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Assessing stream flow regime and basin water storage in occurrence of hydrological drought in Lorestan province

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ABSTRACT

The objectives of this study were to apply base flow index (BFI) for assessing stream flow regime and basin water storage and to validate this index in drought studies in Lorestan Province. To view of this, daily BFI and mean of annual BFI were calculated based on the minimum 5-day periods in 24 gauging stations with period 35 years. The results showed that the regional mean of BFI with 0.77 value (SD=0.08) is stable. BFI ranged between 0.61 and 0.95 and also based on the 25, 50 and 75 percentiles river flow regime in the study area divided to four categories that most of catchments in the study area have stable regime. So the catchments will be able to provide river flow during dry weather. Therefore, the results of this study can be used in classification of stream flow regime of river and hydrological drought monitoring.

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1. Introduction

All of natural hazards including geologic, geomorphic and hydro-meteorological have an increasing trend worldwide (Emanuel, 2005; Wilmking et al., 2005; Hoeppe, 2016) (Fig 1). Hydro-meteorological hazards are among most destructive and intensive hazards with huge human and economic losses and social impacts in the long-term, so required more attentions from mitigation and investigation viewpoints (Wiljite et al., 2000; Guha-Sapir et al., 2011; Balbi et al., 2013). Flood and drought are major disasters in the Asia and also Iran (Fig 1). The studies on drought can be subdivided in four branches including meteorological drought, agricultural drought, hydrologic drought and socioeconomic drought (Delpla et al., 2009). In the hydrologic drought, the studies are focused on fast withdraw of surface flows and falling of groundwater table, lakes and rivers.

Naturally, the drought periods are corresponding and synchronous with periods of Low flows. Understanding the frequency criteria of low flows is so important for meteoric drought studies, designation of water systems, river flow classification, estimation of run-off infiltration, aquifer recharge, wastewater dilution potential (absorption capacity), urban water planning, agricultural and industrial water planning and environmental conservation (McCleskey et al., 2010). The perspective of river flow in the sense of occurrence or continuation of an identical drought is determined by the low flow criteria. The base flow criterion is one of low flow criteria which show the is the minimum flow rate that flows in the river or share of total flow that is extracted from the river regardless of the environmental flow (Hosseini et al., 2017). So the base flow is also an index of effects of geological properties of watershed on river discharge (McCuen, 1989).

The base flow shows the potential of watershed for preservation and releasing water resources during drought period in the context of hydrologic drought. There are many researches on the application of low flow criteria for evaluation of hydrologic drought (Nosrati et al., 2002, 3004; Nosrati and Shahbazi, 2007; Fiala et al., 2010), but less attention paid to the base flow criterion. This paper attempts to consider the efficiency of base flow criterion in evaluation of river regime and water preservation in the watershed for drought studies in the Lorestan Province of Iran.

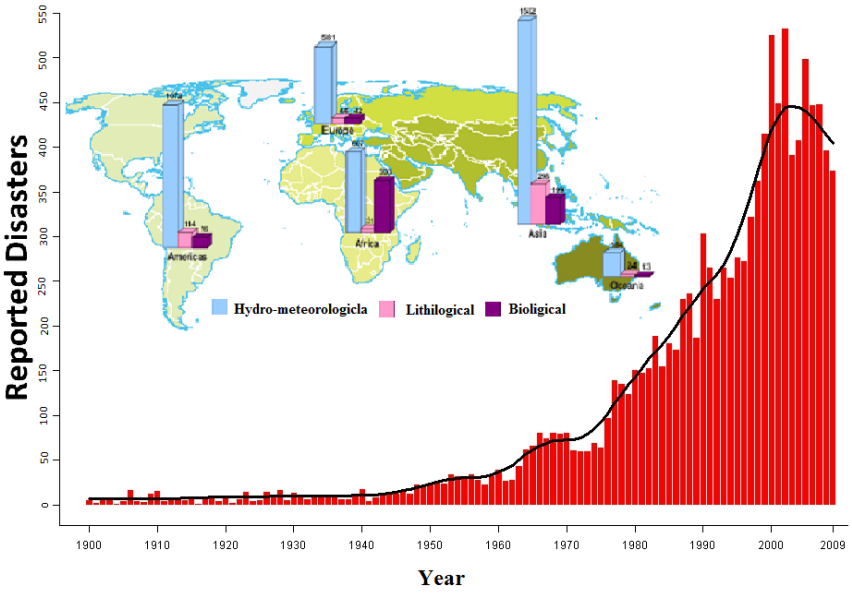

Fig. 1. trendline and distribution map of natural disasters occurrence during (1900-2009)

2. Material and Methods

2.1. Data and Analysis Methods

2.1.1. Data Preparation

To select stations with suitable statistical data, at first, several factors (geology, land-use and flow regulation and control) of hydrometric stations of Lorestan Province that influence on low-flow were assessed. The selected data of daily discharge of 24 stations for 35 years were ordered in the case which the daily discharge of every year pictured sequentially and the data gaps were made from neighboring stations by correlation method (Figure 2).

