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# The Influence of Anthropogenic Activities on Intensifying Runoff Generation and Flood Hazard in Kasilian Watershed

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**Abstract:** Destroy of forest lands and changing them into agricultural and range lands has been followed by the development of human societies and increase of man's activities in the Northern part of Iran. These land use changes and also the development of road network and residential areas have caused to increase runoff generation and flood hazard. We have observed the development of residential areas, road network and destroy of forest lands in Kasilian watershed in the recent several decades. Kasilian watershed is located in the Northern part of Iran. The objective of this study has been the quantitative investigation of the effects of man's activities on the destroy of forest lands, land use changes, impervious surface development and finally the influence of the set of these changes on runoff generation and flood hazard in Kasilian watershed. The study of land use changes and residential area development has been carried out by using aerial photos, topographic maps 1:25000, land use maps and satellite images. Also a runoff-rainfall model has been presented by using GIS (HEC-GeoHMS extension) and hydrologic model (HEC-HMS). We used the SCS method for presenting the hydrologic model. It is noted that the optimized model is evaluated by the other six events of flood. Then land use changes and also the development of the residential areas and roads have been included in the evaluated hydrologic model and their effects on intensifying runoff generation and flood hazard have been investigated quantitatively during the recent forty years.

**Key words:** Anthropogenic activities, runoff, flood, HEC-HMS, Kasilian watershed

## INTRODUCTION

Population increase and thus increase in the needs of human societies have caused the anomalous and incorrect use of natural resources in Iran. Destroy of forest and range lands and changing them into agricultural and residential lands have been very noticeable particularly in the Northern part of Iran because of agricultural activities and development of human societies. The growth process of urban societies in all over the world is increasing and it is predicated that it will continue to increase up to 60% in the year 2030 (McGee, 2001). Cosmopolitan area growth and population increase are accompanied by the destroy of forest and range lands which have undesirable effects as groundwater discharge reduction, surface flow increase and annual runoff increase, peak discharge increase of the watershed, lag time reduction between rainfall start and runoff generation and hydrograph slope increase (Hirsch *et al*., 1990; Burns *et al*., 2005). Dunjo *et al*. (2004) have investigated the effect of land use and land cover changes in runoff generation during different seasons. They found that land use and cover changes can greatly affect runoff and soil erosion. Katrien *et al*. (2006) have studied the runoff generating rainfall threshold and they found a positive correlation with total vegetation cover. Runoff is found to be negligible when the vegetation cover exceeds 65%. Other important variables affecting runoff production in the study sites are soil organic matter, soil bulk density, litter cover and slope gradient. Zimmermann *et al*. (2005) mentioned that there is a considerable memory effect and hence, any assessment of the hydrological functioning in secondary forests, quasi-natural or man-made, must take into account the kind, intensity and duration of land use prior to regrowth. Unfortunately, population increase process, anomalous and incorrect use of natural resources in the northern part of Iran are continuing and its result has caused occurrence of the recent floods in the northern part of Iran. Therefore, it is necessary to prevent such deplorable events by management of environment and natural resources. Various researches have been carried out to investigate these cases including land use

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changes, urban and road network development during the last 40 years; the influence of anthropogenic activities such as land use changes, impervious surface development in intensifying runoff generation and flood hazard on the surface of Kasilian watershed.

## MATERIALS AND METHODS

Kasilian watershed has an area of about 68 $km^2$ and it is located in the Northern part of Iran within the limits of Eastern longitude 53°18' to 53°30' and Northern latitude 35°58' to 36°07' in the Eastern part of Mazandaran Province (Fig. 1). This study has been carried in University of Mazandaran during 2007 to 2009 years.

The climate of the zone is semi- humid, cold and its average annual precipitation is 791 mm with average temperature of 11°C. The average maximum, minimum and height of the watershed are 3349, 1120 and 1672, respectively. The average slope of the watershed and the main channel and the length of the main channel are 15.8, 13 and 16.5 km, respectively. There is a hydrometer station in the outlet of the watershed and a rainfall recorder station in the upstream.

The objective of this study is to investigate the influence of man's activities and the growth of human societies in intensifying runoff generation and flood hazard in Kasilian watershed during the last forty years. Whereas the economy of the local people is dependent on exploiting the natural resources such as agriculture and animal husbandry, which due to forests' destroy and changing them into agricultural and range lands as a result of the population growth during recent decades.

