Chapter 4

Assessing the Impact of Land Use Changes and Rangelands and Forest Degradation on Flooding Using Watershed Modeling System

Nafise Moghadasi, Iman Karimirad and
Vahedberdi Sheikh

Additional information is available at the end of the chapter

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Abstract

Extensive flood damages all over the world necessitate flood risk mitigation. Land use changes affect hydrological characteristics such as total runoff and flood's peak flow. This study investigates the impacts of land use change on flooding of the Boostan dam catchment in Golestan province, Iran. For this purpose, watershed modeling system (WMS) is used to compare different types of land uses between 1996 and 2006 using corresponding maps. After calibration and validation of the model in each period of time, flooding of the catchment was evaluated using two representative parameters of peak flow and volume of flood. Comparison of land use maps in 1996 and 2006 revealed the total rangelands have been increased while good rangeland areas decreased, fair rangeland increased, and poor rangeland remained relatively constant. It means the region faces decrease in high-quality rangelands in the catchment. Also the forest areas decreased. Both degradation of rangeland and deforestation intensify flooding. But peak flow and flood volume of the whole catchment have been mitigated. Because in spite of negligible change in total curve number (CN) of the catchment, rangelands in downstream and near residential areas converted to agricultural lands and upstream agricultural lands transformed to high- and medium-density rangelands. This means that distribution of land use changes was in such a way, influential upstream areas in flooding, associated with reduced CNs. So the implemented biological measures have reduced the flooding potential of the catchment. Sensitivity analysis of the model showed that 5% decrease in CN can cause 40% decrease in peak flow of the catchment and in contrast and 5% increase in CN can enhance flood peak flow up to 60%.

Keywords: flood, sensitivity analysis, curve number, Boostan dam

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1. Introduction

With the rapid population increase and the associated demand on land resources, it is now incumbent upon policy makers and land use planners to adopt preventive and restorative measures [1]. Land use is an indicator of human interaction with nature. Therefore, it is necessary to discover and monitor land use changes in order to either protect the environment or ensure sustainable development [2]. Hydrological response of a watershed is representative of a bunch of its conditions and characteristics, and so land use changes may affect the performance of watershed [3]. Hydrologic impacts of land use and land cover change appear in many ways, such as total runoff, base flow, flood's peak flow, soil moisture, and evapotranspiration [4].

Watershed is a complex open system that should be modeled to achieve the desired objectives such as assessment and forecasting. Through the modeling of complex systems, the cost of studies will reduce, and it will be possible to predict how to manage the watershed for the future. One of the applications that are capable of geometric and hydrological modeling of watershed is the watershed modeling system (WMS). WMS was developed by Brigham University researchers in 1999 in cooperation with the US army corps of engineers. Due to the variety of appropriate hydrologic and hydraulic models included in WMS, nowadays experts use it to assess the watershed management projects [5].

Checking the stats and information about annual damages due to flooding in Iran and the whole world indicates the impact of this phenomenon on human well-being. In Golestan province, over the past four decades, 71 major flood events have been reported that caused total 380 casualties. Therefore, developing integrated programs to curb, control, and utilize the flood using appropriate management measures is inevitable [6]. Our understanding about the effects of mechanical and biological measures on watershed response to rainfall is one of the key issues in the watershed management and flood control studies. Implementation of any treatment in the watershed associates with changes in Manning's roughness coefficient, time of concentration, vegetation, and permeability of the soil. So it can cause changes in rainfall-runoff relation of the watershed and eventually flood peak discharge [7].

Many researchers investigated land use changes in different places. Ariapour et al. [8] studied land use changes of Barabad-Darook district in Sabzevar City, Iran, during 1987–2007 using remote sensing. Results indicated that third-rated and first-rated rangelands have been decreased from 6.85 to 4.14% and from 0.35 to 0.01%, respectively. Also irrigated agricultural lands are to be decreased from 6.53 to 0.07%. Therefore first-rated rangelands and irrigated agricultural lands have been nearly disappeared in this 20-year period. Nasri et al. [9] in Ardestan, Iran, used GIS and showed that almost 31% of the total area of the region had undergone some changes during a 30-year studied period.

Several studies on WMS and the relationship between land use change and floods have been conducted in Iran and other countries that some of them are mentioned here. Khosroshahi and Saghafian [10] used WMS and, according to curve number (CN) parameter sensitivity analysis, introduce it as the most sensitive parameter for calibration. Githui et al. [11] studied River

Nzoia catchment, Kenya, in a time period with an increase in agricultural area from 39.6 to 64.3% and a decrease in forest cover from 12.3 to 7.0%. It caused difference in runoff ranging from 55 to 68%. Assessing the impacts of land cover change on hydrological regimes which has been done by Germer et al. [12] showed influence of land use change and proved that deforestation for pasture may increase runoff volumes over wide regions of Amazonia. Hosseini [13] studied the WMS model capability in determining the flood peak flow in the Khuzestan Province, Iran. The results showed that WMS models' computed flood has a good correspondence with empirical equations' calculated values in this Khuzestan Province.

Asharf et al. [14] assessed the impact of land use change on Rawal watershed, sub-Himalayan region hydrology. They observed a decrease of over 16% in the scrub forest coverage, while built-up land increased threefold during 1992–2010 period that resulted in an increase of about 6% in the water yield and 14.3% in the surface runoff of the watershed. Zadsar and Azimi [15] studied impact of land use changes on hydrological response Gorganroud catchment, Golestan, Iran, using SWAT. Accordingly, biomechanical measures can reduce runoff up to 20.7%.

