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Evaluation of Combined Method of Deconvolution- Genetic Algorithm in Extracting Time-Area Histogram

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ABSTRACT: Runoff production is due to watershed response to rainfall events. Various research has been performed to accurately determine the watershed response. In most response models, as in kinematic wave-based models, require detailed input data such as cover characteristics, slope, initial moisture, and soil infiltration properties. In this study, a time-area histogram extraction technique was presented via genetic algorithm optimization and deconvolution methods and results were evaluated in theoretical and real watersheds. In the model presented, a set of rainfall-runoff events in matrix form were called as inputs while the corresponding time-area diagrams were extracted. The results showed that the accuracy of the model in estimating the response of a theoretical watershed was 99%, while similar accuracy in the direct approach was 74%. The accuracy of the model in estimating the response of the V-shaped geometric watershed and the real Walnut Gulch watershed reached an average of 99%. Therefore, the model introduced in this research is effective in determining the time-area diagram of the V-shaped watershed and may be used in other watersheds.

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1- Introduction

Time-Area method is one of the methods used to determine the watershed output runoff, which is the advanced mode of the rational method; with the difference that the intensity of rainfall is different in time steps [1]. Genetic algorithm has been used as an optimization tool by combining with other methods such as fuzzy model to determine the response of rainfall-runoff calibration models [2] or it is used for the calibration of kinematic wave equations [3]. The genetic algorithm as an optimization model and a complementary model for other software models has been able to work successfully [4].

According to the progress of the time-area method and the desire of researchers for this model, various studies have been conducted to provide the appropriate method for determining the time-area histogram [5-7]. The kinematic wave model as the calculation basis of this method has shown its accuracy and efficiency [6] and [8], the kinematic wave can be used to determine the flow routing similar to the Muskingum-Cunge method [9], and it can also be used to prepare the direct runoff of the watershed [10]. However, the requirement of these models for accurate characteristics of the watershed has made the efficiency of the time-area model dependent on the hydrological parameters of the watershed [11].

Therefore, a fast method in determining the time-area histogram that can be accurate with the minimum required data was required. So, via the genetic algorithm, a model has been presented and evaluated in preparing the time-area histogram based on rainfall-runoff events. To evaluate the performance of the proposed model, an attempt has been made to determine the factor that converts rainfall to runoff. In this research, two types of theoretical watersheds have been investigated and after results evaluation in these watersheds, the real watershed has been examined.

2- Methodology

In the proposed model, the factor of convolution integral, which is the time-area histogram, has been determined by model inputs, including the runoff hydrograph and the rainfall hydrograph. Extraction of the convolution integral factor has been done using the genetic algorithm and the results have been evaluated by two indices; Nash-Sutcliffe efficiency and the fluctuation rate. If the outlet runoff of the watershed (Q) and the excess rainfall of the watershed (P) be known, via the convolution integral and one of the factors of it, the time-area histogram will be determined, which this process is called deconvolution. In the MATLAB modeling software, during the direct deconvolution process by function (1), the time-area matrix (U) is determined using two matrixes of outlet runoff (Q) and watershed excess rainfall (P).

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$$U = deconv(Q, P) \quad (1)$$

3- Results and Discussion

In this research, the optimization method was implemented to determine the hydrological response of the watershed. By evaluating the results, it was found that the genetic algorithm method (as an optimization method) has the capability of an analytical method in determining the watershed response with high accuracy. To express the research subject, in the first step, a theoretical (hypothetical) watershed was examined. The cumulative time-area histogram was used to facilitate the derivation of its equation and by determining the time-area histogram corresponding to each rainfall-runoff event with the initial assumption of the existence of a relationship between the intensity of precipitation and the shape of the time-area histogram, the regression analysis was performed with a polynomial equation of the third power. It was found that with different intensities of rainfall, the coefficients of the regression equation change with a quadratic function. By comparing the calculated hydrograph with the observed one, it was found that the accuracy of the model in estimating the response of the V-shaped geometric watershed is 99% on average (via Nash-Sutcliffe efficiency).

In the third step of the research, using the observational data of the rainfall hyetograph and hydrograph of the Walnut Gulch watershed, the rainfall-runoff simulation was carried out on via the proposed model of the research and the response of the watershed was obtained in the form of time-area dimensionless cumulative histogram. The results showed that the intensity of precipitation is effective on the shape of the time-area histogram, so that with the increase in rainfall intensity, the rising limb of the time-area histogram has a steeper slope, and in other words, a larger area of the watershed has participated in the production of runoff at the beginning of the rainfall event.

4- Conclusion

In this research, via the genetic algorithm as an optimization method, the response of the watershed was investigated in the form of time-area histogram. The proposed model was first investigated in theoretical watersheds, and then it was investigated in the real Walnut Gulch watershed in the state of Arizona, USA. After determining the time-area histogram in the studied watersheds, the computational hydrograph was performed by re-applying the convolution integral it and the precipitation hyetograph. The results showed that the accuracy of this research model as an optimization method in estimating the response of a theoretical watershed was 99% while the direct method (analytical method) was equal to 74%.

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