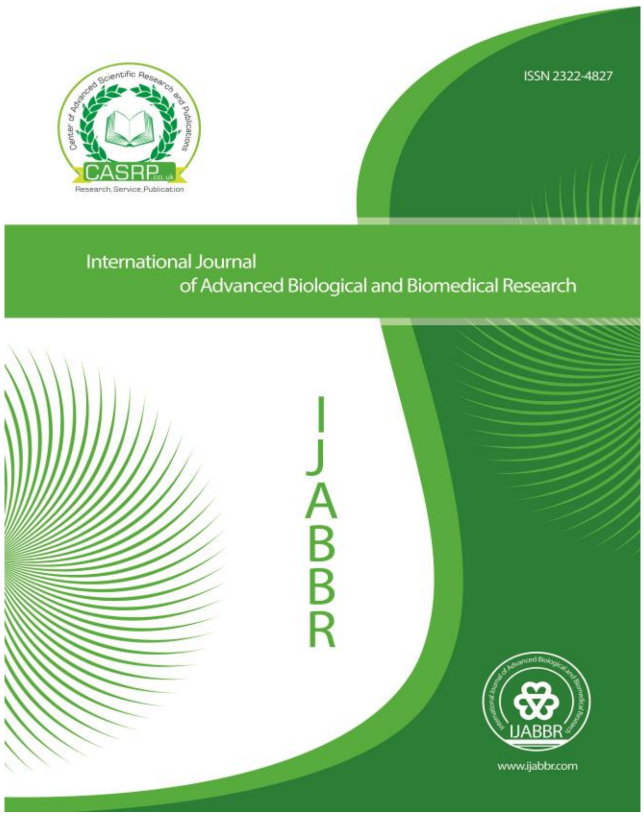
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Evaluating Empirical Methods of Flood Flow Rate Estimation in Bakhtegan Watershed-Iran

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Abstract

Several empirical methods for flood flow rate estimation have been presented. In this study,eight new empirical runoff estimation method including Dredge & Burge, Bourges, Inglis, Faning, Hyderabad, Burkli Ziegler, Cramar and Possenti were calculated in Bakhtegan watershed which is located in Fars province. After studying empirical methods for annual flood flow rate estimation and comparing the results from empirical methods with measured values by hydrometric station existing in the region, it was found that in most watersheds, the most suitable methods were Cramar, Burkli Ziegler, Faning, Dredge & Burge, Bourges, Possenti, Hyderabad, and Inglisrespectively.

Keywords: Flood maximum flow rate, Bakhtegan watershed, Empirical methods.

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1. Introduction

Overally, flood calculation with various return periods is carried out using statistics of hydrometric stations and

analyzing them. But in absence of these stations or defective and short time statistics, indirect methods are used for flood estimation. In Iran also, because of existing this problem, the use of indirect methods have a high importance for flood flow rate estimation. One of these methods is, using empirical formulas. Telvari (1382), evaluated the efficiency of some empirical methods such as Kreager, Horton and Fuller for estimating the peak of flood flow rate in Karkhe watershed and concluded Fuller method is the most proper method for estimating the highest amount of flood flow rate in most basins and sub-basins in study area due to considering ground traits, quantitative morphological, vegetation and climate. Yazdani et al. (1385) evaluated two methods one of which was based on watershed area and another one was based on watershed physiographic and precipitation characteristics, in order to find an acceptable method for estimating peak flow in basins. Among area-based methods, Horton method and among the methods which are based on watershed physiography and precipitation characteristics, graphical approach of SCS had the lowest error. Jafarian et al. (1389) used four regional mathematical methods for flood peak flow rate estimation in Hemmatabad region. In each method, peak flow rate of each sub-basin were calculated in various return period. By comparing achieved peak flow rates from different methods and by considering negligible runoff height and base station, envelope curve was suggested as the best method. Zare et al. (1388), estimated flood peak flow rate in various return period using empirical methods in Tolbane watershed in Gorgan. In this study five methods including Fuller, Kreager, Dicken, Alinavaz and rives which were based on watershed area, were used for estimating flood peak flow rate. Sanginabadi and Abolghasemi (1388). Determined and evaluated flood flow rate and mean annual flow rate equations of Qazvin province rivers. Results showed that, the first involved parameter in flood and mean flow rate equations of these rivers is type of climate. Radmehr and Araghinezhad (1389) conducted a comparison between corrected empirical method and statistic model in predicting flow on Lar River in entry station of Lar dam. In this research, two methods including statistic and corrected empiricalmethod were used to predict monthly flow. Azari and Behnia (1389) studied the application of methods Kreager, Dicken and SCS artificial hydrograph in estimating flood peak flow rate of Bartaj watershed. Comparison of calculated results by Kreager and Dicken method with observed values in stations showed that, Kreager method had a higher accuracy with a correlation coefficient of 0.84 between calculated values and observed values, lower relative error (0.31) and lower amount of maximum relative error (1.7). Tagus et al. (2008) in testing the relationship between maximum flow rate and flow rate using Fuller empirical formula in south eastern Spain by linear regression method, found that, observed peak flow rate values and estimated values have a proper appropriateness. Alcazar and Palau (2010) regionalized flow regimes in a Mediterranean watershed. Totally 51 physical and hydrological variables were measured and collected in 45 stations, and the variables were classified within 5 groups using main components analysis. Tsanis (2010) presented an approach for sudden flood peak flow rate estimation, hydrograph and flood volume in a watershed with a few measurement stations where, few flood hydrological characteristics have been known. In this research, results from 8 empirical flood estimation including Cramar, Burkli Ziegler, Faning, Dredge & Burge, Bourges, Possenti, Hyderabad, and Inglis are evaluated with measures values by hydrometric stations existing in the watershed, in Bakhtegan watershed located in Fars province.

