in the tendency of floods or droughts in an area. Considering the impression capabilities of these two factors due to climate change, the aim of this study is to estimate rainfall and ET0 for future periods due to climate change and to evaluate their uncertainty with the potential for high flooding or drought. This research was conducted in the Singkoyo Watershed by conducting field surveys, daily rainfall data collection and climatology data. The analysis carried out in this study, namely: detection of climate change, projections of climate change and potential evapotranspiration. The conclusion of this study is: there has been a climate change in the Singkoyo watershed marked by $Z \neq 0$ and occurred extreme monthly and annual rainfall. In general, it can be said that a decrease in potential evapotranspiration on one side will cause an increase in the average monthly rainfall on the other side. In the future it is likely that there will be a trend of increasing monthly and annual rainfall which is quite significant so we need to be aware of the danger of flooding. Therefore, it is necessary to implement climate change adaptation procedures.

Keywords: climate change, potential evapotranspiration, Mann Kendall, Sens, Singkoyo Watershed

INTRODUCTION

Climate change that occurs will result in an increase or decrease in rainfall in an area, an increase in air temperature, changes in seasonal patterns, wind patterns, air humidity, and solar radiation. A decrease or increase in rainfall as a watershed input variable due to climate irregularities will affect river flow discharge, both annual total river flow and seasonal dynamics. In general the impact is very simple, namely higher rainfall will result in greater river flow and decreased rainfall will reduce river flow.

Based on the dynamics of the hydrological cycle, one of the main water sources is rain. Rain naturally occurs from the process of condensation of water vapor in the air which subsequently forms a cloud. If physical conditions both inside and outside the clouds support, the rain will take place. Therefore, the nature and conditions of a rain or rainy season are very dependent on the weather / climate conditions that occur. The availability of natural water on a global scale is constant, it only happens, variations both in space and time on a regional scale (Mulyono, 2014).

The study of reduced or greater rainfall related to potential evapotranspiration (ETo) is one of the main references in managing extreme climate events (Abdolhosseini et al., 2012). This can be seen in the hydrological cycle, where the potential for evapotranspiration (ET0) is an important factor so that it has an important role in integrated river basin management. Rainfall and ET0 are two main factors as causes in the

Article History: Received 15 September 2019 ◆ Revised 27 October 2019 ◆ Accepted 27 October 2019

tendency of flooding or drought in an area. An area with high ETo which is not balanced with sufficient and evenly rainfall will be very disturbed by the condition of the water balance, and will cause problems, especially activities that require water, including agricultural activities. Through water balance and evapotranspiration can affect climate (Usman, 2004).

METHODOLOGY

Literature Study

Evapotranspiration

Potential evapotranspiration is calculated by the Penman Monthiet equation (Allen, 1998; Solihin Ansari et al., 2017; Sutapa & Ishak, 2017; Sutapa et al., 2013; Sutapa, 2014, 2015a, 2015b, 2015c, 2017):

$$ET_0 = \frac{\Delta(Rn - G) + \rho a.cp\frac{(es - ea)}{ra}}{\Delta + \beta\gamma\left(a + \frac{rs}{ra}\right)} \quad (1)$$

Mann - Kendall Test

Detection of climate change uses the Mann-Kendall equation (Aksu et al., 2010; Deo et al., 2005; Sutapa et al., 2013; Sutapa, 2014, 2015a, 2015b, 2017). The magnitude of the trend is used the nonparametric Sens method (Deo et al., 2015; Timo, 2002) assuming the trend is linear. Some equations as follows:

$$S=\sum_{k=1}^{n-1}\sum_{j=k+1}^{n} sgn(X_j - X_k) \quad (2)$$

$$\sigma s=\sqrt{n(n-1)(2n+5)/18} \quad (3)$$

$$Z=\begin{cases}(S-1)/\sigma s.......jika......S >...0\\ 0....................jika.....S =..0\\ (S+1)/\sigma s.......jika....S <....0\end{cases} \quad (4)$$

$$f(t) = Qt + B \quad (5)$$

$$Q_i = \frac{X_j - X_k}{j - k} \quad (6)$$

$$Q = Q_{[(N+1)/2]}\ if\ N\ is\ odd\ or\ Q = 0.5\ (Q_{(N/2)} + Q_{((N+2)/2)})\ if\ N\ is\ even \quad (7)$$

Location of Research

The research location is located in the Singkoyo watershed, Central Sulawesi, Indonesia. The area of the Singkoyo watershed is 361.96 km^2. Geographically, the Singkoyo watershed is located between 122° 03' 3.3"- 122° 22' 13" east longitude and 01° 18' 14.4"- 01° 28' 8.8" south latitude. The research location can be seeen in **Figure 1**.

