Change Point Detection in Time Series Data of Annual Maximum Daily Rainfall in Mamminasata Region of South Sulawesi, Indonesia

Wahidah Sanusi[1](✉), Sahlan Sidjara[1], Sudarmin Patahuddin[2], and Muhammad Danial[3]

[1] Department of Mathematics, Universitas Negeri Makassar, Makassar, Indonesia
wahidah.sanusi@unm.ac.id
[2] Department of Statistics, Universitas Negeri Makassar, Makassar, Indonesia
[3] Department of Chemistry, Universitas Negeri Makassar, Makassar, Indonesia

Abstract. This research aim is to detect the change point year of annual maximum daily rainfall at eight rainfall stations in the Mamminasata region for the period 1989 to 2020. The Mamminasata region covers Makassar City, Maros District, Sungguminasa/Gowa District, and Takalar District. Research data were obtained from the Water Resources Management Office of South Sulawesi Province, and the Meteorology, Climatology, and Geophysics Agency of Makassar. The change point of the mean maximum daily rainfall at the Mamminasata region is identified by the cumulative sum (CUSUM) analysis, while a bootstrap analysis is employed to determine a confidence level of the detected change point. Based on a simple linear regression analysis showed that Makassar city, Gowa district, and Panyalingan station (Maros district) have negative trends, while Takalar district and Maroangin station (Maros district) have positive trends. The study results also showed significant changes in the mean maximum daily rainfall detected in 2003 and 2007 at Makassar City, in 1996 in Gowa District, and in 2016 in Takalar District. Meanwhile, in the Maros district, a change point of annual maximum daily rainfall found no significance.

Keywords: Bootstrap analysis · change point · CUSUM · rainfall

1 Introduction

Investigation of rainfall patterns, as well as trends of rainfall, is necessary for planning water resources and management of disasters. The Mann-Kendall and innovative trend methods, and the linear regression are several methods that could be applied to detect the rainfall trend [1–6]. Identification of change points is also needed in the study of climate change to complete the trend investigation results. The aim is to find out the location of changes that occur suddenly in the time series data. Several methods were employed to investigate a change point of rainfall data, for example, the Pettitt test, the

N. I. Inda et al. (Eds.): ISST 2022, APR 7, pp. 297–302, 2023.
https://doi.org/10.2991/978-94-6463-228-6_33

Bayesian method, and the bootstrap cumulative sum method [7–13]. Meanwhile, in this study, a mean change point of annual maximum daily rainfall data in the Mamminasata region is detected using the bootstrap cumulative sum method.

2 Methodology

2.1 The Bootstrap CUSUM Analysis

The cumulative sum (CUSUM) and bootstrap analysis are applied to identify changes in the mean for time series data. This method does not need the normal distribution assumption of data, is robust to outliers, and the calculation is simple [11]. The procedure of CUSUM analysis is as follows:

a. The difference between the value of each data and its mean $(x_t - \overline{x})$ is calculated, and then cumulative is as follows:

$$S_t = S_{t-1} + (x_t - \overline{x}), \overline{x} = \sum_{t=1}^{n} \frac{x_t}{n}, t = 1, 2, \ldots, n \quad (1)$$

where $S_0 = 0$, x_t is the observation data, and n is the sample size (Taylor 2000). Estimation of S_t provides information about an indication of the mean change point of annual maximum daily rainfall data.
b. Determination of the value m so that

$$S_m = \max_{0 \le i \le n} |S_i|, 0 \le m \le n \quad (2)$$

where m is the estimated change point.
c. Determine a confidence level for m.

A confidence level value indicates possibility occurred a mean change in the estimated point obtained. Steps to determine a confidence level as follows:

1) Based on the S_i value ($i = 0, 1, \ldots, n$), get $S_{min} = \min_{0 \le i \le n} (S_i)$ and $S_{max} = \max_{0 \le i \le n} (S_i)$.
2) Calculate $S_{diff} = S_{max} - S_{min}$, where S_{diff} is the estimation of a magnitude of change.
3) Generate n bootstrap sample size $(x_1^b, x_2^b, \ldots, x_n^b)$ by sampling without replacement.
4) Calculate the bootstrap CUSUM $S_0^b, S_1^b, \ldots, S_n^b$, where $S_0^b = 0$.
5) Calculate $S_{min}^b = \min\left(S_0^b, S_1^b, \ldots, S_n^b\right)$.
6) Calculate $S_{max}^b = \max\left(S_0^b, S_1^b, \ldots, S_n^b\right)$.
7) Calculate $S_{diff}^b = S_{max}^b - S_{min}^b$.
8) Calculate a confidence interval (CL) as follows:

$$CL = \left(\frac{n_b}{n_B}\right) 100\%,$$

where n_b is the number of bootstraps that satisfy $S_{diff}^b < S_{diff}$, and n_B is the number of bootstrap repetitions.
9) The probability of change m is said to be significant if the confidence level is minimum $(1 - \alpha)\%$, where a significant level (α) is 0.05 or 0.10 [11].

