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Effect of Land Use Change on Water Balance Components of Gharib Abad Watershed, Sistan and Baluchestan Province

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ABSTRACT

Aims Accurate and timely estimates of the water balance are necessary for the maintenance of surface and underground waters. The purpose of the present study was to investigate effect of land use change on the water balance of Gharib Abad Watershed using the WetSpa model.
Material & Methods The present study was carried out in Gharib Abad Watershed in Zahedan with a total area of 9924.4ha in Sistan and Baluchestan Province. Firstly, the model was implemented for the statistical period of 2008-2016 using the land use map of 2016, so that to calibrate the model, the statistical period of 2008-2012 and to validate the model the statistical period of 2012-2016 were selected. Then in order to investigate the effect of the land use change on water balance, all data and maps used in the model were maintained fixed (except for the land use map) and the model was simulated using the land use map of 2000.
Findings In the land use of 2000 from total precipitation, the evaporation rate was 69.60%. In addition, 4.13% of the total precipitation was stopped and evaporated by vegetation cover. Moreover, 26.27% have been converted to runoff. While in the land use of 2016 the evaporation increased by 9.01%, the vegetation cover decreased by 2.42%, the runoff decreased by 6.59%. Also, k_(g) and k_(ep) were identified as the most sensitive parameters.
Conclusion The WetSpa mode has well estimated the components of the water balance of watershed and has the necessary efficiency in arid areas.

Keywords Simulation; Hydrograph; Hydrological Process; Vegetation

CITATION LINKS

[1] Model projections of an imminent transition to a more arid climate in southwestern North ... [2] An examination of the relationship between erodibility parameters and soil ... [3] Simulation of daily stream flow and the effects of land use changes using WetSpa model in GIS ... [4] The role of land use change on the components of hydrological balance in Kan ... [5] WetSpa extension, a GIS-based hydrologic model for flood prediction and watershed ... [6] Impacts of land use change scenarios on water balance components using bahg Wetspa model ... [7] Evaluation of the effect of land use changes on subsurface flow using WetSpa model, case study: Horo-Dehno ... [8] Simulation of the effect of land use change scenarios on flow hydrograph of Dinour Basin using Wetspa distributed-hydrological ... [9]Quantitative evaluation of effects of land use change on the floodwater of Bahram Jou Watershed of Khorramabad using satellite imagery and the WetSpa ... [10] Investigation the water balance of Chehel Chay Watershed through daily flow simulation using Wetspa ... [11] Hydrologic modeling of the Upper Suriname River basin using WetSpa and arcview ... [12] Prediction of runoff and discharge in the Simiyu River (tributary of Lake Victoria, Tanzania) using the WetSpa ... [13] Simulating the effects of reforestation on floods using spatially distributed hydrologic modeling and ... [14] Wetspa model (instruction and ... [15] A proposed index for comparing ... [16] River flow forecasting through conceptual models part I-A discussion of ... [17] Effect of land use on floodwater behavoiur using WetSpa model in Aharchay ... [18] WetSpa model application in the distributed model intercomparison project ... [19] Evaluating a continuous hydrological model's ability to simulate peak flows with short time step ... [20] Improving WetSpa model to predict streamflows for gaged and ungaged ... [21] Application and development of spatially-distributed hydrological model of Wetspa for runoff simulation in Gorganroud Basin, Golestan ... [22] Stream flow simulation by WetSpa model in Hornad River basin, ... [23] Runoff simulation using WetSpa distributed hydrological model in Ziarat Watershed of Golestan Province ... [24] Evaluation of WetSpa model for rainfall-runoff simulation in semi-arid and mountainous watersheds ... [25] AInvestigating the effects of land use on runoff generation using WetSpa ...

Introduction

The aim of establishing a water balance is to examine and coordinate the input and output elements and determine their quantitative amount of used and stored water [1]. Regarding the critical condition of groundwater extractions and the need to pay more attention to surface waters, understand of water balance status in watersheds is one of the effective ways of managing water resources in arid areas [2]. In most of Iran's watersheds, there are no stations that control all components of daily, monthly, or even annually water balance. On the other hand, planning and management in these watersheds require the availability of statistics and information about these components. In this regards, the necessity of awareness the water balance status of the watersheds for the implementation of water plans on the one hand and the lack of a coherent organization for recording changes in the hydrological system of the watersheds on the other, the importance of using modern technologies to simulate the water balance components of watersheds, especially on a short-term scale, more than before reveals [3].

Considering the importance of studying and simulating water balance processes of watersheds, several models have been developed and used to simulate the water balance of watersheds. First all presented models were integrated, then semi-distributed models were developed and now due to the provision of geographic information system (GIS), most models are developed in the form of fully distributed [3]. There are many water balance models that vary in complexity, accuracy, type of use, and calculation of each of the water balance components. Using a hydrological-physical model based on GIS, such as WetSpa (Water and Energy Transfer between Soil, Plant, and Atmosphere), a method with high accuracy and high efficiency for estimating discharge, penetration, and evaporation can be provided in the watersheds with a lack of statistics and hydrometric stations [4].

