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Impact of 2016 intense drought to small tropical reservoir: An early onset and late recovery experience in Timah Tasoh, Malaysia

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Abstract. This study investigates the hydrological drought impact during the extreme 2016 El-Nino to small tropical reservoir of Timah Tasoh, in Perlis, Malaysia. Small tropical reservoirs are important freshwater supplier due to its economic & strategic factors including (i) closer distance to inhabitants and agriculture footprints, (ii) easy access to the resource, and (iii) cheaper cost of water pipelines system. In theory, small tropical lakes or reservoirs are facing higher risk to drought compared to the bigger ones. However, detail information and evidence are required for site specific drought adaptation in the future especially the onset and offset of the drought at specific hydrometeorological and dam scale. Prior to that, a case study was conducted in one of the small-sized and shallow reservoirs of Timah Tasoh, Perlis to analyze the impact. The larger Pedu reservoir was selected as control site. Both reservoirs were having identical hydro-climatic characteristics (seasonality of rainfall). The observation on the rainfall and reservoir level data indicated that the small sized reservoir (Timah Tasoh) tends to dry about 2 months faster (reached dam critical level) and recover 1 month late compared to the normal dry season. In comparison with the Pedu reservoir, the drought onset and offset in Timah Tasoh was earlier and late respectively although the rainfall pattern is typical. The total impacted drying days for Timah Tasoh is 197 days compared to 78 days of Pedu (about 3 months longer). The findings indicate that the 2016 extreme drought impacted the Timah Tasoh small reservoir where they would suffer longer dry season and experienced slower recovery compared to the bigger Pedu reservoir. The outcome of this investigation signifies that the early drought onset monitoring should be implemented for the small sized reservoirs to take appropriate mitigation and preventive measures in adapting to the intense drought.

1. Introduction

2016 has been identified as the hottest year on record and its subsequent hydrological impact hit across the globe [1]. Small tropical reservoirs are important freshwater supplier due to its economic & strategic factors including (i) closer distance to inhabitants and agriculture footprints, (ii) easy access to the resource, and (iii) cheaper cost of water pipelines system. In theory, small tropical lakes or reservoirs are facing higher risk to drought compared to the bigger ones. This is primarily because of the low quantity of water and relative shallowness of open water surface [2]. A shallow water surface will follow closely meteorological variations, while the deep-water surface reacts otherwise. In that case, the smaller reservoirs (shallow water surface) will have higher sensitivity to drought compared to the bigger lakes (deep-water surface). Knowing the response of these small tropical reservoirs during the most extreme hottest condition would provide us with useful information regarding its behavior and survival. As the intensity and severity of drought is commonly described by the length of the rainfall deficit, the eventual impact on small reservoir is often overlook. One also should not be confused by generalizing the meteorological drought (deficit of rainfall amount) with the eventual storage deficit experienced by the various reservoir. Theoretically, the recharge period of the small reservoir is more frequent and small disruption of the hydrometerological layers (~5km vertical from the land) would impact them more than larger reservoir. Measuring the eventual reservoir-based drought period especially the corresponding onset and offset would be informative for the future adaptation, mitigation and preventive measures for the small tropical reservoirs. The Timah Tasoh reservoir located in Perlis, the northernmost state in Peninsular Malaysia is sustaining the 50% of the state agricultural activities, water supply and flood control purpose. It is a low lying small and shallow reservoir with 13.3 square kilometre surface area. For a record, 2016 has hit this reservoir hard where the dam level recorded among the lowest reading in 24 years [3]. The severe dam deficit had impacted nearly 3000 hectares of paddy field and resulted losses about 56 million Malaysian Ringgit (~14 mil. USD). The water supply has been experiencing 35% deficit and ratioing is implemented as preventive measures [4]. The 2016 drought is recorded to be the most severe drought that hit the state since in mid 70s [3]. Prior to the aforementioned crisis, a decent information and understanding about the drought onset and offset at hydrological and dam level preferences differences at small tropical reservoir would enable proper adaptation and preventive inititatives in the future. The objective of this study is to identify the severity of the 2016 drought in relative to the seasonal dry season at both hydrometeorological scale (rainfall) and dam scale (dam level) at Timah Tasoh reservoir. Primary focus is given to the onset and offset of the drying period; a significant remark that signified the impact of the drought and how much time is required in order to restore the hydrological balance.

