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TREND ANALYSIS FOR DROUGHT EVENT IN PENINSULAR MALAYSIA

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Abstract. In this paper, the geostatistics application is employed for analysis of drought events in verifying the upward or increasing and downward or decreasing trend during the drought occurrence. About 33 years of daily precipitation data obtained from 69 stations during the period of November, 1975 to October, 2008 in Peninsular Malaysia are analyzed to characterize the trend of dry events. The amount of precipitation is classified based on the standardized precipitation index (SPI) to determine the drought periods and proceed with the Mann-Kendall test for trend identification. These results are further verified by applying the kriging method. The kriging results describe that the trend values for drought events in Peninsular Malaysia interprets an upward trend especially in eastern and western parts.

Keywords: Geostatistics; drought; trend; kriging

Abstrak. Dalam kertas kerja ini, penggunaan kaedah geostatistics telah dilaksanakan dalam analisis kemarau untuk mengesah trend naik dan turun kejadian kemarau. Data hujan harian selama 33 tahun yang dibekalkan oleh 69 stesen dalam tempoh dari November, 1975 hingga Oktober, 2008 di Semenanjung Malaysia telah dianalisis untuk mengenalpastikan bentuk trend semasa kejadian kemarau. Data hujan telah dikelaskan dengan merujuk kepada standardized precipitation index (SPI) dalam penentuan kategori kemarau dan seterusnya menggunakan ujian Mann-Kendall untuk mengesahkan trend kemarau. Keputusan ini dilanjutkan dengan menjalankan kaedah kriging. Keputusan kriging menerangkan tentang trend kemarau di Semenanjung Malaysia menunjukkan trend menaik terutamanya di bahagian timur dan barat.

Kata kunci: Geostatistics; kemarau; trend; kriging

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1.0 INTRODUCTION

Drought can be defined as a prolonged time periods of abnormally rainfall deficit leading to water scarcity, crop damage, depletion of streamflow and groundwater or soil moisture reduction. It is also identified as a destructive natural disaster that resulting an extended and substantial effect on the ecosystem and agriculture of the influenced region in the aspect of nature, economy and social. Drought is recognized as an essential aspect which should be noted since the influences of low rainfall associated with drought are dramatic and immediately obvious by comparison with the impacts of high rainfall which are much less noticeable except for extreme events [1]. Drought analysis is important in Peninsular Malaysia due to the severe impacts of previous drought occurrences with the most notable case in 1997 and 1998 where the El Nino produces extensive influences to the nature, economic and social of the whole nation. On the other hand, large regions of Peninsular Malaysia also experienced an extended dry spell in the early 2005. Hence, drought analysis is necessary for managing water, monitoring the dry events and mitigating the drought effects since drought episodes has been determined as a non-trivial issue and this analysis would be used in planning and managing the water resources systems for many decades [2].

Among the existed drought indices, standardized precipitation index (SPI) is a commonly used in quantifying the deficiency of precipitation for various time scales [3]. SPI is employed to characterize the dry events into different categories. The evaluated index values will be applied in trend determination of drought occurrences. The trends results are further demonstrated with the geostatistics method which is depicted as a group of numerical methods that describe the spatial attributes using a primary random model [4]. Kriging method as an interpolation method family is alluded to geostatistics for characterizing the statistical relationship of the drought data.

Therefore, the analysis of drought to verify the trend values for drought occurrences in Peninsular Malaysia is focused in this study. With this in mind, the objectives of this paper are to identify and forecast the trend pattern of drought occurrences for whole areas of Peninsular Malaysia by employing the kriging method.

2.0 STUDY REGION

Peninsular Malaysia or west Malaysia has occupied an overall area of approximately 131,598 square kilometers and contributed for the population and economy of around 80 percent in Malaysia. The climate is ordinarily impacted by monsoon seasons particularly the northeast monsoon during the periods of November to February, southwest monsoon during the periods of May to August and inter monsoon during the periods of March to April and September to October.

Daily precipitation amount under the periods of November, 1975 to October, 2008 among 69 stations of Peninsular Malaysia were analyzed in this study. These rainfall data were obtained from Malaysian Meteorological Department and Malaysian Drainage and Irrigation Department. The locations of the corresponding 69 stations are displayed in Figure 1.