Although flood is mainly a function of climatic conditions, especially the amount, intensity, and spatiotemporal distribution of rainfall, various features of watershed such as land cover and land use that consist of rangeland and forest degradation are other effective parameters. In this chapter, the effect of land use changes, especially rangeland and forest degradation, on peak flow of flood have been evaluated in Boostan dam catchment involving 14 watersheds.

2. Materials and methods

Boostan dam catchment is a part of Gorganroud basin in the east of Golestan province, Iran (**Figure 1**). It drains approximately 1562 km^2 and is situated within 37°23ˈ to 37°46ˈ north latitude and 55°26ˈ to 56°4ˈ east longitude.

In this chapter, impact of land use changes specially rangeland and forest degradation on runoff generation and flooding potential in Boostan dam catchment with 14 sub-basins was studied by employing WMS (version 7). For this purpose, digital elevation model (DEM) is prepared, and land use maps of the catchment in two time periods of 1996 and 2006 (**Figure 2**) are compared in GIS. This time interval was chosen due to major watershed management measures in the region performed in these years. The investigation involves amount of changes in land use as well as its spatial distribution. So areas of each land use types such as forest, rangeland, and agriculture are calculated and compared. Then distribution of the changes in upstream and downstream areas of each watershed was determined.

In general, watershed management measures in the Boostan dam catchment area can be classified in mechanical operations including construction of debris dams (61 items), rocky mortar structures (5 cases), and gabioning (55 items) and biological measures such as grazing plans, pitting along with seeding, and fertilizing. Also in Chenarly, Gharnave, and Karim ishan sub-basins' extensive forestation has been carried out.

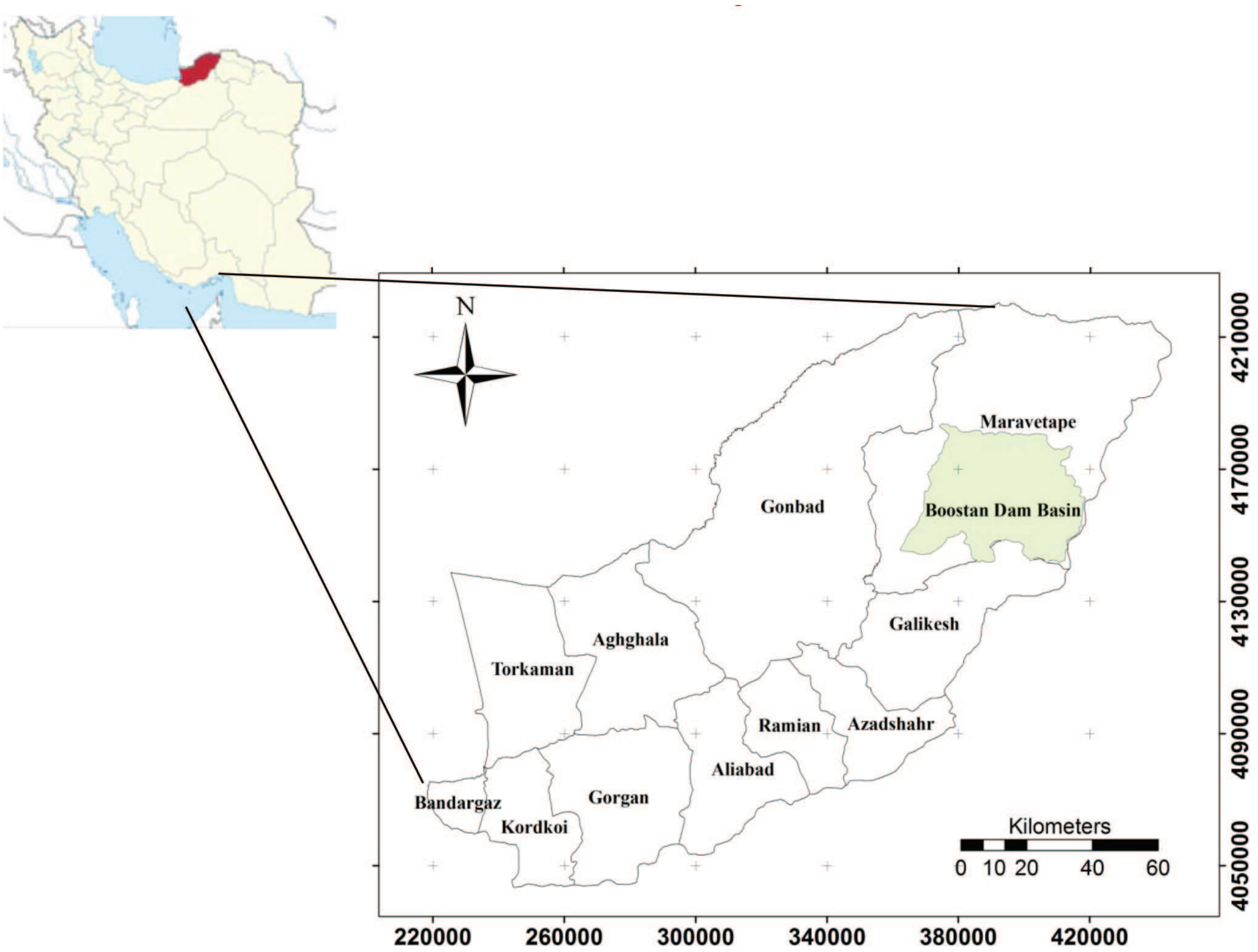

Figure 1. The situation of Boostan dam catchment in Golestan province, Iran.

