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Effects of Land Use Changes on Water Balance in Taleghan Catchment, Iran

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ABSTRACT

In recent years, changes in catchments water balance due to land use management have become the main concern of water resources authorities in Iran. Due to rapid population growth and land use changes, especially construction of Taleghan dam, Taleghan catchment has undergone rapid changes such as urban development, declining of rangelands, and deterioration of environment and erosion of soil resources by cultivating the hilly lands along the slopes for wheat or barely production. The extent of rangeland area shrinkage is substantial: from 83% during the early stages of dam construction down to 35% by the end of the study period. The 'good' rangeland area decreased to 5.90% from 34.49% while the poor rangeland increased from 19.04 to 23.35% during the period of 1987 to 2007. These changes could potentially have devastating impacts on water balance of the catchment. The main objective of this research was to examine the effects of land use changes on water balance of the Taleghan catchment before and after the dam construction. The Soil and Water Assessment Tools (SWAT) model was applied for predicting water balance in the middle and outlet of the catchment. The main input data for simulation of SWAT are Digital Elevation Model (DEM), soil type, soil properties, and hydro-climatological data. Comparing the water balance for 1987's land use for the middle station (Joestan) and the outlet station (Galinak) showed that surface runoff was 21% of the precipitation for the upper part of the catchment and 33% at the outlet. Total groundwater and lateral flows were 37 and 19%, respectively. The water balance at the outlet was predicted for two other scenarios of 2001 and 2007. The results showed 7.3% increase in surface runoff and 11.3 and 11% decrease in the lateral flow and groundwater flow, respectively. These results indicated progressive increase in surface runoff and decline in interflow and groundwater flow.Therefore, one of the main challenges facing development planners is the control of the accelerated degradation of the natural resources that has been taking place during the last decade.

Keywords: Land use, Taleghan, SWAT, Water balance.

INTRODUCTION

In recent years, the Taleghan catchment has undergone rapid land use change, urbanization, and water resource systems development for agricultural, industry, and domestic water supply. Design and construction of Taleghan dam was started in the last decade and water storing in the dam reservoir started in 2006. Since then, the government environmental authorities have been worried about the alarming land use changes resulting from the accelerating expansions of villages and urban areas. These changes could have devastating impacts on both water balance and water quality of the catchment.

The prediction of water fluxes in a changing environment with changing

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boundary conditions is a difficult task that requires use of hydrological catchment models. Such models should be evaluated for different environmental conditions (e.g. climate, topography, soil and vegetation cover) enabling users to estimate the impacts induced by environmental changes (DeFries and Eshleman, 2004). Different physically based approaches built in conceptual models are available to be used for environmental change studies and analyzing the consequent hydrological processes (TOPOG: Hatton and Dawes, 1993; TOPMODEL: Beven *et al.,* 1995; GSSHA: Moria *et al.*, 2007). In most cases physically-based models are performing satisfactorily as many of related parameters are measurable at small scale and, hence, predictable, if the boundary conditions change.

Simulation of the major components of the hydrological budget is very important for determining the impacts on both water supply and quality of either planned or proposed land management projects, vegetative changes, groundwater withdrawals, and reservoir management practices and plans. Since obtaining field data is time-consuming and quite costly, a variety of models and modeling approaches, e.g., GSSHA (Moria, *et al.* 2007) and TOPOG (Hatton and Dawes, 1993), have been developed to examine and quantify effects of a multitude of land use changes and practices on catchment hydrologic budgets and eventually provide forecasts for the future.

Effects of land use change on hydrological flows of watersheds have been the focus of many studies. However, the complexity of issues still attracts considerable \studies around the world (Fohrer *et al.*, 2005). Quantification of the effects of land use and land cover changes on the runoff dynamics of a river basin has been considered as an area of interest for hydrologists in recent years. So far, little is known about a well-defined quantitative relationship between the land use properties and the runoff generation mechanism. Different methodologies have been implemented in attempts to fill in the absence of knowledge about the subject, but no general and credible model has been recognized yet to predict the effects of land use changes (Kokkonen and Jakeman, 2002).

Land use and cover changes have significant impacts on the generation of runoff, forms of water fluxes, and pollutant transport to water bodies. In order to evaluate effective and sustainable use of land and water resources, comprehensive hydrological models are needed to assist in the management of land and water resources. High pressure on land and water resources in Taleghan catchment and deterioration of water quality therein have led to management issues of the water resources and raised concerns over the importance of the water quality. Therefore, catchment hydrology analysis with the aid of comprehensive models is required for evaluation of the land and water interactions. One of the comprehensive hydrological models of this type is the Soil and Water Assessment Tool (SWAT) model, which is used in the present research (Arnold *et al.*, 1998).