Table 1. The geographical information of the rainfall station

Station Name	Code	Location	South Latitude	East Longitude	Altitude (m)
Panyalingan	S1	Maros	$04^{\circ}55'05''$	$119^{\circ}33'45''$	1
Maroangin	S2	Maros	$04^{\circ}58'0''$	$119^{\circ}35'0''$	3
Paotere	S3	Makassar	$05^{\circ}06'49.5''$	$119^{\circ}25'11.5''$	4
Ujung Pandang	S4	Makassar	$05^{\circ}12'16''$	$119^{\circ}25'39''$	11
Paku	S5	Gowa	$05^{\circ}17'0''$	$119^{\circ}27'0''$	18
Sungguminasa	S6	Gowa	$05^{\circ}12'31.6''$	$119^{\circ}27'38.7''$	13
Palleko	S7	Takalar	$05^{\circ}21'30.2''$	$119^{\circ}27'47.1''$	16
Campagaya	S8	Takalar	$05^{\circ}20'44.2''$	$119^{\circ}23'43.6''$	12

2.2 Data

The Mamminasata area covers Makassar city, Maros district, Sungguminasa/Gowa district, and Takalar district. Makassar city is the capital of South Sulawesi. This study uses the annual maximum daily rainfall data (in mm) from 8 raingauge at the Mamminasata region for 1989–2020 (Table 1). Research data were obtained from the Water Resources Management Office of South Sulawesi Province, and the Meteorology, Climatology, and Geophysics Agency of Makassar.

3 Result

Figure 1 presents the maximum daily rainfall trend. The trend pattern in Fig. 1 used the simply linear regression model. Figure 1 shows that Makassar city, Gowa district, and S1 station (Maros) have negative trends, while Takalar district and S2 station (Maros) have positive trends. A positive trend means that in the next few years, there will be an increase in the maximum daily rainfall, and vice versa decreasing trend (a negative trend).

Figure 2 displays the trend and change point patterns for annual maximum daily rainfall. Figure 2 shows the change point year (location of a change point), i.e. the time of change in the mean maximum daily precipitation.

The estimation results of the change point and the confidence level value are shown in Table 2. Table 2 shows that four rainfall stations experience significant changes in the annual maximum daily rainfall indicator in 2003 and 2007 at Makassar city, in 1996 at Sungguminasa station, as well as, in 2016 at Campagaya station. Meanwhile, this result found no significant change at Maros district. These results show that there were mean changes in maximum daily rainfall at Makassar city, Takalar district, and Gowa district.

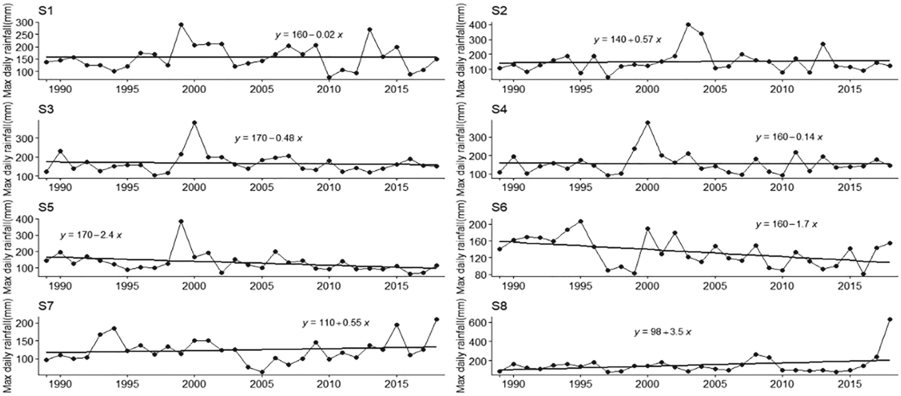

Fig. 1. The maximum daily rainfall trends

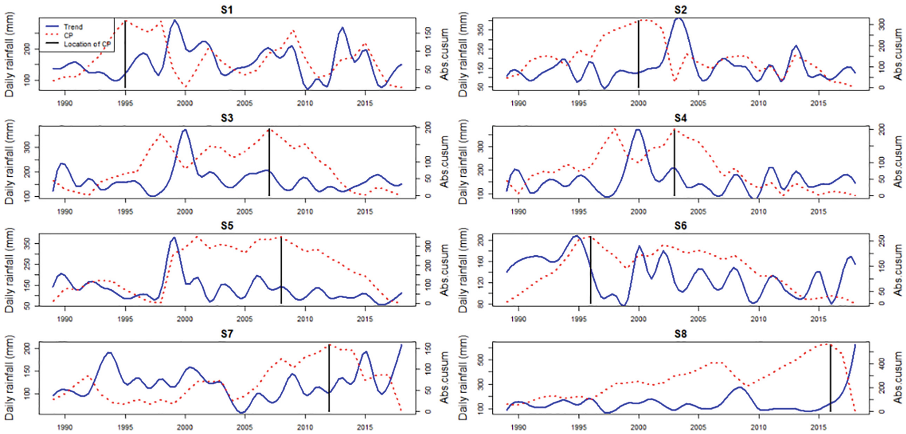

Fig. 2. The pattern of the trend and change points

Table 2. The estimated mean change point and confidence level

Station code	Change Point Year	Confidence Level (%)	Station code	Change Point Year	Confidence Level (%)
S1	1995	79.283	S5	2008	85.235
S2	2000	74.134	S6	1996	99.556**
S3	2007	97.931**	S7	2012	74.552
S4	2003	90.368*	S8	2016	99.482**

