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Drought Characterisation in Peninsular Malaysia Using DrinC Software

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ABSTRACT

Prolonged drought conditions have adverse environmental and socio-economic impacts due to unmet water demands. Defining drought is difficult because of its onset and ending time. Therefore, characterisation of drought is essential for drought management operations. Thus, drought indices come in handy and are a practical approach to assimilate large amounts of data into quantitative information which can then be applied for drought forecasting, declaring drought levels, contingency planning and impact assessments. This study analyses drought events using indices, namely SPI and Deciles Index, computed with DrinC software program but are not popular in Malaysia. It is observed that both indices are identical and suitable for drought occurrences.

Keywords: DrinC, drought, indices, Malaysia, SPI & DI, water

INTRODUCTION

Drought is one of the extreme hydrological events that can cause great socio-economic and environmental damages. Drought and water scarcity have different causes. Table 1 shows timescale and causes of water scarcity and drought (Vlachos, 1982). According to some studies, one half of the world's population will face water crisis by 2025, particularly in South Asia, Middle East and Africa (Diwan, 2002). More than 10 million people have died in the last century between 1900 to 2005 (Wilhite, 2000; Below et al. 2007). In Malaysia, 1.8 million residents living around Kajang, Bangi and south of Kuala Lumpur City, were affected by severe droughts in

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1998. The water supplies came from upper Langat River basin. The drought also affected Sarawak, Sabah, Penang, Kedah and Kelantan.

Table 1
Timescale and causes of water scarcity, drought and related concepts

Timescale		Short-term (days, weeks)	Mid-term (months, seasons, years)	Long-term (decades)
Causes	Natural	Dry Spell	Drought	Aridity
	Man-made	Water shortage	Water scarcity	Desertification

The complex climatic functions can be simplified using drought indices and which can also quantify anomalies of climatic conditions as for their frequency, severity and duration. Therefore, they are essential tools for characterisation and the monitoring of drought events. They are also very useful for communicating with the wider audiences by providing comprehensible information such as the severity of drought episodes (Tsakiris et al., 2007). As a common practice, the drought indices are calculated either by using tools designed for this purpose or by manual calculations following the corresponding equations and procedures. On the basis of the stated considerations above, DrinC - a software package was used in this study. This software program was developed at the Center for the assessment of natural hazards and proactive planning of the National Technical University of Athens, Greece. Currently, major river basins in Malaysia have limited quantifiable information of drought occurrence, frequency and severity. In addition, there is lack of sufficient and appropriate drought assessment and forecasting tools. To prepare for effective mitigation of drought risks in peninsular Malaysia, evaluation of drought conditions is vital. Thus, this study focuses primarily on drought characterisation.

MATERIALS AND METHODS

Standardized Precipitation Index (SPI)

The SPI is a drought defining and monitoring tool. It is specifically based on the probability of records for a given amount of precipitation and duration. The probabilities are standardised. When an index value is calculated as zero, it indicates the median precipitation amount. The SPI can easily be computed by dividing the difference between the normalised seasonal precipitation and its long-term seasonal mean by the standard deviation as given in equation (1). Thus,

$$\text{SPI} = \frac{Xi_j - \bar{X}}{\sigma} \tag{1}$$

where, (x_{ij}) is the seasonal precipitation at the i^{th} rain gauge and j^{th} observation, ($\bar{X}$) is the long-term seasonal mean and (σ) is its standard deviation. This method requires only a set of precipitation data for 30 or more years. The most frequent time scales being 1, 3, 6, 12 and 24 months of duration. Table 2 shows the classification of drought levels according to SPI.

Table 2
Classification of drought conditions according to SPI (Mckee et al., 1995)

SPI Values	Classification
2.0 or more	Extremely wet
1.5 to 1.99	Very wet
1.0 to 1.49	Moderately wet
-0.99 to 0.99	Near normal
-1.0 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
-2 or less	Extremely dry

Deciles Index (DI)

Gibbs and Maher (1967) introduced Deciles' Index (DI) to improve the percentage of normal precipitation or precipitation anomaly index. Deciles are arranged from 1 to 10. The lowest values such as 1 and 2 show drier climate compared with average conditions, whereas greater values of deciles point to more wet & humid conditions. The amount of precipitation for the preceding three months are ranked against climatologic records. The ranking may fall within the lowest decile or highest decile depending on the historical distribution of 3-month totals (Kininmonth et al., 2000). The formula for DI calculation is given in equation (2):

$$P_i = \frac{I}{N+I} \times 100 \qquad (2);$$

where, P_i is probability of rain in number ith and N is the number of rainfall data. The deciles are grouped into five classes as presented in Table 3 below.