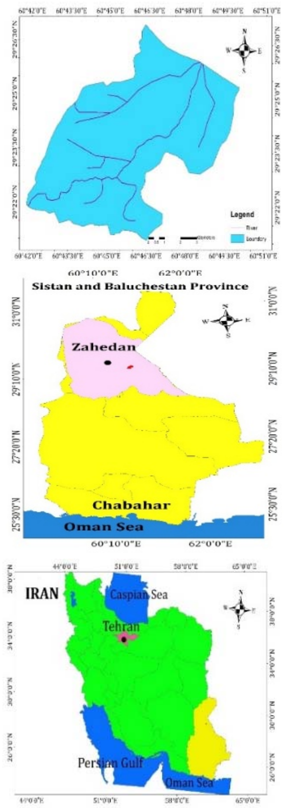
The WetSpa hydrological model is a mathematic-physical, fully distributed, and continuous-time model for predicting the transfer of water and energy between soil, plants, and the atmosphere on a basin-scale and based on time steps. This model has the ability to simulate in the basin and sub-basin scale and has a cellular network with different time steps [5]. In this regard, Javidan *et al.* studied the effects of land use changes under scenarios of deforestation and the residential areas increasing and combination these two scenarios on the water balance components of Ziarat Watershed in Golestan Province between 2007 and 2011 using the WetSpa model. The results showed that sub-surface flow, groundwater, and total runoff have increased in the applied scenarios. The greatest change was observed in the surface runoff component, which increased from 5.2mm in the first scenario (Current land use status) to 18mm in the fourth scenario (increasing total of residential areas and deforestation) [6]. Daraei *et al.* examined the effect of land use changes on subsurface flow using the WetSpa model in Horo-Dehno Watershed located in Lorestan Province. The results showed that by changing land use in a positive direction in two optimistic tendencies (scenario one. positive) and very optimistic (scenario two. positive), sub-surface flow and groundwater levels increase and surface runoff decreases and by changing usage in pessimistic direction (pessimistic and highly pessimistic) and increasing residential areas in the negative scenarios, the amount of subsurface and groundwater flows decrease, which indicates a decrease in depth infiltration and an increase in runoff. Based on Nash-Sutcliffe efficiency coefficient, the model simulates the watershed's discharge flow with relatively good accuracy of 70% and 66% in the calibration and validation periods, respectively [7]. Azinmehr *et al.* by simulating the effect of scenarios of land use changes on the flow hydrograph of the Dinavar Watershed in Kermanshah Province using WetSpa model observed that the model predicted a daily hydrograph with fairly good accuracy [8]. Yousefvand *et al.* studied the quantitative evaluation of the effects of land use change in the floodwater of Bahram Jou Watershed located in Khorramabad, using satellite imagery and the WetSpa model. They concluded that the WetSpa model based on Nash-Sutcliffe efficiency coefficient, predicted the peak discharge of floodwater with a fairly good accuracy of 69% and 78% for calibration and validation periods, respectively. The comparison between output hydrographs in the current status of land use and simulated results from five scenarios suggests that due to land use change and degradation of rangelands in the watershed, the peak discharge of flood has increased. Also, by increasing the density of rangeland cover, the river flow hydrograph has reached its peak with slightly late and on the other hand, this amount in comparison to the used hydrograph with a poor cover density has subsided later [9]. Yaghubi *et al.* using the Wetsap model in the Chehel-Chai Region located in Golestan Province, showed that the potential runoff coefficient in silty clay soils is more and in forest lands is less than arable lands and rangelands. The simulation results also showed that the WetSpa model well estimated the distributed hydrological factor and water balance of the watershed [10]. Nurmohamed *et al.* studied the hydrologic modeling of the Upper Suriname River basin using WetSpa, Arcview GIS, baseline input maps, and meteorological information from 1978-1983. Nash-Sutcliffe's criterion was estimated at 85%. Also, the factors of subsurface scale, groundwater recession coefficient, and previous soil moisture content were recognized as most sensitive [11]. Rewetabula *et al.* used the WetSpa hydrological model to predict runoff in Simiyu River from the branches of the Victoria Lake. Model error criterion in calculating water balance and Nash-Sutcliffe were obtained 2.4% and 57%, respectively. The results of the model test showed that the model appropriately has the ability to find the flow trend in the river. In this watershed, surface and subsurface runoffs are 38.6% and 67.4% of the total runoff, respectively. Also, about 9% of the total runoff is produced from agricultural areas [12]. Bahremand *et al.* simulated the flow stream using the WetSpa hydrological model in the three basins of the Hornád River in Slovakia, and the results indicated that in the outlet of the basin and in the main sub-basins there is a good compliance between the hydrographs obtained from the model and observed hydrographs and based on the Nash-Sutcliffe index, the model predicted daily hydrographs by a precision of 75% to 85% [13].

The ability of WetSpa model to simulate complex hydrological processes of watersheds in the GIS environment and their spatial-temporal analysis has made this model more distinct than integrated models. Different land uses and various land coverage have considerable impacts on hydrological processes in watersheds. However, the nature and extent of these effects on the watersheds have not been clear due to the randomness of hydrological phenomena, heterogeneity in the watersheds, and being non-linear of hydrological processes. By using distributed modeling, the evaluation of these impacts has been possible in recent years. According to studies, it can be concluded that the WetSpa model has the necessary efficiency to study the effects of land use changes on the hydrological characteristics of watersheds, as well as the ability to simulate runoff for various purposes. Also, WetSpa model has been used in wet areas more, and few studies have been done in arid and semi-arid regions.

The purpose of present study was to implement, calibrate and validate the WetSpa model, simulate the water balance components and study the effect of land use changes on these components in Gharib Abad Watershed in Zahedan as an arid region of Iran.

Materials and Methods

Gharib Abad Watershed with a total area of 9924.2ha is located in Zahedan County, central district, rural district of Cheshme Ziarat in Sistan and Baluchestan Province, between 60˚42' to 60˚51' E. longitude, and 29˚22' to 29˚26' N. latitude. The maximum and minimum elevation are 2542.6m and 1416.1m a.s.l, respectively (Figure 1).



(a)

(b)

(c)

Figure 1) The Location of study area, a) Gharib Abad; b) Sistan and Baluchestan Province; c) Iran

In the study area, the mean annual precipitation and temperature are 134.82mm and 18.48°C, respectively.

Water balance of Watershed

Equation 1 expresses the water balance of the watershed [14]:

$$P = RT + ET + \Delta SS + \Delta SG \quad (1)$$

Where P is the total precipitation of the watershed during the simulation period (mm); RT total runoff (mm); ET total evapotranspiration (mm); ΔSS changes in soil moisture storage at the beginning and end of simulation period (mm); ΔSG is the changes of the watershed groundwater storage (mm).

