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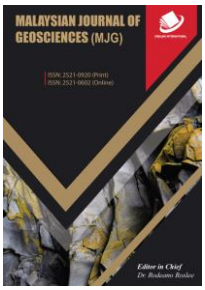

ANALYSIS OF SEVERAL HYDROLOGICAL-DROUGHT DURATION PARAMETERS IN MENGALONG RIVER BASIN, SIPITANG, SABAH

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ABSTRACT

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Drought is a phenomenon of water shortage that will impact the wellbeing of human life. The hydrological drought is a situation of water shortage compared to normal conditions. The degree of severity of drought events can be explained via duration and water deficits of drought events. The duration is an important parameter in understanding the event of drought. Duration refers to a period in which the value of river discharge remains below a certain threshold level. This study attempts to identify the severity of drought based on two drought duration parameters namely the duration of drought event (DE) and the inter arrival time (IAT). In the context of this study, the Q_{90} percentile value was obtained from the flow duration curve and the minimum drought period (MDP) of drought events for 45 days is used as a threshold level of drought events. The 39 year discharge data for Mengalong stations is used to determine the Q percentile value. From the analysis, the cumulative period of the drought events is recorded around 390 days covers 3.6% of the entire record. There were four drought events throughout the record that is in 1992, 1998, 2015 and 2016. The lowest duration was 59 days recorded in 1992, while the longest was 135 days recorded in 1998. This long period is associated with the presence of extreme weather phenomena such as El-Niño.

KEYWORDS

Hydrological Drought, Drought Duration.

1. INTRODUCTION

In Malaysia, the presence of two hot sessions during January - March and June - August will result in reduction of rainfall. This situation is further intricate by the warming effect of the earth that changed the pattern of rainfall. The presence of ENSO phenomenon that links the events of El Nino / La Nina and Southern Oscillation has also changed the pattern of rainfall. The extreme El Nino phenomenon occurred in 1982/1983, 1997/1998 and the latest in 2015/2016 [1]. The hot and dry sessions that hit Malaysia at the end of 2015 until middle of 2016 have reduce the amount of rainfall between 20 - 60%. This rainfall reduction has threatened the sustainability of water resources. This is due to the interruption of water treatment plant operation due to low and inadequate water coupled with the presence of contaminated materials that exceed the permitted standards. Therefore, this paper attempts to identify the drought event in Sipitang, Sabah using duration parameter to describe the drought properties, identify the patterns and trends of hydrological drought.

2. DROUGHT: CONCEPT AND DEFINITION

In a study, states that droughts have a multiple meanings based on human diversity, their specific needs and interests [2]. Although all types of droughts are due to lack of rainfall, however, drought is seen differently by different water users and therefore the definitions are depending on the user [3,4]. For farmer community, drought means lack of moisture in plant root zones. For hydrological experts, drought means the state of water in rivers, lakes and ponds that below the normal levels. For economists, it means deficiencies that affect economic growth. To this end, there is a need to define drought differently as it affects various sectors of society [3].

Although there are more than 150 definitions related to drought published in different field of studies (Wilhite & Glantz, 1985), but generally the drought phenomenon can be depicted as a prolonged deviation from the normal state of water variable such as precipitation, stream discharge, groundwater and soil moisture [3,5]. “Duration” is a term that is widely used in describing the definition of drought. Terms such as "a duration of inadequate water usage to a particular water supply management system", "a duration where water is insufficient for the normal use" and "duration of current discharge is insufficient " needs to be understood and analyzed according to spatial and time so the drought interpretation is appropriate and meets the current requirements [6-8]. In general, the drought event (DE) refers to a period in which the value of river discharge remains below a certain average level or the sequence of sequential time series that is below specific threshold levels as illustrated in Figure 1 [9,10]. The duration of DE is indefinable, and it may involve a short period of one week to several years and the unit may use day, month and years [11,12].

