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Calibration of IHACRES Hydrological Model Using Social Spider and Search and Rescue Multi-Objective Optimization Algorithms

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1-Introduction

Over the past few decades, a wide range of rainfall-runoff conceptual models have been developed. These models are often preferred to other types of watershed hydrological models (eg physics-based models) due to their high logical accuracy and simplification of calculations. The IHACRES model has always been considered due to the need for low data and high power in daily estimation. This model was investigated by Ismaili et al. (2015) during simulations in different climatic regions in Iran. Borzi et al. (2019, p. 18) evaluated the IHACRES modified rainfall-runoff model to predict the hydrological response of the river basin with a deep groundwater aquifer. Duniai et al. (2016) compared the performance of ultra-exploration algorithms in optimizing reservoir efficiency. Also in another study, Donyaei et al. (1398) evaluated the multifunctional optimization of the water tank using the gray wolf algorithm. Studies have shown that local optimization methods in determining a series of optimal model parameters may fall into the trap of local optimal points because the objective functions of an optimization problem can be nonlinear and have several local optimal points. (Beta et al., 2001 p. 16). Global optimization methods such as Exploration algorithms have solved this problem and for this reason today these methods have been greatly developed and their application in engineering problems has increased (Fine et al., 2008 p. 4). Accordingly, the purpose of this paper is to calibrate the IHACRES hydrological model and determine the optimal value of its various parameters by considering the range of their changes with a multi-objective optimization approach in which the techniques of social spider algorithm (SSO) and search and rescue operation (SAR)) will be used.

2-Methodology

IHACRES Hydrological Model

IHACRES is an integrated concept metric model for precipitation-runoff simulation developed by Jackman in 1990. This model requires five to seven variables for calibration and is suitable for implementation in large basins. The basis of the mentioned method consists of two nonlinear reduction modulus and a linear hydrograph modulus It becomes. In this model, the statistics of input variables are daily, hourly or minute, which in this research, daily statistics are considered. For this purpose, first, precipitation (rk) and

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temperature (tk) are converted to effective precipitation (Uk) at any time K by a nonlinear modulus and then converted to surface runoff at the same time step by the linear modulus of a single hydrograph.

Table (1): Global parameters of rainfall-runoff model IHACRES

Parameter	Unit Parameter	Title
1	**C** [mm]	mass balance term
2	τ_w [day]	drying rate reference temperature
3	**f** ©	temperature dependence of drying rate
4	τ_q --	time constant 2
5	τ_s --	time constant 1
6	υ_s --	volume proportion

Optimization Algorithms

Due to the complexity and scale of the multi-objective calibration problem of rainfall-runoff models, multi-objective evolutionary algorithms have been used by researchers in recent years (Veraget et al., 2003), Boyle et al., 2000), (Bahmand et al., 1999). The Social Spider Optimization (SSO) algorithm is a new optimization method proposed in 2013 by Chaos Et al. Spiders have been an important research topic in artificial engineering for many years. Another optimization method used in this paper is the Search and Rescue Operation Optimization (SAR) algorithm. In this algorithm, human situations are equal to the solutions of the optimization problem, and the amount of clues found in these situations shows the target performance of these solutions.

Objective Functions and Model Evaluation

In this paper, in order to evaluate the model, five statistical indices of correlation coefficient (r), mean square root of error (RMSE), mean absolute value of error (MAE), Nash-Sutcliffe index, and Nash-Sutcliffe A logarithm is used.

3-Results and Discussion

In this part of the paper, the calibration results of the IHACRSE model using social spider and search and rescue algorithms are presented. It should be noted that the problem codes have been prepared in MATLAB software. The problem decision variables are the six global parameters presented in Table 2. Objective functions must be selected in such a way that at the end of the calibration process the best match between the observed and computational values can be obtained. Some functions give more weight to high currents, while others attach more importance to low currents. Therefore, in this article, an attempt has been made to consider the balance between the two in the formulation of several objectives; In this regard, Nash-Sutcliffe (NS) criterion and its logarithmic form (NS-Log) have been used. In this research, the results obtained based on these two functions will be presented. Each of the optimization algorithms was implemented with an initial population size of 100 and over 200 generations (number of times the optimization model was run); As a result, the total number of simulations performed per run of the algorithm is 20,000. After the calibration process, the best values of the two objective functions (ie NS and NS-Log criteria) in the calibration time period are shown in Figure 4.

