



Assessing the effect of climate and land use changes on the hydrologic regimes in the upstream of Tajan river basin using SWAT model

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Abstract

Climate change is the most important challenge in achieving sustainable development. Semi-arid and arid areas (such as Iran) are particularly susceptible to the effects of climate change on water supply. In this research, the effect of climate change and upstream land use is investigated on Tajan, a river in the north of Iran. The data regarding the climate were produced via second-generation Canadian Earth System Model (CanESM2) and adopted as the input to SWAT hydrologic model under RCP2.6 and RCP8.5 for the period of 2016–2066. The results showed that the peak streamflow will increase by 4% and 5.7% and the average annual discharges will decrease by 16% and 16.5% from 2016 to 2066 for RCP2.6 and RCP8.5 scenarios, respectively. Besides, the effect of different land use change scenarios on streamflow was investigated under four diverse scenarios selected to represent a comprehensive range of possible land use map of the basin. Land use change scenarios led to 8.5–15.8% increase in the average annual streamflow, highlighting the fact that it is less effective than climate change on streamflow. It could be concluded that downstream water users in the basin should adopt strategies to cope with water-stressed condition under the changing climate.

Keywords Streamflow · SWAT · Climate change · Land use · Iran

Introduction

Climate change has been a persistent concern throughout various epochs and this is not the initial occasion where it has resulted in modifications across diverse geological periods (Lotfirad et al. 2021). Alterations in weather patterns, along with transformations in soil quality and land use, can have a significant impact on the survival and wellbeing of countless organisms within a given area (Pourgholam-Amiji

et al. 2021). The effects on agricultural and environmental systems in developing nations, as well as wet and semi-humid regions, are anticipated to be less severe compared to countries that experience dry and semi-arid conditions (Calanca 2007; Pourmohamad et al. 2019), such as Iran. Several studies have demonstrated that alterations in land use can have a notable impact on water flow, groundwater recharge, and the average yearly flow of each watershed (Kumar et al. 2022). The impact of climate change on regional land use change will be substantial, as it affects carbon storage in the soil, leading to changes in climatic factors like temperature and precipitation. Additionally, human activity, such as hasty alterations to land use, non-scientific and non-environmental irrigation practices, overexploitation of grasslands and deforestation, poses a threat to the biodiversity of regions, particularly in central Asia, including Iran. Precipitation-runoff dynamics in a watershed are a result of the interplay between various factors, such as climate and land use practices (Hernandez et al. 2000). Moreover, acknowledging the connection between these alterations, their causative factors, and their consequential impact on the hydrological patterns of the watershed can provide essential insights for devising strategies to meet future needs

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and achieve sustainable management of natural resources (Palamuleni et al. 2011). Exploring the time series of climate and hydrological parameters, as well as analyzing land use changes, can provide valuable insights into the contributions of human and climatic factors. The trend of climate change in future can be evaluated by utilizing Atmospheric-Ocean General Circulation Models (AOGCMs), which have been established as the primary tools for climate forecasting (Coulibaly et al. 2001). Furthermore, along with the development of a downscaling model and the creation of climate scenarios, conducting an in-depth analysis of the trends in these variables and utilizing appropriate statistical methods can be an effective approach. To facilitate integrated analysis and management of the watershed, geographic information system (GIS) can be employed as a suitable tool. With GIS, the various characteristics of the basin, such as soil layers, land cover, and climate, can be accurately analyzed (Jarvie et al. 2002; Maidment 2008). Furthermore, an appropriate hydrological model is necessary to explore the impacts of land use change and efficient management of water resources (Schmalz and Fohrer 2009). A study conducted on Goseng basin, Tennessee River Basin, and Tekeze Dam in northern Ethiopia aimed to examine the impact of land use change on hydrological fluctuations by using the Genriver model to analyze and predict changes in the basin. The study demonstrated that land use changes have a noteworthy impact on the hydrological fluctuations of the basin (Nugroho et al. 2013; Zhu and Li 2014; Welde and Gebremariam 2017). Guzha et al. (2017) investigated the impact of plant coverage and land use on flow rate, base flow, and surface runoff in the East African region. The study demonstrated that different land use scenarios, such as those modeled by the SWAT and HEC-HMS hydrological models, could be defined to assess the effects of changes in forest cover. The research showed that with the loss of forest cover, only 31% of the drainage basin experienced a continuous increase in discharge, while 63% remained unaffected. In general, the results suggested that reducing forest cover could lead to increased annual flows and surface runoff in the basin, while the minimum outflow of the basin decreased. Conversely, increasing forest cover led to a reduction in the annual flow and surface runoff of the basin.

In addition to assessing water stress levels in the basin and sub-basin, especially during dry seasons, a recent study investigated the impact of short-term and long-term land use scenarios on the upstream region of the Hawaiian river basin. The outflow rate resulting from these scenarios was incorporated into the hydrological SWAT model, which showed that both short-term and long-term land use scenarios resulted in a decrease in total and peak discharge, while evapotranspiration increased. Furthermore, the hydrological response of the basin was greater for the long-term scenario compared to the short-term scenario

(Yu et al. 2018). Rivas-Tabares et al. (2018) utilized the SWAT model to assess the water balance of the Cega-Eresma-Adaja watershed, which involved evaluating land uses and management practices to determine agricultural water demand from 2004 to 2014. The Nash–Sutcliffe coefficient efficiency value, which is the primary index of calibration and validation, was found to be 0.86 and 0.67 for the Eresma-Adaja River and the Cega River, respectively. In a study of dry hydrological years, it was shown that estimating ecological flows for sub-arid zones required consideration of the shallow aquifer–river relationship. Monitoring shallow aquifer levels during spring–summer periods, when the flow is very low, is essential to ensure a satisfactory ecological condition. Özcana et al. (2017) conducted a study using the SWAT model to evaluate the effectiveness of Best Management Practices (BMP) in the Lake Mogan watershed, situated in a semi-arid region. They found that the most effective BMP scenario was a combination of three individual BMP scenarios: no-tillage, 30% fertilizer reduction, and terracing. This scenario resulted in an average annual load reduction of 8.0% for total nitrogen, 8.6% for nitrate, 9.3% for sediment, and 11.1% for total phosphorus. Nguyen et al. (2019) conducted a study to examine the impact of land use changes on streamflow, sediment, and nutrient loads in a catchment area using both the SOURCE and SWAT models. The findings revealed that SOURCE model produced high-quality metrics for flow estimation, whereas SWAT model provided more realistic estimations of nutrient loads.