2. Materials and methods

2.1. Study area

Tashtak-Bakhtegan lakes and Maharloo watershed (Code:4-1) with an area of 31492 km^2 is located in Fars province. This watershed expands in western north-eastern south direction and parallel with Zagrosmountains. In this study, among 54 hydrometric, 13 proper stations for analysis in study area considering statistics duration and suitable distribution (Figure 1). Table 1 also shows the characteristics of selected stations in Bakhtegan watershed.

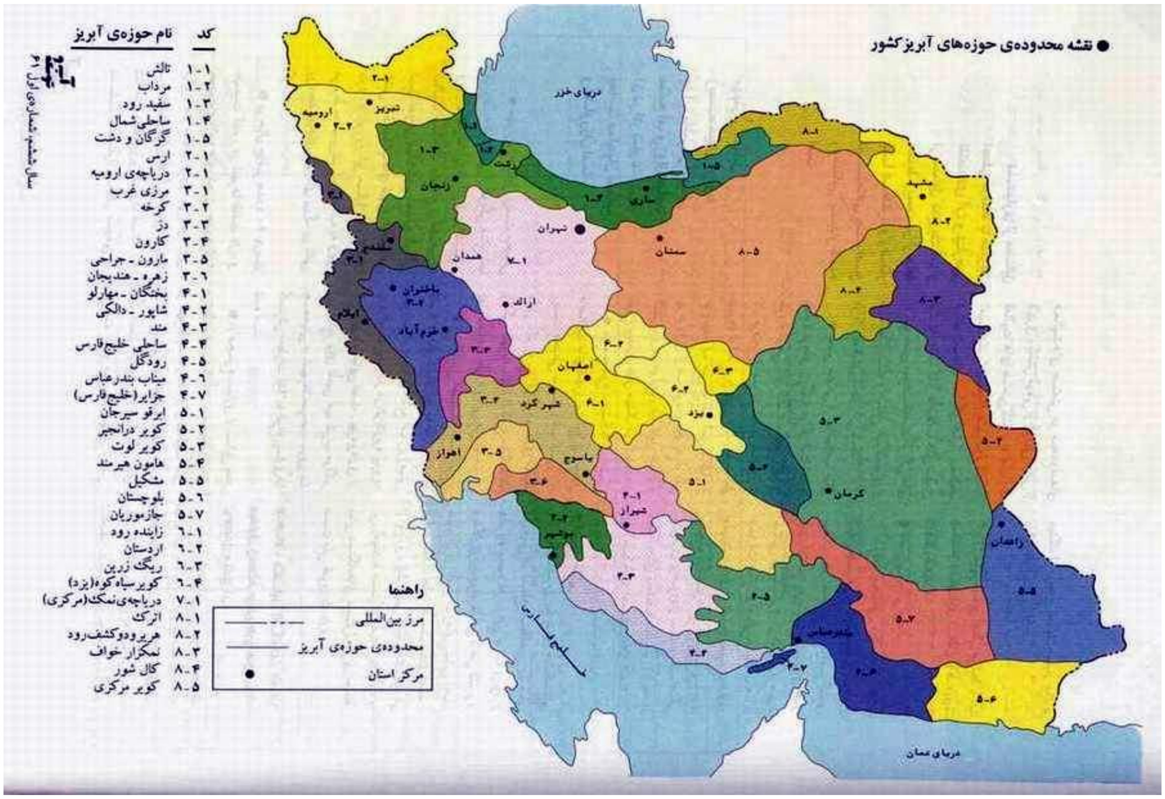

Fig. 1. Study area.