Saadati *et al*. (2006) investigated different land use scenarios in Kasilian catchment, Iran, using SWAT model. They showed that the maximum mean monthly discharge was dependent on land use changes from forest and rangeland to agriculture, while the minimum was related to changes from agriculture to forest. Although a few research and studies have been fulfilled on application of SWAT model in Iran, none of them has considered the impact of land use changes on water balance.

The objective of the present study was to assess the performance of the hydrological model SWAT (Arnold *et al*., 1998) for the Taleghan River in predicting water balance at the catchment outlet in view of evaluating the impact of land use change before and after the operation of the Taleghan dam. These land use changes were detected from image processing of satellite data for 1987, 2001, and 2007 (Hosseini, 2011). The Taleghan catchment is located in the north

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west of Tehran, Iran, and is important for agriculture and water supply. After construction and the commencement of the dam operation in 2006, it is intended to use the reservoir for multi-purpose activities including weekend recreation. These high demands and the increasing numbers of visitors have put enormous pressure on utilization of land and water resources in Taleghan catchment.

During last two decades, Taleghan catchment has been intensively influenced by land use changes. Since the approval of the dam construction, the whole rangeland area decreased gradually. The catchment has experienced substantial decrease of rangeland area from 83% during the early stages of dam construction to 35% by the completion. In addition, Inactive Dry Farming lands (IDF) which appear by plowing along land slopes has increased from 6.5% in 1987 to 42% in 2007. The good rangelands (GR) area that was 32,287 ha in 1987 decreased to 5,524 ha by late 2007 due to overgrazing, weak land use management, and climate change. This means that during the last twenty years, the good rangeland area decreased from 34.49 to 5.90%. The difference is accounted for by switching uses of these areas to moderate (MR) or poor (PR) quality rangelands or to IDF, while PR increased from 19.04% in 1987 to 23.35% in 2007(Hosseini, 2011).

MATERIAL AND METHODS

Study Area

The Taleghan catchment is located in the north west of Tehran, Iran. The maximum and minimum mean annual precipitations are recorded as 814 and 454 mm at Dizan and Galinak Stations, respectively. According to the FAUT (1993), most of the precipitation in the study area takes place as snow.

Figure 1 shows the study area of Taleghan watershed located in the upper part of Taleghan dam, within 36° 04' to 36° 21′ N latitude and 50° 38′ to 51° 12′ E longitude. The mean annual precipitation and runoff are 701 mm and 11.75 m^3 s^{-1}, respectively. The outlet stream gauging station is named Galinak with an area of 800.5 km^2. A second stream gauge, Joestan Station, was selected to compare the results drawn from Galinak Station. Joestan Station lies in the upper part of the watershed and has an area of 412.7 km^2. In this research, data of eight hydro-climatological stations located inside and around the catchment were analyzed. These stations were Zidasht, Galinak, Asara, Joestan, Giliard, Nesa, Dizan and Sokran (Figure 2).

The topographical elevation of the study area varies between 1,775 and 4,362 m above mean seal level (amsl) with weighted average of 2,753 m. The highest proportion of the study area belongs to the elevation class of 2,500-3,000 m with 35% of the total area while the lowest proportion belongs to the 4,000-4,500 m class with 6% of the area.

Modelling Principles

The Soil and Water Assessment Tool (Arnold *et al*., 1998) is a continuous, spatially semi-distributed model, developed to simulate the impacts of management decisions on water, sediment, and agricultural chemical yields in river basins in relation to soil, land use, and management practices. The model represents the large-scale spatial variability of soil, land use and management practices by discretizing the catchment into a number of sub-units using a two-step approach. First, a topographic discretization is done by dividing the catchment into sub-catchments based on a threshold area. In the second stage, each sub-catchment is further divided into homogeneous hydrological response units (HRUs) representing unique combinations of soil and land use.

The hydrologic model is based on the water balance equation in the soil profile where the processes simulated include precipitation, infiltration, surface runoff,