Kundu et al. (2017) conducted a study on a part of the Narmada basin in Madhya Pradesh, India, to investigate the impacts of individual and combined scenarios of climate change and land use using the SWAT hydrologic and SDSM climatic models. The study showed that climate change has a greater impact on water performance and surface runoff compared to land use change. Anand et al. (2018) evaluated the effect of land use change on the hydrologic regimes of the Ganga River basin using the SWAT model. They compared the simulated streamflow at various gauge stations throughout the Ganga River and its tributaries, and found that urbanization was the main factor contributing to increased surface runoff.

The purpose of this study was to assess the impact of climate change and land use on the outflow rate of Tajan Basin upstream. To achieve this goal, the researchers employed the SDSM downscaling model to evaluate climate parameters and produce RCP2.6 and RCP8.5 climate scenarios. Additionally, GIS software was used to create land use maps based on positive and negative climatic trends. The SWAT model was then used to simulate the outflow rate from the data collected at the Soleyman Tangeh hydrometric station. The SWAT-CUP software and SUFI2 method were utilized to calibrate and validate the model.

Materials and methods

Study area

The study area of this research is the Tajan River drainage basin with a total area of 4015.88 square kilometers and is situated in the Alborz Mountains in the south. The Tajan River is a 155 km long river that flows in the south of the city of Sari and drains into the Caspian Sea in the north. The majority of the basin is located at an altitude of 200–500 m, while a small portion is situated over 2500 m above sea level. The study utilized streamflow measurement data from Soleyman Tangeh station and climate data from Kiasar synoptic station from 2005 to 2015. The average annual precipitation during this time was 615 mm and the mean temperature was 14.42 °C. The study was focused on the basin that drains into the Shahid Rajae Dam, located 45 km southwest of Sari (36° 14' N, 53° 14' E). The basin's elevation, drains, and outlet are shown in Fig. 1.

SWAT model

The SWAT model is a widely used drainage basin scale model for various hydrological applications. It divides each basin into multiple sub-basins, and each sub-basin is further divided into Hydrological Response Units (HRUs) based on specific land use, management, and soil characteristics. HRUs are total areas in a sub-basin, which are assumed to have no interaction with other HRUs. Although individual fields with specific land use and management may be scattered throughout a sub-basin, they are grouped together to form an HRU. The model calculates loadings,

such as sediment and nutrient transport, separately for each HRU and then adds them together to obtain the total loadings from the sub-basin (Di Luzio et al. 2002).

The SWAT model simulates the hydrologic cycle by utilizing the water balance equation (Eq. (1)):

$$SW_t = SW_0 + \sum_{i=1}^t (R_{\text{day}} - Q_{\text{surf}} - E_a - W_{\text{seep}} - Q_{\text{gw}}) \quad (1)$$

where SW_t is the final soil water content (mm) at day t , SW_0 is the initial soil water content (mm) on day i , t is the time (days), R_{day} is the amount of rainfall on day i (mm), E_a is the amount of evapotranspiration on day i (mm), W_{seep} is the amount of water entered into the vadose zone from the soil profile on day i (mm), Q_{surf} is the amount of surface runoff on the day i (mm), and Q_{gw} is the amount of return flow on day i (mm).

In this study, Muskingum, SCS curve number, and Penman–Monteith methods were employed for routing, estimation of surface runoff volume, and potential evapotranspiration. To run the SWAT model, several basic information such as meteorological data, streamflow gauge data, digital elevation map, soil map, and slope map of the basin were required. The climate data of Kiasar synoptic station and soil data based on the global soil base data were used in the model. The digital map of the basin was prepared by the regional water company and provided information on the minimum and maximum altitude of the basin, which is 385 and 3720 m, respectively (Nikkhoo Amiri et al. 2019a). Streamflow gauge data from the Solyman Tangeh Hydro-metric Station were used to assess the hydrologic regime of Tajan Basin, which is the hydrometric station upstream of Shahid Rajae Dam.

Streamflow simulation

The basin streamflow was modeled using the SWAT model input database for the period of 2005–2015. The calibration and validation of the model were carried out using the SWAT-CUP software with the Sequential Uncertainties Fitting Ver-2 (SUFI-2) algorithm. SWAT-CUP is a public domain program that integrates various calibration and uncertainty analysis procedures for SWAT in one user interface. The calibration phase used streamflow gauge data from Soleyman Tangeh for the period of 2006–2012, and the same data were used for validation in the period of 2013–2015. Sensitivity analysis of 20 parameters from the SWAT input set was performed using the SUFI-2 algorithm, as shown in Table 1.

In the SUFI-2 algorithm, the level of uncertainty estimated is measured by the P factor, which represents the percentage of measured data enclosed by the forecast uncertainty of 95% (95PPU). To calculate 95PPU, the