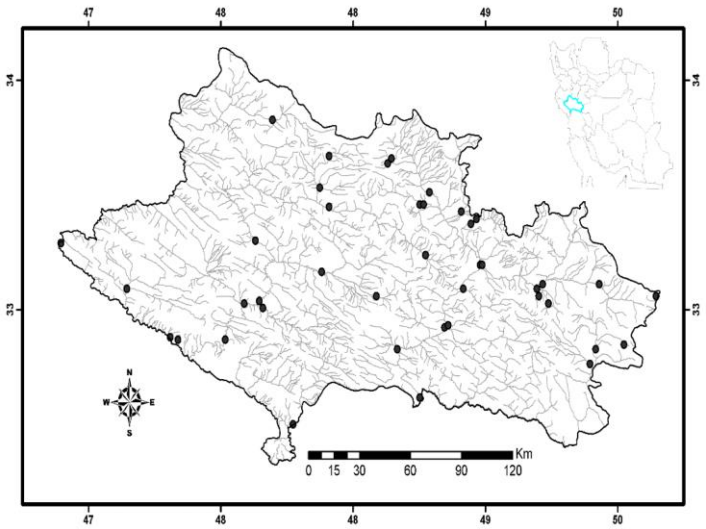

Fig. 2. distribution map of hydrometric stations of Lorestan Province

2.2. Base Flow index (BFI)

BFI is one of low-flow indexes which is defined as the ration of base-flow volume to the total volume, and has the potential to be used as the indicator of hydrological drought and watershed capability for preservation and release of water resources in drought periods. This index is calculated using daily discharge hydrograph for a year and averaged for long-term applications. To calculate BFI, we firstly divided the daily discharge into five-days categories. Then we selected the minimum discharge of each category as the inflection or turning point to determine central inflection value for all time-series. Afterward, the diagram of inflection points was plotted by linear interpolation to determine daily base-flow. Then, the base-flow volume (the area below the base-flow curve) and total volume of water (the area below the hydrograph) were calculated by annual comparison. Finally, by using equations 1 and 2, the BFI and its annual average were calculated (Tallaksen and Lanen, 2004).

$$BFI = \frac{\sum_i b_i}{\sum_i d_i} \quad (1)$$

In which the BFI is Base-Flow Index, b_i is base-flow values, d_i is total flow for all time-series in appropriate time scale.

$$MBFI = \frac{\sum_a BFI_a}{n} \quad (2)$$

In which MBFI is average of annual BFI, BFI_a is annual base-flow index when "a" refered to year or season and n refer to number of years or season. In order to evaluate the annual average of BFI in long-term periods, 25, 50 and 75 percentiles of index were determined by which the study area were categorized for stream flow regime.

3. Results and discussion

Time-series of base-flow is a useful criterion for evaluation of dynamic behavior of groundwater. Our results showed that the base-flow ranges between 0.61 and 0.95. Zonal average of annual base-flow index is about 0.77 with standard deviation 0.08 that is constant in long-term period. Figure 3 presents the hydrograph of long-term average base-flow and discharge for two stations (Barfab and Derrehtang). The Barfab station has lowest BFI (0.61) and Darrehtang has the highest BFI (0.95). high BFI indicate the permanent flow of watershed that can supply the river flow in intense drought periods.