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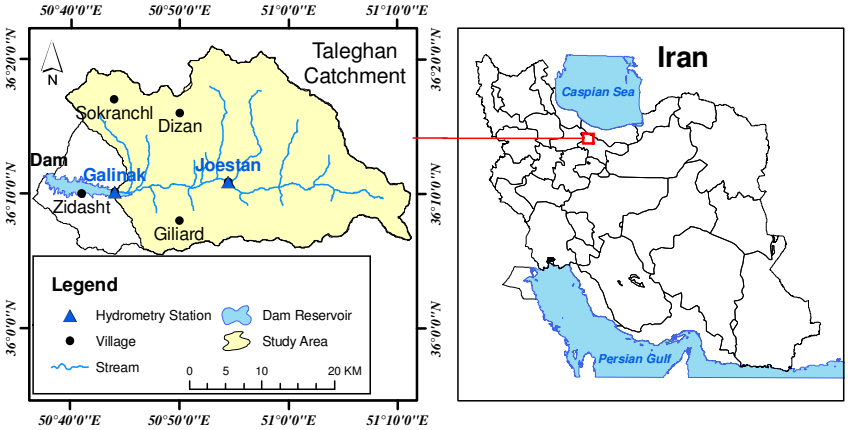

Figure 1. Location of Taleghan Watershed.

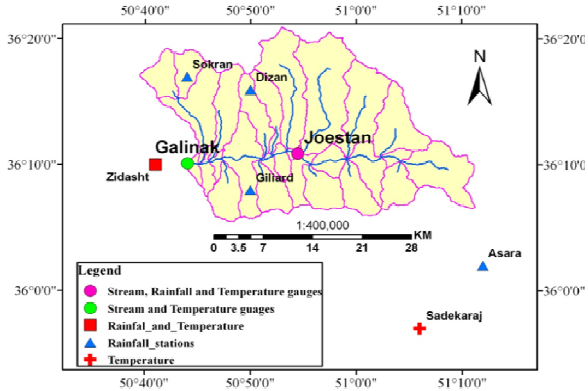

Figure 2. Locations of the Hydrometeorologic Stations in Taleghan Catchment.

evapotranspiration, lateral flow and percolation. SWAT partitions groundwater into two storage systems: a shallow unconfined aquifer, which contributes to the return flow, and a deep and confined aquifer that, besides pumping, is disconnected from the system. Surface runoff volume is predicted from daily rainfall by using the Soil Conservation Services (SCS) curve number equation (USDA, 1972). For the present study, the Priestley and Taylor (1972) approach was selected to determine the potential evapotranspiration (PET).

Actual evapotranspiration (AET) was determined based on the methodology developed by Ritchie (1972). Sediment yield was estimated for each HRU with the Modified Universal Soil Loss Equation (Williams, 1975) using the surface runoff, peak flow rate, and the soil erodibility, crop management, erosion control practice, and slope length and steepness factors.

For the present study, default values provided by SWAT crop database (Arnold *et al*., 1998) were used.

SWAT uses Manning's equation to calculate the rate and velocity of flow in a reach segment (Neitsch *et al.*, 2005). Water is routed through the channel network using the variable storage routing method, which was developed by Williams (1969), or the Muskingum routing method. The variable storage routing method was used in this study. Additional details are given by Arnolds *et al*. (1998).

The SWAT model is able to add up snow melt proportion to the water balance on the basis of the elevation classes and their areas. Therefore, this study subdivided the Galinak and Joestan Stations according to their

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catchment areas into six and four elevation classes, respectively.

Modelling Set-up and Calibration

The available time series for daily precipitation covered the period of January 1992 to December 2004. Eight precipitation stations were chosen for the simulation. A 1:50000 pedological soil map was available from the FAUT (1993) as well as some textural soil profiles description for all the major soils. A land use/ land cover map was detected from image processing. An 85 m grid DEM was available for the catchment discretization procedure. This discretization resulted in the definition of 28 sub-basins. The overlay of soil and land use maps resulted in 288 HRUs. The discretization was done trying to preserve the original distribution of soil and land use, while keeping the number of HRUs down to a reasonable number.

The model calibration by SWAT is time consuming, therefore, in this study, SUFI-2 (Sequential Uncertainly Fitting Ver. 2 (Abbaspour and Yang, 2006) was used to evaluate SWAT by performing calibration and uncertainly analysis. SUFI-2 is a semi-automated inverse modeling procedure for combined calibration-uncertainly analysis (Abbaspour *et al*., 2007). Monthly discharge simulation was based on a calibration using sum of square of errors objective function. In SUFI2, parameters uncertainty accounts for all sources of uncertainties. These sources include variables (e.g. rainfall), the conceptual model, model parameters, and measured data. To evaluate such uncertainties, SUFI2 offers two criteria as *P*-factor and *R*-factor. The *P*-factor indicates the percentage of measured data bracketed by the 95% prediction uncertainty (95PPU), whereas the *R*-factor calculates the average thickness of the 95PPU band divided by the standard deviation of the measured data. Theoretically, the value of the *P*-factor ranges from 0 to 100%, while that of the *R*-factor ranges from 0 to infinity. A *P*-factor of 1 and *R*-factor of zero indicate a simulation that exactly complies with the measured data. The degree to which the factors are away from these numbers can be used to judge the strength of the calibration. Further goodness of fit can be quantified by the R^2 and Nash-Sutcliff (E_{NS}) coefficient between the observation and the final "best" simulation.