Stages of Research

The research stages can be described as follows:

Data collection

The data used in this study is secondary data, i.e. climatology and rainfall data at Station Singkoyo in year 1986-2017. The data was obtained from the Office of the Sulawesi III River Region Office, Palu, Central Sulawesi Indonesia.

Evapotranspiration

Evapotranspiration was analyzed by the Montieth Penman method. The input is in the form of monthly climatology data (air temperature, air humidity, duration of sun exposure, and wind speed, while the output is monthly evapotranspiration data.

Climate trends and projections

Climate trends and projections were analyzed by the Mann-Kendall-Sens (Makesens) method. The inputs are rainfall data (monthly, yearly) and potential evapotranspiration (monthly, yearly). The output is in the

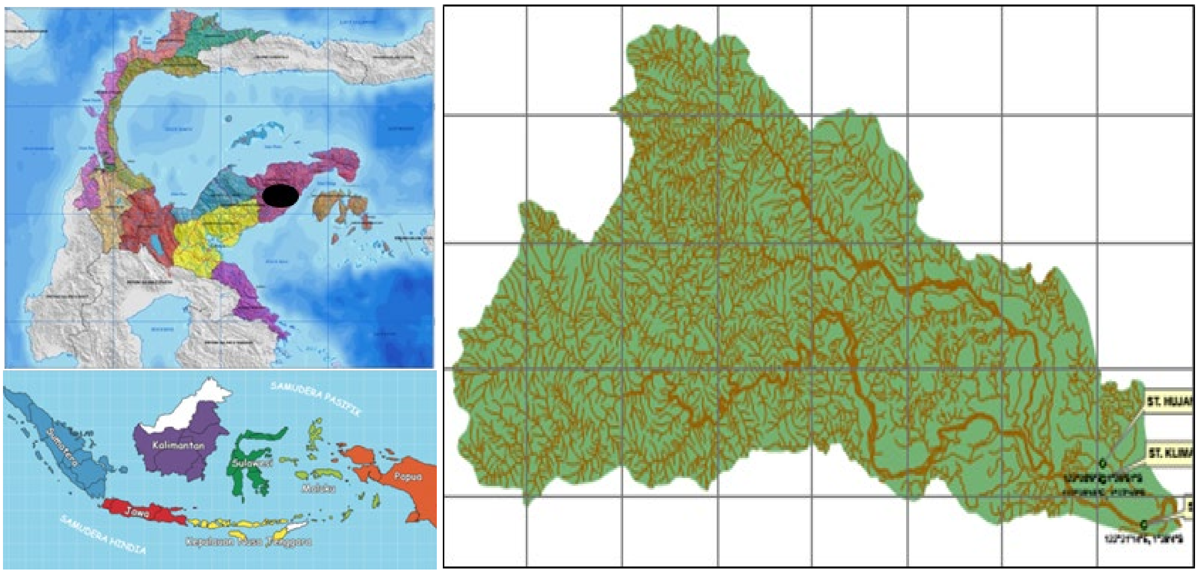

Figure 1. Research location

Table 1. The results of Mann Kendall

Rain/Evapo.	From	To	n	Trend											
				Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
R, Monthly (mm/month)	1986	2017	32	1.30 Pos, NS	1.67 Pos, YS	1.27 Pos, NS	0.18 Pos, Ns	1.51 Pos, NS	1.41 Pos, NS	1.52 Pos, NS	1.14 Pos, NS	0.97 Pos, NS	1.19 Pos, NS	-0.15 Neg, NS	-0.19 Neg, NS
R, Yearly (mm/year)	1986	2017	32	1.90 Pos, YS											
ETo, Monthly (mm/month)	1986	2017	32	-2.25 Neg, YS	-1.35 Neg, NS	-1.67 Neg, YS	-2.19 Neg, YS	-1.83 Neg, YS	-0.89 Neg, YS	-1.44 Neg, YS	-0.83 Neg, YS	-2.58 Neg, YS	-1.77 Neg, YS	-2.01 Neg, YS	-0.47 Neg, NS
ETo, Yearly (mm/year)	1986	2017	32	-2.97 Neg, YS											