* and ** indicate the significant change point at the 90% and 95% confidence levels, respectively.

4 Conclusions

In this paper, the detection results of the year change point of the annual maximum daily rainfall in the Mamminasata region are presented. Significant change points were detected in 2003 and 2007 at Makassar city, in 1996 at Gowa district, and in 2016 at Takalar district, but at Maros district, there were no significant change points. The results identified that there was a change point year with decreased trends at Makassar city and Gowa district, meanwhile an increasing trend occurred at Takalar district. In the identified areas there is an increasing trend of rainfall with a long duration of rain, of course this can result in flooding in the area. On the other hand, a decrease in the trend of continuous rainfall can cause the area to experience drought. The study results could be helpful information for researchers to understand a change point year of maximum daily rainfall at Mamminasata region, and also for authority parties to plan and manage water resources.

In this study, trends and points of change in rainfall have been identified for the period 1989–2020 at Mamminasata region, but this study has not yet obtained information about the amount of rainfall for the next few years. Therefore, future studies will estimate the amount of rainfall using time series analysis.

Acknowledgments. The authors would like to thank KEMDIKBUDRISTEK for providing funding with grant number: 2392/UN36.11/LP2M/2022. The authors also thank the staff of the Water Resources Management Office of South Sulawesi Province, and the Meteorology, Climatology, and Geophysics Agency of Makassar for supplying rainfall data.

References

1. Malik, A., Kumar, A., Pham, Q.B.: Identification of EDI trend using Mann-Kendall and Şen-Innovative Trend methods (Uttarakhand, India). Arab J Geosci 13, 951 (2020).
2. Humphries, U. & Kaewmesri, P., Varnakovida, P.: Rainfall trend by linear regression analysis over Indochina Peninsula during 1981-2017 (37 Years). International Journal of GEOMATE 15, 206-213 (2018).
3. Sanusi, W & Abdy, M, Sulaiman: Innovative trend analysis of annual maximum precipitation in Gowa regency. Journal of Physics: Conference Series. 1899. 012092 (2021).
4. Wu, H, Qian, H.: Innovative trend analysis of annual and seasonal rainfall and extreme values in Shaanxi, China, since the 1950s. International Journal of Climatology 37(5), 2582-2592 (2017).
5. Caloiero, Tommaso, Coscarelli, Roberto, Ferrari, Ennio: Analysis of rainfall trend in southern Italy through the application of the ITA technique. European Water 59, 199-206 (2017).
6. Bojago, E., Yaya, D.: Trend analysis of seasonal rainfall and temperature pattern in Damota Gale districts of Wolaita Zone, Ethiopia. Research Square (2021).
7. Juan D., Jian F., Wei X., Peijun S.: Analysis of dry/wet conditions using the standardized precipitation index and its potential usefulness for drought/flood monitoring in Hunan Province, China. Stoch. Environ. Res. Risk. Assess (2012).
8. Ogungbenro, S.B., Morakinyo, T.E.: Rainfall distribution and change detection in northern Nigeria. Research Journal of Applied Sciences 8(1), 27-32 (2013).

9. Zarenistanak, M., Dhorde, A.G., R. H. Kripalani, R. H.: Trend analysis and change point detection of annual and seasonal precipitation and temperature series over southwest Iran. Journal of Earth System Science, www.ias.ac.in/jess/forthcoming/JESS-D-13-00049.pdf, last accessed 2014/01/24.
10. Zin, W.Z.W., Jemain, A.A., Ibrahim, K.: Bayesian change point analysis of the extreme rainfall events. Journal of Mathematics and Statistics 8(1), 85-91 (2012).
11. Taylor, W. A.: Change-Point Analysis: A powerful new tool for detecting changes. http://www.variation.com/cpa/tech/changepoint.html, last accessed 2013/12/12.
12. Rois, R., Prima, A.T., Shanta, M.A.: An Application of Bootstrapping for CUSUM Test in Mean Change-Point Model and Forecasting. World Scientific News 125, 217-229 (2019).
13. Getahun, Y.S., Li, M.H., Pun, I.F.: Trend and change-point detection analyses of rainfall and temperature over the Awash River basin of Ethiopia. Heliyon 7(9) (2021).