Six types of objective functions and six statistical variables were linked to SUFI2 program. The a multiplicative form of the square error (mult), a summation form of the square error (sum), the R^2, Chi-squared, χ^2, the Nash-Sutcliffe (E_{NS}) coefficient, and the coefficient of determination multiplied by the coefficient of the regression line (BR^2). Performance of SUFI2 program on the monthly discharge of Galinak stream gauge station during the calibration and validation periods was evaluated by the aid of statistical measures for all objective functions using six variables, namely, the *P*-factor, *R*-factor, R^2, E_{NS}, BR^2, and the mean square error (MSE). The objective function values computed for Galinak Station indicated that E_{NS} coefficient was the best indicator criterion. For Galinak Station, these coefficients assumed the monthly values of 0.92, 1.01, 0.89, 0.89, 0.87, and 18.59 in the calibration period, and 0.71, 1.31, 0.80, 0.79, 0.67, and 25.76 in the validation period, respectively. Therefore, for both the calibration and validation, the E_{NS} coefficient was selected for the objective function.

This simulation passed through three consecutive separate periods. These, as well as their durations, were: (i) the setup (also known as warm-up) period from 1992 till the end of the year 1994 (three years); (ii) the calibration period that extended from the beginning of 1995 to the end of 2000 (six years), and (iii) the validation period that covered the period of 2001 to the end of 2004 (four years).

A number of statistical tools were used for evaluating the performance of the watershed model. These were the mean of the simulated outputs, relative error (RE), coefficient of determination (R^2), and Nash-Sutcliffe simulation efficiency (E_{NS}) (Nash and Sutcliffe, 1970).

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RESULTS AND DISCUSSION

In this study, SUFI-2 was used for model calibration and validation. By using SUFI-2, we could perform uncertainly analysis and calibrate the model for more number of parameters.

The results of the observed and predicted annual runoff volume at Joestan and Galinak stream gauges are shown in Table 1 with high R^2 values for both the calibration and validation periods. Table 2 presents some statistical criteria including Deviation (Dv), Mean Annual Relatively Error (MARE), Coefficient of Determination (R^2), and Nash-Sutcliffe efficiency (E_{NS}). The coefficient of efficiency for Joestan and Galinak validation periods were 0.83 and 0.84. They were more reliable in this period because the values were more than 0.75 (Motovilov *et al.,* 1999). This coefficient for calibration periods of both Joestan and Galinak was, respectively, 0.45 and 0.47 that seems acceptable. Motovilov *et al.* (1999) stated that according to common practice, the simulation of a model is considered good for values greater than 0.75, and acceptable for values between 0.75 and 0.36. These ranges were adopted in this study to classify model performance. Thus, the results derived from both stream gauges of this study can be used for further analysis.

Monthly Discharge Output

The monthly results implied that the observed average discharges and those

Table 1. Observed and predicted mean annual runoff at Galinak and Joestan Stations during model calibration and validation over the period of 1992-2004.

		Galinak		Joestan	
		Observed	Predicted	Observed	Predicted
Period	Year	($m^3 s^{-1}$)	($m^3 s^{-1}$)	($m^3 s^{-1}$)	($m^3 s^{-1}$)
Warm-up	1992	15.13	16.28	13.02	15.22
Warm-up	1993	11.85	11.82	8.12	8.94
Warm-up	1994	19.16	21.76	12.01	13.92
Calibration	1995	15.13	20.59	11.11	14.98
Calibration	1996	13.75	12.57	7.88	10.01
Calibration	1997	9.84	8.88	6.47	6.41
Calibration	1998	15.52	16.32	9.53	11.27
Calibration	1999	6.21	5.16	4.15	3.44
Calibration	2000	8.71	6.5	5.6	5.82
Validation	2001	4.79	2.93	3.47	2.71
Validation	2002	11.93	9.84	8.25	9.53
Validation	2003	17.1	18.93	10.94	9.21
Validation	2004	14.53	14.72	9.91	10.50
Average	12.59	12.79	8.50	9.38	

Table 2. Results of the statistical evaluation of model performance on the annual discharge in the calibration (1995-2000) and validation (2001-2004) periods at Joestan and Galinak Stream Gauging Stations.