For a simulation period, the initial moisture status and groundwater storages of the water balance components of the watershed are in noted the form of Equations of 2 to 6:

$$\mathrm{P} = \sum_{t=0}^{T} \sum_{i=1}^{N_w} \mathrm{P_i(t)} \quad (2)$$

$$\mathrm{RT} = \sum_{t=0}^{T} \sum_{i=1}^{N_w} [\mathrm{RS_i(t)} + \mathrm{RI_i(t)}] + \sum_{t=0}^{T} \sum_{s=1}^{Nr} \left[\frac{\mathrm{QG_s(t)}}{\mathrm{A_s}} \Delta \mathrm{t}\right] \quad (3)$$

$$\mathrm{ET} = \sum_{t=0}^{T} \sum_{i=1}^{N_w} [\mathrm{EI_i(t)} + \mathrm{ED_i(t)} + \mathrm{ES_i(t)}] + \sum_{t=0}^{T} \sum_{s=1}^{N_r} [\mathrm{EG_i(t)}] \quad (4)$$

$$\Delta SS = \sum_{t=1}^{N_w} D_i \, [\theta_i(T) - \theta_i(0)] \quad (5)$$

$$\Delta SG = \sum_{s=1}^{N_r} [SG_s(T) - SG_s(0)] \quad (6)$$

In these equations, $\theta_i(0)$ and $\theta_i(t)$ respectively are soil moisture content in the beginning and end of the period (m^3/m^3); and $SG_s(T)$ and $SG_s(0)$ are the groundwater storage of the sub-watersheds in the beginning and end of the simulation period (mm) respectively. All of these components change over time. Changes in each of the components cause changes in other components [14]. Towards these points, the present study analyzed the effect of the land use changes in the hydrological processes of the watershed.

Data provision

The basic data needed were precipitation, evapotranspiration potential, and discharge, which were received on a daily basis with a period of eight years from the meteorological office of Sistan and Baluchestan Province (http://sbmet.ir), the province office of natural resources and watershed management (http://sistanbaluchestan.frw.org.ir) and the water and soil management organization of the province (http:// sbrw.ir). Also, temperature statistics is required when there is snow accumulation and melting in the area, the snow coefficient is medium and equal to 2.73% in the study area. According to meteorological studies, the probability of snowfall in the region is very low and the coefficient values of snowfall are zero in some years, therefore the temperature statistics were not used in the present study. Also, in the GIS environment, three basic maps of digital elevation model (DEM), land use and soil texture with a dimension of 90m were prepared. The raster map of DEM derived from the map of the topographic lines, requires that its spatial and altitudinal resolution to be sufficient to permit the accurate determination of the information required by the watershed which is affected its hydrologic behavior.

Soil texture map was prepared using soil information contained in the soil map. The soil codding system used in the WetSpa model is based on the triangle classification of soil texture and is determined based on the percentage of clay, silt, and sand. The soil map (2016) of the study area has four soil textures, of which 31.42, 28.64, 23.78, and 16.14% of the area are respectively covered by clay, silty-loam, clay loam and sandy loam textures (Figure 2).

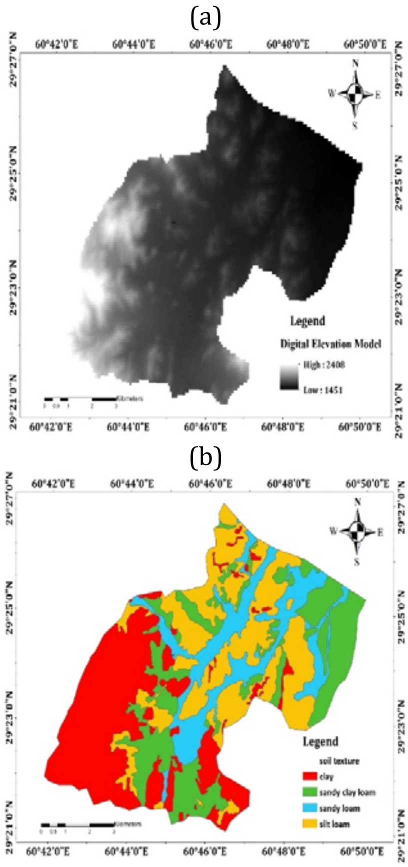


Figure 2) a) DEM and b) soil texture (2016) of Gharib Abad Watershed

The land use information is considered as one of the important inputs of the WetSpa model, which has the same pixel size and the environment as the DEM map of the watershed. In the present study, two land use maps of 2000 and 2016 were utilized. Based on the land use map of 2016, the topography status, climate and soil conditions have caused the nine types of land uses. 54.2% of the area is covered by rangeland, 10.6% by industrial, 13.4% by urban, 6.5% by residential area, 20.9% by rocky coverage, 3.8% by agricultural lands, 2.3% by green space coverage, 1.4% by garden cover, and 0.6% by poor rangeland (Figure 3).

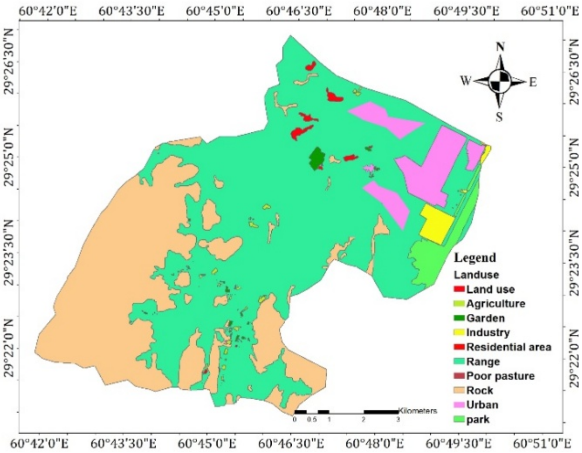


Figure 3) Land use map of Gharib Abad Watershed (2016)

To prepare the land use map of the region for the year 2000, satellite images from Landsat 7, ETM+ sensor, were used. Appropriate satellite images were downloaded from the US Geological Survey site. After making the atmospheric corrections, the results of the previous studies, satellite imagery of Google Earth, expert opinion and field assessments were used to study the land use of the area such as human-made areas (towns, villages, industrial facilities, etc.), agricultural lands, rangelands, salt marsh, and so on. Then by constructing false bands combinations and exploring the spectral reflection of phenomena, seven land uses were considered for the study watershed. The training samples of each land use were taken in the Google Earth software and processed by the ENVI 5.3 program. Then the land use map was classified. In the prepared map, small individual areas of land uses were merged into larger land uses using the Majority Filter tool. 72.55, 20.9, 3.54, 1.02, 1.36, 0.03, and 0.6% of the area was covered by rangeland, rocky, industrial, residential area, agricultural land, green space, and garden. Also, Raster map of DEM, soil texture and land uses of 2016 and 2000 have been reported (Figures 2-4).