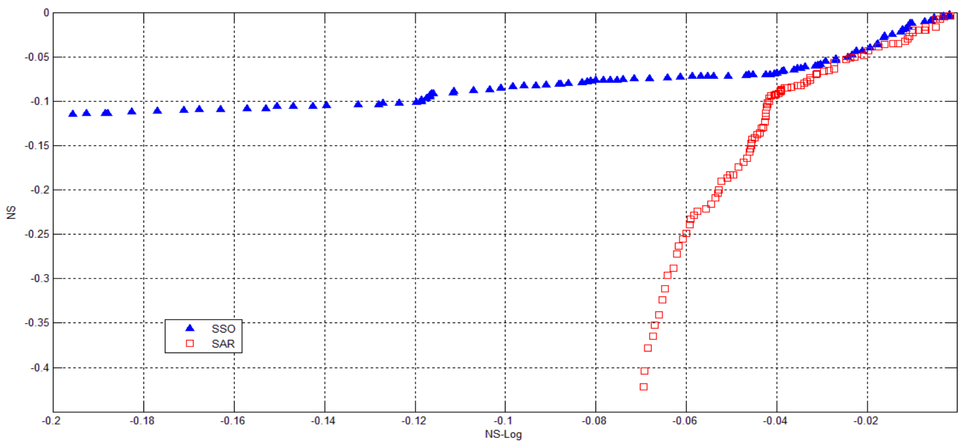
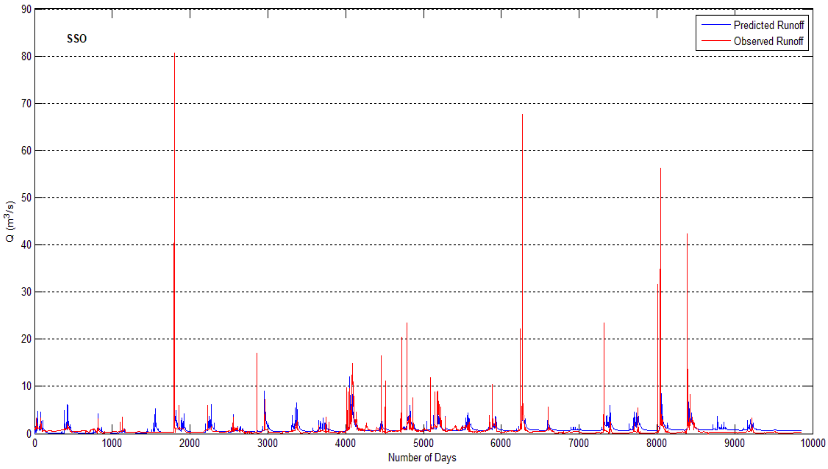


Figure (4): Parto procedure obtained by SSO and SAR algorithms in calibration time period

It is observed that the answers obtained by SAR are better than the answers obtained by SSO; because its NS values are higher. According to the results, NS values are generally between -0.07 and 0 and NS-Log values are between -0.45 and zero. This indicates that the calibrated model has been more successful in simulating low discharges. The output hydrographs obtained from the IHACRES model calibration in the Herat Azam River Basin are presented in Figure 5. In fact, since the model is run continuously, the simulation results in 1986 are referred to as the Warm up period.

Table 3 shows the allowable limits of changes and values obtained in the calibration process of six global parameters of the IHACRES model using the SSO algorithm.