Gauging station	Model development stage	Dv^a (%)	$MARE^b$	R^{2c}	E_{NS}^d
Joestan	Calibration	16	0.17	0.98	0.45
	Validation	27.26	0.15	0.86	0.83
Galinak	Calibration	1.24	0.17	0.87	0.47
	Validation	-5.31	0.20	0.98	0.84

[a] Deviation; [b] Mean Annual Relatively Error; [c] Coefficient determination, [d] Nash-Sutcliffe Efficiency.

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calibrated by SWAT during the model calibration period for Galinak Station were in good agreement. The observed discharge was equal to 11.5 m^3 s^{-1} compared with the calibrated discharge of 11.7 m^3 s^{-1}. Similarly, for the validation period, the above values were 12.1 and 11.4 m^3 s^{-1}, respectively. Notably, the comparative evaluation of the average monthly discharge values at Joestan Station showed relatively good fit between the estimates during the calibration and validation periods. As far as the calibration period is concerned, the average monthly observed and predicted discharges assumed the values of 7.5 and 8.7 m^3 s^{-1}, respectively. Similarly for the validation period, the observed average monthly discharge was 8.1 m^3 s^{-1}, whereas the predicted value was equal to 10.4 m^3 s^{-1}. Meanwhile, the average deviation of the predicted discharges at Joestan Station from the observed ones were 16.1 and 27.3% in the calibration and validation stages, respectively (Table 3).

The values of MARE calculated for the two stations are generally low and close to zero (Table 4). The R^2 and E_{NS} coefficient are two important statistical indicators for evaluation of the results. In the case of Joestan Station, the R^2 values corresponding to the relationships between the observed and predicted average monthly discharges were found to be 0.76 and 0.83 during the calibration and validation periods, respectively. However, the corresponding values for Galinak Station were 0.84 and 0.90. Therefore, all of results in both stations and both periods (calibration and validation) for mean monthly flow showed the goodness fit of the simulation in the study area. Therefore, in general, SWAT model was reasonably capable to reproduce mean monthly discharge in Taleghan area. Consequently, based on statistical analysis, the results show: (i) the model can predicate the runoff accurately; (ii) the model is suitable and recommended for the study area.

Runoff Components

The runoff components encompass surface runoff, lateral flow, and groundwater flow. According to Linsley *et al.* (1949); Linsley *et al.* (1982), and Klemes (1986), drawing distinction between the components of runoff is arbitrary and the source(s) of the water passing a gauging station cannot be identified, therefore, comparing the predicted fluxes against any observation at the two gauging stations within the Taleghan basin is not possible. Figures 3 and 4 show the monthly surface runoff, lateral flow, and

Table 3. Mean monthly discharge values during the calibration and validation periods at Galinak and Joestan Stations**.**

Station	Period	Observed (m^3 s^{-1})	Predicted (m^3 s^{-1})	Deviation (%)
Joestan	Calibration	7.5	8.7	16.1
	Validation	8.1	10.4	27.3
Galinak	Calibration	11.5	11.7	1.2
	Validation	12.1	11.4	-5.3

Table 4. Results of the statistical evaluation of model performance on the monthly discharge in the calibration and validation periods at Joestan and Galinak Stream Gauging Stations.

Gauging station	Period	*MARE*	R^2	E_{NS}	Results
Joestan	Calibration	0.43	0.76	0.75	Acceptable
	Validation	0.61	0.83	0.73	Acceptable
Galinak	Calibration	0.33	0.84	0.84	Good
	Validation	0.34	0.90	0.89	Good

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groundwater flow at Galinak and Joestan stream gauges. The results indicate strong response of surface runoff during the model calibration (1995-2000) and validation (2001-2004) periods. The low lateral flow in both periods is due to the heavy soil texture. Groundwater flow appears to be relatively moderate. The results of Joestan Station almost reflected the trends in response observed at Galinak Station. However, lag time in groundwater flow was more pronounced in the former than in the latter.

The Water Balance

The water balance results at Joestan and Galinak Stations predicted for the watershed from the 1987 land use data are shown in Table 5 for the period of January 1995 to December 2004. It can be seen that around 21and 33% of the precipitation were as surface runoff at Joestan and Galinak Stations, respectively. Total groundwater and lateral flows at both stations, which take place mostly in the upper part of the watershed, were 37 and 19%, respectively. At Joestan and Galinak Stations, around 38 and 49% of the precipitation, respectively, is lost through evapotranspiration.