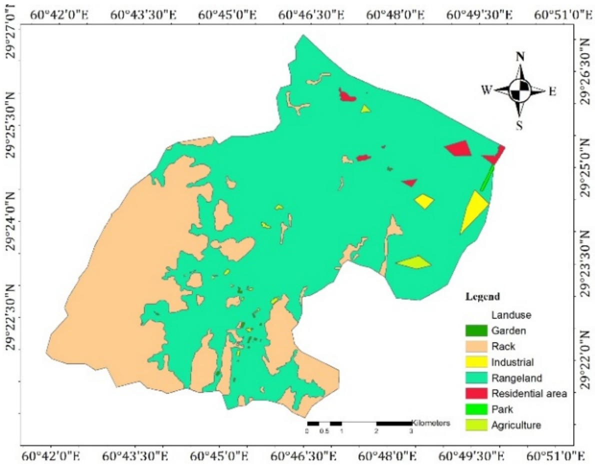


Figure 4) Land use map of Gharib Abad Watershed (2000)

Model simulation

Using WetSpa hydrological model and integrating maps of DEM, land use and soil texture and other input data such as data of hydrometric and meteorological stations (discharge, rainfall, and daily evapotranspiration), distributed spatial simulation of the water balance of watershed were performed. To calibrate the model, the statistical period of 2008-2012 and to validate the model the statistical period of 2012-2016 were selected. In order to investigate the effect of the land use change on water balance, all hydrometeorological data and maps used in the model were maintained fix (except land use map), and land use map of 2000 was entered in the model. By maintaining fix the other parameters, the role of land use is shown well. Finally, simulated and observed hydrographs were analyzed.

Calibration and validation of the model

The calibration step in the models is necessary to reduce the difference between predictions and observations so that at this step the values of the parameters are adjusted by raising and lowering the values to minimize the difference between simulation and observation values [6, 8]. Most models in order to check the accuracy of the model implementation in the calibration stage require to test the optimized parameters in the calibration step. Of course, the validation step should be done in a statistical period other than the period used for calibration. Thus, the evaluation and simulation work is incomplete without calibration and validation steps, and in order to use the simulation results in the planning and management decisions, these two steps of calibration and validation must be done; otherwise, the results just will be approximate. However, it can be described that if the intention of the modeling is to obtain a general result for obtaining watershed status by calculating and analyzing a number of parameters, then without calibration and validation, the results can be used [13]. For ease of the model calibration, 11 general parameters are used in the WetSpa model. In the present study, to calibrate the model, two methods of the manual method (test and error) and PEST automatic calibration method were used. In the calibration method with PEST software, the calibration of the model is performed automatically. In this way, it adapts the parameters according to its algorithm step by step and repeats the execution of the program with a local search method to obtain the best parameters. In fact, the PEST software is a method for non-linear estimation of the parameters that can be used independently by any model [14].

Model efficiency criteria and evaluation

In the WetSpa model in order to evaluate the efficiency of the model in simulating the observed hydrographs, in addition to a graphical comparison, a series of statistical methods including model reliability and Nash-Sutcliffe coefficients were used which indicated the matching degree of observations and predictions [14].

Model error

Model error is expressed as the following equation:

$$CR1 = \frac{\sum_{i=1}^{N}(QS_i - Qo_i)}{\sum_{i=1}^{N} Qo_i} \tag{7}$$

Where CR1 is the model error in calculating the water balance of the model, Qs_i and Qo_i are the simulated and observed flow discharge in the time step of i (m^3/s) and N is the number of time steps during the simulation period [15]. CR1 values represent a better fit and zero value represents the appropriate simulation of the observed flow and negative values indicate lower estimates than the actual value and positive values indicate higher estimates than actual value [14].

Model reliability

The reliability of the model is determined by Equation 8:

$$CR2 = \frac{\sum_{i=1}^{N}(Qs_i - \overline{Qo_i})^2}{\sum_{i=1}^{N}(Qo_i - \overline{Qo})^2} \tag{8}$$

Where CR2 is the certainty coefficient of the model, $\overline{Qo}$ is the average of observed flow discharge in simulation. Qs_i and Qo_i are simulated and observed flow at time step i (m^3/s), respectively. Also, N represents the number of time steps during the simulation period. In addition, CR2 is the representative of the variance share in observed discharges, which is described by simulated discharges. Its value is between zero and one, and the value of one represents the high reliability of the model [15].

Nash-Sutcliffe coefficient

The Nash-Sutcliffe coefficient shows that to what extent the flow discharges were correctly simulated by the model and is determined by Equation 9:

$$CR3 = 1 - \frac{\sum_{i=1}^{N}(Qs_i - Qo_i)^2}{\sum_{i=1}^{N}(Qo_i - \overline{Qo})^2} \tag{9}$$

Nash-Sutcliffe efficiency coefficient is used to evaluate the time series of the stream's flow. The CR3 value can be from a negative value to one and in a complete prediction, CR3 is equal to one [16].