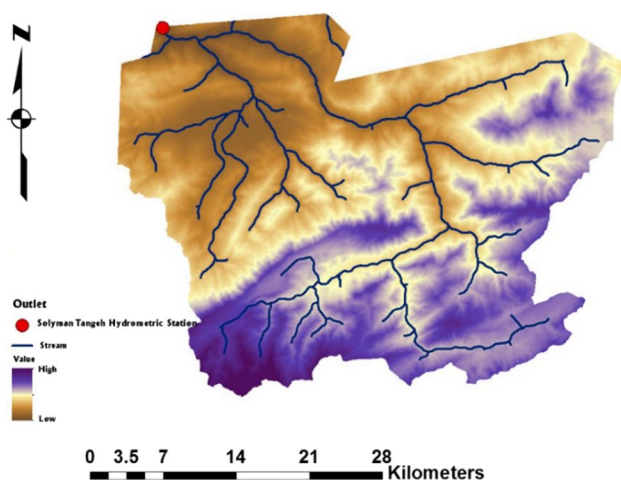


Fig. 1 Elevation position, drains and basin outlet

Table 1 Parameters used in calibration

The optimum amount is matched	Minimum	Maximum	Parameter	Symbol parameter in model	Sensitivity rating
0.01	-0.13	0.05	Base water α	v__ALPHA_BF.gw	1
214.12	117.18	254.68	Delay time transfer of water from the last soil profile to the groundwater level (day)	v__GW_DELAY.gw	2
1.03	0.99	1.45	Minimum melting point on June 21 (mmH ₂ O / C-day)	v__GWQMN.gw	3
0.55	0.55	0.76	Available Water Capacity	r__SOL_AWC(1).sol	4
0.28	-0.01	0.48	Hydraulic conductivity of soil (mm / hr)	r__SOL_K(1).sol	5
0.31	0.26	0.34	Main River Manning coefficient	v__CH_N2.rte	6
102.06	89.61	140.43	Effective hydraulic conductivity of the main river bed (mm / hr)	v__CH_K2.rte	7
-0.26	-0.33	-0.22	Manning coefficient for surface flow	r__OV_N.hru	8
0.16	0.12	0.19	Soil evaporation coefficient	a__ESCO.hru	9
0.09	0.07	0.10	Average length (tilt)	r__SLSUBBSN.hru	100
1.99	0.69	3.22	Average snow temperature (Celsius)	v__SFTMP.bsn	11
4.66	4.02	5.86	Storage time for normal flow	v__MSK_CO1.bsn	12
5.54	4.66	7.00	Storage time for low flow	v__MSK_CO2.bsn	13
0.07	-0.01	0.13	The base water abundance α for coastal channel storage	v__ALPHA_BNK.rte	14
-15.98	-27.58	-13.97	Snow melting temperature (degrees Celsius)	v__SMTMP.bsn	15
7.89	7.70	9.04	Maximum melting point on June 21 (mmH ₂ O / C-day)	v__SMFMX.bsn	16
-26.35	-0.50	0.60	Soil density in wet condition	r__SOL_BD(1).SOL	17
0.00	-0.20	0.20	Curve number under moisture conditions	r__CN2.mgt	18
16.91	16.17	19.62	Minimum melting point on June 21 (mmH ₂ O / C-day)	v__SMFMN.bsn	19
47.60	37.11	97.09	The minimum amount of snow in the snow is 100%	v__SNOCOVX.bsn	20

cumulative distribution of an output variable is sampled using Latin hypercube sampling, excluding 5% of very poor simulations, and the 2.5% and 97.5% levels are used. Another metric used to assess the calibration and uncertainty analysis is the R factor, which measures the strength of the analysis by dividing the average thickness of the 95PPU band by the standard deviation of the measured data.

The initial stage of SUFI2 involves defining an objective function for calibration purposes. Next, a range of acceptable minimum and maximum values is established for each parameter, and a considerable number of samples are generated using the Latin Hypercube technique. The model is then updated at each iteration by incorporating the permissible range and the latest parameter values, and calculating the corresponding target function value. Finally, the P and R factors are computed and communicated to the modeler as the outcome (Abbaspour 2009).

In this study, P and R factors, Nash–Sutcliffe function (NS), the coefficient of determination (R^2) and RMSE statistic were used to evaluate the results of the calibration and validation stages of the model.

Climate scenarios

General Circulation Models (GCMs) are complex computer models that simulate the physical mechanisms governing the atmosphere, cryosphere, ocean, and land surface to predict changes in the global climate system. Although GCMs are the most sophisticated tools available for this purpose, their resolution is often too coarse (usually no less than 2.5 degrees) to provide accurate information at the local or regional level. Therefore, it is essential to generate high-resolution climate data from the outputs of coarse-resolution climate models to support impact evaluations (Wilby et al. 1998).

In this study, utilized the Canadian Earth System Model (CanESM2), which is a global climate model of the second generation. To obtain more detailed and localized climate projections, applied statistical downscaling techniques using the Statistical Downscaling Model (SDSM) to the outputs of CanESM2 (IPCC 2001; Chen et al. 2012).

Climate surveys utilize emission scenarios to create plausible depictions of potential future climate conditions across a spectrum of forcing values. These scenarios are utilized

in climate model simulations and provide a framework for assessing potential climate impacts. The Representative Concentration Pathways (RCPs) represent a series of greenhouse gas concentration pathways that cover a wide range of possible climate outcomes, as outlined in the IPCC's Fifth Assessment Report (AR5). The RCPs have proven to be a significant advancement in climate research and serve as the foundation for further analysis, such as evaluating the impacts of climate change. In this particular study, utilized both the most stringent climate policy scenario (RCP2.6) and the scenario without any climate policy (RCP8.5) to assess the potential impacts of climate change in the region.

To simulate precipitation, minimum and maximum temperature, radiation, wind, and relative humidity, observational data from the Kiaser synoptic station from 1979 to 2005 were utilized as input for the SDSM model. Predictor variables that have a physically meaningful interpretation and exhibit high variance were selected for calibration and validation of the model after undergoing routine screening procedures. The performance of the downscaling model was assessed by comparing the standard deviation, simulated average, and observational data. The SDSM downscaling model was then utilized to statistically downscale climate data from the CanESM2 climate model under two RCP scenarios (RCP4.5 and RCP8.5) for the period of 2016–2066.

This downscaled data were subsequently employed as input for the SWAT hydrologic model to evaluate the impact of climate change on streamflow (Nikkhoo Amiri et al. 2019b).

Land use change scenarios

In order to study the effect of land use change on the streamflow, the land use map prepared for 2011 by Mazandaran Regional Water Company was used as the benchmark. Flow simulation was initially carried out by SWAT model using the benchmark land use map. In order to have a scenario-driven modeling approach, four land use scenarios were adopted including (I) optimistic, (II) highly optimistic, (III) pessimistic and (IV) highly pessimistic (Fig. 2). The adopted land use change scenarios for Tajan river basin have been used as the input to SWAT model.

