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Innovative trend analysis of annual maximum precipitation in Gowa regency

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Abstract. Floods and drought are two events that can have a negative impact on human survival. In addition, the impact of these two events can also affect agriculture, fisheries, tourism, housing, transportation and others. Trend analysis is an analysis that can be used to identify extreme rainfall events such as floods and drought. The results of the trend analysis can be useful for water resource planning and management. Therefore, the aim of this study is to obtain an overview of the annual maximum precipitation trend in Gowa Regency. The study uses the daily precipitation data from the Sungguminasa and Bonto Sallang Stations of Gowa Regency for 31 years (1988 – 2018). The data was obtained from the Water Resources, Human Settlements, Spatial Planning and Development Office of South Sulawesi Province. The method used is the Mann-Kendall test, Theil-Sen approach, and innovative trend analysis. The results of a lag-one serial correlation test found that all stations are serially independent. Based on the MK method that both stations show negative trend, but significant only at Sungguminasa station at the 95% confidence level. The results of the ITA method show that all stations are significant negative trends at the 95% level. One of advantages of the ITA method is the ability to detect the significant hidden trends in time series.

Keywords: Innovative Trend Analysis, Theil-Sen approach, Precipitation, Mann-Kendall test

1. Introduction

Monitoring and handling of extreme rainfall events, such as floods and droughts, are still a major concern for researchers and managers of water sources. Because the negative impact of these extreme climate events can affect the community, water sources, ecosystems and the economy of a region [1].

Precipitation as a climate variable is a major component of the water cycle and its variability is related to flooding and drought. Analyzing long-term trends and rainfall variability is essential for the sustainable management of water sources. The study of precipitation trends has enormous benefits for researchers to describe the spatial and temporal variability [2]. In addition, the results of trend analysis are also important in assessing the impact of climate change on water resources management and planning [3]. Several methods have been developed to analyze trends for rainfall time series data such as regression analysis, the Mann-Kendall (MK) test, and the Theil-Sein approach (TSA) [4],[5],[6].

The MK test is the most popular method that has been used by several researchers. [7] have used the MK test to detect variations in precipitation spatially and temporally in the western part of China during the period 1960-2013. Likewise [6] also used the MK test to investigate the trend of mean annual precipitation and temperature extremes in China. However, the application of the MK method is limited

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by several assumptions such as serial independence for time series data [8],[9]. In addition, the MK method cannot identify whether the trend is in the high, medium or low category. Therefore, this information can be obtained through the application of innovative trend analysis (ITA) methods. This ITA method is a graphic technique to explore trends from data, and also to avoid errors in detecting hidden significant trends [10],[11].

The ITA method was introduced by [12] which has been applied to detect rainfall trends. Several other researchers have also used it in analyzing trends, such as [13],[14],[15],[1],[16]. The purpose of this study was to obtain an overview of the annual maximum precipitation trends in Gowa Regency using the MK and ITA methods.

2. Methodology

2.1. Data
The study uses the daily precipitation data from the Sungguminasa and Bonto Sallang Stations of Gowa Regency for 31 years (1988 – 2018). The data was obtained from the Water Resources, Human Settlements, Spatial Planning and Development Office of South Sulawesi Province.

2.2. Trend analysis
The non-parametric Mann-Kendall test was used to identify trends for the annual maximum precipitation whether increasing, decreasing or without trend. The test statistic of the Mann-Kendall as follows

$$S = \sum_{t=1}^{n-1} \sum_{s=t+1}^{n} sign(x_s - x_t), \tag{1}$$

where x_t and x_s are the data points for each indicator at time t and s $(s > t)$, n is sample size and

$$sign(x_s - x_t) = \begin{cases} 1, & (x_s - x_t) > 0 \\ 0, & (x_s - x_t) = 0. \\ -1, & (x_s - x_t) < 0 \end{cases} \tag{2}$$

Under the null hypothesis, statistics S approach normal distribution if $n \geq 8$ with the mean value is zero and the variance value is given as follows [17].

$$Var(S) = \frac{1}{18}\left\{n(n-1)(2n+5) - \sum_{j=1}^{p} t_j \left(t_j - 1\right)(2t_j + 5)\right\}, \tag{3}$$

where p is the number of groups of data pairs that are the same value (series) and t_j is the amount of data in the *j-th* series group. The significance of the trend could be obtained by using the standard Mann Kendall test Z_S as follows [18].