Logarithmic Nash-Sutcliffe coefficient

Logarithmic Nash-Sutcliffe coefficient is calculated by Equation 10:

$$CR4 = \frac{\sum_{i=1}^{N}[\ln(Qs_i + \varepsilon) - \ln(Qo_i + \varepsilon)]^2}{\sum_{i=1}^{N}[\ln(Qo_i + \varepsilon) - \ln(\overline{Qo} + \varepsilon)]^2} \tag{10}$$

Where CR4 is logarithmic Nash-Sutcliffe efficiency coefficient for evaluation of time series efficiency of low flows [14]. ϵ indicates an arbitrarily small amount to avoid problems caused by observed and simulated discharges that are equal to zero. The error amount of the model should be sufficiently low and observed discharges less than ϵ can be ignored. Otherwise, the CR4 factor causes a model error in the calculation of the water balance. Like CR3, in a complete simulation, CR4 will also be equal to one [14].

Nash-Sutcliffe coefficient for evaluation of high flows

This coefficient is presented in equation 11.

$$CR5 = 1 - \frac{\sum_{i=1}^{N}(Qo_i + \overline{Qo})(Qs_i - Qo_i)^2}{\sum_{i=1}^{N}(Qo_i + \overline{Qo})(Qo_i - \overline{Qo})^2} \tag{11}$$

In this equation, CR5 is Nash-Sutcliffe efficiency coefficient for the evaluation of high flows. In a perfect simulation, CR5 will be equal to one [14].

Findings and discussion

WetSpa model for land use map in 2016

In order to evaluate the efficiency of the WetSpa model, the results of simulation and observed hydrographs in the calibration and validation periods of the model implementation using the land use map of 2016 were presented (Diagram 1 and 2). In addition, the values of model efficiency indicators during the calibration and validation period of the land use map of 2016 in Gharib Abad Watershed were reported (Table 1).

WetSpa model for land use map in 2000

The results of observed and simulated discharge in the calibration and validation phases of the model implementation with the land use map of 2000 in Gharib Abad Watershed were reported (Diagram 3 and 4). The values of model performance indicators during the calibration and validation of the land use map in 2000 were shown (Table 2).

Water balance

Among the system's components, the water content of the soil as an important variable affects the flow movement inside and outside of the root zone (penetration, evapotranspiration and subsurface flow), and energy balance on the surface of the ground. Leaf interception storage, depression storage, soil moisture, and groundwater are other important components that act individually but in conjunction with each other [14]. Also, the water balance for the Gharib Abad Watershed was calculated (Diagram 5).

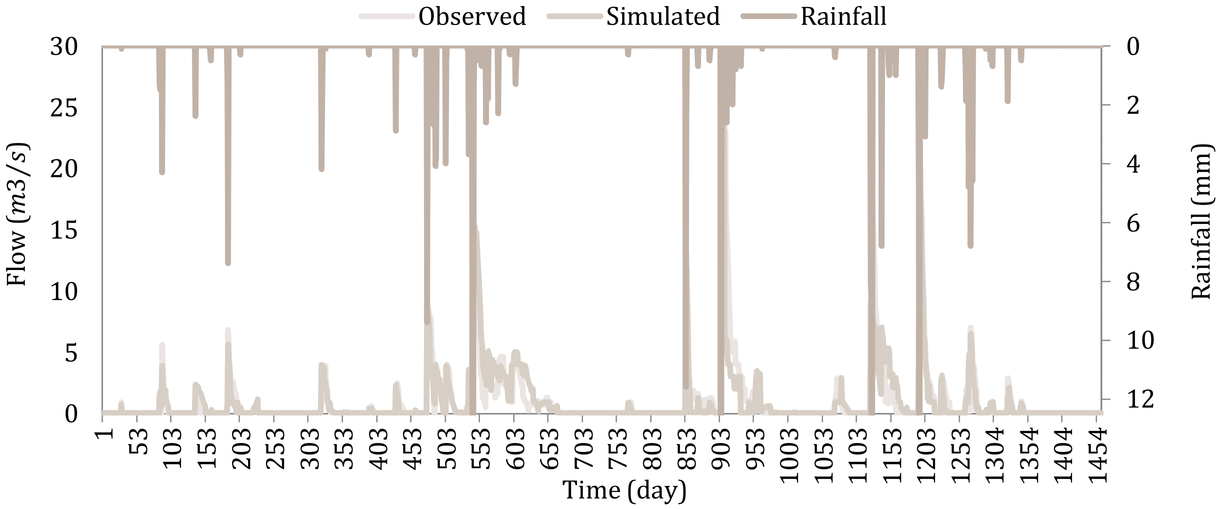


Diagram 1) Comparison between measured and simulated daily flow for calibration period (2008-2012) of the land use map of 2016

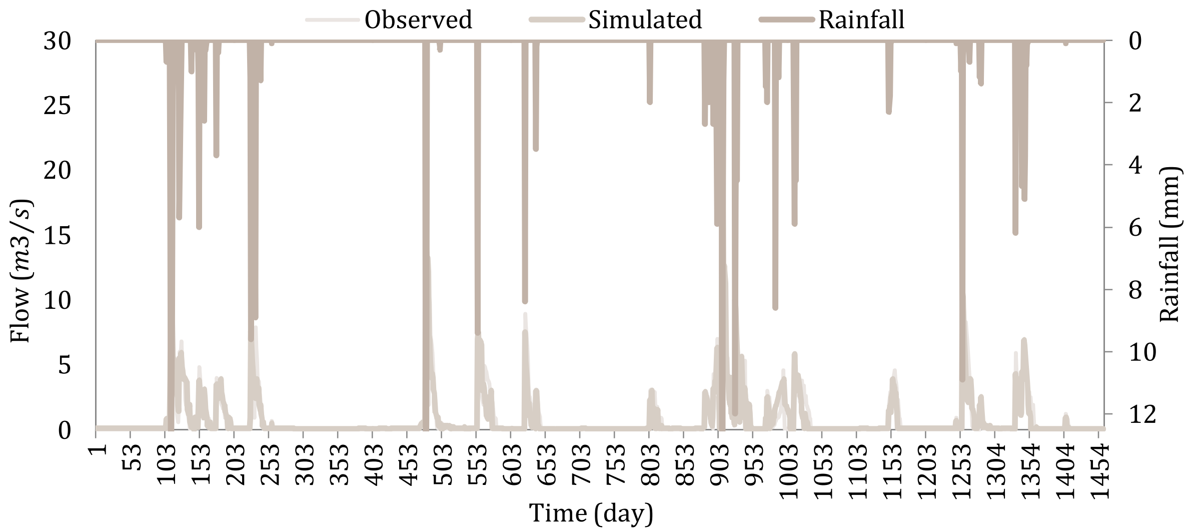


Diagram 2) Comparison between measured and simulated daily flow for the validation period (2012-2016) of the land use map of 2016