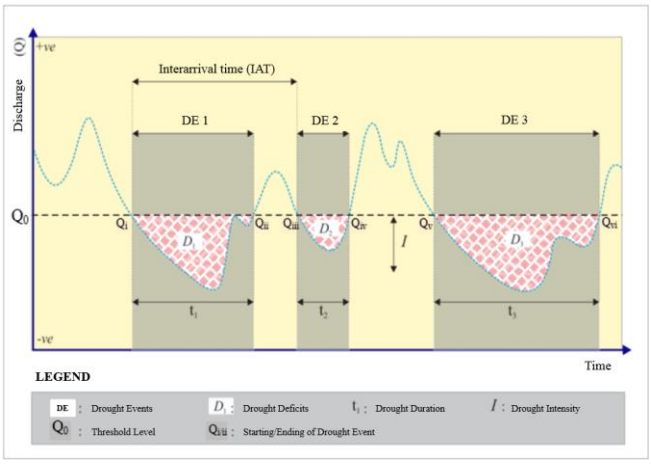

Figure 1: Drought Events based on Runoff Theory [13].

Duration is an important feature in defining drought. The drought season in early 2014 that hit Malaysia is exemplar of a mistake in defining drought. Most local newspapers refer the word drought when describing the hot weather at that time. The word "drought" was later translated into "dry season" after the Malaysian Meteorological Department denied that Malaysia was in drought condition [14]. This confusion is due to uncertainty regarding the definition of drought used in Malaysia, as most community perceives that dry session is a sign of drought phenomenon. Although there are a number of minimum drought period (MDP) that have been used such as 10 consecutive days, 15 consecutive days or 25 consecutive days [15,16]. However, based on Regulation of Operation of Drought Hazard Control issued by the National Security Council (MKN), Malaysia has established that situation of drought occurs when water supplies (rain and rivers flow) are deficient within 3 consecutive months [17]. Therefore, in this paper the severity of the drought will be analysis using two duration parameters – duration of drought event and inter arrival time (IAT). The DDE refers to a duration when the value of river discharge remains below certain threshold level while IAT is a duration between the initiation date of current drought until the next commencement date of the drought events as illustrated in Figure 1.

3. METODOLOGY

3.1 Study Area

Mengalong river basin is located at longitude 115° 20 '00 "- 115° 50' 00" E and latitude 4° 50 '00 "- 5° 10' 00" N (Figure 2) situated between Sabah, Sarawak and Brunei boarder. The basin is the main water resource for Sipitang and surrounding areas such as Mesapol and Sindumin area and also to several mega projects such as Sabah Ammonia Urea (SAMUR) a project by Petronas.

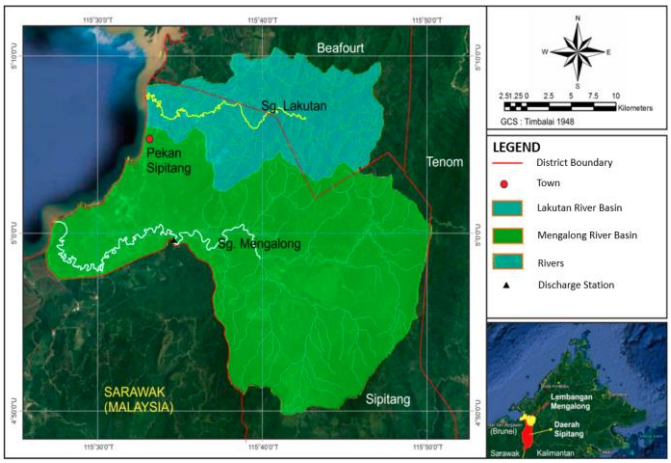

Figure 2: Study Area

3.2 Research Method

The Mengalong river (station 4955403) data channel was obtained from DID Inanam, Sabah. The data collected consist of daily discharge data (m^3s^{-1}) for 29 years from March 1987 to June 2016. Time series data is the sequence of reading values or measurement that has different time to describe certain quantity which involve repeat measurement of discharge at river observation station. The discharge station takes place at 4° 59 '33 "U and 115° 34' 40" T. The daily discharge data is used for consideration particularly in tropical environments when average annual data is not able to indicate which event is more severe. The missing data was corrected using reconstruction and filtering process by utilizing simple interpolation, linear regression and average arithmetic. The threshold level method was used to produce drought events. The Q_{90} and Q_{95} percentile were used to determine threshold levels with the value of Q_{90} = 3.45 m^3s^{-1} and Q_{95} = 1.69 m^3s^{-1} was obtain using flow duration curve [5, 18]. Minimum drought period of 45 days and 90 days were selected as the drought event [14,17]. The 7 days moving average method combined with 7-day inter-event time used for the pooling of mutually dependent droughts and to remove minor drought.