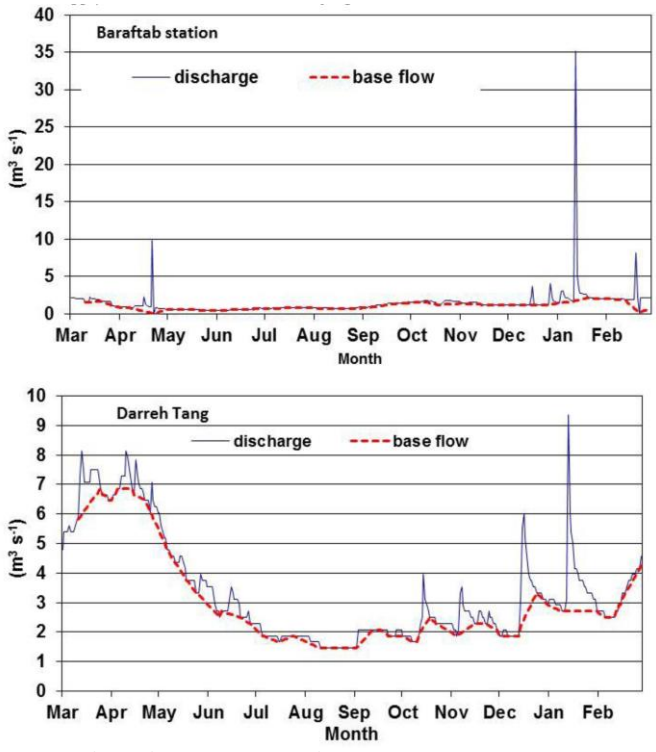

Fig. 3. daily hydrograph of base-flow and discharge for two stations with lowest and highest BFI (m^3/s).

Additionally, Figure 4 shows average long-term base flow and discharge of two other stations including Rahimabad and Darrehtakht with BFI of 0.84 and 0.75 respectively. Fleig (2004) reported the BFI for permanent flowing and permeable watersheds is more than 0.8 while for occasional flowing impermeable watersheds is less than 0.5.

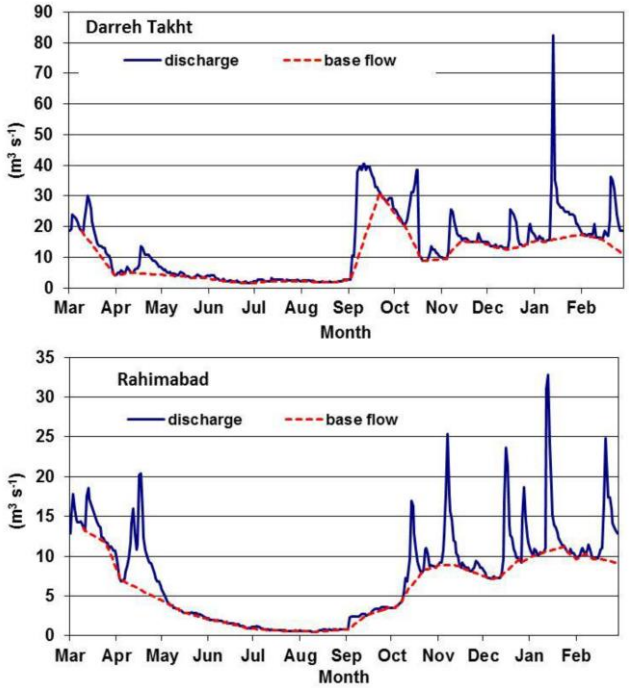

Fig. 4. daily hydrograph of base flow and discharge for some stations in the study area (m^3/s).

The frequency of annual average of BFI in the long-term was calculated on the base of 25, 50 and 75 percentiles by which the area was subdivided into four flow regimes (Table 1). Figure 5 shows the frequency of each subdivision and the situation of flow regime. The results showed that most of stations have relatively stable flow regime with preamble watersheds. So the water flow will be supplied in drought periods. However, it should be noted that the changes of land-use can modify the permeability of watersheds considerably and then reduce the BFI.

Table 1. categorization and variation range of BFI

Subdivisions	Watershed condition	Symbol
BFI ≥0.84	permeable with permanent flow	EP
0.77> BFI<0.84	semi-permeable with quasi-permanent flow	SP
0.72≥BFI<0.77	low permeability with low permanent flow	MP
BFI<0.72	impermeable with occasional flow	IP

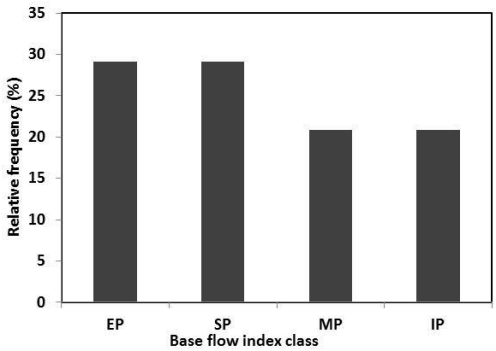

Fig. 5. frequency of BFI subdivisions in the study area. The table 1 defines each category.

4. Conclusion

BFI was calculated for 24 stations of Lorestan Province using the ratio of base-flow to total flow and daily stream discharge hydrograph. As a criterion of influent-river discharge, BFI can be used for estimation of intensity and duration of hydrological drought. So the BFI can be used for evaluation of groundwater recharge, water supply systems, hydrological drought monitoring and water resource management. Although, with consideration of the hydrogeologic relationship between watershed and base flow, the BFI can be used for regional modeling and estimation of water resources and hydrological drought where there are few statistical data in short-term.

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