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Analysis of Hydrological Drought on Kurdistan Province

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Abstract: Hydrological drought was analyzed by method of truncation level in 4 main hydrometry stations from Kurdistan province west of Iran. The data were daily discharges. The flow duration curves (FDC) were derivate base on daily flow time series then 70 % truncation level was determined and drought periods were assigned. Frequency analysis was carried out for annual maximum series (AMS) of drought deficit volume and duration series. The maximum liklihood method (ML) was applied to determine model parameters. The average of drought duration and drought deficit volume was 76 days and 17.7 MCM respectively. The Johnson, Pearson and Double Exponential distributions were the better ones for deficit volume and duration analysis. The average of return periods of drought was 4 year almost.

Key words: hydrological drought, daily flow, truncation level Kurdistan

INTRODUCTION

Drought typically costs the USA around 6 to 8 billion Dollars per year (FEMA 1995), with losses on the order of 20 billion The main objective of this study is to extend, in space, at-site hydrological drought characteristics to the region of interest through a comprehensive regional analysis. This is done by determining the factors that most affect the hydrological drought, obtaining multivariate regional models, and producing drought maps at sub-basin scale. The study area encompasses major river basins in southwestern Iran, where surface water use and water transfer are pivotal. The study region benefits from considerable surface water which constitutes roughly a quarter of total surface water resources in the country. Vast agricultural areas rely on surface water in this region, making droughts a challenging economic and social disaster.

Study Area and Data:

Kurdistan province extending from $34^{\circ},44$ to $36^{\circ},30'$ N latitude and $45^{\circ},31'$ to $48^{\circ},16'$ E longitude that includes parts of Sefidrood, Karkhe, Oromieh, and Marzi Gharb basins. This area has Mediterranean climate type with wet winters and dry summers. Lowland area receives surface water Zagros tributaries and has great potential for agricultural activities.

Themoisture from the Mediterranean Sea, Red Sea and Northern Atlantic Ocean is the source of precipitation (Jamab Engineering consultants Company, 2000). The daily discharge series of 4 hydrometric stations was included in this study. These data were made available by Iranian Water Resource Management Organization (Table 1).

Methodology:

The threshold level method introduced by Yevjevich (1967) based on theory of runs defines droughts as periods during which the water supply is lower than the current water demand. Yevjevich (1983) later simplified this method by applying a constant demand that was represented by a threshold level, Q_α, thus droughts are defined as periods during which the stream flow is below the threshold level.

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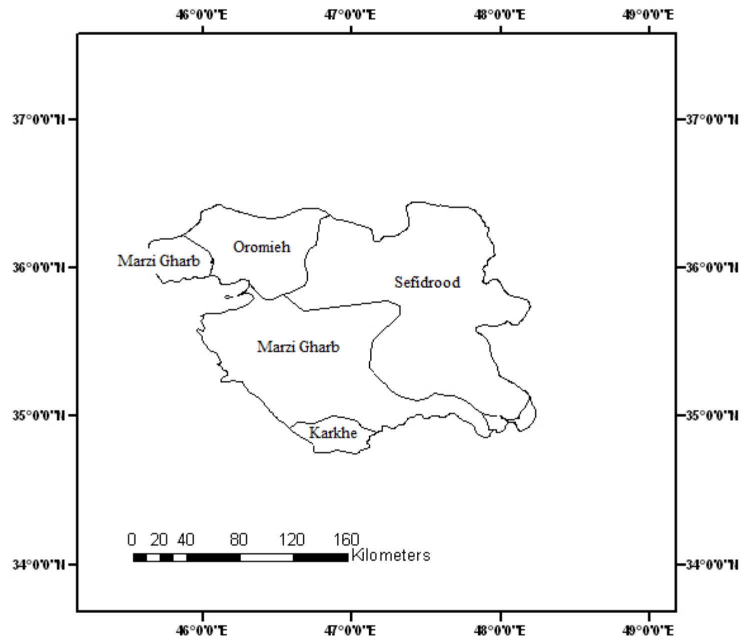

Fig. 1: The Kurdistan map that divided by basins.

Table 1: The properties of hydromtry stations.