Table 1) The values of model efficiency criteria during the calibration and validation period of the land use map of 2016

Efficiency criterion	Calibration	Validation
Model bias for flow volume balance	2.97	1.76
Model reliability	87.37	83.62
Nash-Sutcliffe coefficient	57.49	73.35
Nash-Sutcliffe coefficient for low flows	54.39	50.37
Nash-Sutcliffe coefficient for high flows	76.14	72.23

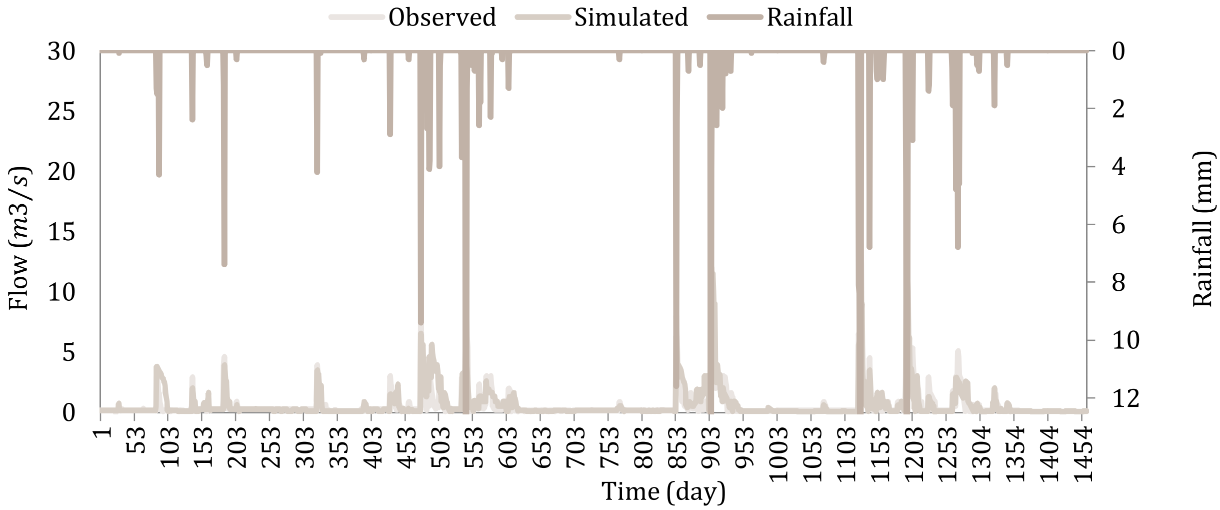


Diagram 3) Comparison between measured and simulated daily flow for the calibration period (2008-2012) of the land use map of 2000

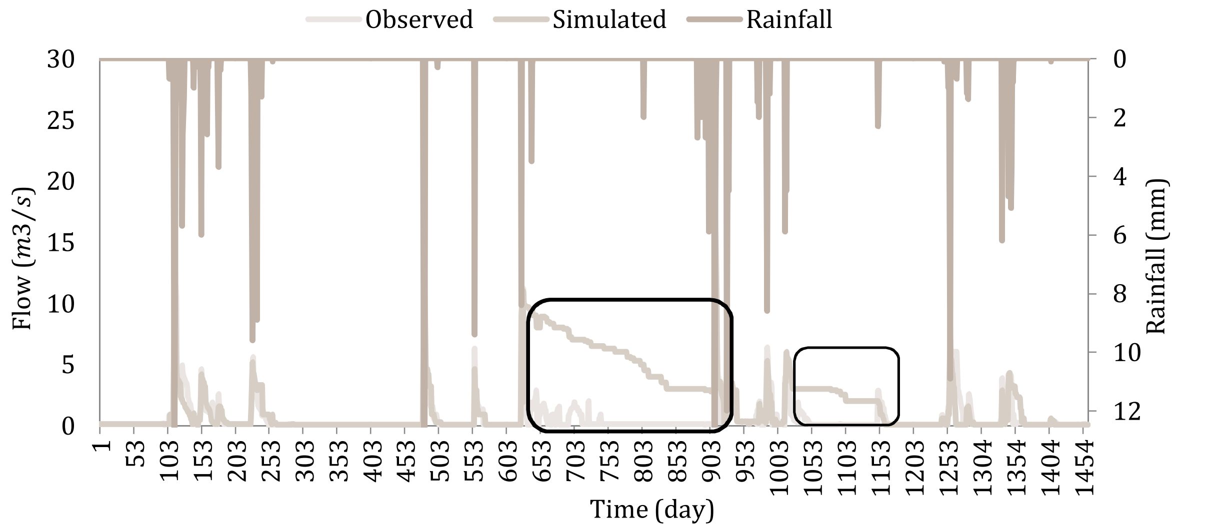


Diagram 4) Comparison between measured and simulated daily flow for the validation period (2012-2016) of the land use map of 2000 (The specified sections in the hydrograph of Diagram 4 represent an error in simulating the validation period of land use map of 2000.)