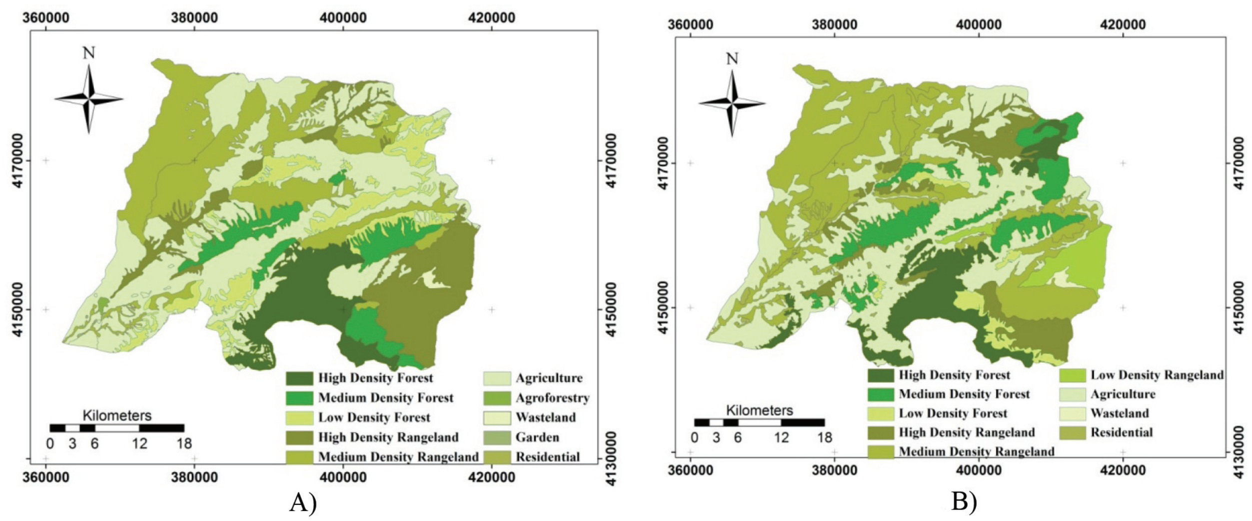

Figure 2. Boostan dam catchment land use map: (A) 1996 and (B) 2006.

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In order to incorporate spatial distribution of land use changes, the catchment was divided into 14 watersheds using WMS. Runoff curve number values were obtained and rainfall-runoff modeled according to soil conservation service (SCS) method. The runoff curve number (also called a curve number or simply CN) is an empirical parameter used in hydrology for predicting direct runoff caused by rainfall. CN is a dimensionless number that relates to soil and covers conditions of the catchment and has a range of 0–100. CN = 0 means no runoff, and CN = 100 means no infiltration, and it is documented by SCS [16]. The soil conservation service (SCS) model estimates precipitation excess as a function of cumulative precipitation, soil cover, land use, and antecedent moisture. This method generates CN values integrating land use/land cover and hydrologic group of soil to determine precipitation lost [17]. S in this method is potential maximum retention after runoff begins (Eq. 1). On the other hand, R indicates total runoff (Eq. 2). This equation is only valid for $P > 0.2S$; if P is less than or equal to 0.2S, there is no runoff. In this section, the lag time is calculated using the SCS method, which is done separately for each sub-basin. The SCS CN method relationships are as follows (Eq. 3 to Eq. 6):

$$S = \frac{25400}{CN} - 254 \tag{1}$$

$$R = \frac{(P - 0.2S)^2}{(P + 0.8S)} \tag{2}$$

$$T_{lag} = \frac{L^{0.8}(S + 1)^{0.7}}{1900\sqrt{Y}} \tag{3}$$

$$T_P = \frac{\Delta t}{2} + T_{lag} \tag{4}$$

$$U_P = 2.08\frac{A}{T_P} \tag{5}$$

$$T_c = 1.67\, T_{lag} \tag{6}$$

where P = accumulated rainfall depth at time t; T_{lag} = the basin lag, defined as the time difference between the center of mass of rainfall excess and the peak of the unit hydrograph (UH); L = hydraulic length (the longest flow path in the watershed); Y = average watershed slope in percent; T_p = time to peak; Δt = the excess precipitation duration (which is also the computational interval in the run); U_p = peak of standard UH; A = watershed area; and T_c = time of concentration.

The model calibration performed by optimizing estimated curve number and efficiency of optimized model is evaluated by comparing observed and simulated hydrographs of real flood events. Some other flood hydrographs used to indicate validity of the model. After validating the hydrological model of Boostan dam catchment, the effect of land use changes that caused changes in curve numbers was examined in several rainfall events. It should be noted that to investigate the impact of rangeland and forest degradation on flooding of the catchment, two representative parameters of peak flow and volume of flood were considered.

Watershed modeling system (WMS) is equipped with automatic calibration in a feasible range. In this approach changing of some parameters continues until the best matching of the observed hydrograph and simulated one is achieved, and the most suitable values of calibration parameters are obtained. In calibration phase, due to the importance of peak discharge of flood, maximum discharge is considered as the fitting index. Regarding the use of SCS method, the curve number (CN) is considered as calibration parameter.

Physiographic characteristics are main inputs of hydrological modeling software WMS. In order to calculate physiographic characteristics of the catchment, 1:250,000 topography maps of national cartographic center of Iran in 2006 have been used. Calculated values for each watershed of Boostan dam catchment are shown in **Table 1**.

Soil hydrologic group map is another input data for SCS model, and the amounts of runoff depend on it. Map of soil hydrologic group of the catchment is presented in **Figure 3**. In **Figure 3**, B and C represent soil hydrologic groups with permeability in range of 3.8–7.5 and 1.3–3.8, respectively.