Results and discussion

Database analysis

According to the results of the sensitivity analysis, parameters of the base water α coefficient, the time delay of the water transfer from the last soil profile to the groundwater

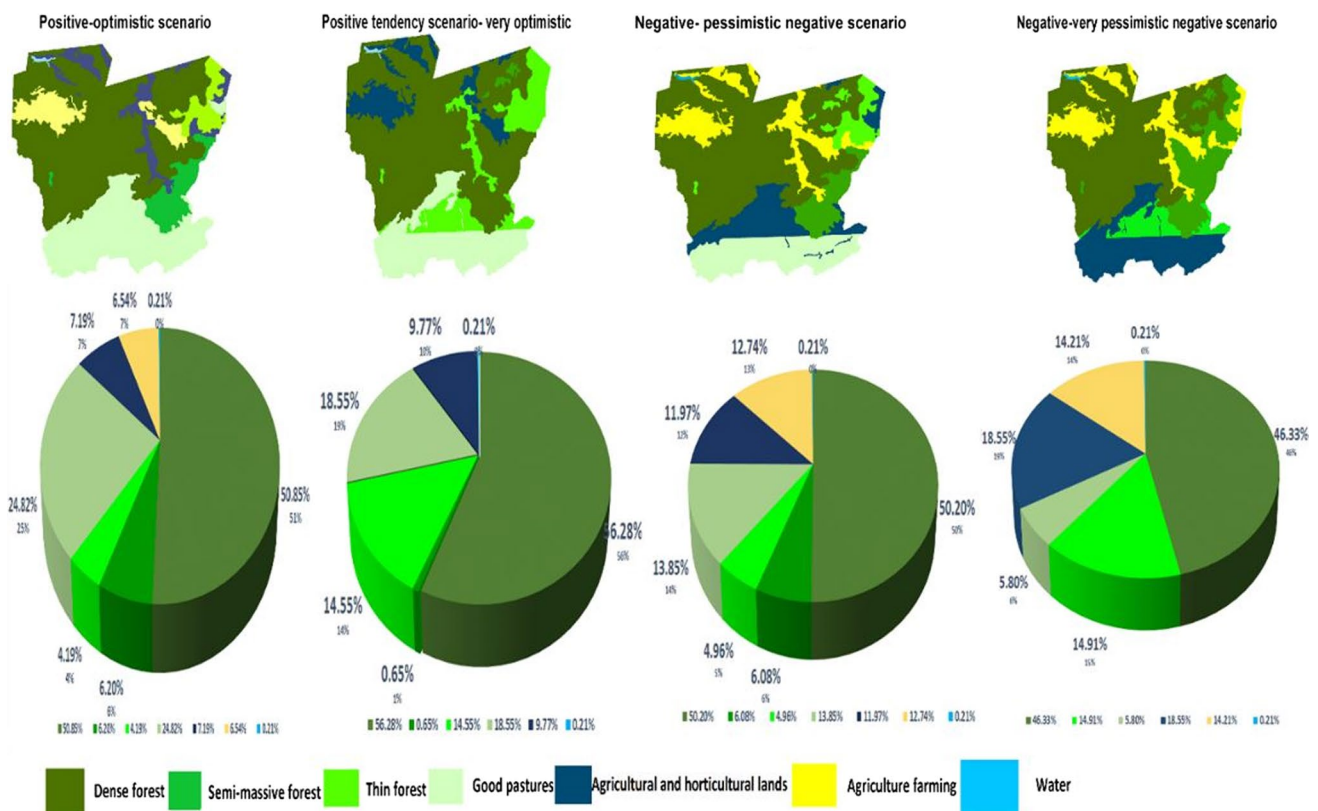


Fig. 2 Quantitative changes of different land use changes in scenarios with positive and negative trends in Tajan basin

surface and the minimum amount of snow melting had the highest sensitivity and the moisture curve number 2, showing the soil density in the wet state and the maximum amount of snow melting on June 21st had the least sensitivity to the calibration operation and validation stages using SWAT-CUP model.

Figure 3 illustrates the results of the model calibration and validation. This assessment was introduced to the model during the calibration period on a monthly basis for the years 2006–2012, and during the validation period (i.e., 2013–2015). The highest and lowest simulated discharge are 19.32 and 0.83 m³/s, respectively, and the observed value is equal to 19.41 and 0.43 m³/s, according to the measured discharges of Soleyman Tangeh hydrometric station. SWAT-CUP model has very well simulated peak and base discharges for most of the months. According to the distribution curve of Soleyman Tangeh hydrometric station outflows which is simulated by the model (Fig. 3), the model for simulating the basin flow has an appropriate accuracy ($R^2 = 0.71$) except for the first few months of the year.

The simulation results were evaluated during the calibration and validation stages based on the P-factor, R-factor, Nash–Sutcliffe efficiency (NS), and coefficient of determination (R^2). In a study by Nguyen Khoi and Thi Thom (2015), the SWAT model was used to simulate river flow in the Vietnam drainage basin. The statistical profile coefficients obtained from flow simulations during the calibration and validation stages of the SWAT-CUP model and SUFI2 method indicated a good performance of the SWAT model in flow simulation. The NS coefficient for the three study stations, Ban Don, Cau 14, and Giang Son, was 0.86, 0.84, and 0.87, respectively. Lio et al. (2017) investigated the impact of fertilizers on the outflow of the Xiangxi River basin using the SWAT model, and found that NB fertilizers yielded better results with calibration-derived NS and R^2 assessment indexes of 0.45 and 0.77, respectively, among the fertilizers examined. According to

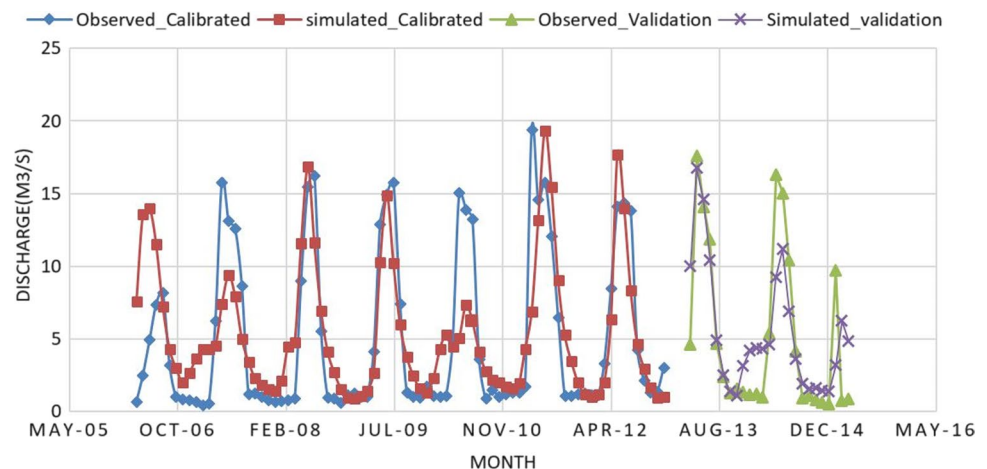
the results of this study, the R^2 statistical parameters were 0.58 and 0.71 for the calibration and validation stages, and 0.57 and 0.70 for NS. Some other studies have reported relatively similar R^2 and NS values, such as 0.45 and 0.77 in the Xiangxi River basin, respectively, and for Vietnam, indicating high accuracy of the SWAT model (agreement index of 0.9) for the upper basin of Shahid Rajaei dam.