Station	pole adinan	Pnbe Dane	Ghare Goni	Doab Nosood
code	33015	33011	17011	21047
Longitude	46.43	46.37	47.95	46.23
latitude	36.2	36.28	36.23	35.12
RIVER	CHOGHA TOCHAE	ZARINE ROOD	GHEZEL AOZAN	SIRWAN
DORATION	1980-2006	1980-2006	1975-2006	1959-2006
FLOW (m^3/s)	18.1	11.2	33.6	87.3

Based on the run theory a run is the period between two consecutive crossings of the truncation level and it delineates a drought event. The run length then explains the duration of the drought event and the run sum describes the cumulative deficit volume. The drought characteristics include deficit volume or severity, V_i, duration, d_i and the start of drought t_i. The threshold level should represent the lower boundary to "normal" condition and is set to a percentile of the daily flow duration curve (FDC), e.g. the 70- percentile flow (Q_{70}), which represents that flow exceeded 70 percent of the time.

Minor droughts have short duration and small deficit volume and should be reduced in an extreme value analysis. Dependent droughts can occur during long–term periods of low discharge when divide the period of low discharge into several drought events. There are three different pooling procedures; moving verage (MA), sequent peak algorithm (SPA) and the inter event time criterion (IT- Criterion). They were compared and discussed in (Tallaksen, L.M. and H. Hisdal, 1997; Hisdal, H. and L.M. Tallaksen, (Eds), 2000; Fleig, A.K., 2006).

$$DQ = \begin{cases} Q_\alpha - Q_k & if \quad Q_k < Q_\alpha \\ 0 & if \quad Q_k >= Q_\alpha \end{cases} \quad (1)$$

Based of IT- Criterion two dependent droughts are pooled if they occur less than a critical number of days, t_c, apart, i.e. $t_i \le t_c$.

The duration of pooled drought is defined from the starting (first) day of the first pooled event to the last day of the last pooled event.

$$d_{pool} = d_i + d_{i+1} + t_i \tag{2}$$

where d_i and d_{i+1} are the duration of events i and i+1, respectively. In references (Tallaksen, L.M. and H. Hisdal, 1997) and (Fleig, A.K., 2006) recommend that $t_c = 5day$. The pooled drought deficit volume of the pooled events is as follows:

$$V_{pool} = V_i + V_{i+1} \tag{3}$$

The minor droughts are excluded when their deficit volume is smaller than a certain coefficient (%) multiple by maximum observed deficit volume ($V_i \leq \alpha \times V_{\max}$). The value of α must be from 0.5 to 1%.

Annual Maximum Series (AMS) of drought derived from time series of daily discharge based on threshold level (Q_{70}) ethod as discussed above. The distribution of the drought deficit volume and duration AMS in a given time interval, [0,t], e.g. one year, $F_t(x)$, is stated based on, the distribution model of the number of droughts combined with the distribution function of the magnitudes of all events within the time interval, $H_t(x)$:

$$F(x) = \Pr(Z_t = 0) + \sum_{k=1}^{\infty} H^k(x) \Pr(Z_t = k) \tag{4}$$

Where Z_t is the number of drought events and $\Pr(Z_t = k)$ is the probability of k events during the time interval (Fleig, A.K., 2006). The Nizowka software is used for extraction and analysis of droughts (Jacubowski, W. and L. Radczuk, 2003).

Minor droughts were excluded with $\alpha = 0.5\%$ and dependent droughts were pooled with $d_{\min} = 5$ days and $t_c = 3$ days. Several probability distributions, including Gamma, Weibull, Log-Normal, Johnson, Gumbel and Generalized Pareto, fit to series of deficit volume and duration by applying the method of maximum likelihood. Also, the Pascal and Poisson distributions applied for the event numbers.

The statistical models that were applied include:

Gumma:

$$f(x) = \frac{\alpha^{\nu}}{\Gamma(\nu)}(x-S)^{\nu-1}e^{-\alpha(x-1)}, \qquad x > S \tag{5}$$

Wibule:

$$f(x) = \alpha\lambda(x-S)^{\alpha-1}e^{-\lambda(x-S)^{\alpha}}, \qquad x > S \tag{6}$$

Log Normal:

$$f(x) = \frac{1}{(x-S)\sigma\sqrt{2\pi}}e^{\frac{(\ln(x-S)-\mu)^2}{2\sigma^2}} \qquad , \qquad x > S \tag{7}$$

Johnson:

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma}\frac{b-a}{(x-a)(b-x)}\exp\left[\frac{1}{2\sigma^2}(\ln\frac{x-a}{b-x}-\mu)^2\right] \qquad , \qquad b > x > a \tag{8}$$