As the next step, each of land use maps of 1996 and 2006 was integrated with soil hydrologic group map in WMS, and then using the table of CN (**Table 2**), curve numbers per watershed were determined. **Figure 4** represents curve number map of Boostan dam catchment in 1996 and 2006.

To simulate the catchment in WMS, flood hydrographs recorded in Tamar hydrometric station at the catchment's outlet were investigated. To determine the corresponding rainfalls, daily

Watersheds	Area (km^2)	Slope (m/m)	Average altitude (m)	Length of main stream (m)	Slope of main stream (m/m)
Kalshor	116.65	0.118	414.90	32580.5	0.013
Shordare	123.23	0.181	461.21	24668.4	0.015
Aghemam	143.02	0.192	548.49	20832.1	0.015
Chenarli	69.04	0.165	756.52	12495.7	0.022
Gharnave	94.97	0.239	934.82	19967.9	0.034
Karimishan	128.40	0.208	675.61	25972.3	0.026
Ghopan	46.19	0.174	396.39	13068.8	0.029
Azizabad	112.87	0.188	375.25	25304.3	0.011
Zav	135.01	0.245	906.04	17861.9	0.025
Golidagh	190.20	0.221	860.51	38121.7	0.015
Yelcheshme	265.01	0.161	1333.48	30862.5	0.028
Sub-basin 1	55.64	0.129	307.54	10875.7	0.017
Sub-basin 2	45.34	0.067	212.55	14189.6	0.011
Sub-basin 3	41.41	0.082	174.94	9477.4	0.015

Table 1. Physiographic characteristics of Boostan dam catchment.

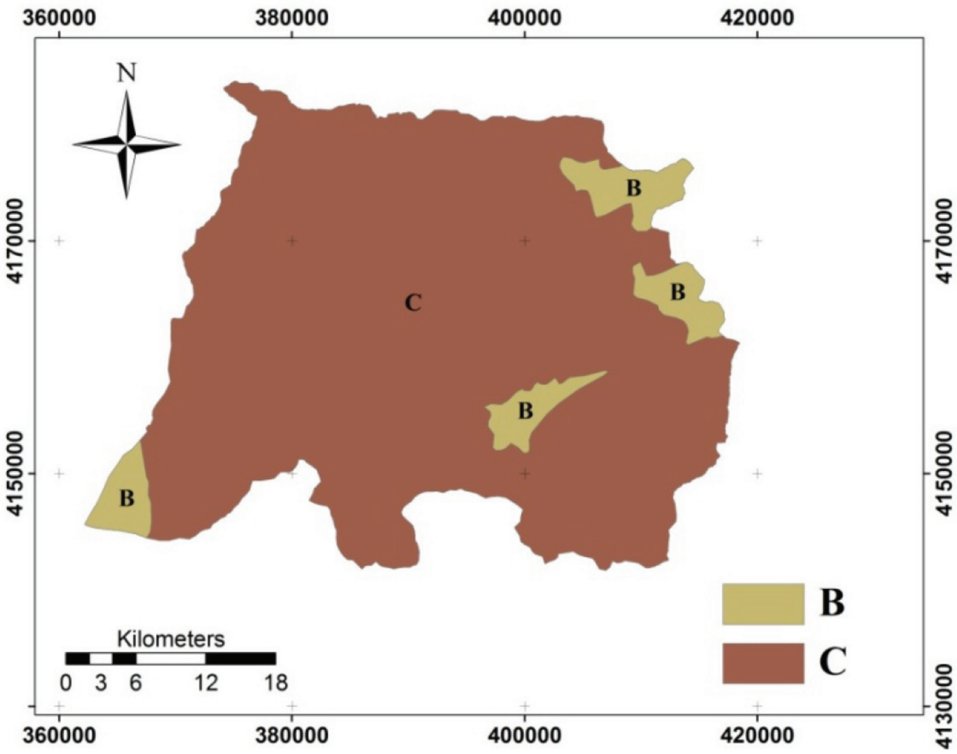

Figure 3. Soil hydrologic group map of Boostan dam catchment.

Cover description		**Curve number for hydrologic soil group**			
Cover type	Hydrologic condition	A	B	C	D
Pasture, grassland, or range-continuous forage for grazing	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Woods	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30	55	70	77
Farmstead building, lanes, driveways, and surrounding lots	—	59	74	82	86

Table 2. Runoff curve number for some land use types.

rainfall records of rain-gauge stations in and around Boostan dam catchment provided by Golestan Regional Water Authority are used. **Table 3** shows some information about these stations.

It should be noted that in this chapter, to analyze the model's results, observed and simulated hydrographs of three flood events are compared using four statistics including root mean square error (RMSE), coefficient of determination (R^2), Nash Sutcliffe efficiency index (E), and index of agreement (d). RMSE indicates the error rate, and zero is the best value for it [18]:

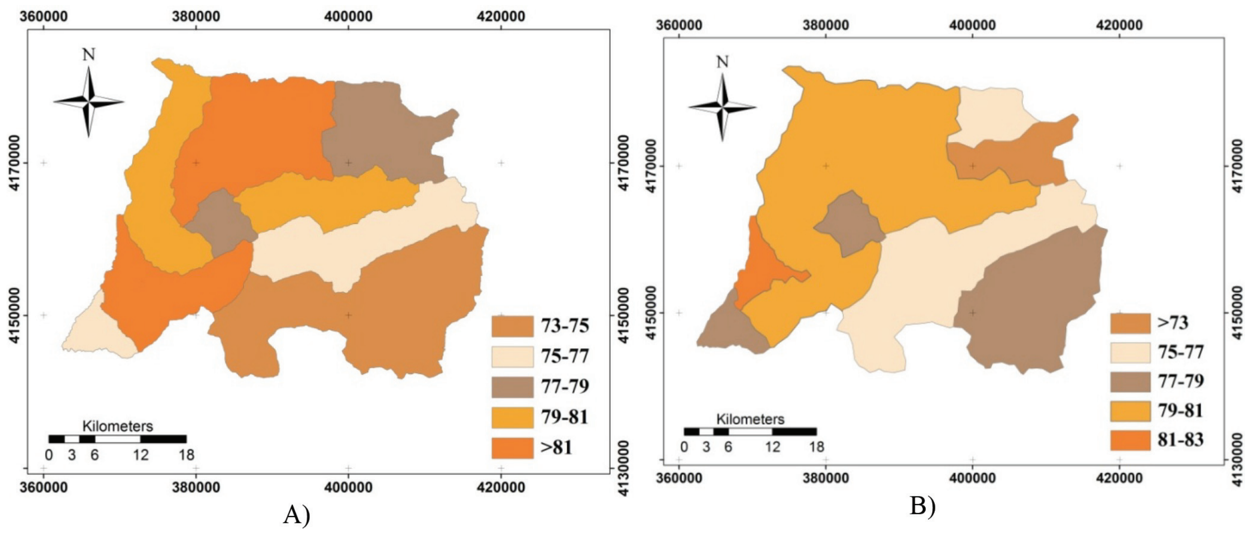

Figure 4. The curve number map of Boostan dam catchment: (A) 1996 and (B) 2006.

Station name	Date of establishment	Altitude (m)	Geographical coordinates	
			Latitude	Longitude
Tamar	1965	132	37°28'	55°29'
Park meli Golestan	1997	460	37°24'	55°49'
Gharnagh	1996	500	37°43'	55°43'
Golidagh	1996	1000	37°39'	56°00'
Pishkamar	1970	250	37°36'	55°35'
Zavebala	1997	700	37°31'	55°45'

Table 3. Some information about rain-gauge stations in and around Boostan dam catchment.

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} (O_i(t) - P_i(t))^2}{n}} \tag{7}$$

in which O_i (t) is observed discharge at time t, Pi (t) is calculated discharge at time t, and n is the number of observations.

Coefficient of determination is a number between 0 and 1 and the number closer to 1; the correlation between the observed data and computed values is better [19]:

$$R^2 = \left(\frac{\sum_{i=1}^{n} \left(O_i - \overline{O}\right)\left(P - \overline{P}\right)_i}{\sqrt{\sum_{i=1}^{n} \left(O_i - \overline{O}\right)^2} \sqrt{\sum_{i=1}^{n} \left(P_i - \overline{P}\right)^2}} \right)^2 \tag{8}$$

Nash Sutcliffe efficiency index ranges from negative infinity to 1 that means observation data and calculated ones are entirely corresponded [20]. An efficiency of 1 (E = 1) corresponds to a perfect match between model and observations. An efficiency of 0 indicates that the model predictions are as accurate as the mean of the observed data, whereas an efficiency less than zero ($-\infty < E < 0$) occurs when the observed mean is a better predictor than the model. Essentially, the closer the model efficiency is to 1, the more accurate the model is:

$$E = 1 - \frac{\sum_{i=1}^{n} (O_i - P_i)^2}{\sum_{i=1}^{n} \left(O_i - \overline{O}\right)^2} \tag{9}$$

Finally index of agreement is between 0 and 1; the values closer to 1 show higher accordance between the observed and computed data [19]:

$$d = 1 - \frac{\sum_{i=1}^{n} (O_i - P_i)^2}{\sum_{i=1}^{n} \left(\left|P_i - \overline{O}\right| + \left|O_i - \overline{O}\right|\right)^2} \tag{10}$$

Sensitivity of the model to CN was analyzed to assess effectiveness of this variable factor on floods in the region. In this chapter, the sensitivity of flood peak flow at the catchment's outlet to the curve number was determined. For this purpose, the parameter changed from −10 to +10%, and its impact on the flood discharge was determined.

3. Results

Land use changes were assessed using GIS in ArcMap 9.3 framework. Land use maps have been prepared by the Department of Natural Resources and Watershed Management in Golestan province. The results are presented in **Table 4**. Accordingly the whole area of forests and rangelands decreased from 1060.36 to 1027.67 km^2 in 10 years. Although the total area of rangeland increased by 17.24 km^2, high-density rangeland decreased by 78.47 km^2, medium-density rangeland increased by 93.24 km^2, and low-density rangeland area remained relatively constant. This represents a decrease in rangeland quality of the catchment, which has a negative impact on its flooding.

Result also revealed that rangelands in downstream and near residential areas changed to agriculture. On the other hand, upstream agriculture areas in 1996 changed to high- and medium-density rangeland probably due to lack of precipitation. Also some areas located in Golestan National Park territory changed from medium-density forest to medium-density rangeland that can be caused by natural or anthropogenic factors that have a great importance from environmental point of view.