Table 3
Classification of drought conditions according to deciles (Gibbs & Maher, 1967)

Decile Class	Description
Deciles 1-2:Lowest 20%	Much below normal
Deciles 3-4: Next lowest 20%	Below normal
Deciles 5-6: Middle 20%	Near normal
Deciles 7-8: Next highest 20%	Above normal
Deciles 9-10: Highest 20%	Much above normal
-1.5 to -1.99	Severely dry
-2 or less	Extremely dry

The first decile denotes 10% of the lowest quantity of precipitation and the second decile denotes precipitation values ranging between 10 and 20%. Each group represents the level of dryness or humidity. The state of humidity marked as "Normal" (30-70%) in the original index has been classified as "Slightly lower than normal", "Normal" and "Slightly above normal". This classification was simplified and converted into a single category so that easier comparison with other methods can be made as shown in Table 4 (Smakhtin & Hughes, 2004; McKee et al., 1995).

Table 4
Limit values for Standardised Precipitation Index (SPI), Deciles Index (DI)

DI Values	SPI Values	Classification
> = 90	2.0 or more	Extremely wet
80 to 90	1.5 to 1.99	Very wet
70 to 80	1.0 to 1.49	Moderately wet
30 to 70	-0.99 to 0.99	Normal
20 to 30	-1.0 to -1.49	Moderately dry
10 to 20	-1.5 to -1.99	Severely dry
< = 10	-2 or less	Extremely dry

Drought Analysis Using DrinC Program

Drought Indices Calculator abbreviated as “DrinC”, is a program that facilitates the calculation drought indices, especially in assessing the spatial distribution of indices. The main consideration was the broader applicability such as all types of meteorological, hydrological and agricultural drought and at different locations. It was noted that drought studies are particularly essential in semi-arid and arid lands, given that data availability is usually limited in those areas. Two indices developed recently, namely Reconnaissance Drought Index (RDI) and Streamflow Drought Index (SDI), were included in DrinC software as well as two more widely known indices such as Standardized Precipitation Index (SPI) and Deciles Index (DI). By default, the calculation period begins in October and the primary reference base in DrinC is the hydrological year (October-September). The main calculation steps are of 1-month, 3-month, 6-month, 9-month and annually. Therefore, DrinC may be useful for several real-world applications such as to study drought effects on specific crops to coincide with the crop growth period (Tigkas, 2008).

Study Area and Data Collection

The selected catchment area in this study is Langat River and it is about 2350 sq.km and 200 km long. The basin is about 1854 sq.km from southern part of Selangor and about 450 sq.km from the western parts of Negeri Sembilan, the neighbouring state, with 41 sq.km covering Putrajaya and 5 sq.km covering Kuala Lumpur. Figure 1 shows the map of Langat river basin and Kampung Sungai Lui rainfall station.

Figure 1. Map of Langat Basin

Sekolah Kebangsaan Kampung Sungai Lui was chosen in this study as one of the rainfall stations for Langat river basin. The rainfall data was obtained from Drainage and Irrigation Department (DID, Malaysia). Figure 2 below shows the mean and median monthly rainfall recorded by Sekolah Kebangsaan Kampung Sungai Lui rainfall station. Dry months were generally observed between January and March and June to September in Malaysia.

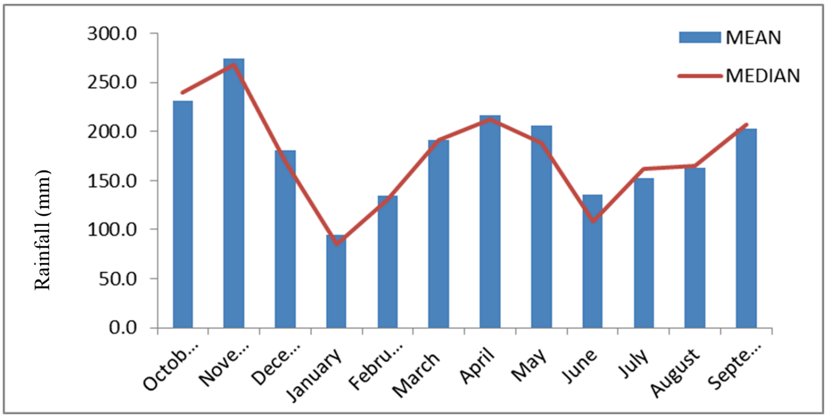

Figure 2. Mean and median monthly rainfall of Sekolah Kebangsaan Kampung Sungai Lui