Simulation of climate parameters for the upcoming period

The daily climate parameters including precipitation, maximum and minimum temperature, radiation, wind speed, and relative humidity were introduced to SDSM downscaling model. After calibration and validation of the model, RCP2.6 and RCP8.5 climate scenarios were produced for the next 50 years by SDSM climate model. Considering that the temperature and precipitation are the most effective variables on environmental changes among climate processes, especially on the flow rate, Maximum and minimum temperatures and the amount of precipitation for both RCP2.6 and RCP8.5 scenarios were compared to the observation period (from 2006 to 2015). The results of the climatic model illustrated that the temperature will increase and the precipitation will decrease significantly in the upcoming years.

The average annual precipitation is 209 mm in the RCP2.6 scenario and it is 216 mm in the RCP8.5 scenario which are 55% and 53% lower than the period of 1979–2005, respectively (463 mm). Moreover, the average maximum and minimum temperature is 21 and 8 °C in the RCP2.6 scenario, and it is 22 and 8.5 °C in the RCP8.5 scenario, which in comparison with that period (19.22 and 6.74 °C), it shows an increase by 8.5%, 14%, 12%, and 23.5%, respectively.

Fig. 3 The observed and simulated flow rates of Tajan basin hydrometric station in the calibration and validation phases



Fluctuations of flow under climatic scenarios

This study utilized the SDSM downscaling model in the SWAT model to assess the impact of climate change on the variations in the outflow rate of Soleyman Tenge station in the Tajan basin.

The results show that in the RCP2.6 scenario, which experiences a 58% decrease in precipitation and a 14% increase in temperature, the outflow rate will decrease by 16% in the upcoming period (2016–2066) compared to the observed discharge from 2005 to 2015. Similarly, in the RCP8.5 scenario with a 59.5% reduction in precipitation and 21% increase in temperature, the outflow rate will decrease by 16.5% in the upcoming period compared to the observed period from 2006 to 2015. The reduction in precipitation is particularly significant during the warm summer months, leading to a further decrease in outflow during this time. The peak monthly average discharge has also increased by 4% and 5.7% in the RCP2.6 and RCP8.5 scenarios, respectively, compared to the observed peak discharges. Additionally, peak discharges in scenarios will occur five months earlier than the period of 1979–2005, which will have a significant impact on agriculture, aquatic organisms, and the entire ecosystem of the region (Mekong River Commission 2010). Nilawar and Waikar (2019) conducted a study on the impact of climate change on streamflow in Purna river basin. They used the SWAT model on a monthly basis for the period of 1980–2005, with a calibration period of 1980–1994 and a validation period of 1995–2005. Their findings showed a significant increase in both precipitation and temperature compared to the baseline condition for both RCPs. The average monthly streamflow was estimated to increase from 24.47 to 115.94 m³/s, while the average monthly sediment concentration increased from 32.58 to 162.96 mg/l under RCP 4.5 and 8.5.

The outflow rate was compared under different climate scenarios using SPSS 16.0 software and an independent *t*-test. The results showed a significant difference between the historical outflow rate (belonging to the years 1979–2005) and the simulated outflow rate under both RCP climate scenarios (Table 2). The differences were

significant at a 95% confidence level for the outflow rate, 99% for temperature changes, and 97–98% for precipitation changes. These findings suggest that climate change will have a considerable impact on the outflow rate of the Soleyman Tenge hydrometric station.

As a result of the increase in temperature and decrease in precipitation in the area under study, there will be an increase in irrigation demand for rice and other crops downstream of the dam. Additionally, due to the decrease in inflow to the dam, the water supply for agricultural use will also decrease. Karimi et al. (2017) have shown that climate change has an impact on Iranian agriculture, affecting the yield of crops due to changes in precipitation and temperature. Therefore, changes in the flow rate to the Shahid Rajaee dam will affect the existing water supply, water requirement for crops, and the income and welfare of farmers. In view of the impact of climate change on the flow rate, it is expected that water storage in the study area will decrease. To ensure proper water supply, essential changes should be made in irrigation networks and their management to prevent water wastage. Since rice cultivation requires a large amount of water to prevent weed growth, appropriate herbicides can be used to eliminate weeds and reduce the need for water, thereby decreasing the reduction of crop yields due to water shortages.

Du et al. (2019) investigated how climate change impacts stream temperature patterns in the Athabasca River Basin by using the SWAT model. Initially, the streamflow and stream temperatures were calibrated and validated. Next, the impact of climate change was evaluated using three climate models under RCP4.6 and RCP8.5 scenarios. The findings indicate that the basin's streamflow would rise, despite the projected increase in evapotranspiration due to the warmer conditions. Additionally, the annual stream temperatures are projected to rise by 0.8–1.1 °C in the mid-century and by 1.6–3.1 °C in the late century. This increase in stream temperatures could affect water quality dynamics by increasing biochemical reaction rates and reducing dissolved oxygen concentrations in the streams.

Table 2 Average changes in temperature, precipitation, and outflow rate in the years 2015 to 2006 compared to the next 50-year period under RCP scenarios for 2016–2066

Variation	RCP2.6 scenario			RCP8.5 scenario		
	Temperature	Precipitation	Outflow rate	Temperature	Precipitation	Outflow rate
Percentage of difference	+ 14	+ 58	– 16	+ 21	+ 59.5	– 16.5
<i>T</i>	– 2.69*	4.61*	0.960*	– 3.87*	4.55*	0.960*

*Indicates a significant difference (95% confidence level) of the mean of the data in the considered scenario compared to the historical period

+ Means increase

– Is in the sense of reduction

Flow fluctuations under land use scenarios

In order to investigate the impact of land use change on the outflow rate of Tajan river basin four new land use maps were produced under various scenarios with positive and negative trend toward the current map, as it is shown in Fig. 4, using the available tools in the GIS software. According to Table 3, based on vegetation development, positive trend land use scenarios include optimistic and highly-optimistic scenarios while negative trend land use scenarios toward reducing vegetation in the upper basin of Tajan have been developed under two pessimistic and highly pessimistic scenarios to assess their effect on the outflow rate, and based on that, the land use has been improved to reduce the vegetation.