Land use	1996		2006		Percent of change
	Total catchment (%)	Area (km^2)	Total catchment (%)	Area (km^2)	
Agriculture	32.20	508.31	33.76	533.02	4.84
Agroforestry	0.14	2.14	0.01	0.20	−92.86
Garden	0.05	0.81	0.02	0.30	−60.00
High-density forest	9.21	145.36	10.24	161.73	11.18
Semi-density forest	7.39	116.58	9.66	152.46	30.72
Low-density forest	9.07	143.19	2.60	41.01	−71.33
High-density rangeland	14.22	224.39	9.24	145.92	−35.02
Semi-density rangeland	23.48	370.44	29.56	466.68	25.89
Low-density rangeland	3.83	60.40	3.79	59.87	−1.04
Residential	0.10	1.51	0.74	11.65	640.00
Wasteland	0.31	4.83	0.38	6.01	22.58

Table 4. Land use distribution of Boostan dam catchment.

The other land use changes occur in this region are change from medium-density forest to low-density forest. Moreover, some high-density forests and low-density forests have been cultivated. Of course in few cases low-density forest changed to medium-density forest.

Determined curve numbers using calibrated Boostan dam catchment model before and after the implementation of watershed management measures are presented in **Table 5**. As demonstrated the total catchment's CN decreased from 78.21 to 78.05 that is ignorable.

Soil moisture retention, lag time, and time of concentration are calculated using SCS method and CN values. These calculations are performed by WMS software for each 14 watersheds. These parameters before and after implementation of watershed management measures are shown in **Table 6**.

Calibration and validation of WMS models are performed using three and two flood events in Tamar hydrometric stations, respectively. These flood hydrographs are shown in **Figures 5** and **6**.

The results of model verification indicate that there was a good coincidence between observed data and computed hydrographs in WMS. For example, coefficients of determination values were between 0.87 and 0.92 which suggests a high correlation. **Table 7** shows calculated statistics for the flood events used in model validation.

Table 8 demonstrates the impacts of land use changes due to rangeland and forest degradation on peak flow, and volume of flood in different return periods is shown. The mentioned results show that, for example, the mean 25-year peak flow decreased 15% between 1996 and 2006.

Table 9 shows different impacts of land use change due to rangeland and forest degradation on peak flow and volume of flood in all 14 watersheds of the catchment in 25-year return period.

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Watersheds	1996	2006	Percent of change
Kalshor	80.06	79.66	−0.50
Shordare	81.51	80.52	−1.21
Aghemam	8170	79.94	−2.15
Chenarli	78.83	76.99	−2.33
Gharnave	78.04	70.29	−9.93
Karimishan	82.13	79.58	−3.10
Ghopan	78.94	78.07	−1.10
Azizabad	82.47	79.68	−3.38
Zav	73.44	75.14	2.31
Golidagh	74.48	75.73	1.68
Yelcheshme	74.42	78.82	5.91
Sub-basin 1	80.95	80.50	−0.56
Sub-basin 2	82.10	82.31	0.26
Sub-basin 3	74.80	77.15	3.14
Total	78.21	78.05	−0.20

Table 5. Curve number values of the watersheds in 1996 and 2006.

Watersheds	1996			2006		
	Soil moisture retention (mm)	Lag time (h)	Time of concentration (h)	Soil moisture retention	Lag time (h)	Time of concentration (h)
Kalshor	12.65	3.23	5.39	12.97	3.27	5.46
Shordare	11.52	2.56	4.28	12.29	2.64	4.41
Aghemam	11.38	2.19	3.66	12.75	2.31	3.86
Chenarli	13.64	1.89	3.16	15.18	1.99	3.32
Gharnave	14.29	2.10	3.51	21.47	2.62	4.38
Karimishan	11.05	2.40	4.01	13.04	2.61	4.36
Ghopan	13.55	1.78	2.97	14.27	1.83	3.06
Azizabad	10.80	2.49	4.16	12.96	2.72	4.54
Zav	18.37	2.23	3.72	16.81	2.13	3.56
Golidagh	17.41	3.86	6.45	16.28	3.72	6.21
Yelcheshme	17.46	3.92	6.55	13.65	3.44	5.74
Sub-basin 1	11.95	1.73	2.89	12.31	1.75	2.92
Sub-basin 2	11.08	2.83	4.71	10.92	2.80	4.68
Sub-basin 3	17.11	2.53	4.23	15.05	2.36	3.94

Table 6. Soil moisture retention, lag time, and time of concentration before and after implementation of watershed management measures.