Table 2) The values of model efficiency criteria during the calibration and validation period of the land use map of 2000

Efficiency criterion	Calibration	Validation
Model bias for the balance of flow volume	3.58	1.39
Model reliability	50.46	53.70
Nash-Sutcliffe coefficient	65.49	50.73
Nash-Sutcliffe coefficient for low flows	55.37	33.37
Nash-Sutcliffe coefficient for high flows	73.14	63.64

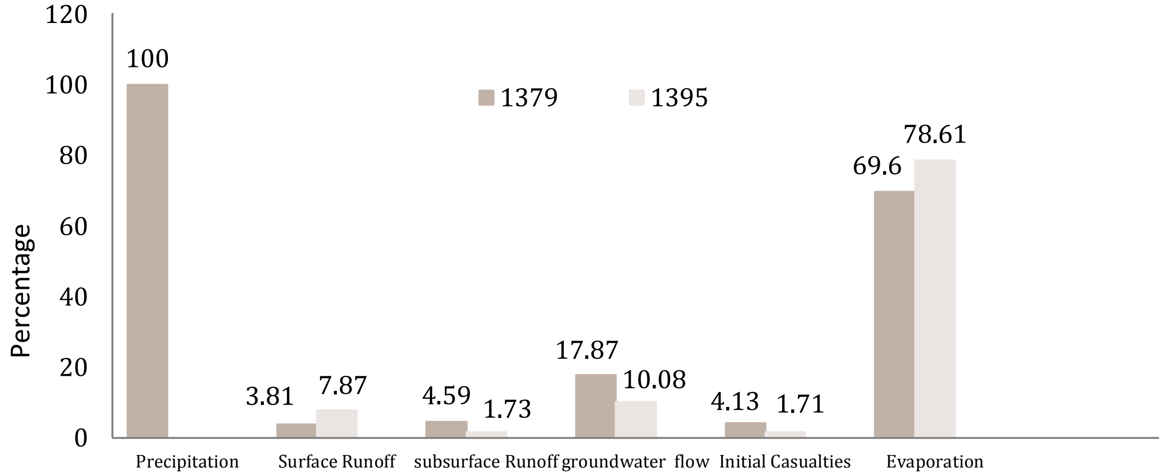


Diagram 5) Calculated water balance for Gharib Abad Watershed

Investigation of the water balance results from the WetSpa model using land use map of 2016 of the watershed showed that 78.61% of the total precipitation returns to the atmosphere by evaporation; 1.71% is stopped by the vegetation cover and evaporated and 19.68% is converted into the runoff. Of this amount runoff, 7.87% was surface runoff, and 1.73% and 10.08% were runoff and groundwater flow, respectively (Diagram 5). These findings are consistent with the hydrological characteristics of the area as well as with other studies' results (e.g., Nazar Gleico *et al.* [17]) noted that the evaporation in large watersheds is greater than runoff. In addition, most of the rainfall-induced flows are in the form of surface runoff in the watershed and less penetrate into the lower layer of the soil, so the greatest amount of the flow waste is through evaporation. The results of the water balance of the land use of 2000 indicated that 69.60% of the total precipitation returned to the atmosphere by evaporation, and 4.13% was stopped and evaporated by the vegetation cover. In addition, 26.27% was converted into the runoff, which included 3.81% surface runoff, 4.59% subsurface runoff, and 17.87% groundwater flow. These values indicated that to what extent the changes of land cover and land use affect the water balance of the watershed. In rangeland, most of the rainfall-induced flows were infiltrated into groundwater aquifers by plants' root and reduced surface runoff and increased subsurface runoff, while with the conversion of rangelands into urban and industrial lands, an increase in the area of bare soil, a decrease in infiltration, an increase in areas with less drainage, and an increase in surface runoff were observed, which these changes were seen in the amount of balance and hydrograph of the flow. Therefore, it can be argued that the model has well estimated the hydrological factors, runoff components, and water balance.

Sensitivity analysis

Investigating the sensitivity analysis and uncertainty of the effective parameters on the simulation and focusing on the sensitive parameters lead to better understanding and more accurate estimation, thus it reduces the uncertainty in model results [18]. The calibration of the parameters for land use maps of 2016 and 2000 using the PEST model, as well as the model sensitivity analysis in the Gharib Abad Watershed of Zahedan were calculated (Table 3).

In the present study, k_g (groundwater recession coefficient) was identified as the most sensitive factor in the model. k_{ep} (correction factor for PET) was the second most sensitive factor in the model, and the reason was that evapotranspiration stations were located at lower elevations and therefore, the model estimated the evaporation less than the actual value, especially in the dry period [6]. In addition, K_{ep} was the only parameter that had a reverse relationship with parameter K_{ss} (initial moisture of soil), and evaporation was one of the main inputs to the model (if the evaporation of the watershed was higher, runoff was lower and vice versa). In the small watersheds and watersheds where the simulation period was short, the effect of this factor was further determined. k_i was interflow scaling factor. G_0 and G_{max} were the groundwater storage and maximum of groundwater storage, respectively, when there was evaporation from groundwater (such as plain watersheds) these factors were very sensitive. They were also sensitive in the study watershed. k_{run} was a power that reflected the effect of rainfall intensify on the surface runoff coefficient when rainfall intensify was low. p_{max} was the maximum of rainfall intensity, which depended on cell characteristics such as soil, land use, and slope. This factor was less sensitive in the watershed because there was no snow accumulation in the study watershed. The parameters c, b, and h were estimated to be 1 and had no sensitivity in this basin. The parameters of T_0, k_{snow}, and k_{Rain} were estimated to be -1 and they had no effective sensitivity in this watershed.

The results of the model calibration for land use of 2016 for the statistical period of 2008-2012 showed that the total Nash-Sutcliffe criterion is about 57.49%, and the maximum and minimum discharges of this criterion are 76.14% and 54.39%, repectively. In the validation phase of the model, the total Nash-Sutcliffe criterion is 73.35%, and the size of this criterion for the maximum discharge is 72.23% and for the minimum discharge is 50.37%, hence these results indicate good efficiency of the WetSpa model in the simulation of daily flow [8, 12, 13].