The maps produced under each scenario were introduced to SWAT model and then, the outflow rate of Tajan basin was simulated based on every land use scenario. According to Fig. 5, flow fluctuations under the positive (optimistic and highly optimistic) scenarios are shown in comparison with the flow rate measured at Soleyman Tangeh hydrometric station under the current land use scenario and they have led

to the increase in outflow rate by 9% and 8.5%, respectively. In addition, under negative trend land use scenario (pessimistic and highly pessimistic), the output flow rate increased by 10.5% and 15.88%, respectively. Flow fluctuations were simulated under negative trend land use scenario and measured at the hydrometric station; this procedure is illustrated in Fig. 6. Based on the obtained results and considering the results of fluctuations under RCP2.6 and RCP8.5 climate scenarios and their effect on decreasing flow rate, discharge can be effective in raising the flow to the dam, and subsequently increasing the water supply in combination with climate and negative trend land use scenario.

The study found that in all four scenarios, changes in flow rate occurred during the colder months of the year. This suggests that temperature increases and precipitation changes during these seasons directly exacerbate the impact of land cover changes on the inflow rate from upstream of the dam. This finding is consistent with the results of a study by Bussi et al. (2016), which examined the impacts of land use and climate change on the hydrologic regime and sedimentation rate of the Thames River Basin in England. Other studies by Lutz et al. (2014), Lauri et al. (2012), Johnston and Kumm

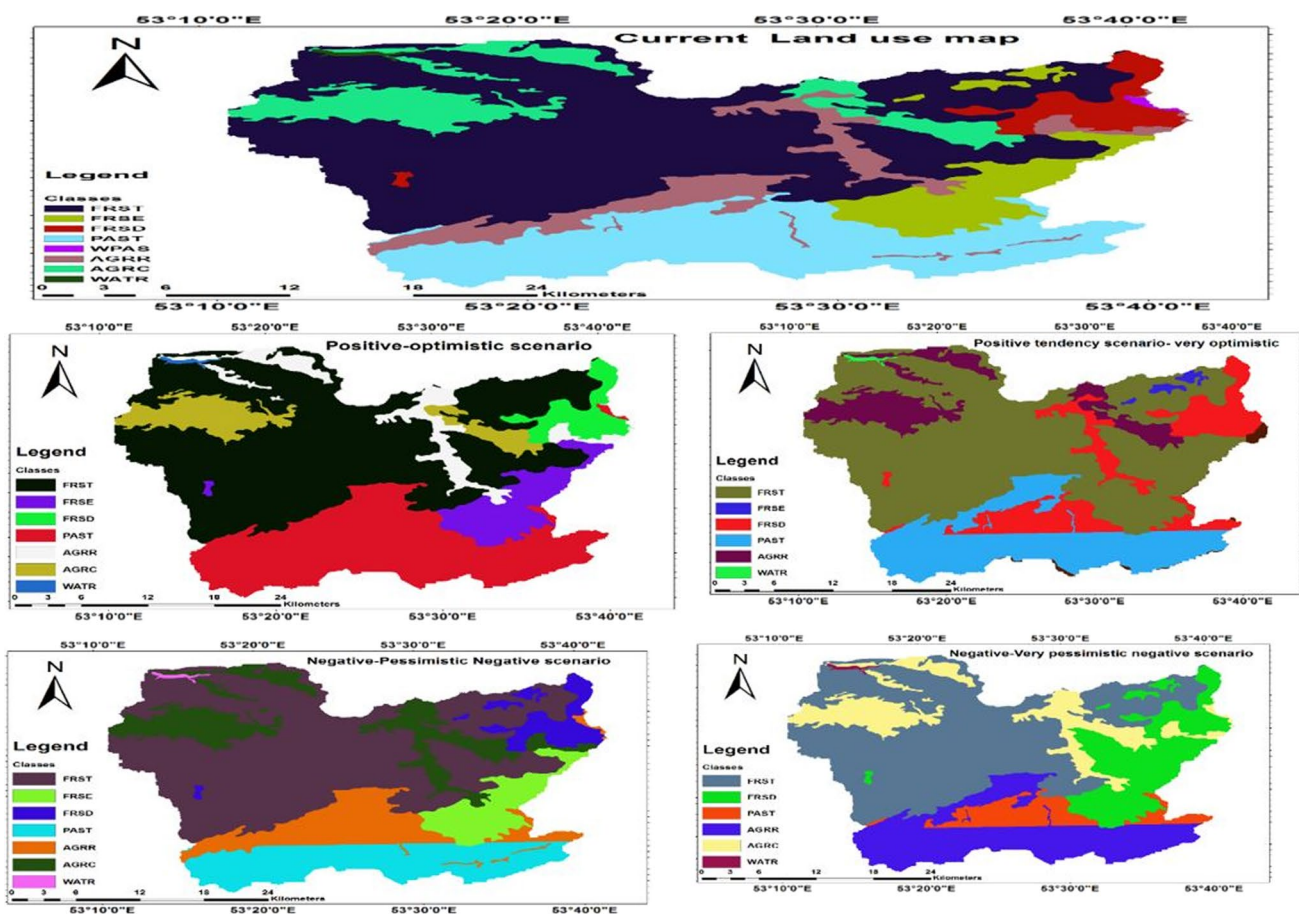


Fig. 4 Current land use map and land use maps of Tajan basin under the produced scenarios

Table 3 Land use scenarios produced to assess the outflow rate fluctuations of the upper basin of Tajan