Double exponential:

$$f(x) = \alpha e^{-\alpha(x-\mu)}e^{-e^{-\alpha(x-\mu)}} \tag{9}$$

Generalised Pareto:

$$f(x) = \frac{1}{\alpha}\left[1-k\frac{x-s}{\alpha}\right]^{\frac{1}{k}-1} \qquad , \qquad x > s \tag{10}$$

χ^2- goodness of fit test was used to examine different distributions at 0.05 significance level (Haan, C.T., 1977). The return period of drought characteristics (deficit volume and duration) calculated by:

$$T = \frac{1}{1-F(x)} \tag{11}$$

Results:

In each one of the 4 hydrometric stations in the study area, drought periods were determined based on 70% threshold level. The Q70 were 23.06, 4.92, 0.98, and 0.90 for Doab Nosood, Ghare Goni, Panbe Dane, and Pole Adinan stations respectively. The average of drought characteristics in such stations showed at Table 2. The maximum and minimum of number of drought were79 and 32 and related to pole adinan and Doab Nosood stations respectively. Also the maximum and minimum of of drought deficit volume were 40.5 and 4.2 MCM and related to mentioned stations respectively Vice versa the maximum and minimum of drought duration were 83 and 64 and related to Doab Nosood and pole adinan and stations respectively.

Table 2: The average of drought characteristics for stations.

Drought characteristic	Station			
	POLE ADINAN	PNBE DANE	GHARE GONI	DOAB NOSOOD
Num. of Drought	79	43	33	32
Average of Dv ($10^{\wedge 6}$ m^3)	40.5	21.6	4.4	4.2
Average of duration (days)	64	75	82	83
Average of severity($10^{\wedge 6} m^3$/day)	0.51	0.24	0.05	0.04

In Doab Nosood station the drought was occurred on 1960, 1962, 1979, 1995, and 1999-2003 with higher intensity as most intensive drought related to year 2000. In this station drought was trivial on other years. In Ghare Goni station on 1976- 1987 droughts had occurred with moderate severity equal 15-45 MCM. Also on 1983 and period 1992-1997 droughts were light. The most intensive drought in this station had occurred on 2001. In Pnbe Dane station on 1980, 1984, 1989-1991, and 1996-2005 droughts were severe, on 1983, 1993, 1986-1998, and 2003 droughts were moderate, and on other years droughts were light. The most intensive drought in this station had occurred on1999 and 2001. Also In Pole Adinan station on 1981-1989 and period 1995-2005 periods droughts had occurred with moderate severity, on 1990-1994 and 2006 droughts were light. The most intensive drought in this station had occurred on 2001. Allgemein the most intensive occurrences related to 1999-2002 period for whole region.

The drought duration of all station are show in Figure 2. This index has similar treatment in all station on common years and varied from 5 to 200 days.

Frequency analysis on annual maximum series of duration and deficit volume was performed.

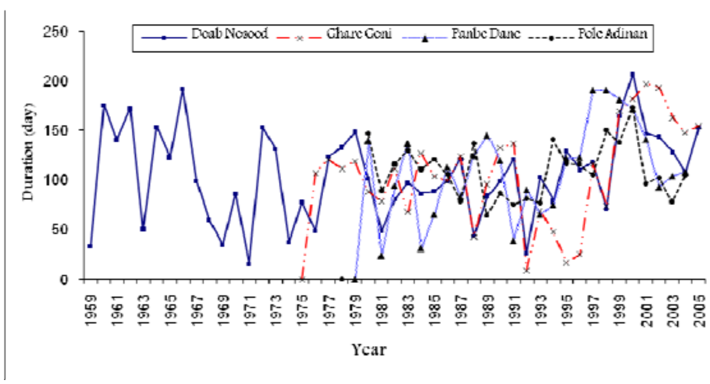

Fig. 2: Drought duration of all stations.

The result of Frequency analysis is shown in table 3. The Johnson Pearson and Double Exponential distribution were the better ones respectively for deficit volume and duration analysis.

Table 3: The results of frequency analysis for drought characteristics.

Drought characteristic		Station			
		POLE ADINAN	PNBE DANE	GHARE GONI	DOAB NOSOOD
Deficit Volume	Model	Pearson	Pearson	Pearson	Johnson
	K^2	.0.15	0.1	0.23	0.06
Duration (days)	Model	Exponential	Exponential	Johnson	Johnson
	K^2	0.21	0.17	0.44	0.16

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