4. RESEARCH FINDINGS

4.1 Inter Arrival Time and Drought Frequency

Based on Figure 3, between a year 1987 and 2016, Sipitang was experienced with drought at Q_{90} levels in 1992, 1998, 2015 and 2016. This represents 13.8 per cent of drought event from the total of year reviewed. The frequency and repetition of drought events can be explained with IAT. Analyzing the time series data of Mengalong river station, the duration of IAT at Q_{90} level between each DE are varies. The lowest IAT was recorded 304 days from 9 February 1992 (initiation of DE1) until 29 December 1997 (initiation of DE2). The longest duration of IAT was 6,271 days from 29 December 1997 (initiation of DE2) until 28 February 2015 (initiation of DE3). Average duration of IAT was 2909 days. This indicates that at the Q_{90} level, the drought recurrence period is once in every 8 years within 29 years. In contrast to Q_{95} level, the droughts was recorded in 1998 and 2016, which accounted for 6.9 per cent of the overall year. Duration of IAT between DE1 and DE2 was 6,571 days starting on 12 January 1998 until 8 January 2016. This implies at Q_{95} level, the drought events in Sipitang area discovered once in every 18 years.

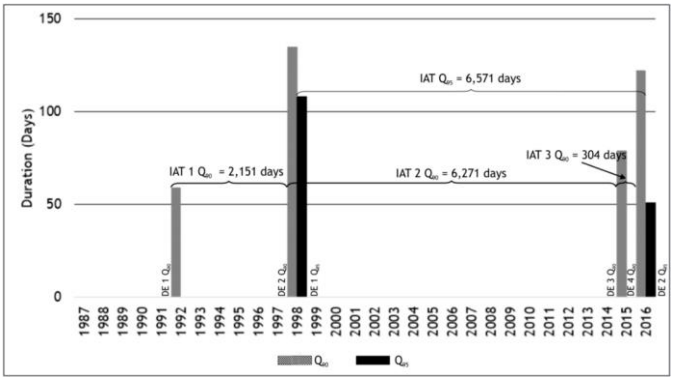

Figure 3: Frequency and inter arrival time (IAT) of drought event.

4.2 Duration of Drought Events

Table 1 shows the cumulative period was 395 days at Q_{90} level. The lowest drought period was recorded for 59 days in 1992 and the longest was 135 days in 1998. The average period of drought in Sipitang area was 99 days. There were two years of severe drought that's are in 1998 and 2016 (above average level). In contrast to Q_{95} level, the overall duration of drought event was around 159 days with the lowest was 51 days in 2016. The highest value was recorded for 108 days in 1998. The average period of drought in the study area was around 80 days. In year 1998 severe drought occurred when the duration recorded was exceeding 4 times of the average of Q_{95} level.

Table 1: Duration of drought events in Sipitang district

Q_{90}	Duration (Days)	Deficit (m^3s^{-1})	Starting	Ending
DE 1	59	-100.0	9-Feb-92	7-Apr-92
DE 2	135	-330.4	29-Dec-97	12-May-98
DE 3	79	-123.6	28-Feb-15	17-May-15
DE 4	122	-226.7	28-Dec-15	27-Apr-16
MIN	59	-100.0		
MAX	135	-330.4		
AVERAGE	99	-195.2		
STANDARD DEVIATION	36	105.6		

Q_{95}	Duration (Days)	Deficit (m^3s^{-1})	Starting	Ending
DE 1	108	-115.4	12-Jan-98	29-Apr-98
DE 2	51	-34.6	8-Jan-16	27-Feb-16
MIN	51	-34.6		
MAX	108	-115.4		
AVERAGE	80	-75.0		
STANDARD DEVIATION	40	57.1		