Where:

Pos	= Positive or increasing trend	Z > Zα .... Yes significant (YS)
Neg	= Negative or decreasing trend	Z < Zα .... No significant (NS)
YS	= Yes significant	Z = 0 .... No trend (NT)
NS	= No significant	
NT	= No trend	

form of "Z" values which indicate the presence and absence of climate change and "Q & B" values as projected climate change for the next few years.

RESULTS AND DISCUSSIONS

Mann-Kendall-Sens (Makesens)

Based on the results of Mann Kendal calculations like **Table 1**, it can be seen that there has been a climate change in the Singkoyo watershed which is statistically marked with the value "Z" not equal to zero ($Z \neq 0$). Z value in the average monthly rainfall (R) almost all months there is a positive trend or an increase in rainfall except in November and December. Z value in annual rainfall is a trend of increasing rainfall and occurs significantly. The opposite occurs in the monthly average potential evapotranspiration (ETo), where there is a significant downward trend in ETo for all months except in February, June, August and December. Whereas ETo for the year there was a significant downward trend in ETo.

Rainfall (R) and Potential Evapotranspiration (ETo)

In **Figure 2** shows a graph of the relationship between monthly rainfall (R) and potential evapotranspiration (ETo). The straight-line equation for monthly rainfall is $R = 0.2669X + 186.02$ in the form of an uptrend and for potential evapotranspiration $ETo = -0.0225X + 111.84$ in the downtrend. This graph shows that the higher the monthly rainfall, the lower the evapotranspiration. This can be seen for the monthly rainfall in 2001 where the highest monthly rainfall occurred during this period and the potential

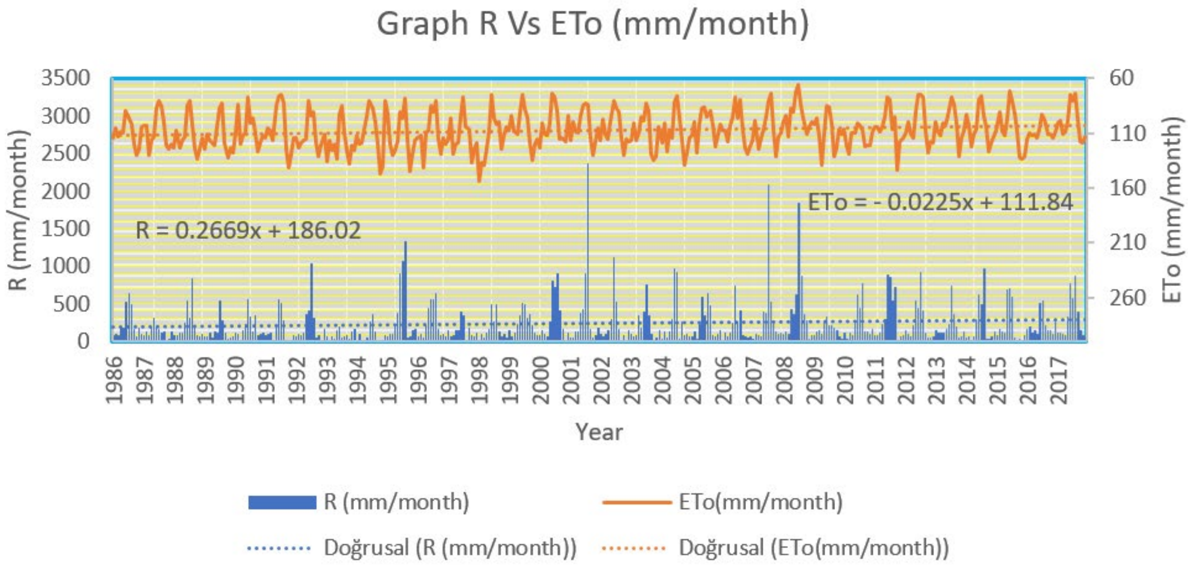

Figure 2. Relationship between rainfall and evapotranspiration (1986-2017), mm/month