A complete comparison of the water balance components from 1995 to 2004 and estimated using three land use maps of 1987, 2001 and 2007 (Hosseini, 2011) shows that

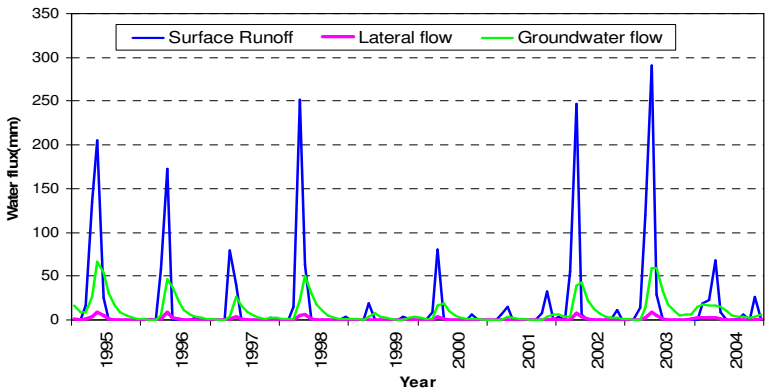

Figure 3. Predicted monthly surface runoff, lateral flow, and groundwater flow at Joestan Station from 1995 to 2004.

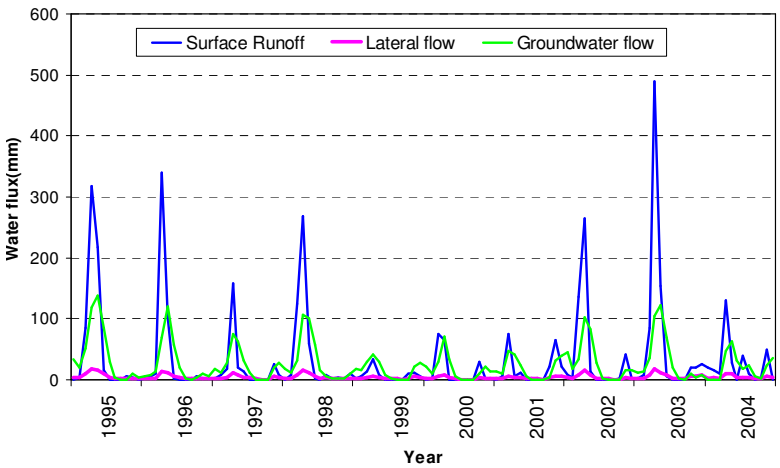

Figure 4. Predicted mean monthly surface runoff, lateral flow, and groundwater flow at Galinak Station from 1995 to 2004

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the ratio of the total surface runoff to the total volume of precipitation at Joestan Station increased from 21 to 26%. The corresponding ratio at Galinak Station showed an increase from 33 to 36% during the same period. For the same period, the total lateral and groundwater flows decreased at both stations. However, the total evapotranspiration at both stations changed the least during the same period (Tables 6 and 7).

Effects of Land Use Changes on Water Balance Components

The trend of water balance components in the mean annual water yield including surface runoff, lateral flow, and groundwater flow during the years are not similar (Figures 5 respectively). These figures reveal that a trend of increase in the surface runoff occurred after degradation in land

Table 5. Water balance at Joestan and Galinak Stations predicted for the simulated watershed from 1987 land use data for the period January, 1995, to December, 2004.

Variable	Joestan		Galinak	
	Mean annual precipitation (mm)	Fraction of precipitation (%)	Mean annual precipitation (mm)	Fraction of precipitation (%)
Precipitation	1005.7	100.0	701.0	100.0
Evapotranspiration	384.6	38.2	342.4	48.9
Surface Runoff	212.8	21.2	232.4	33.2
Lateral flow	140.3	14.0	11.8	1.7
Groundwater flow	233.0	23.2	118.3	16.9
Water loss	35.0	3.5	-4.0	-0.6

Table 6. The Water balance at Joestan Station during the period 1995 to 2004.

Variables	LU_1987		LU_2001		LU_2007	
	Mean annual precipitation (mm)	(%)	Mean annual precipitation (mm)	(%)	Mean annual (mm)	(%)
Precipitation	1005.7	100.0	1005.7	100.0	1005.7	100.0
Evapotranspiration	384.6	38.2	384.4	38.2	383.4	38.1
Surface Runoff	212.8	21.2	228.0	22.7	262.8	26.1
Lateral flow	140.3	14.0	137.7	13.7	126.9	12.6
Groundwater flow	233.0	23.2	221.9	22.1	201.0	20.0
Water loss	35.0	3.5	33.8	3.4	31.4	3.1

Table 7. The Water balance at Galinak Station during the period 1995 to 2004.