2. Materials and Methods

2.1. Study site description

Timah Tasoh reservoir (6°33'56.3"N, 100°13'01.2"E) is in the state of Perlis is the most essential dam. It has a total surface area of 13.33 km² with a storage capacity of 40 million cubic meter of storage [5]. Moreover, the reservoir has two main river inputs; Tasoh River and Pelarit River which contributed a catchment area of ~191 km. There are two distinct tapping seasons (Fig. 1(a)) experienced by the reservoir area; major tapping seasons (September until November) and minor tapping seasons (April, July and August). In addition, the region also experienced dry seasons during the months of January until February (Fig. 1(a)) which has average rainfall less than mm. Pedu reservoir (6°14'31.3"N, 100°45'53.3"E) is in the district of Padang Terap, Kedah with the total surface area of 52 km² and has a larger storage capacity of 1073 million cubic meter [6]. Pedu reservoir plays an important role in providing sufficient irrigation water to the Muda area. Both of the reservoirs were experiencing similar hydro-climatic characteristics (Fig. 1b) and Pedu reservoir is among the nearest reservoir that suitable and available to be used as reference control site.

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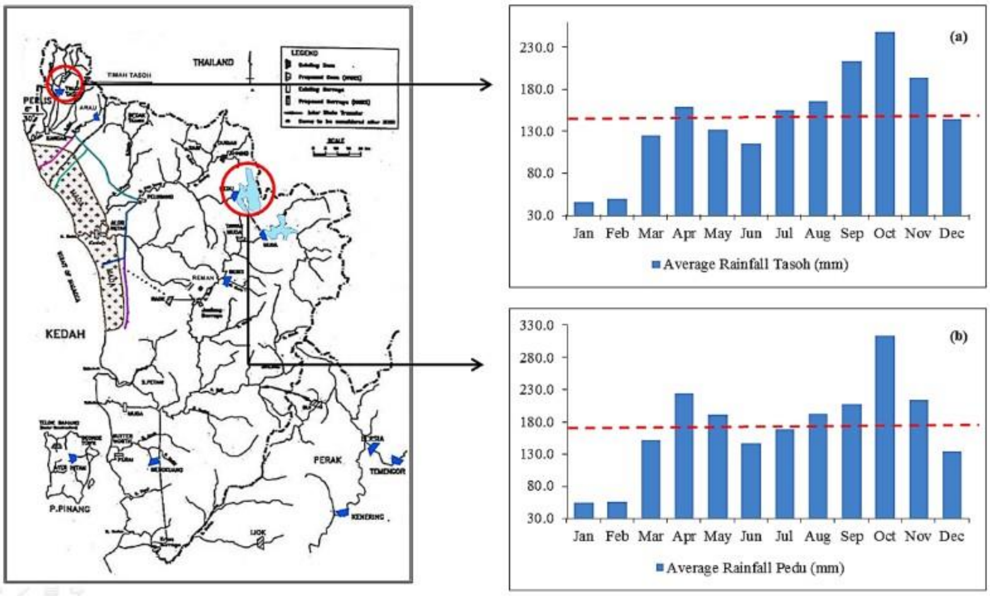

Figure 1. Location of Study site and its average rainfall; (a) Tasoh and (b) Pedu.

2.2. Data

2.2.1. Rainfall and dam level data
The main data used in this study was daily rainfall and dam level data. Both data was obtained from the Department of Irrigation and Drainage, Malaysia. There are approximately 63 discrete rain gauge stations; 17 stations located in Perlis, and 46 stations located in Kedah. Daily rainfall data was used to provide information about the hydrometeorological drought while the dam level indicates the actual reservoir status.

2.3. Methods

2.3.1. Drought period analysis 1: 2016 vs. normal dry season
The constructed time series from cumulative rainfall are produced for both Timah Tasoh and Pedu (control) within the period of study; 1st September 2014 until 31st October 2015 (Non- Drought) and 1st September 2015 until 31st October 2016 (Drought). The onset is computed based on changes of the slope that is computed at 3 days time interval. The slope that has value less than 1 indicates that the period is dry and vice versa. For non-drought interpretation, value more than 1 was used. Equation 1 described the computation process.

$$m = (Crb - Cra)/(Tb - Ta) \quad (1)$$

where m is the slope value, Cr_b and Cr_a is the cumulative rainfall at time b and a.

The threshold for the dam deficit is referred to the standard value according to the Department of Irrigation and Drainage, Malaysia. The standard that we referred as critical is 50% (warning level). Any deficit further than 50% is considered as critical drought impact to the dam.

2.3.2. Drought period analysis 2: Comparison with bigger reservoir

To measure the severity of the 2016 extreme drought to the small reservoir, comparison with the bigger reservoir was conducted. The onset and offset of the dam deficit (<50% and recover) were compared for both Timah Tasoh and Pedu reservoir. The length of the affected period were analyzed. In addition, the ensure the identicality of rainfall of both reservoirs, the cumulative rainfall pattern were also compared. High agreement temporal rainfall pattern indicated that the rainfall pattern between both areas is similar.