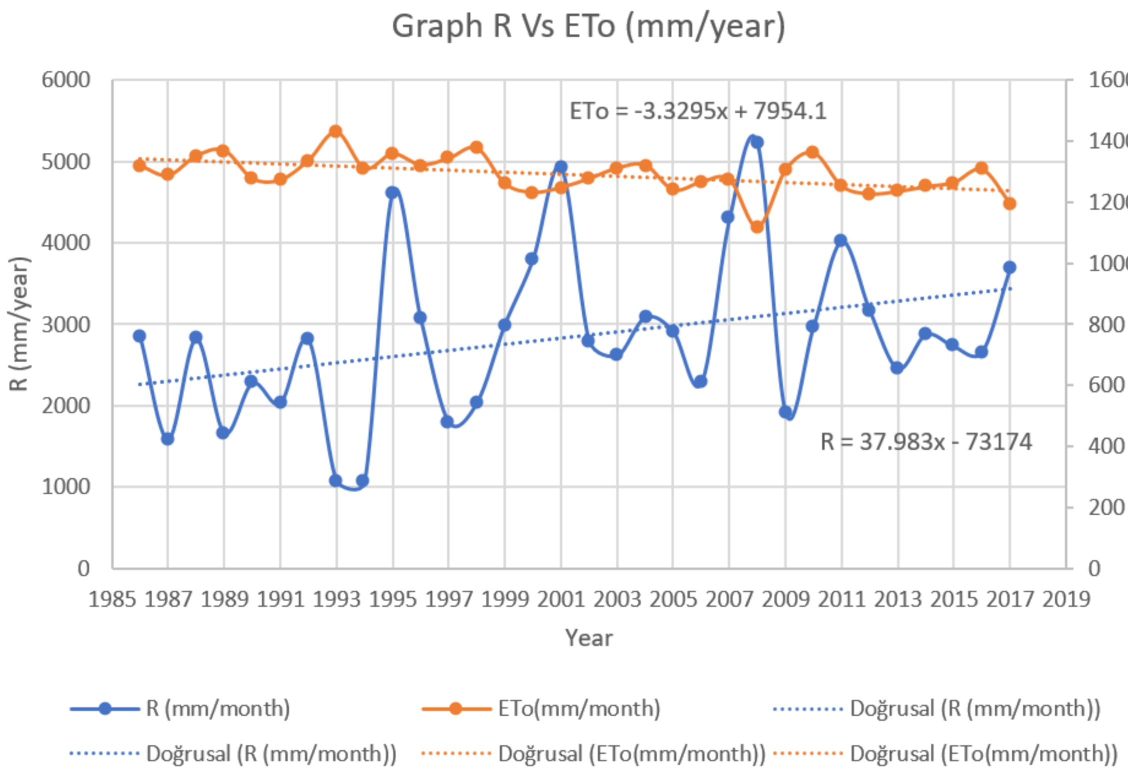

Figure 3. Relationship between rainfall and potential evapotranspiration (mm/year)

evapotranspiration is also low although not the lowest. The same thing happened in the months for 2007, 2008 and 1995 where high monthly rainfall and low potential evapotranspiration. Taking into account the extremely extreme monthly rains in 1995, 2001, 2007 and 2008, the results of the Z value in Mann Kendall's calculation that climate change has occurred in the Singkoyo watershed are increasingly apparent.