Variables	LU_1987		LU_2001		LU_2007	
	Mean annual precipitation (mm)	(%)	Mean annual precipitation (mm)	(%)	Mean annual (mm)	(%)
Precipitation	701.0	100.0	701.0	100.0	701.0	100.0
Evapotranspiration	342.4	48.9	341.8	48.8	340.5	48.6
Surface Runoff	232.4	33.2	237.5	33.9	249.4	35.6
Lateral flow	11.8	1.7	11.2	1.6	10.4	1.5
Groundwater flow	118.3	16.9	114.5	16.3	105.3	15.0
Water loss	-4.0	-0.6	-4.1	-0.6	-4.7	-0.7

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uses during the time. However, the lateral and groundwater flows declined in the same period.

CONCLUSIONS

The water balance analysis simulated using land use map of 1987 at Joestan and Galinak Stations showed that around 38% and 49% of the precipitation, respectively, is lost through evapotranspiration. The results indicated that more evapotranspiration took place in lower elevation areas with higher temperature. This indicated that temperature had higher effect on evapotranspiration than land cover. As to the other components, about 21 and 33% of the precipitation formed the surface runoff at the upper part of the watershed (Joestan Station) and at the outlet (Galinak Station), respectively.

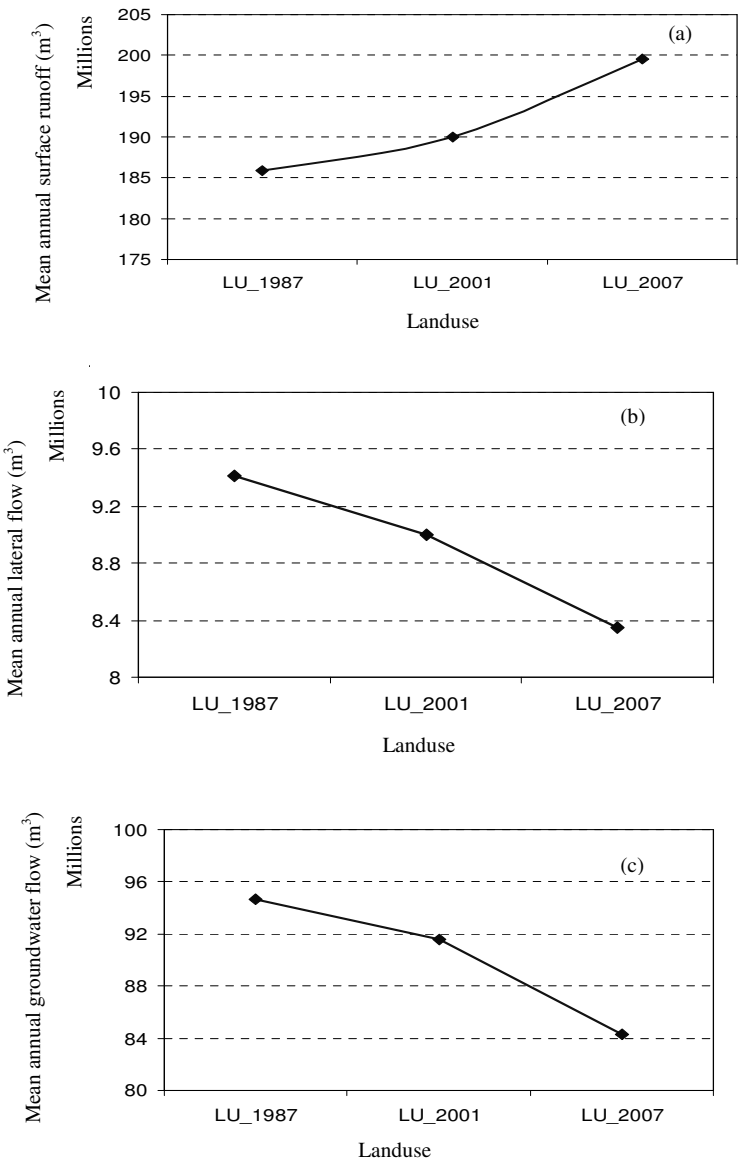

Figure 5. Effects of land use changes in the years 1987, 2001, and 2007 on the mean annual (a) surface runoff, (b) lateral flow and (c) groundwater flow.

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Groundwater and lateral flows took place mostly in the upper part of the watershed. Main reason for this process was a gradual melting of snowpack at higher elevations. Low temperatures at high elevations allow for gradual melting of snow followed by infiltration, therefore, more interflow took place at these elevations. Another possible reason for this process is the existence of good rangeland that is mostly located in the upper part of the watershed and is inaccessible for grazing animals, providing opportunity for infiltration. Even though most of the steep land areas are located in the upper part of the watershed, the lower elevation, which starts downstream of Joestan Station, has higher effects on producing runoff and interflow. Therefore, managing the land cover downstream of Joestan Station is important in water balance components adjustment.