Therefore, this study presents a rainfall-runoff model, the growth process of residential areas and road network in different time frames and also the destroy rate of forests and land use changes by using GIS (Geographic Information System) and remote sensing data. The aerial photos of the year 1967, land use map of the year 1995, topographic maps 1:25000 of the years 1995 and 2002 and ASTER satellite images from 2007 are used for investigation the growth process of residential areas, road network and also land use changes during the last forty years. The growth process of the residential areas, service installation equipments and asphalt road network are investigated by these data. Their growth rate in Kasilian watershed and the quantitative rate of these changes are presented in Fig. 4a, b, 5a, b and Table 2, respectively. The land use map of the watershed surface can also be observed in the two different time frames, 1967 and 2007 in Fig. 2 and 3 and the curve number changes with the antecedent moisture conditions (AMC)[22] in Table 1. Therefore, the effects of man's activities on land use changes, the growth rate of residential areas and asphalt road network are also investigated during the last forty years.

The hydrologic model (HEC-HMS) is used for presenting the runoff-rainfall model. The physical model of the watershed is simulated by using the HEC-GeoHMS extension in GIS medium (Arcview) and the Digital

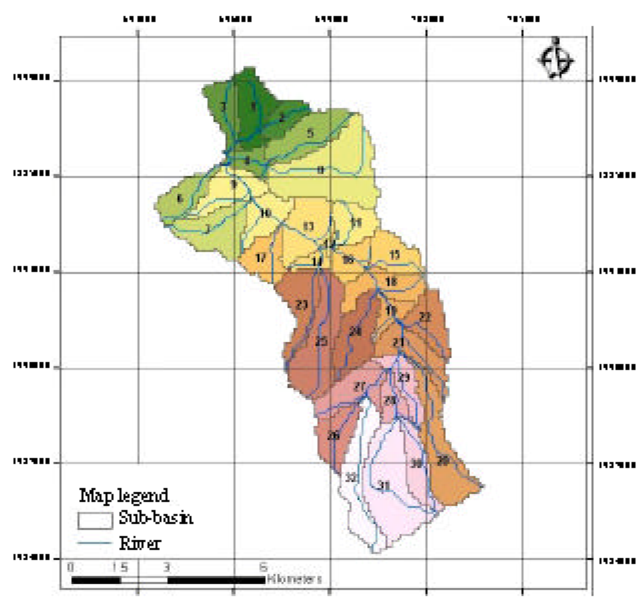


Fig. 1: Kasilian watershed, channels network and 32 sub-basins

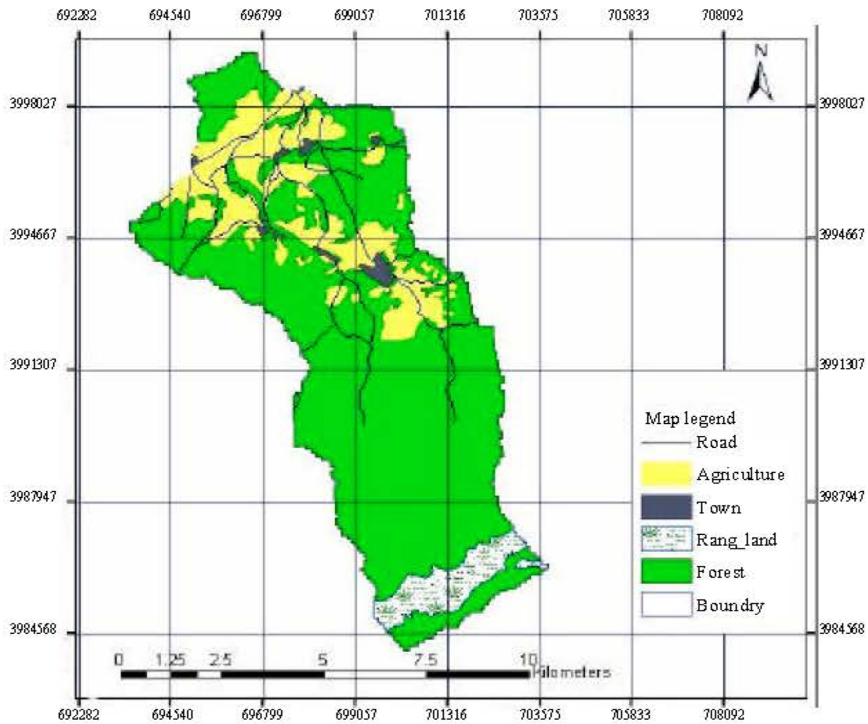


Fig. 2: Land use map (1967)