Figure 3 shows the relationship between the amount of annual rainfall and the potential annual evapotranspiration. The linear line equation for annual rainfall R = 37.988X -73174 is an upward trend and a straight-line equation for annual evapotranspiration ETo = -3.3295X + 7954.1 is a downward trend. By taking into account the extreme amounts of annual rainfall in 1995, 2001, 2007 and 2008, there is a possibility that

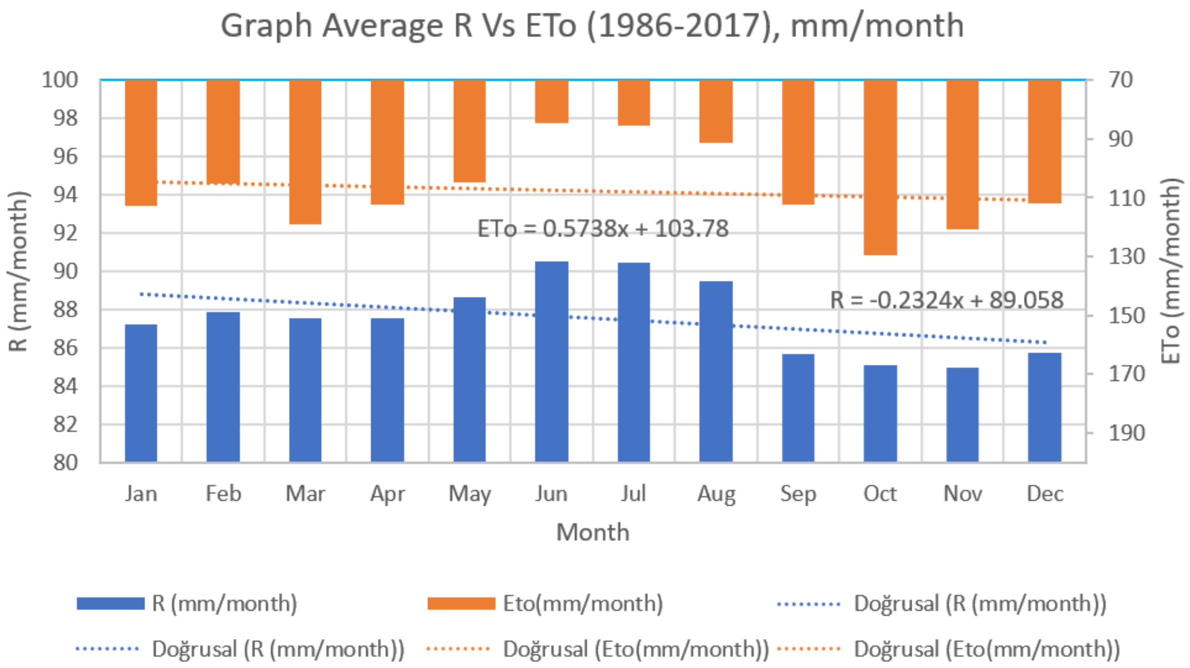

Figure 4. Relationship between average rainfall and evapotranspiration (1986-2017) (mm/month)

substantial floods will occur in those years. The opposite happened in 1993 and 1994, where there was an extremely small amount of annual rain, there was a possibility of drought in those years.

Figure 4 shows the graph of the relationship between the mean monthly rainfall and the potential evapotranspiration rate for the period 1986 to 2017. The straight-line equation for rain is R = -0.2324X + 89.058 in the form of a downward trend and for potential evapotranspiration ETo = 0.5738X + 103.78 in the form of an uptrend. It can be said that the average monthly rainfall is not too much different between 1986 and 2017. The opposite occurs in the average potential evapotranspiration where in June, July and August the value of ETo is quite small when compared with other months. In general, it can be said that a decrease in potential evapotranspiration on one side will cause an increase in the average monthly rainfall on the other side.

Rainfall (R) and Potential Evapotranspiration (ETo) Projection

By using the Makesens method, it can make rain and potential evapotranspiration projections as desired as shown in **Figure 5**.

Based on **Figure 5**, it can be seen the ETo linear line equation using the Makesens method, ETo = -3.052 (year-first year) +1334.7 and if using a regression equation, ETo = -3.1466x + 7588.1. Both of these equations produce a straight line that is almost the same as a downward trend. As for the annual rainfall linear equation, R = 35,257 (year-first year) +2186.3 and by using a regression equation, R = 32.905x - 63030. Both of these produce a straight line that is almost the same and with an upward trend. With the equation of the projection line, then in the future it is likely that there will be a trend of significant increase in annual rainfall so that it is necessary to be aware of the danger of flooding. Therefore, it is necessary to implement climate change adaptation procedures. The opposite occurs in the annual potential evapotranspiration trend, where the trend is declining. If related to climate parameters, where the main factor influencing evapotranspiration is temperature. This means that if the temperature is low then evapotranspiration is also low and at the same time there is a large amount of rain so that it is likely to cause the danger of flooding.