The scenario with a positive trend	Optimistic scenario	Areas with low slope	Poor pastures to good pastures
			Rainfed lands to irrigated and horticultural lands Semi-dense forest to dense forest
		Areas with high slopes	Irrigated and horticultural lands to good pastures Thinning forest to dense forest
	Highly optimistic scenario	Areas with low slope	Poor pastures to good pastures Irrigated, rainfed and horticultural lands to thinning forests Thinning forest to semi-dense forest
		Areas with high slopes	Good pastures to thinning forest Irrigated and horticultural lands to good pastures
The scenario with a negative trend	Pessimistic scenario	Areas with low slope	Irrigated and horticultural lands to rainfed lands
			Poor pastures to irrigated and horticultural lands Semi-dense forest to thinning forest
		Areas with high slopes	Part of the good pastures to irrigated and horticultural lands Thinning forest to good pasture
	Highly pessimistic scenario	Areas with low slope	Irrigated and horticultural lands to rainfed lands Poor pastures to rainfed lands Semi-dense forests to thinning forest
		Areas with high slopes	Part of the dense forest to the semi-dense forest Thinning forest to good pastures Good pastures to poor pastures

(2012), and Nesbitt et al. (2004) also support the idea that climate change in drainage basins affects the flow rate and land cover use. The study concludes that the effect of precipitation and temperature on the outflow rate is greater than that of land use changes. Jodar-Abellan et al. (2019) used the SWAT model to analyze the complex hydrological dynamics in five Mediterranean ravine basins. They used GIS-based tools from 1990, 2000, 2006, and 2012 to assess five land use scenarios, including a baseline scenario with no urbanization. Their findings revealed that flood risk in the study areas has increased due to changes in land use, with large urban growth having a significant impact. Furthermore, they found that some discharges increased significantly from the baseline land use scenario (50 m³/s, 190 m³/s, and 380 m³/s) to the most urbanized scenario (235 m³/s, 385 m³/s, and 940 m³/s), respectively.

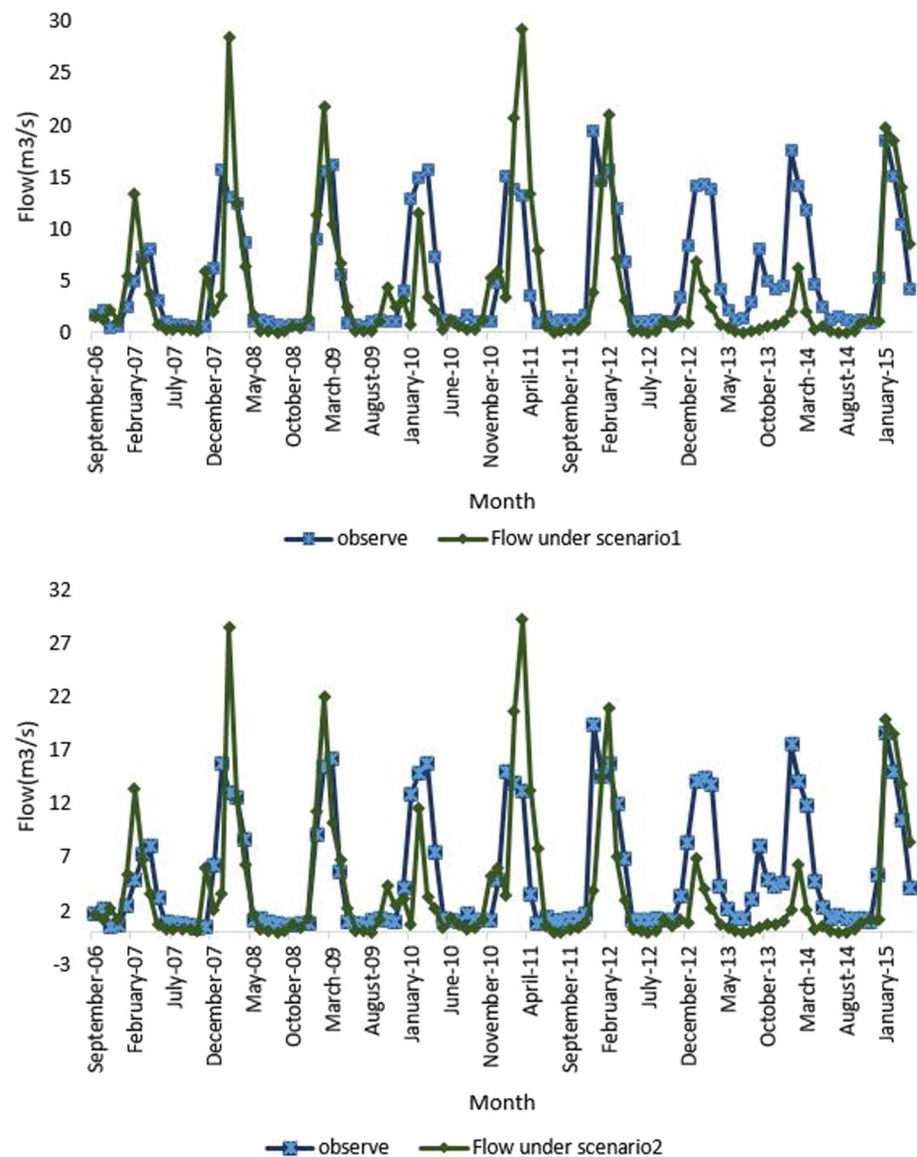
Conclusion

According to R^2 which is 0.58 and NS which is 0.75, in the calibration stage and NS s which equal 0.71 and 0.70 in the validation stage, the accuracy of SWAT model was evaluated in the simulation of the flow rate; afterward, it was done based on the meteorological data of Kiasar synoptic station,

which is selected for more accurate and complete data. The climate parameters were produced by SDSM climate model under minimum and maximum RCP scenarios and introduced to SWAT hydrologic model to simulate the flow. The results regarding the assessment of the effect of climate parameters on the outflow rate of Tajan Basin have shown the discharge under RCP2.6 scenario, and will decrease by 16% and 16.5%, respectively, in RCP8.5 scenario. In the next stage, the land use scenarios were developed in two positive and negative trends based on the ability to decrease or increase the vegetation via GIS software. Under the optimistic land use scenario, the existence of 60.57% of forest cover, 26% of pasture, 13.11% of agricultural land and 0.22% of groundwater resources led to the increase in the flow rate by 9% and RCP2.6, and RCP8.5 scenarios were 1.56% and 1.55% less in comparison with the impact of climate change on discharge fluctuations. Moreover, in a highly optimistic scenario with land cover, 70.43% of forest land, 19.76% of pasture, 9.6% agricultural land and 22% of aqueous levels resulted in an increase by 8.6% in outflow rate while it has been less effective by 1.54% and 1.52%, respectively, on flow rate fluctuations in basin when it is compared to the effect of climate change under RCP2.6 and RCP8.5 climate scenarios.