3. Results and Discussions

3.1. Drought onset and offset analyses vs. normal dry season

At hydrometeorological scale, the 2016 rainfall deficit occurred about 15 days earlier in comparison with the normal rainfall during the dry season (Table 1). It occurred in early December while the normal dry season would start in late December (Fig.2). While the dry season offset somewhere in end of March, the 2016 dry season was to offset in early May. There is one month of lag between the 2016 extreme drought offset compared to the normal dry season.

Table 1. Tensile test results of hexagonal wire mesh and square wire mesh.

Variable(s)	2016 drought		Normal Dry Season	
	Onset	Offset	Onset	Offset
Rainfall	9 Dec. 2015	2 May 2016	24 Dec. 2014	28 Mar. 2015
Dam water Level	22 Feb. 2016	7 Sept. 2016	22 Apr. 2015	9 Sept. 2015

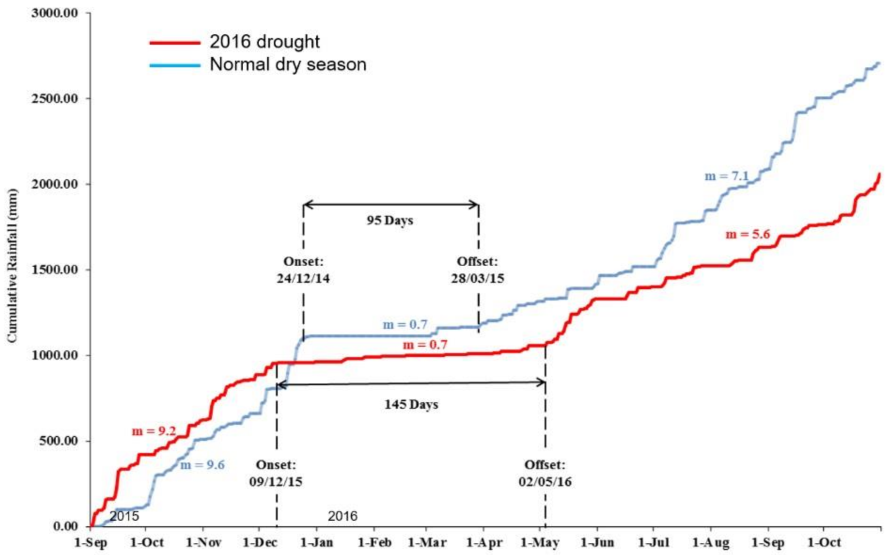

Figure 2. Cumulative rainfall comparison in Timah Tasoh during the drought period in 2016 and normal dry season in 2014.

The severe dam level deficit (<50%) during the 2016 also was longer than normal dry season. It tooks about four months longer (119 days) (Fig. 3). The subsequent dam level pattern followed the hydrometeorological drought where the deficit onset occurred earlier and recover late. Both analyses also indicated that prior to the early onset on hydrometeorological scale, the dam level deficit will also be experiencing an early deficit. Another important fact related to the severe 2016 drought is that the lag between the onset at the hydrometeorological scale and the dam level deficit would be shorter (2 months).

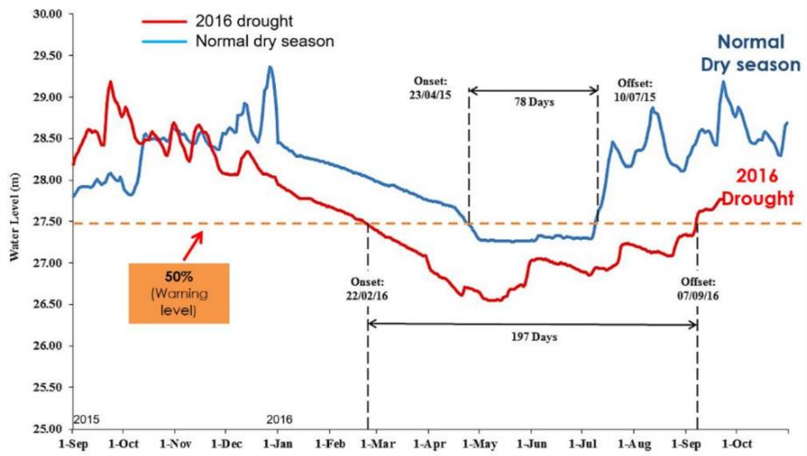

Figure 3. Dam level comparison during the drought period in 2016 and normal dry season in 2014.