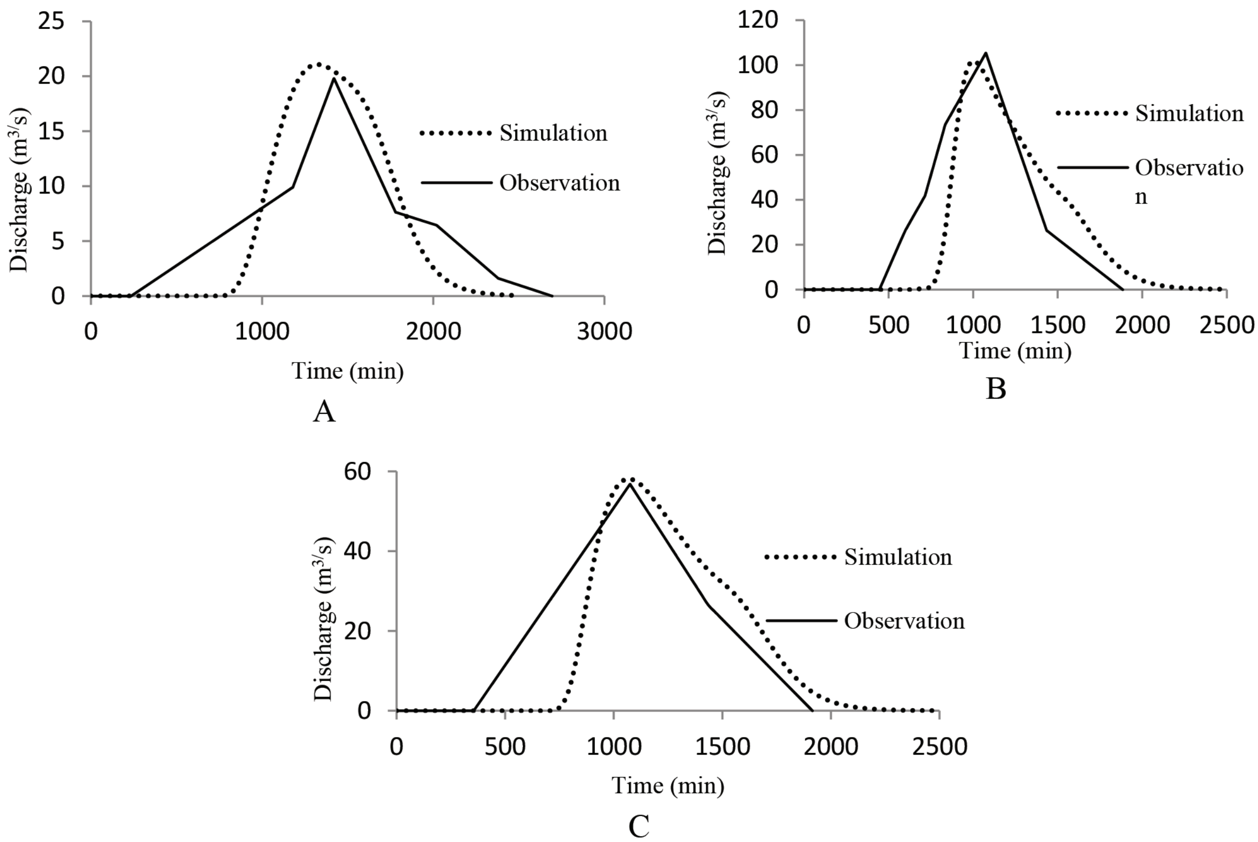

Figure 5. Observed and simulated flood hydrographs in Tamar station (used for calibration): (A) 11/6/1997, (B) 5/30/1998, and (C) 9/11/1998.

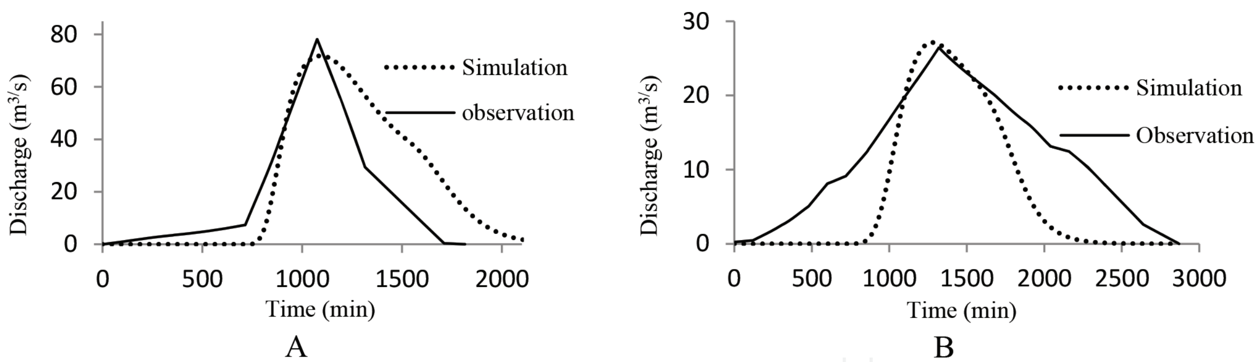

Figure 6. Observed and simulated flood hydrographs in Tamar station (used for validation): (A) 7/25/1998 and (B) 4/10/1999.

Sensitivity analyses investigate the model's sensitivity to changes in CN of watersheds of Boostan dam catchment. **Figure 7** shows flood's peak flow sensitivity to changes in curve number. Accordingly, 10% decrease and increase in CN values can cause up to −50 and 150% change in peak flow, respectively.

Date of event	Index of agreement	Nash Sutcliffe efficiency index	Coefficient of determination	Root mean square error
1997/11/6	0.92	0.54	0.92	0.58
1998/5/30	0.93	0.74	0.87	0.66
1998/7/25	0.92	0.63	0.88	0.88
1998/9/11	0.93	0.75	0.87	0.64
1999/4/10	0.87	0.32	0.89	0.57

Table 7. Statistics for model performance evaluation in different flood events.

Return period (years)	1996		2006	
	Peak flow (m^3/s)	Volume flood (1000m^3)	Peak flow (m^3/s)	Volume flood (1000m^3)
2	324.64	11213.59	283.72	11203.49
5	617.42	20424.06	531.52	20402.26
10	819.08	26579.50	701.29	26514.12
25	1076.05	34309.64	917.60	34188.83
50	1262.85	39820.19	1074.23	39668.44
100	1448.11	45265.43	1229.64	45075.48
200	1633.98	50697.64	1385.87	50473.60

Table 8. The impacts of land use change on peak flow and volume of flood in different return periods.

4. Discussion

According to statistics, simulated hydrographs are modeled properly compared to observe ones, so that the index of agreement ranges from 0.87 to 0.93, coefficient of determination (R^2) from 0.87 to 0.92, and root mean square error from 0.66 to 0.58 and Nash Sutcliffe efficiency indices are between 0.32 and 0.75. So the model showed good performance that it corresponds with results of Hosseini [13].