RESULTS AND DISCUSSION

This study used precipitation records of 43 years i.e. 1972-2014 from a rainfall station, Sekolah Kebangsaan Kampung Sungai Lui; SPI values (3, 6, 9 and 12-month) and DI values were calculated. The results are shown in Figures 3 to 10 below, with X-axis being the years and Y-axis being the SPI values. Figure 3 shows 3-month & 6-month SPI values having negative SPI levels from 1972-1973, 1976-1978, 1982-1983, 1986-1987, 1991-1992, 1997-1999, 2000-2001 and 2013-2014 years which indicate moderately dry and nearly normal conditions except for the period 1975-1977, 1986-1987, 1992, 1998, 2001-2002 when extreme dry conditions were observed according to SPI values. In February 1998, the level of water of Langat dam came close to 14m above critical level (Shaaban & Sing, 2002), whereas, very wet conditions were observed in the years 1981-1983, 1994 and 2011-2012.

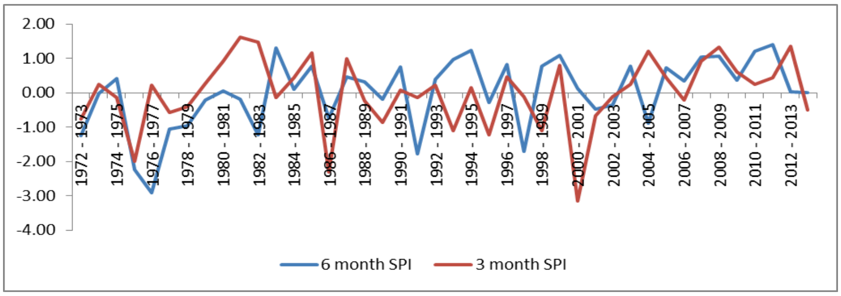

Figure 3. 3-month and 6-month SPI Values for Langat River Basin

There was a demand for extra water from the dam for abstraction downstream at km 18, Cheras treatment plant and Tampoi treatment plant in early April 1998. The water supply department (JBA) estimated water demand for Kuala Lumpur/Selangor in that year was 2658 million litres per day. However, the supplied amount was 2553 million litres per day (Shaaban & Sing, 2002). In 1976, for 6-month and 9-month SPI values, moderate and severe drought conditions were observed in 1976, 1977, 1992, and 1998 which were very similar to 3-month SPI values. As seen in Figure 4, for 12-month SPI values, moderate and severe drought conditions were observed in 1972, 1978, 1984, 1995 and1997 which have similarity with 9-month SPI values. On the contrary, only 3-month SPI values showed drier conditions in 2014. As reported by Sanusi et al. (2014), longer periods of droughts were experienced especially in the urban areas of the south-western part of peninsular Malaysia in 2014.

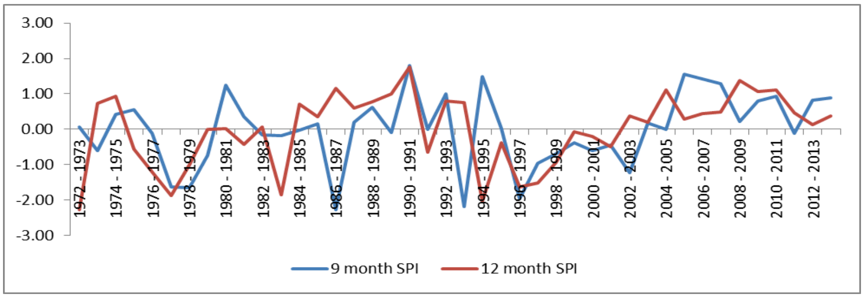

Figure 4. 9-month and 12-month SPI values for Langat River Basin

Based on the Decile Indices, 1972, 1976, 1978, 1987, 1988, 1992, 1997, 1998 and 2008 are in the decile class of 1-2 which means "Much below normal" and identical with the results for 3, 6, 9 and 12-month SPI values respectively as shown above. A previous similar study (Nohegar et al., 2015), compared three indices, SPI, DI & PNI, and they found the values of Decile Index (DI) and SPI values remained within closer characteristics at more than half of the time for drought index calculations.