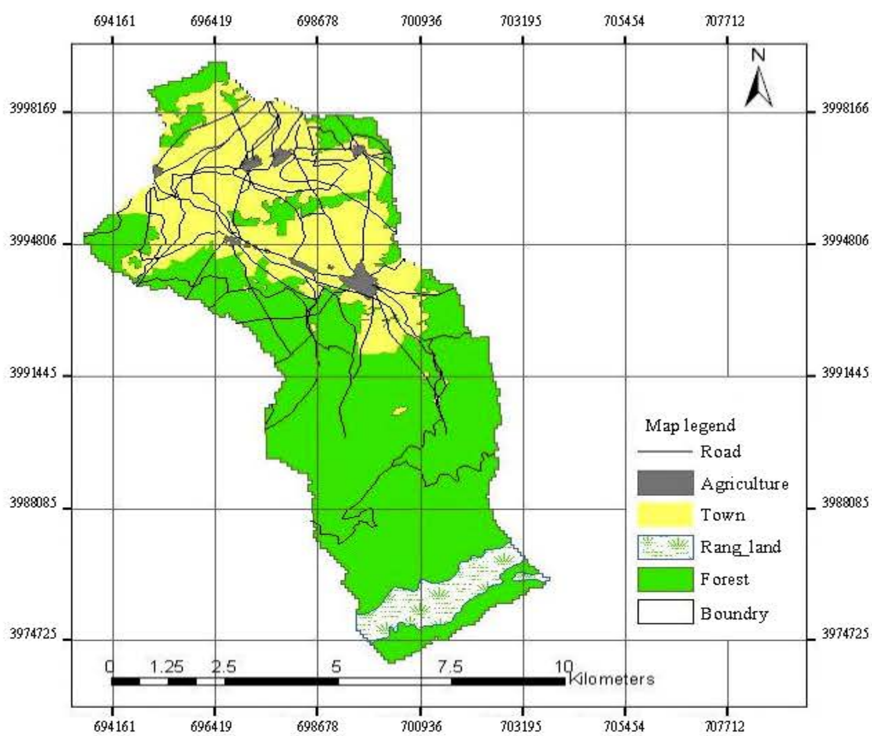


Fig. 3: Land use map (2007)

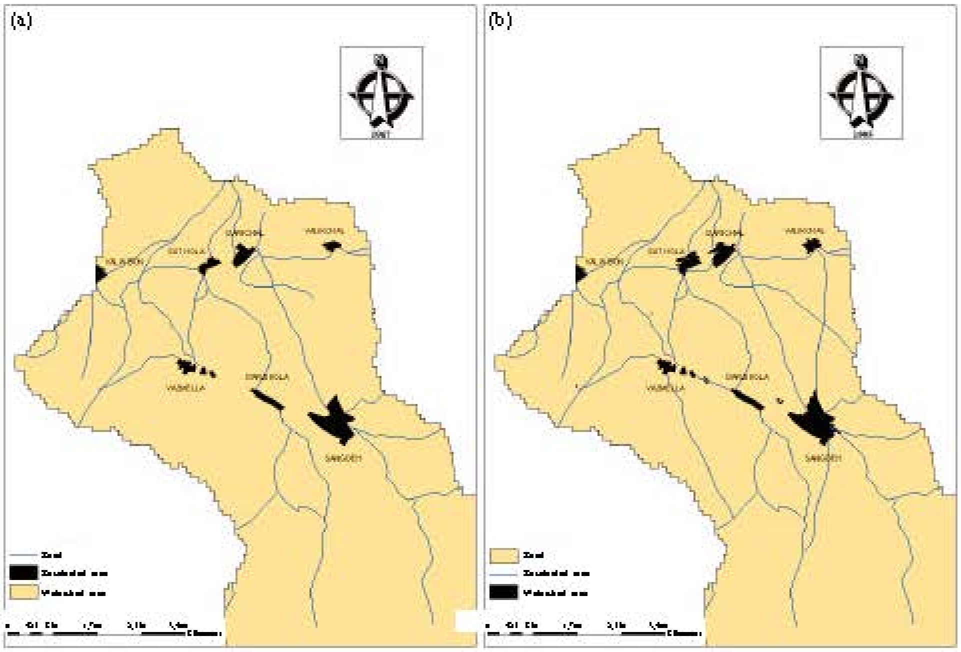

Fig. 4: The year (a) 1967 and (b) 2002 (reference : aerial photos) (reference: topographic map 1:25000 and TM Image)