In the second step, the findings of the model calibration for the land use map of 2000 indicated that the total Nash-Sutcliffe criterion is 65.49% and the maximum and minimum discharges of this criterion are 73.14% and 55.37%, respectively. In the model validation phase, the value of total Nash-Sutcliffe criterion was estimated at 50.73% and for the maximum and minimum discharges were estimated at 63.64 and 33.37%, respectively. These values represent the acceptable results of the model for simulating daily flows. Considering that the amount of rainfall in this period has been higher than in recent years, however, due to the type of land use that was mainly rangeland, most of the rainfall was evaporated by the leaf of vegetation or entered into groundwater aquifers and less was flowing in the surface of the watershed. The reason for the low Nash-Sutcliffe coefficient for low flows can be attributed to model and its assumptions, such as the simplification of the groundwater model that in which uses a simple method called linear reservoir to calculate groundwater, (e.g., Mashari Eshghabad *et al.* [19]), or it may be related to the conditions in the watershed, namely, water harvesting in the summer for agricultural crops and small reservoir in the downstream, because in the WetSpa model, the impact of lakes and reservoirs on flow discharge is not considered, (e.g., Safari and De Smedt [20], Kabir [21]). In the present study, the existence of error and a low Nash-Sutcliffe coefficient in predicting low flows were due to the weakness of the model structure in the estimation of low flow or presence of diversion dams prior to the outlet of the watershed for the water extraction (Diagram 4). The results of this part were in line with the findings of Bahremand *et al.* [22], Dahmardeh Ghaleno [23] and Rahmati *et al.* [24]. But in general, the model had simulated the total flow with acceptable accuracy.

Regarding the effect of land use change and vegetation on evaporation rate in the Gharib Abad Watershed, based on the calculated water balance, it was determined that during the land use period of 2000, the evaporation rate from 100% precipitation was 69.60%, while this amount is 78.6% during the period of 2016. Therefore, although the study watershed had a dry and semi-arid climate and evaporation was high and often constant, but the effect of land use and vegetation on evaporation values was evident during these two periods of time. When heavily rainfall occurs in a short time, it causes floodwater, resulting in irreparable human and material damages. In the study watershed, the amount of runoff coefficient has increased dramatically with the change of land use from rangeland to urbanization and industrialization. The results of this part are in line with the findings of Derafshi [4], Liu and De Smedt [5], and Yousefvand *et al.* [9]. According to the results of sensitivity analysis in the model simulation stage, the groundwater recession coefficient was the most sensitive factor and the factors of potential evapotranspiration correction and soil's initial moisture were the second and third most sensitive factors. k_{rain}, k_{snow}, and G_{max} were identified as insensitive parameters. These results are in line with the findings of Javidan *et al.* [6], Azinmehr *et al.* [8] and Rahmati *et al.* [24].

Comparison of the effects of land use changes between two periods indicated that the decrease in the area of rangelands has affected the amount of penetration in the watershed, which has affected the evaporation from the surface of the watershed, root depth and Manning roughness coefficient and consequently the groundwater runoff has decreased.

Groundwater runoff has reduced the recharging of groundwater aquifers, increased the maximum discharge of the watershed and increased the time of concentration of the watershed. These results are in line with the findings of Mohammadi *et al.* [25]. According to the results, it can be argued that the WetSpa model has the necessary efficiency in rainfall-runoff simulation and the study of the effect of land use change on hydrological components of the watershed and calculating the water balance; and simulates them with great accuracy. These results are in line with the findings of Yaghubi *et al.* [10] and Kabir [21].

In arid and semi-arid areas, rain often occurs in the short-term but with high intensity. On the other hand, changing the land use in the watersheds of these areas, especially modifying the land use of rangelands to urban lands, has a great effect on increasing peak discharge and floodwaters. It also reduces the recharging of groundwater aquifers and soil moisture and increases the rate of evaporation from the surface of the watershed area.

Table 3) The calibration of factors by PEST model

The mark	factor and parameters	Initial value	Numerical values calibrated by PEST	Sensitivity rank
$\mathbf{K_i}$	Interflow scaling factor [-]	1.04	1.36	4
$\mathbf{k_g}$	Groundwater recession coefficient [d^{-1}]	0.000253	0.000279	1
$\mathbf{k_{ss}}$	Initial soil moisture [mm]	0.13647	0.16802	3
$\mathbf{k_{ep}}$	Correction factor for PET [-]	0.74925	0.7651	2
$\mathbf{G_0}$	Initial active groundwater storage [mm]	22.7	24	5
$\mathbf{G_{max}}$	Maximum active groundwater storage [mm]	1247.2	1200.2	6
$\mathbf{T_0}$	Threshold melt temperature [^oc]	-1.031	-1.03	9
$\mathbf{k_{snow}}$	Melt-rate factor [$md^{-1}{}^oc^{-1}$]	-1.638	-1.63	10
$\mathbf{k_{rain}}$	Rainfall melt-rate factor [$^oc^{-1}d^{-1}$]	0.00113	0.0011	11
$\mathbf{k_{run}}$	Moisture or surface runoff exponent [-]	3.34	3.3426	7
$\mathbf{p_{max}}$	Maximum rainfall intensity [mm d^{-1}]	43.03	46.21	8

Conclusion

The WetSpa hydrological model simulated the hydrological components of the watershed based on total Nash-Sutcliffe criteria of 57.49% and 65.49%, respectively for land use maps of 2016 and 2000. Changes in vegetation cover caused changes in the extent of evapotranspiration of the watershed. By comparing the diagrams of water balance in two periods of land use change, it was found that the amount of wasted water as evaporation in the land use period of 2000 is less than land use of 2016, because most of the watershed area was covered by rangeland vegetation in 2000 and most of the flows caused by rainfall were infiltrated to the groundwater aquifers by roots of plants or became as subsurface flows. However, with the development of urban and industrial lands (12.38% and 7.06%, respectively) and reducing the area of vegetation cover (18.35%), the amount of water penetration into the earth has decreased and the rate of evaporation from the surface of the watershed has increased. The WetSpa model has well estimated the distributed hydrological factors and components of runoff and water balance.

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