Table 1
Characteristics of selected stations in Bakhtegan watershed

longitude	latitude	Height (m)	Area (km^2)	river	station	Station code	number
52-07	30-39	2100	1622	Gavdar	Dehkade sefid	43-001	1
52-07	30-39	2100	425	Sefid	Sefid	43-003	2
51-58	30-36	1900	178	Shur	Jamalbeig (Kharestan)	43-011	3
51-59	30-36	1880	380	Shuroshirin	Jamalbeig (Shirin)	43-013	4
52-07	30-28	1800	3431	Kor	Chamriz	43-019	5
52-15	30-15	1750	195	Tangshul	Badamak	43-019	6
58-52	30-02	1660	5967	Seivand	Dashtbal	43-035	7
52-10	30-21	1740	177	Tangbostanak	Manjan	43-071	8
52-29	29-41	1650	193	Khoshk	Chenarsukhte	43-043	9
52-39	29-29	1480	452	Babahaji	Polefasa	43-045	10
52-24	29-37	1650	197	Rahdar	Chenar (Rahdar)	43-073	11
52-32	29-38	1520	879	Khoshk	Baghe safa	43-087	12
52-29	29-42	1650	432	Nahreazam	Chenare sukhte (Azam)	43-089	13

2.2. Empirical runoff estimation methods

Climatically, Iran is among the arid and semi-arid regions in the world and use of empirical formulas in order to estimate annual flood has been recommended in those watersheds without hydrometric stations for hydrology studies.

2.2.1. Dredge and burge method

This formula has been presented from India rivers statistics and considers watershed shape and area.

$$Q = 19.5 \frac{A}{L^{\frac{2}{3}}} \quad (1)$$

Where, Q is flood peak flow rate, A is watershed area by km2, L is watershed length by km.

2.2.2. Burges method

$$Q = 19.6 \frac{A}{L^{\frac{2}{3}}} \quad (2)$$

Parameters are exactly similar with above.

2.2.3. Inglis method

This formula has been achieved from Maharashtra rivers watershed which is applied for fan-shape watersheds of Bombay state.

$$\mathrm{Q} = \frac{124\mathrm{A}}{\sqrt{\mathrm{A}+10.4}} \quad (3)$$

Parameters are similar with two methods above.

2.2.4. Faning method

$$Q = 200A^{\frac{5}{6}} \quad (4)$$

Where, Q is by ft3/S, A is area by mile 2.

2.2.5. Heydarabad method

$$Q = 1750A^{(0.92-\frac{1}{14}\log A)} \quad (5)$$

Where Q is flow rate by by ft3/S, A is area by mile^2.

2.2.6. Burkli Ziegler

Applicable for the US.conditions

$$Q = 4.12A^{\frac{3}{4}} \quad (6)$$

Where, Q is flood peak flow rate by m^3/s, A is area by km^2.

2.2.7. Cramar method

For Mahavak river US.

$$\mathrm{Q} = \frac{0.884\mathrm{A}}{1+0.0985\mathrm{A}^{\frac{1}{2}}} \quad (7)$$

Where, Q is flood peak flow rate by m^3/s, A is area by km^2.

2.2.8. Possenti method

Applicable for the US.conditions

$$Q = 48.4\sqrt{A} \quad (8)$$

Where, Q is flood peak flow rate by m^3/s, A is area by km^2.

2.3. Evaluation of empirical runoff estimation methods

To evaluate various methods, statistical standards including mean square errors, oriental coefficient and mean difference were used (Khosravi et al. 2013). The method with lower RMSE, BIAS and MD would be the most suitable method. With regard to the nature of this study, various used empirical methods were in continuous flows group and to evaluate different methods, statistical standards are used for their accuracy which are explained as below:

2.3.1. Mean difference

$$\bar{D} = 1/n\left[\sum_{i=1}^{n}(r_1 - r_2)\right] \quad (9)$$

Where, r_1 is the first observed peak flow rate, r_2 is the first estimated peak flow rate, n is number of statistical years, D is mean difference per unit (r)

2.3.2. BIAS

$$BIAS = \frac{1}{n}\sum_{i}^{n}\frac{Eo - Ee}{Eo} \quad (10)$$

In this equation, E_0 and Ee are observed values and estimated values of peak flow rate, respectively.

2.3.3. RMSE

Low amount of RMSE represents lower error and model accuracy (Davoodirad, 1384).

RMSE tends to aero is suitable.

$$RMSE = \left|\frac{1}{n}\sum_{i=1}^{n}\frac{(Qi - Qo)^2}{Qi}\right|^{1/2} \quad (11)$$

In equations above, $Q_i$and $Q_o$are observed values and estimated values of peak flow rate, respectively.

