The Quantification of Rainfall Variability Based on The Standardized Precipitation Index

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The Quantification of Rainfall Variability Based on The Standardized Precipitation Index

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Abstract. The objective of this research is to detect a pattern of rainfall in Gowa Regency using the standardized precipitation index (SPI). The SPI is a tool to investigate wetness and dryness events based on rainfall data in an area. In this study, monthly rainfall data are obtained from 6 rainfall stations. Data are collected from 1988 to 2017. The research result shows that the all stations have the highest frequency of normal condition of rainfall. Meanwhile, the frequency of both extreme wet and extreme dry events is the lowest about 2 percent in most stations. The result also shows that in general, Gowa Regency experiences very wet and very dry events with duration is one month, respectively.

Keywords: extreme rainfall, dryness event, wetness event, rainfall frequency, Standardized Precipitation Index

1. Introduction
One of the impacts of climate change is floods and droughts. These impacts can disturb the survival of humans and other living things. Other impacts such as landslides, decreased agricultural production, increased health risks, reduced water supply, forest fires, and infrastructure damage are caused by climate change as well. Because the losses incurred both from physical and life aspects are so huge, the initial steps that can be made are by monitoring flood and drought events in an area. Several indices have been used to monitor drought events and to evaluate water supply deficits, including Palmer Drought Severity Index (PDSI), China-Z Index (CZI), Deciles Index (DI), Standardized Precipitation Index (SPI), and Streamflow Drought Index [1][2][3][4][5].

Recently, Standardized Precipitation Index (SPI) is widely used by researchers at the drought index [6][7][8]. The SPI has some advantages over other indices: it is simple and not affected by the difference in geographical or topographical position of an area, only requires precipitation data, and can be used in different time scales. SPI was initially developed by McKee to measure precipitation deficits at multiple time scales [9]. At first, SPI was a drought/dry index, but in recent years, the index
has been used to identify and to assess floods or wet conditions as well [10][11][5]. The objective of this study is to describe the rainfall condition in Gowa Regency based on SPI.

2. Methodology

2.1 Standardized precipitation index

SPI value is obtained by fitting Gamma distribution function to monthly rainfall data based on SPI for the one-month timescale for each station. Two-parameter Gamma distribution is defined by probability distribution function in Eq. (1).

\[ f(y) = \frac{1}{\beta \Gamma(\alpha)} y^{\alpha-1} e^{-y/\beta}, y > 0 \]  

where \( y \) is the monthly rainfall amount, \( \alpha > 0 \) is a shaping parameter, \( \beta > 0 \) is scale parameter and \( \Gamma(\alpha) \) is Gamma function. The values of \( \alpha \) and \( \beta \) can be estimated with the maximum likelihood method using Thom approach[12]. Further, an estimated parameter obtained is then used to determine the cumulative probability of \( Y \), as in Eq. (2).

\[ f(y) = \int_0^y f(u)du = \int_0^\hat{\alpha} \frac{1}{\hat{\beta} \Gamma(\hat{\alpha})} u^{\hat{\alpha}-1} e^{-u/\hat{\beta}} du \]  

If the rainfall value is zero (\( y = 0 \)), the cumulative probability function for \( Y \) is given in Eq. (3)

\[ H(y) = q + (1-q)F(y) \]  

where \( q = \text{Prob}(y = 0) > 0 \). Hence, \( H(y) \) is used to determine the estimation of SPI values which was initially introduced by Abramowitz & Stegun [13]. The SPI values are categorized as shown in Table 1.

| SPI value | Weather category |
|----------|------------------|
| SPI ≥ 2  | Extreme wet      |
| 1.5 ≤ SPI < 2 | Severe wet   |
| 1 ≤ SPI < 1.5 | Moderate wet   |
| -1 < SPI < 1   | Near Normal     |
| -1.5 < SPI ≤ -1 | Moderate dry   |
| -2 < SPI ≤ -1.5 | Severe dry     |
| SPI ≤ -2      | Extreme dry     |

2.2 Data

This study uses monthly rainfall amount data (in mm) from 6 rainfall stations in Gowa Regency from 1998 to 2017. The selection of rainfall stations is based on completeness and length of the data. The data was obtained from the Meteorology, Climatology and Geophysics Agency (BMKG) of Regional IV Makassar, the Water Resources, Human Settlements, Spatial Planning and Development Office of South Sulawesi Province. The names of the rainfall stations are shown in Table 2.
3. Results and discussion
The SPI values for all rainfall stations are shown in Fig. 1. The figure shows that Gowa Regency experienced extremely dry conditions (SPI < -2), even though in general it was rain throughout the year. Moreover, all rainfall stations ever had SPI values of less than -3, in March 1998, except G4 station in February 1998. The extreme dry events occurred in the El Nino event in a period of 1997/1998.

![Figure 1. Performance of SPI values](image-url)
Table 3. The frequency of SPI categories

| Category       | G1 | G2 | G3 | G4 | G5 | G6 |
|----------------|----|----|----|----|----|----|
| Extreme wet    | 7  | 5  | 11 | 7  | 8  | 8  |
| Severe wet     | 19 | 16 | 12 | 18 | 19 | 20 |
| Moderate wet   | 39 | 33 | 36 | 36 | 27 | 26 |
| Near normal    | 250| 271| 262| 255| 278| 276|
| Moderate dry   | 22 | 23 | 26 | 28 | 14 | 17 |
| Severe dry     | 18 | 5  | 4  | 8  | 6  | 5  |
| Extreme dry    | 5  | 7  | 9  | 8  | 8  | 8  |

Table 3 indicates that generally, all stations experience more normal weather conditions than other weather categories. But, the G3 station experienced 14 times of extreme wet events for 30 years, while the G6 station experienced severe wet event is 20 times.

Figure 2. The maximum duration of the very wet event

Fig. 2 and Fig. 3 respectively display the maximum duration of the very wet event (SPI ≥ 1.5) and the maximum duration of the very dry event (SPI ≤ -1.5) every year for the period of 1988 – 2017. Both figures show that in general, Gowa regency experienced very wet and very dry events with the maximum duration is one month. However, in 2010, the G3 station experienced a very wet event for 4 consecutive months. In the same year, G6 station experienced the very wet event for 7 months. Fig. 3 also shows that all studied rainfall stations experienced very dry events for two consecutive months in 1998.
4. Conclusion
Based on the results, Gowa Regency generally experienced normal weather conditions based on SPI. However, in certain years, there have been extremely wet and dry conditions, despite the short duration which is about one month. Both of these extreme conditions can impact on agriculture, especially for vegetables that have a planting period of about 1 – 2 months.

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