3.2. Drought severity relative to bigger reservoir

Comparison with Pedu reservoir showed that the Timah Tasoh reservoir experienced significant dam deficit (<50%) onset almost four months earlier onset (Fig. 4). While the Timah Tasoh reservoir endured about 197 days of severe water deficit, Pedu reservoir experienced only 78 days. Meanwhile, the offset of both reservoirs are about the same (>50%). This finding indicated that the smaller reservoir tend to dry up faster about four months earlier in comparison with a reservoir that have the capacity of 25 times larger. Interestingly, despite the similar rainfall pattern of both areas (Fig. 5), the recovery of the smaller reservoir tend to consume longer period. Three plausible factors could explain this phenomenon; first is the extreme dry period had increased the water table depth; thus require more run-off percolation to saturate the soil. The second factor is high evaporation rate had reduced the amount of run-off. The third one could be the anthropogenic factors where the remaining dam water was continuously being extracted (in cautious mode) although the level is low. This could slow down the recharge process and full capacity recovery.

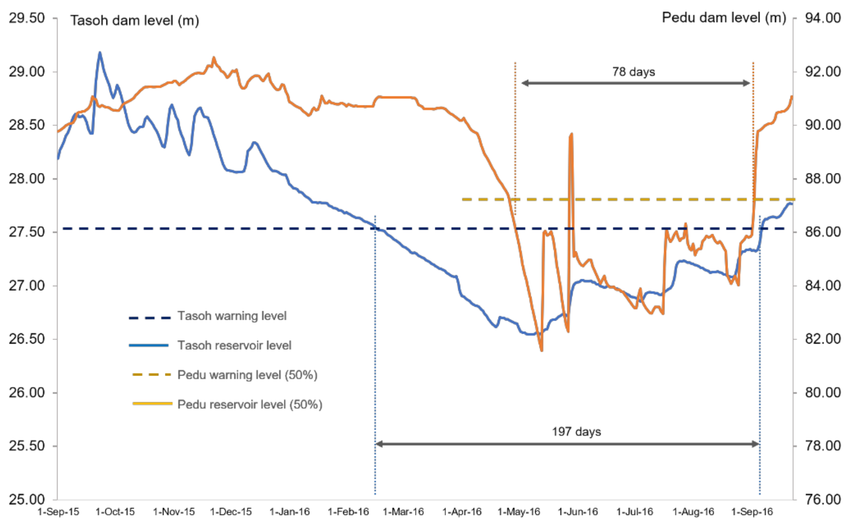

Figure 4. Comparison between the onset and offset of the Timah Tasoh & Pedu reservoir during the 2016 extreme drought.

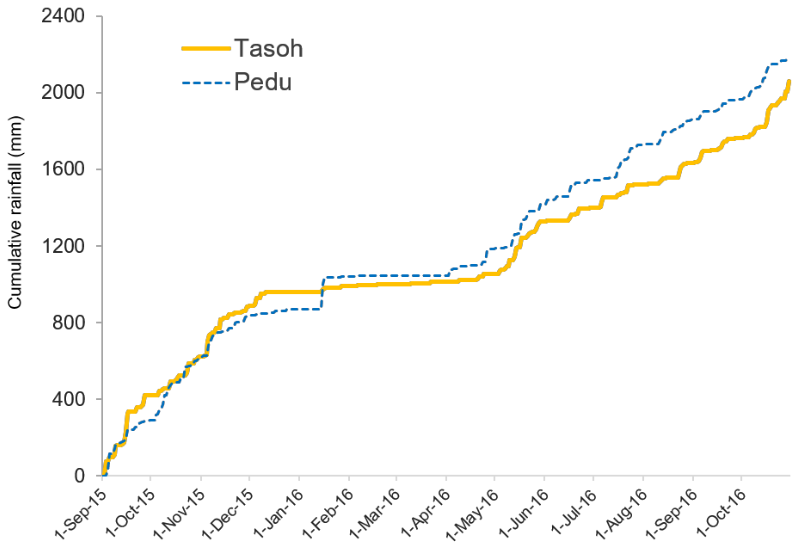

Figure 5. Cumulative rainfall of Timah Tasoh and Pedu reservoir.

4. Conclusion

The 2016 extreme drought due to the El-Nino had caused severe hydrometeorological deficit (rainfall) and prolonged dry season. This is caused by the early onset and late offset. The similar subsequent impact was occurred to the small Timah Tasoh reservoir. The onset and offset of the dam level deficit to warning level had occurred earlier and recover latter than during the normal season. Comparison with larger reservoir indicated that the smaller reservoir experienced dam level deficit about four months earlier and twice longer of deficit level. The outcome of this case study would provide us with knowledge on the time taken for the small reservoir recovery during extreme drought and affected time period with very limited rainfall. This information are required for adaptation, mitigation and preventive plan against the more frequent drought in the future.

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