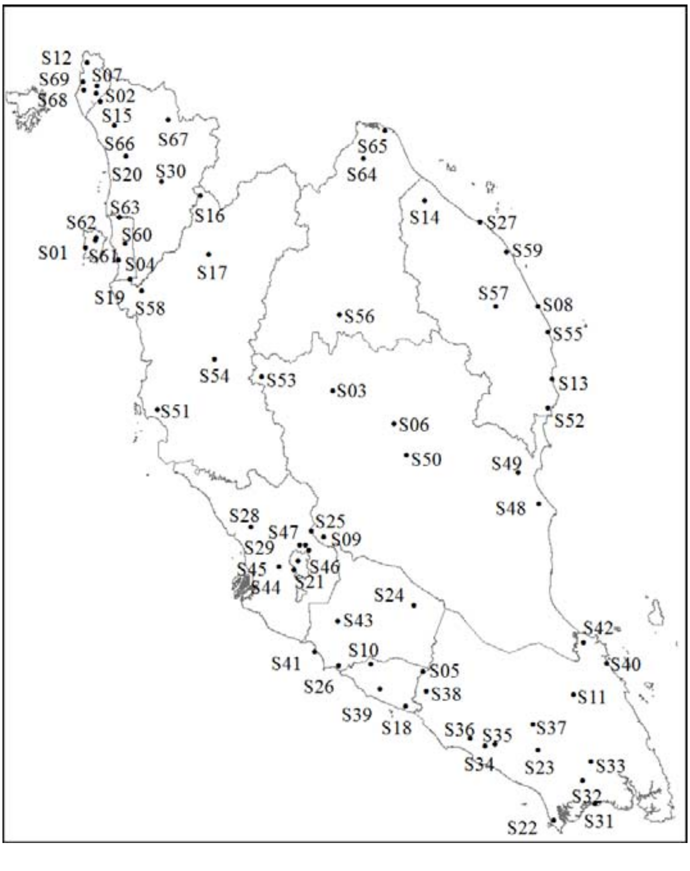

Figure 1 The coordinates of rainfall stations in Peninsular Malaysia

3.0 METHODOLOGY

3.1 Standardized Precipitation Index

Standardized precipitation index (SPI) was designed to identify the level of deficiency in rainfall on various time scales [3]. It is a generally used index among multiple drought indices to track the meteorological drought events where the results less than or equal to -1 is categorized as drought spell [5]. The SPI applied is expressed as

$$SPI = \frac{\ln(x) - \hat{\mu}_y}{\hat{\sigma}_y} \tag{1}$$

where x is the rainfall data, $\hat{\mu}_y$ and $\hat{\sigma}_y$ are the mean and standard deviation of $\ln(x)$ respectively.

The categories of precipitation data which is classified based on SPI values are displayed in Table 1. The dataset under drought category are then utilized to verify the trend behaviour. The computation of SPI is referred to the monsoon seasons as the monsoonal climate impact of Peninsular Malaysia.

Table 1 The SPI classification

Category	**SPI**
Drought	-1.00 and below
Near Normal	-0.99 to 0.99
Wet	1.00 and above

3.2 Mann-Kendall Test

Mann-Kendall test is an applicable technique for identifying and interpreting the trend pattern of dry events. The Mann-Kendall trend test is evaluated based on the correlation between the observed ranks and order of time [6]. The application of trend is expressed as

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i) \tag{2}$$

$$sign(x_j - x_i) = \begin{cases} 1 & ; x_i < x_j \\ 0 & ; x_i = x_j \\ -1 & ; x_i > x_j \end{cases} \tag{3}$$

$$V(S) = \frac{n(n-1)(2n+5)}{18} \tag{4}$$

$$Z = \begin{cases} \frac{(S-1)}{\sqrt{V(S)}} & ; S > 0 \\ 0 & ; S = 0 \\ \frac{(S+1)}{\sqrt{V(S)}} & ; S < 0 \end{cases} \tag{5}$$

where $\{x_t : t = 1,2,\ldots,n\}$ is a time series for *n* sample size and *m* is the number of tied rank group.

3.3 Kriging

Kriging is classified as a geostatistical method for output results detection in a particular area by applying a mathematical function to the dataset. The accuracy of kriging prediction relies on the distance in between the dataset and the predicted location.

The kriging method is utilized to calculate the surrounded values in verifying a forecasted value for the unmeasured region. The kriging computation is defined as

$$\hat{Z}(s_0) = \sum_{i=1}^{N} \lambda_i Z(s_i) \tag{6}$$

where $Z(s_i)$ is the measured value at i[th] location, is an unknown weight for the measured value at the i[th] location, s_0 is the predicted location and *N* is the number of measured values.