In spite of abovementioned land use changes that all had negative impact on flooding, the peak flow of modeled floods reduced. For example, the 25-year peak flow was decreased 15% that is in contrast with results of Githui et al. [11] as well as Asharf et al. [14]. The reason seems to be the distribution of changes that can be represented as the key achievement of this study. There were rangelands in downstream and near residential areas that changed to agriculture and upstream agriculture areas changed to high- and medium-density rangeland. So despite negligible change in total CN of the catchment, changes were in such a way that curve numbers of high slope areas in upstream lands that are effective in generating flood have been reduced that had decreasing impact on flood characteristics. Results of the sensitivity analysis

Watersheds	1996		2006	
	Peak flow (m^3/s)	Volume flood ($1000m^3$)	Peak flow (m^3/s)	Volume flood ($1000m^3$)
Kalshor	112.84	2823.06	114.04	2815.06
Shordare	140.76	2883.78	130.29	2739.41
Aghemam	179.70	3299.65	156.97	3011.69
Chenarli	91.14	1529.22	78.70	1384.95
Gharnave	118.74	2150.82	55.78	1321.51
Karimishan	163.52	3320.00	144.14	3003.88
Ghopan	66.51	1073.54	64.64	1044.43
Azizabad	152.88	3103.46	127.56	2734.36
Zav	113.04	2244.08	130.35	2468.34
Golidagh	122.40	3038.27	132.45	3750.61
Yelcheshme	163.48	4875.48	245.94	6348.19
Sub-basin 1	98.41	1533.42	102.71	1549.30
Sub-basin 2	56.35	1234.12	58.91	1261.53
Sub-basin 3	34.24	703.30	38.26	770.34

Table 9. The impacts of land use change on peak flow and volume of flood in different watersheds in 25-year return period.

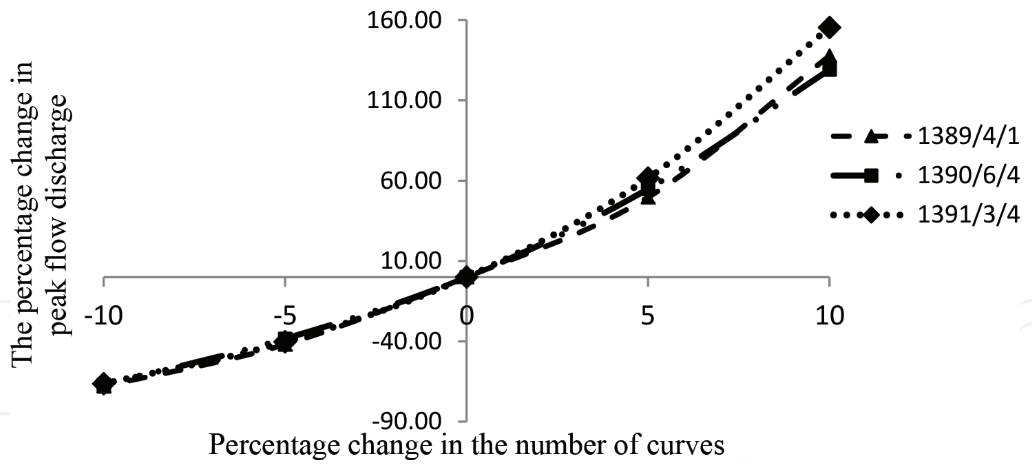

Figure 7. Flood peak flow sensitivity analysis to changes in CN.

emphasize on the importance of curve number parameter that is used to calibrate the model, and it corresponds with Khosroshahi and Saghafian [10]. The sensitivity analysis showed that if CN reduce 5%, peak flow of the catchment would decrease 40%, and on the other hand, 5% increase in CN will increase flood peak flow up to 60% that prove the importance of biological watershed management measures and prevention of forest and rangeland degradation.

5. Conclusions

In this chapter, hydrologic response of Boostan dam catchment in 1996 and 2006 simulated using WMS. Land use map investigation showed that the study area has 11 types of land uses. Assessment of changes in land use of Boostan dam catchment in the period 1996–2006 indicates that due to deforestation, more than 1.56% of the area is added to the farm lands. According to the results during the 10-year period, the total forest area has decreased, from 25.67 to 22.50%, and in contrast the rangeland area has increased from 41.53 to 42.63%. So the total forest and rangeland land uses in the catchment decreased almost 3%. Moreover in this period of time, high-density rangeland decreased 78.47 km^2 in other words 35.02% of its initial area; semi-density rangeland increased 96.24 km^2 that means 25.89% of its initial area, and low-density rangeland area remained relatively constant. This represents a decrease in rangeland quality of the catchment, which has a negative impact on its flooding. On the other hand, residential area increased more than seven times that has a negative impact on flooding too. It can be concluded that the implemented biological measures during this period of time have been effective to mitigate floods of the catchment.

It can be suggested that forestation in high lands as the main factor to mitigate flooding of a reign should continue and amplify. On the other hand, land management plans should focus on not only changes in main land uses (forest, rangeland) but also degradation in a particular land use, such as decline in quality of rangelands in the current study.

Author details

Nafise Moghadasi[1]*, Iman Karimirad[2] and Vahedberdi Sheikh[1]

*Address all correspondence to: nafisehmogadasi@yahoo.com

1 Department of Watershed Management, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran

2 Deptartment of Irrigation and Reclamation Engineering, Faculty of Agricultural Engineering and Technology, College of Agriculture and Natural Resources, University of Tehran, Tehran, Iran

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