$$Z_S = \begin{cases} \frac{S-1}{\sqrt{Var(S)}}, & S > 0 \\ 0, & S = 0. \\ \frac{S+1}{\sqrt{Var(S)}}, & S < 0 \end{cases} \tag{4}$$

where Z_S follows the standard normal distribution. If $Z_S > 0$, then it indicates an increasing trend and $Z_S < 0$ indicates a decreasing trend, and $Z_S = 0$ indicates no trend in the time series. The null hypothesis of no trend is rejected if $|Z_S| > 1.96$ for the 95% confidence level, and the null hypothesis of no trend is rejected if $|Z_S| > 1.645$ for the 90% confidence level.

2.3. Sen's slope estimator test
The trend magnitude is calculated by slope estimator methods [16]. The slope (b) of a trend in sample data estimated by the Theil-Sen approach [17], as follows

$$\boldsymbol{b} = \underset{t^*<t}{\mathbf{median}} \left(\frac{x_t - x_{t^*}}{t - t^*}\right). \tag{5}$$

where x_t and x_{t^*} are the sequential data series at the interval t and t^* $(t > t^*)$. The sign of b shows whether the trend is increasing or decreasing.

2.4. Innovative trend analysis (ITA)
The ITA method has been used to investigate hydrometeorological observations and its accuracy was compared with the result of the MK method [1]. In the ITA method, data points were divided into equal halves, and then sort both sub-series in ascending order. After that, the two halves placed on the Cartesian coordinate system, namely $x_i, i = 1, 2, \dots, \frac{n}{2}$ on the horizontal axis and $x_j, j = \frac{n}{2} + 1, \frac{n}{2} + 2, \dots, n$ on the vertical axis.

3. Result and discussion
Before identifying trends in all study stations, autocorrelation testing for data is first carried out. Table 1 displays the results of the lag-one autocorrelation coefficient test. Furthermore, the Mann-Kendall test was applied on the independent original series. The results of a Mann-Kendall test are given in Table 2. Based on Table 2, the results of the Mann-Kendall test show that each station gives a negative trend, but only one station is significant at the 95% confidence level, namely at Sungguminasa station. Fig. 1 and Fig. 2 also show negative trend for all stations.

Table 1. The estimated value of the lag-one correlation coefficient.

Station	Correlation coefficient	LCI	UCI	Decision
Sungguminasa	0.091	-0.329	0.262	serially independent
Bonto Sallang	-0.077	-0.329	0.262	serially independent

Table 2. Result for the Mann-Kendall trend test

Station	Z-value	P-value	Theil-Sen value	Decision
Sungguminasa	-1.655	0.049	-1.217	A significant negative trend
Bonto Sallang	-1.496	0.067	-1.333	No significant trend

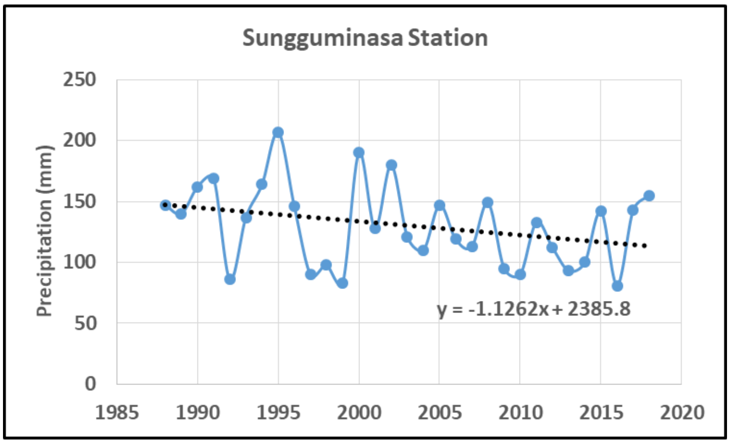

Figure 1. Plot time series data for Sungguminasa station.