Figure 6 shows a graph of the relationship between average rainfall and potential evapotranspiration rates and their projections until 2050. The graph model is almost the same as the annual rainfall and evapotranspiration charts in **Figure 5**. This further reinforces that in the future there will be a significant increase in monthly rainfall so it needs be aware of the danger of flooding.

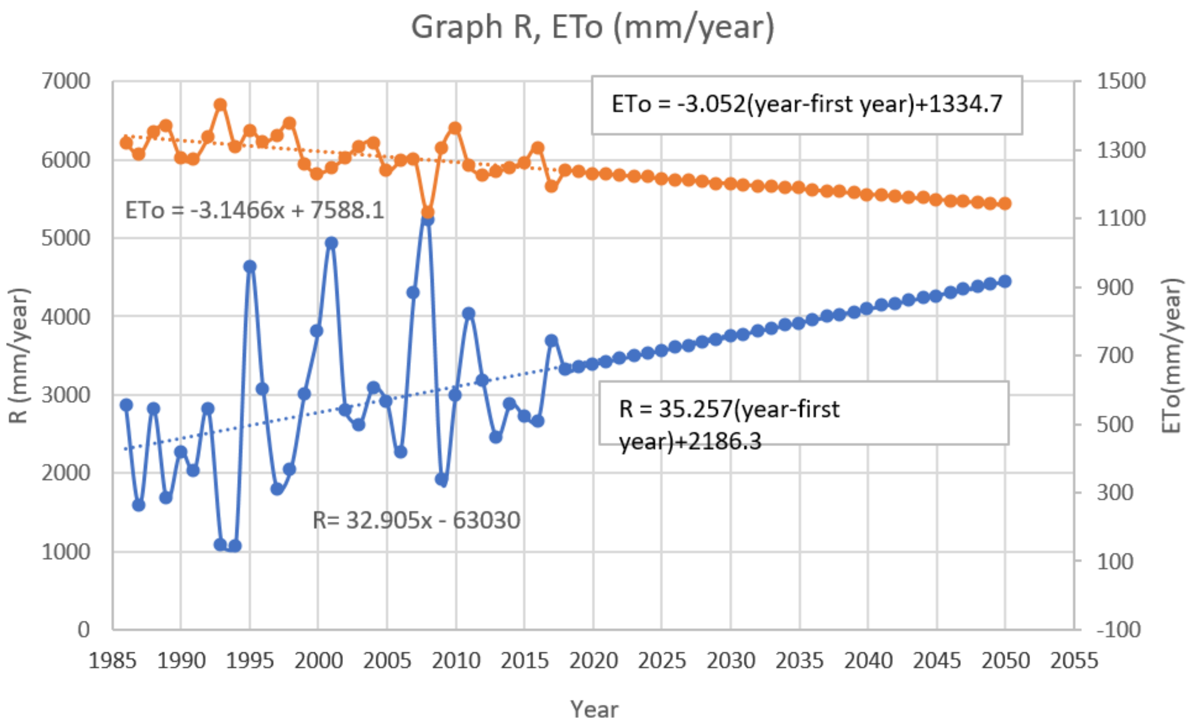

Figure 5. Projection rainfall data and evapotranspiration (mm/year)