In the pessimistic scenario with land cover, the existence of 60.6% of forested lands, 14.7% of pasture, 24.47%

Fig. 5 Current fluctuation curve under positive land use scenarios



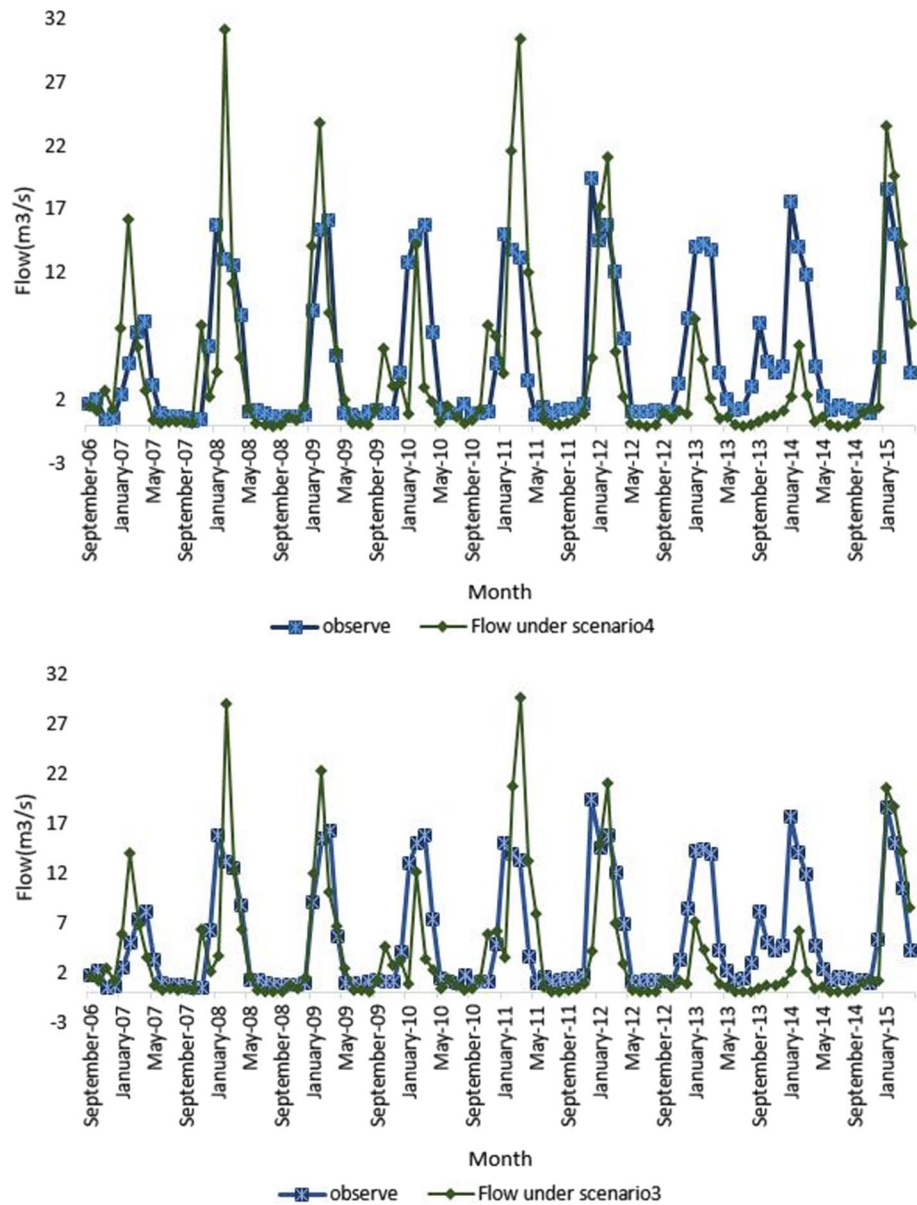
of agricultural land and 0.22% of water levels has led to an increase of 10.63% in the flow rate while it has been less effective at 1.66% and 1.64% respectively on flow fluctuations when it is compared to the effect of climate change scenarios RCP2.6 and RCP8.5 Besides, the simulated flow rate under highly pessimistic scenario with land cover raised by 15.9%, having 60.9% of forests (45.14% of dense and 15.44% of thinning forests), 6.19% of pasture, 33.02% of agricultural land and 0.22% groundwater resources while it has been less effective by 2% and 1.96% respectively when it is compared to the effects of climate scenarios on fluctuations.. It is obvious in scenarios that pasture and agricultural lands are more effective on the increase in flow rate.

The impact of temperature increase and precipitation decrease will reduce the flow rate brought to Shahid Rajaee Dam and it can reduce water supply for agricultural and drinking purposes in the downstream of the dam. So,

cultivation and harvesting season should also be changed for the optimal water use in agriculture. This issue will have a significant impact on the efficiency of agricultural production in the downstream of the dam, as well as the adverse environmental effects. Through comparing the impact of land use scenarios with climate scenarios on the flow brought to the dam, it can be seen that upstream land use should approach a very pessimistic scenario in order to raise the flow rate and change the negative effect of climate on bringing it to Shahid Rajaee Dam.

According to the analysis, it can be concluded that the effect of climate change on the outflow rate fluctuations is higher than land use change. Moreover, according to Branger et al. (2013), to study the impacts of land use changes, these applied changes should be investigated based on the type and range of the research and its requirements in case of area, and the ability of suitable land cover should be maintained

Fig. 6 Current fluctuation curve under negative land use scenarios



and increases as much as possible to achieve the project purposes.

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Declarations

Conflicts of interest The authors of this article declared no conflict of interest regarding the authorship or publication of this article.

Ethical standards All procedures followed were in accordance with the ethical standards of the local Ethical Committee of Cerrahpasa Medical faculty and with the Helsinki Declaration of 1975, as revised in 2000.

Informed consent The authors confirm independence from the sponsors; the content of the article has not been influenced by the sponsors. Informed consent was taken.

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