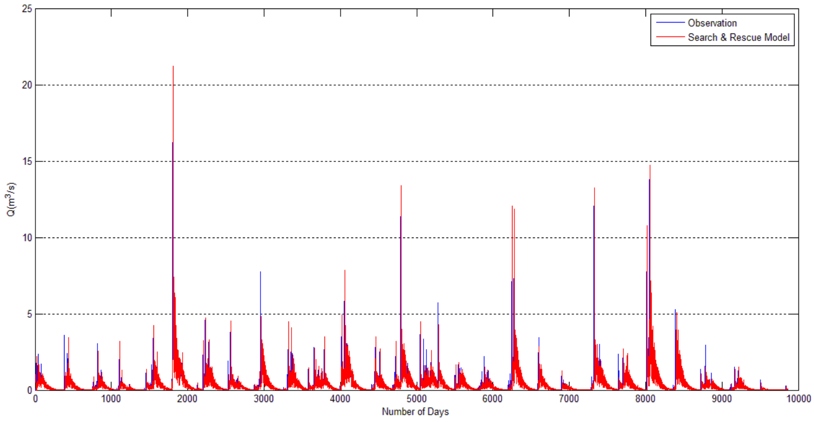


Figure (5): Output hydrograph obtained from IHACRES model calibration in Herat Azam river basin for calibration period

Table (2): Global parameters obtained from model calibration in Herat Azam river basin

^{s}v	$^{s}\tau$	$^{q}\tau$	w	f	C	Parameter H.
0.01	1000	10	2	0.1	$0.1*10^{-5}$	Min
1	4000	30	30	4	600	Max
0.659	3131.105	25.22	2.8	4	$92.9*10^{-5}$	the amount of

Sensitivity Analysis of Models

In order to analyze the sensitivity, first the model was adjusted according to the data in Table 3 and by changing each of the parameters in its possible range, and keeping the other parameters constant, repeated simulations were performed. In each simulation, the initial population and number of generations were equal to 100, and the target functions were NASH-HF and RMSE, respectively. In this analysis, error evaluation is performed for all calibration and validation data. The results obtained from the application of the model in this basin show the satisfactory capability of these algorithms in calibrating the IHACRES model. Comparison of the results obtained from the SAR and SSO algorithms showed that in the multi-objective calibration problem, the SAR algorithm was slightly more successful than the SSO model. The weakness of the developed model in predicting some floods may be due to the limitations of the data used in the vast basin of the Great Herat River; Therefore, increasing the length of the simulation period can increase the accuracy of the model used. The results also showed that the simulation quality of low discharges was higher than high discharges. The reason for this can be firstly due to the lower frequency of high discharges in the studied data set and secondly to the relatively slow response of the model to the change of hydrological conditions in flood conditions in the Great Herat Basin; Because the volume ratio of the slow flow that participates in the river (Us) is a large amount that can have a direct impact on reducing surface runoff. On the other hand, the weakness of the results in predicting some low discharges can be related to the optimal amount of moisture holding capacity of the basin (C), which has taken a small amount in the calibration process; because groundwater has the highest effect on the production of low discharges in the basin. In order to evaluate the sensitivity of the calibrated model to global parameters and evaluate their importance in the Great Basin of Herat, having the optimal values of global parameters, the sensitivity of the model was analyzed.

4-Conclusions

The present paper calibrates the IHACRES distributed rainfall-runoff model. To calibrate the model, two evolutionary optimization algorithms SSO and SAR were used in the basin of Azam River in Herat, Yazd. The results obtained from the application of the model in this basin show the satisfactory capability of these algorithms in calibrating the IHACRES model. Comparison of the results obtained from the SSO and SAR algorithms showed that in the multi-objective calibration problem, the SAR algorithm was slightly more successful than the SSO model. The weakness of the developed model in predicting some floods may be due to the limitations of the data used in the Great Herat River Basin; therefore, increasing the length of the simulation period can increase the accuracy of the model used. The results also showed that the simulation quality of low discharges was higher than high discharges. The reason for this can be attributed firstly to the lower frequency of high discharges in the studied data set and secondly to the relatively slow response of the model to changing hydrological conditions in flood conditions in the Great River Basin of Herat.

Keywords: Runoff precipitation model, calibration, social spider algorithm, search and rescue operation algorithm, IHACRES, Herat Azam river basin, Yazd.

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