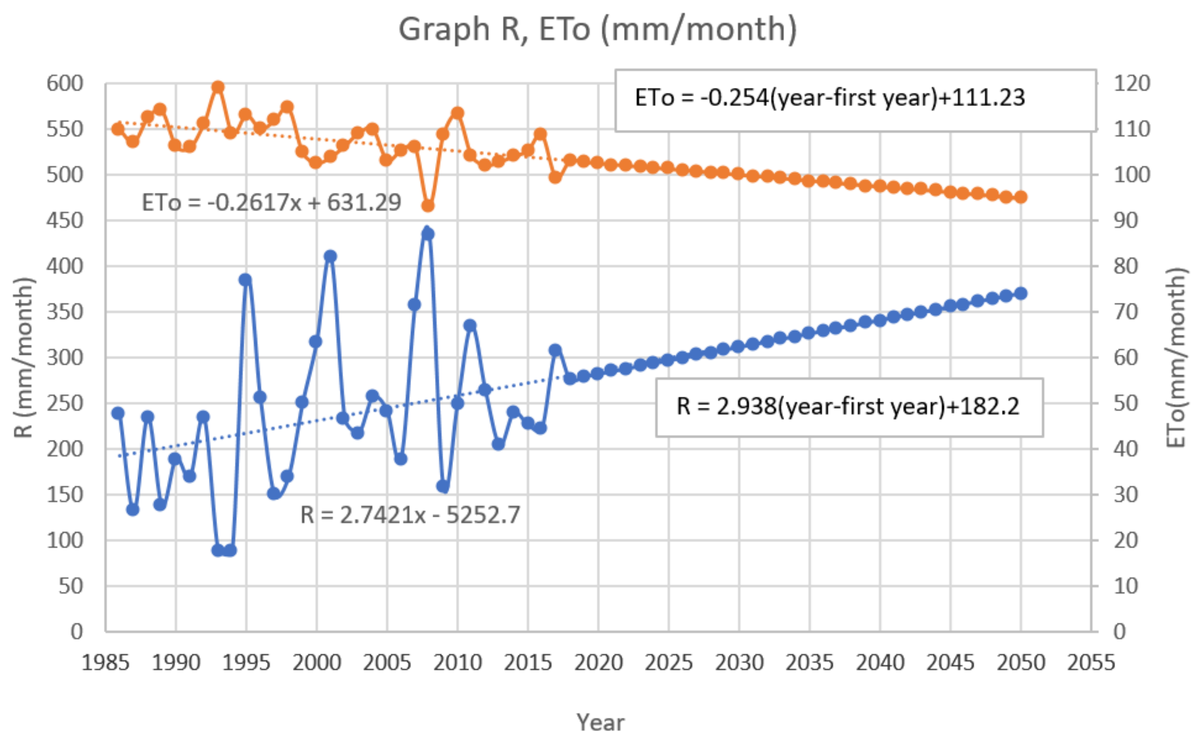

Figure 6. Projection rainfall data and evapotranspiration (mm/month)

CONCLUSIONS

Based on the data and analysis that has been conducted, it can be concluded that the effects of climate change on the potential evapotranspiration are as follows:

1. There has been a climate change in the Singkoyo watershed marked by a value of $Z \neq 0$

2. Monthly rainfall in 1995, 2001, 2007 and 2008 which is very extreme then reinforces the results of the Z value in the calculation of Mann Kendall that climate change has occurred in the Singkoyo watershed is increasingly apparent.

3. The amount of extreme annual rainfall in 1995, 2001, 2007 and 2008 then the possibility of substantial flooding occurred in those years. The opposite happened in 1993 and 1994, where there was an extremely small amount of annual rain, there was a possibility of drought in those years.

4. In general, it can be said that the decrease in potential evapotranspiration on one side will cause an increase in the average monthly rainfall on the other side.

5. In the future it is likely that there is a trend of monthly and annual rainfall increases which is quite significant so we need to be aware of the danger of flooding. Therefore, it is necessary to implement climate change adaptation procedures. The opposite occurs in the annual potential evapotranspiration trend, where the trend is declining. If related to climate parameters, where the main factor influencing evapotranspiration is temperature. This means that if the temperature is low then evapotranspiration is also low and at the same time there is a large amount of rain so that it is likely to cause the danger of flooding.

ACKNOWLEDGEMENT

The authors would like to thank several parties who have supported this research, including:

1) Tadulako of University which has supported funding of the research; 2) The Office of the Sulawesi River Region III in Palu, Central Sulawesi, Indonesia that have supported this research by preparing hydro climatology data.

Disclosure statement

No potential conflict of interest was reported by the authors.