4.0 RESULTS AND DISCUSSION

Figure 2 illustrates the trend pattern of dry events in Peninsular Malaysia with respect to the kriging prediction. As referred to the illustration, the region with the lighter colour implies a more negative trend while the darker colour indicates a more positive trend. Dependent upon the kriging results, most of the areas in Peninsular Malaysia exhibit an upward trend specifically the eastern and western regions with a darker colour in the range from 1.06 to 3.28. This implies that a lower precipitation amount will be received throughout the dry spell for these particular regions. These areas therefore will experience a drier dry event.

The kriging results also describe that the majority parts of Peninsular Malaysia are expected to endure the dry spell and this situation is expected to rise with times. Therefore, further attention should be given on the high risk regions for the prevention and mitigation of drought effects in order to reduce the damaging impacts of drought occurrences to the nature, economy and social.

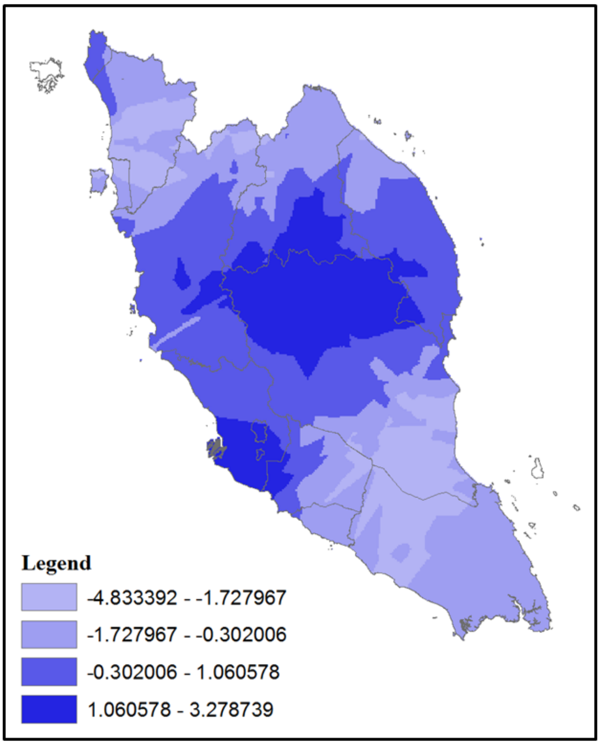

Figure 2 Kriging results for trend of drought occurrences in Peninsular Malaysia

5.0 SUMMARY AND CONCLUSION

Kriging method is useful and applicable to determine and predict the trend pattern of dry spell. The rainfall dataset are categorized with respect to the standardized precipitation index (SPI) to identify the drought data for further analysis of trend verification by Mann-Kendall test. The kriging computation is then proceeded to forecast the trend value of dry spell for the unmeasured regions in order to verify the severity of drought occurrences. The results interpret that the major regions of Peninsular Malaysia are dominated with an upward trend throughout the dry spell specifically the eastern and western regions. This situation indicates the receiving of lower precipitation amount during the drought occurrences that will contributes to a higher risks of future dry spell. Hence, an organized drought management and planning are indispensable to regulate the dry events for minimizing the serious impacts to the environment, economy and human lives.

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REFERENCES

[1] S. Khan, H. F. Gabriel, and T. Rana, Standard Precipitation Index to Track Drought and Assess Impact of Rainfall on Watertables in Irrigation Areas. *Irrig. Drainage Syst.* 22: 159-177.

[2] A. Cancelliere, and J. D. Salas, 2004. Drought Length Properties for Periodic-Stochastic Hyfrologic Data. *Water Resource Research.* 40: 02503.

[3] T. B. McKee, N. J. Doesken, and J. Kleist, 1993. The Relationship of Drought Frequency and Duration on Time Scale. Preprints, *Eighth Conf on Applied Climatology.* Anaheim CA. Am. Meteor. Soc., Boston. 179-184.

[4] R. A. Olea, 1999. *Geostatistics for Engineers and Earth Scientist.* London, Kluwer Academic Publishers.

[5] F. K. Sonmez, A. U. Komusu, A. Erkan, and E. Turgu, 2005. An Analysis of Spatial and Temporal Dimension of Drought Vulnerability in Turkey Using Standardized Precipitation Index. *Nat. Hazards.* 35: 243-264.

[6] K. H. Hamed, 2008. Trend Detection in Hydrologic Data: The Mann-Kendall Trend Test Under Scaling Hypothesis. *J. Hydrol.* 349: 350-363.

[7] Q. Zhang, C. Y. Xu, and Z. Zhang, 2009. Observed Changes of Drought / Wetness Episodes in the Pearl River Basin, China, Using The Standardized Precipitation Index and Aridity Index. *Theor. Appl. Climatol.* 98: 89-99.