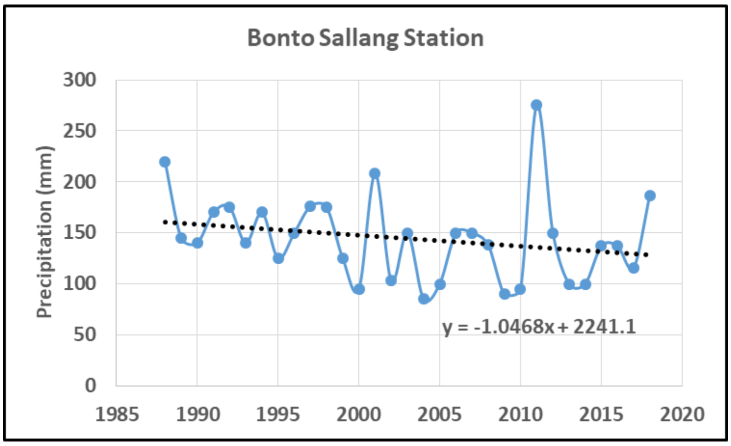

Figure 2. Plot time series data for Bonto Sallang station.

Furthermore, the ITA method is used to identify the presence of a trend at both stations. Visually, Fig. 3 and Fig. 4 show that in general the data is below a straight line (1:1) for the two stations. The figures show that there are a tendency for time series data at these stations to experience a negative trend. Testing the existence of a trend using the ITA method shows that at the 95% confidence level, there is a significant negative trend at each station as shown in Table 3.

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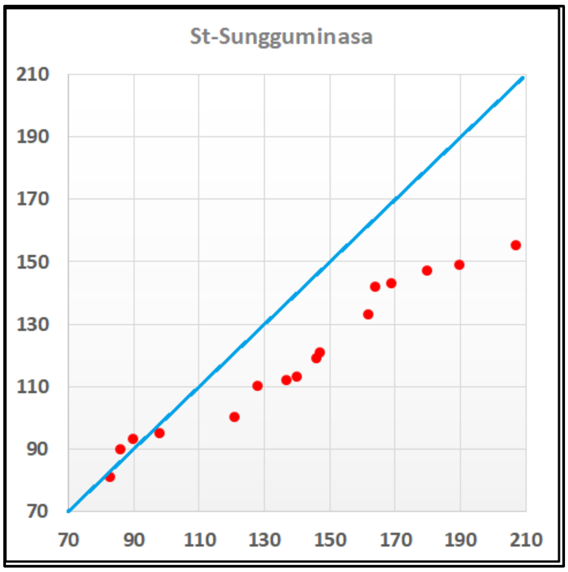

Figure 3. Innovative trend plot for Sungguminasa station.

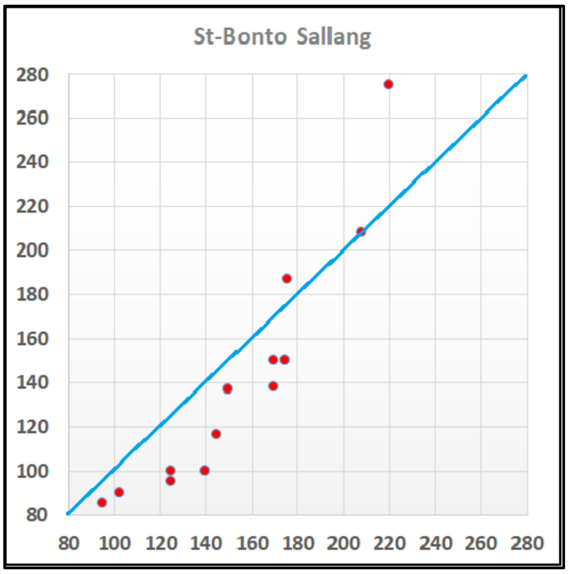

Figure 4. Innovative trend plot for Bonto Sallang station.

Table 3. Result for the ITA trend test

Station	Slope (ϕ)	Slope SD	The 95% CL	Decision
Sungguminasa	-1.391	0.078	± 0.152	A significant negative trend
Bonto Sallang	-1.004	0.195	± 0.381	A significant negative trend

4. Conclusions

This paper presents the results of investigation of trend of the annual maximum precipitation in Gowa Regency. The results of a lag-one serial correlation test found that all stations are serially independent. Based on the ITA method, the study results show that all stations had a significant negative trend, although the MK method detected that Bonto Sallang station is not significant trend.

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