Notes on contributors

I. Wayan Sutapa – Faculty of Engineering, University of Tadulako, Palu, Central Sulawesi, Indonesia.

I. Gede Tunas – Faculty of Engineering, University of Tadulako, Palu, Central Sulawesi, Indonesia.

REFERENCES

Abdolhosseini, M., Eslamian, S., & Mousavi, S. F. (2012). Effect of climate change on potential Evapotranspiration: A case study, Gharehsoo sub-basin, Iran. *Int. J. Hydrology Science and Technology, 2*(4), 1-13. https://doi.org/10.1504/IJHST.2012.052373

Aksu, H., Kuşçu, S., & Şimşek, O. (2010). Trend Analysis of Hydrometeorological Parameters in Climate Regions of Turkey. BALWOIS 2010 – Ohrid, Republic of Macedonia.

Allen, G. R. (1998). Crop Evapotranspiration-Guidelines for Computing Crop Water Requirement-FAO Irrigation and Drainage Paper No. 56. Rome, Food Agriculture Organization of the United Nation, p. chapter 2.

Deo, R. C., McAlpines, C. A., Syktus, J., McGowan, H. A., & Phinn, S. (2005). On Australian Heat Waves: Time Series Analysis of Extreme Temperature Event in Australia, 1950-2005, Centre for Remote Sensing and Spatial Information Sciences School of Geography, Planning and Architecture The University of Queensland, Brisbane 4072 Australia: Climate Change Centre of Excellence Queensland Department of Natural Resources and Water 80 Meiers Rd, Indooroopilly 4068, Australia.

Mulyono, D. (2014). Analysis of Rain Characteristics in South Garut Regency. *Journal of Construction, 13*(1), 1-9.

Solihin Ansari, A., Sutapa, I. W., & Galib Ishak, M. (2017). Model Hydrology MockWyn-UB to Analyse Water Availability in Gumbasa Watershed Central Sulawesi Province. *Int. Journal of Engineering Research and Application, 7*(1), 94-101. https://doi.org/10.9790/9622-07010394101

Sutapa, I. W. (2014). Application Model Mann-Kendall and Sen'S (Make sens) for Detecting Climate Change. *Infrastructure J. Civil Eng. Univ. Tadulako., 4*, 31-40.

Sutapa, I. W. (2015a). Study Water Availability of Malino River to Meet the Need of Water Requirement in District Ongka Malino, Central Sulawesi of Indonesia'. *International Journal of Engineering and Technology, 7*(3), 1069-1075.

Sutapa, I. W. (2015b). Modeling Discharge of Bangga Watershed under Climate Change. *Applied Mechanics and Materials J., 776*, 133-138. https://doi.org/10.4028/www.scientific.net/AMM.776.133

Sutapa, I. W. (2015c). Long-Term Trend Climatology in Sigi, Central Sulawesi province', *National Seminar on Civil Engineering Narotama of University*, February 28, 2015, Surabaya. pp. 267-277.

Sutapa, I. W. (2017). Effect of Climate Change on Recharging Groundwater in Bangga Watershed, Central Sulawesi of Indonesia. *Environ. Eng. Res. J., 22*(1), 87-94. https://doi.org/10.4491/eer.2015.127

Sutapa, I. W., & Galib, I. M. (2017). Application of non-parametric test to detect trend rainfall in Palu Watershed, Central Sulawesi, Indonesia. *Int. J. Hydrology Science and Technology, 6*(3), 238-253. https://doi.org/10.1504/IJHST.2016.077399

Sutapa, I. W., Moh. Bisri, Rispiningtati, & Montarcih, L. (2013). Effect of Climate Change on Water Availability of Bangga River, Central Sulawesi of Indonesia. *J. Basic. Appl. Sci. Res., 3*(2), 1051-1058.

Timo, S., Anu, M., Pia, A., Tuija, R. A., & Toni, A. (2002). *Detecting Trends of Annual Values of Atmospheric Pollutants by the Mann-Kendall Test and Sen's Slope Estimates*, Finnish Meteorological Institute. Helsinki. Firland.

Usman. (2004). Sensitivity Analysis of Several Methods for Estimating Potential Evapotranspiration to Climate Change. *Journal Natur Indonesia, 6*(2), 91-98.