In both catchments, the runoff coefficient from 1995 to 2004 showed an increase of 4.9 and 2.4% at Joestan and Galinak Stations, respectively. This could be because of decrease in land use and slope steepness at the study area. However, runoff coefficient increased in both catchments. The higher runoff coefficient at higher elevation can be due to factors such as overgrazing and weather condition (dry years). In the same period, the total lateral and ground water flows decreased at both stations. However, the total evapotranspiration at both stations changed the least during the same period. The ratio of the total runoff to the total lateral and groundwater flows increased from 1.79 to 2.15 (20%) at Galinak Station and from 0.69 to 0.94 (36%) at Joestan Station. This ratio also indicates an increasing surface runoff in the study area during the last two decades.

To investigate

the effects of land use changes on the water balance before and after the dam construction, two other land use scenarios (2001 and 2007) were examined with the optimized parameters. There was an increasing trend in surface runoff following degradation of land use. However, the lateral and groundwater flows declined in the same period. A complete comparison of the water balance components from 1995 to 2004 showed 2.4% increase in runoff coefficient in the study area. The trends interpretations on water components at the outlet indicate a progressively ascending surface runoff (7.3%) and progressively descending lateral flow (11.3%) and groundwater flow (11%) during the study period. This implies land use degradation in Taleghan catchment during the last decades. Therefore watershed management operations and planners should concentrate on the reduction of surface runoff and control of the accelerated degradation of land use.

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اثر تغییر کاربری اراضی بر روی بیلان آبی در حوضه آبخیز طالقان

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چکیده

در سالهای اخیر اثرات تغییر کاربری اراضی بر روی بیلان آبی بعنوان یکی از مهمترین نگرانی ها در مدیریت آب حوضه های آبخیز بحساب می آید. حوضه سد طالقان بدلیل رشد فزاینده جمعیت ناشی از احداث سد تحت تاثیر تغییر کاربری اراضی، شهر سازی و توسعه منابع آبی شرب، کشاورزی و صنعتی قرار گرفته است. اینگونه تغییرات نقش ویران کننده ای در تعادل آبی حوضه آبخیز ایفا می نماید. آنچه مشخص است مطالعه ای در رابطه با برآورد اثر تغییرات کاربری اراضی بر روی بیلان آبی در این منطقه انجام نشده است. بنابر این برای انجام چنین تحقیقی به مدل مبنا فیزیکی و توزیعی با بهره گیری از سامانه اطلاعات جغرافیایی (GIS) به منظور ارزیابی اثرات تغییر کاربری اراضی بر روی بیلان آبی نیاز می باشد. هدف اصلی این تحقیق بررسی تاثیر تغییرات کاربری اراضی بر روی بیلان آبی طالقان واقع در شمال غربی ایران می باشد. به این منظور تصاویر ماهواره ای سالهای ۱۹۸۷، ۲۰۰۱ و ۲۰۰۷ برای تشخیص کاربری اراضی انتخاب شد. با بررسی مدل های مختلف هیدرولوژیکی، مدل نیمه توزیعی SWAT برای این تحقیق انتخاب شد. مدل مذکور برای برآورد بیلان آبی در میانه و خروجی حوضه استفاده شد. اطلاعات ورودی مدل مشتمل بر مدل رقومی ارتفاع (DEM) ، ویژگی های خاک، اطلاعات هیدروکلیماتولوژی و نقشه های کاربری اراضی مختلف بود. مقایسه بیلان آبی با استفاده از نقشه کاربری سال ۱۹۸۷ حاکی از تلفات تبخیر و تعرق ۳۸٪ و ۴۹٪ کل بارش سالانه در ایستگاههای آبسنجی جوستان (میانه حوضه) و گلینک (خروجی حوضه) می باشد. میزان جریان سطحی بترتیب مقادیر ۲۱٪ و ۳۳٪ کل بارش را در ایستگاههای مذکور نشان میدهد. مجموع جریانهای زیر زمینی و جریان های جانبی بترتیب معادل ۳۷٪ و ۱۹٪ می باشد که بیشتر در ارتفاعات بواسطه وجود پدیده ذوب تدریجی برف رخ می دهد. بیلان آبی در خروجی حوضه برای دوره زمانی ژانویه ۱۹۹۵ تا آگوست ۲۰۰۴ برآورد شد که نتایج آن حاکی از افزایش ۷/۳٪ جریان سطحی و کاهش ۱۱/۳٪ و ۱۱٪ بترتیب در جریان های جانبی و زیرزمینی می باشد. نتایج حاکی از افزایش تصاعدی جریان های سطحی و کاهش جریان های زیر قشری می باشد.

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