4.3 Drought Duration Trend

The drought events in Sipitang district show a different trend based on Q_{90} and Q_{95} levels. Through Mann-Kendall Trend and linear regression analysis, the trend at Q_{90} level has increase as shown in figure 4. The increase was indicate by positive values of b = 0.7322x as well as Mann-Kendall test S = 2. Contrary to Q_{95} level, there is a trend of decline as illustrated by negative values of coefficient b = -3.1667x and Mann-Kendall test S = -1. It shows that moderate severe drought (Q_{90}) has increase, but severe drought (Q_{95}) showed a decline pattern. However, these findings are not significant at confidence level of α = 0.1.

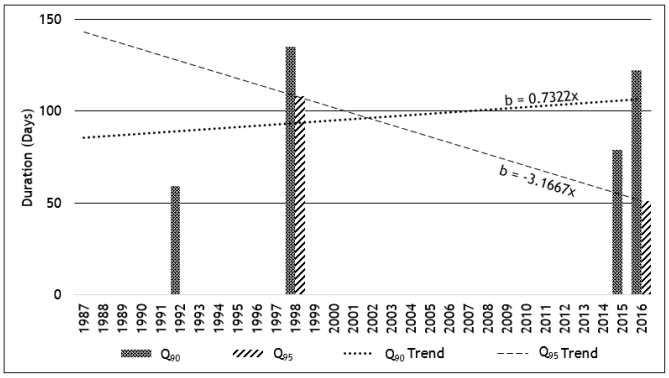

Figure 4: Drought duration trend in Sipitang

5. DISCUSSION

Duration is an important aspect in interpreting the properties of drought. During the study period, Sipitang area is in a state of drought for 4 years and it represents 13.8 percent of the total year. This percentage is lower compared to other studies such as in Langat basin of 31.3 per cent [12]. The number of days recorded is 135 days and exceeds the MDP level set by the MKN of 3 months, but this period is lower than the one previously studied in the Langat basin of 250 days. The difference is related to the environmental factors of the basin. The rapid development rate and high-water demand in the Langat basin become a major factor in severity level. In contrast to Mengalong basin with low development rate, extreme weather become the major contributor to severity of the events.

Based on the El-Nino pattern plotted the entire drought incidence is associated with the presence of extraordinary weather phenomenon (El-Nino) [1]. This is shown by Person correlation value of r^2 = 0.71 which indicates a high correlation at confidence level of α = 0.05. Drought events that took place over a long term period (more than 3 months) are associated with the presence of El-Nino on a very strong scale (scale 2.0 - 2.5) as shown in 1997/98 and 2015/16 episodes. While drought that lasted less than 3 months occurred on a strong scale (scale 1.5 - 2.5) as shown during 1991/92 and 2014/15 episodes.

The study also found that year 1998 and 2016 indicate a severe drought in the study area. At Q_{90} threshold level, the drought years recorded was 4 DE ie 1992, 1998, 2015 and 2016. However, when Q_{95} threshold level was used, only year 1998 and 2016 could be consider as drought year. In 1998 the period of drought decreased from 135 days to 108 days but remains above the level of 3 months. For 2016, the period of drought decreased from 122 days to 51 days. This study also proves that year 1998 was considered a year with an extreme drought due to its long duration with a high river discharge deficit between 100 - 350 m^3s^{-1}. In terms of frequency, the occurrence of drought in Sipitang is still acceptable with the occurrence average is once in 8 years. This is in contrast to the Langat river basin that records the occurrence is once in 3 years [12].

6. CONCLUSION

Drought is a phenomenon that can occur in all climatic areas either in wet or dry. Malaysia in general and Sabah in particular are not free from drought session. This is evidenced by four droughts that occurred in study area with repetition rate once in every 8 years. The long period of drought is strongly influenced by the presence of the El-Nino phenomenon. The phenomenon is greatly affected the study area especially in 1998 and 2016. This shows that Sipitang districts will faced with raw water supply issues in the future. The trend of drought is also expected to increase with the presence of El-Nino. Hence, stakeholders in particular those who involved in water supply industry required to plan the water needs in the future.

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