3. Results and discussion

Various empirical flood peak flow rate estimation methods were compared with measured values by hydrometric stations existing in the watershed. With regard to comparison standards, for the best standard, a low rank and for the worst method a high rank was considered in each standard. By putting these standards in the table, the method which has had the lowest rank in all standards can be considered as the most proper method. Considering the conducted evaluation, the three standards (RMSE, BIAS and MD), have almost same results. Table 2. shows ultimate result of various empirical flow rate estimation methods ranking in Bakhtegan watershed. In Figure 2. also values of each method were evaluated with special observed values from hydrometric station.

Table 2
Ultimate result of various empirical flow rate estimation methods ranking in Bakhtegan watershed

Possenti	Cramar	Burkli Ziegler	Hyderabad	Faning	Inglis	Bourges	Dredge & Burge	
6	1	2	7	3	8	5	4	MD
6	1	2	7	3	8	5	4	RMSE
6	1	2	7	3	8	5	4	BIAS
6	1	2	7	3	8	5	4	prior

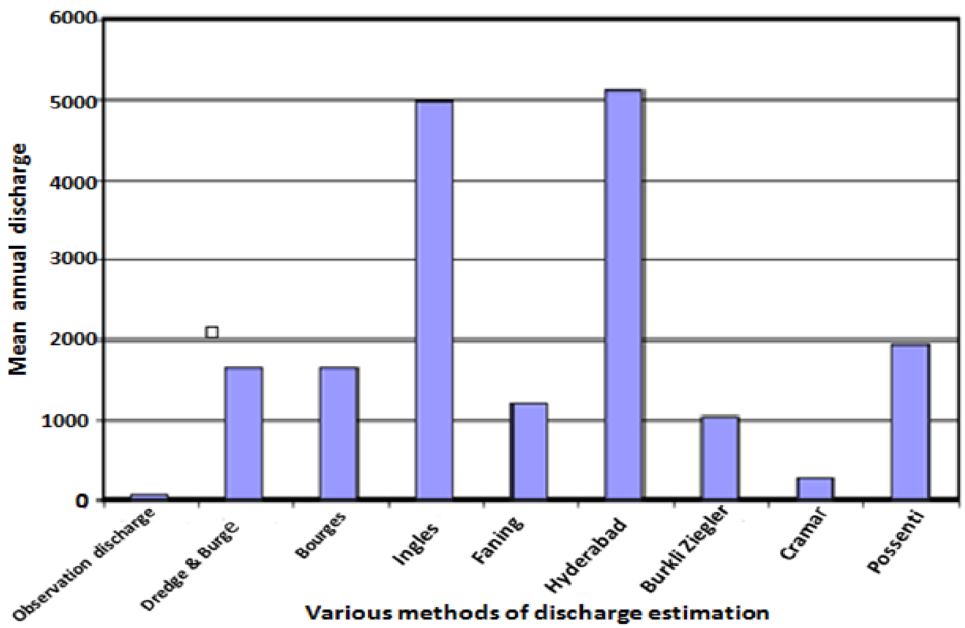

Fig. 2. Comparison of evaluated methods with observed values

4. Conclusion

The best and most accurate method of flood flow rate estimation with a certain return period, is use of hydrometric stations statistics but, selected sub-basins in those regions without hydrometric statistics, estimation of peak flood is possible only by empirical methods. In this study, after carrying out all steps above, and comparing data resulted from empirical methods with measured values by hydrometric stations existing in the watershed, 8 empirical flood estimation methods including Dredge & Burge, Bourges, Inglis, Faning, Hyderabad, Burkli Ziegler, Cramar and Possenti in Bakhtegan watershed located in Fars province were evaluated. In statistical comparison of the results from empirical runoff estimation methods with observed data, some statistical indexes such as RMSE, BIAS and MD were used. By conducted evaluation, it was found that all three standards have almost same results. Data resulted from three statistical standard showed that, best empirical methods in Bakhtegan watershed were Cramar, Burkli Ziegler, Faning, Dredge & Burge, Bourges, Possenti, Hyderabad, and Inglisrespectively, and showed a high correlation. Therefore, among all empirical methods, Cramar was determined as the best method for flood peak flow rate estimation in studied watershed.Some of yeast species are pathogenic to human being like *Filobasidilla neoformans*, Candida and Trichosporon except *Trichosporon beigelii* B, which are cosmopolitan (Soil, water, air, and human skin). Therefor aseptic condition and environmental hygiene are recommended during Enset processing time.

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