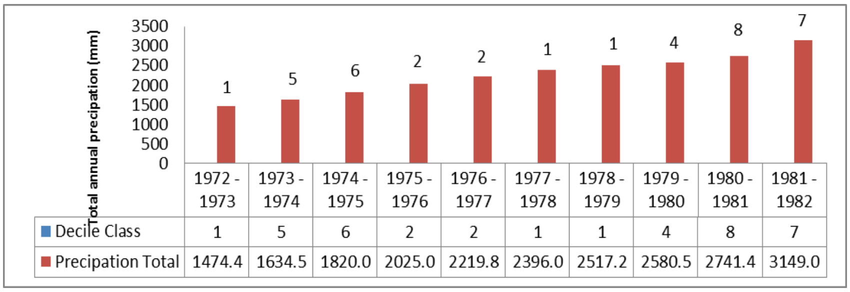

Figure 5. DI values for Langat River Basin (1972-1982)

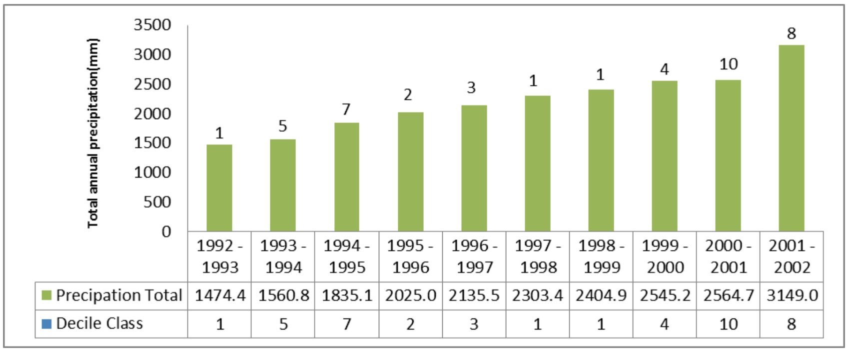

Figure 6. DI values for Langat River Basin (1992-2002)

Figure 7 shows the frequency of decile classes. It can be observed that decile classes 1 and 2 (much below normal) equals to 34% of the whole events observed between 1972 and 2014 (rainfall data). It is found that among all SPI values calculated, the severely dry, moderately and extremely dry conditions equal to 26%.

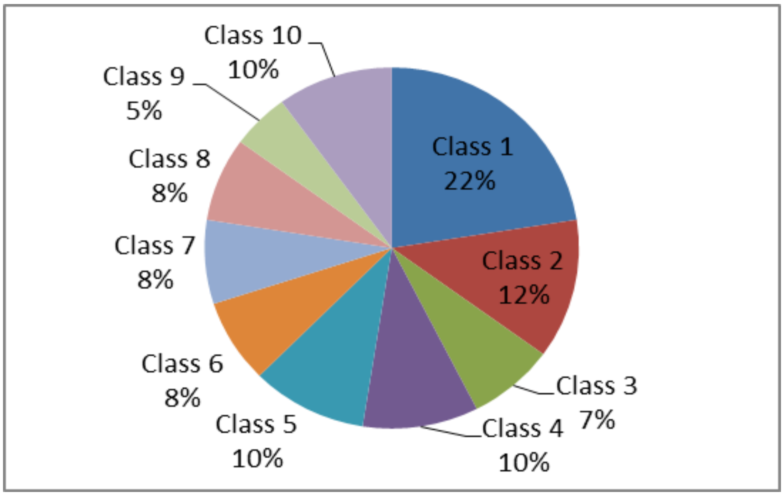

Figure 7. Frequency of decile classes (1 -10)

CONCLUSION

Two drought indices, namely Deciles Index (DI) and SPI (Standardised Precipitation Index), were used in this study. Both indices were identical and suitable for describing drought occurrences in the chosen area of this study. A gradual increase has been observed using DrinC software to characterise and analyse droughts in many parts of the world. It can be used for assisting early estimation of drought consequences and mitigating future impacts.

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