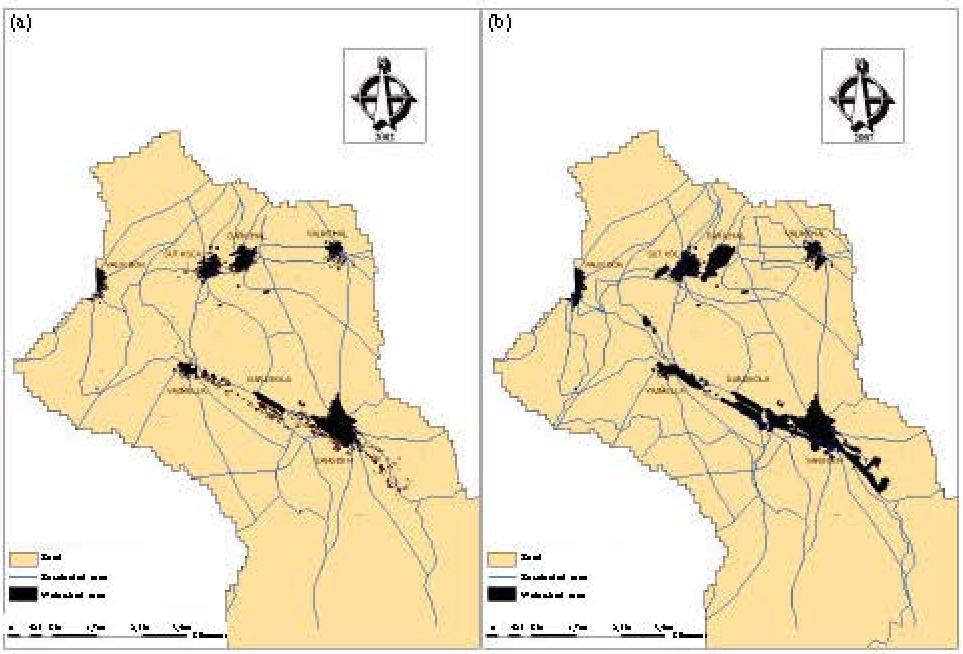

Fig. 5: The year (a) 1995 and (b) 2007 (reference: topographic map and ETM+ Image) (reference: ASTER Image)

Elevation Model (DEM) and the surface of the watershed is divided into 32 small sub-basin areas. The implications of urbanisation on runoff processes depend on the scale of the watershed area and magnitude of urban development. Small-sized river basins, which are densely urbanised, are more affected by the urban runoffs than large-sized rivers flowing through large cities, where the local urban runoff peaks contribute towards a rather small proportion of the river flow. Hence, for the study of these effects small urban rivers are more fitting (Foster *et al*., 1995). The physical model of the watershed is entered into the HEC-HMS software medium. The information of the

Table 1: Curve number (CN) changes on the sub-basin areas of Kasilian watershed due to land use changes

| | CN | | Initial loss (mm) | |
|---|---|---|---|---|
| Sub-basin | 1967 | 2007 | 1967 | 2007 |
| 1 | 77.30 | 81.36 | 14.91 | 11.63 |
| 2 | 79.95 | 85.50 | 12.73 | 8.61 |
| 3 | 70.06 | 74.74 | 21.70 | 17.10 |
| 4 | 84.28 | 88.00 | 9.47 | 6.92 |
| 5 | 77.40 | 82.38 | 14.83 | 10.86 |
| 6 | 69.20 | 70.02 | 22.61 | 21.75 |
| 7 | 64.57 | 70.00 | 27.87 | 21.77 |
| 8 | 71.72 | 81.17 | 20.03 | 11.78 |
| 9 | 79.50 | 84.12 | 13.09 | 9.58 |
| 10 | 70.73 | 77.41 | 21.02 | 14.82 |
| 11 | 75.82 | 80.82 | 16.20 | 12.055 |
| 12 | 79.97 | 84.21 | 12.72 | 9.52 |
| 13 | 74.94 | 81.18 | 16.98 | 11.77 |
| 14 | 72.99 | 72.99 | 18.79 | 18.79 |
| 15 | 69.52 | 70.53 | 22.27 | 21.22 |
| 16 | 79.01 | 82.58 | 13.49 | 10.71 |
| 17 | 63.61 | 63.62 | 29.06 | 29.04 |
| 18 | 74.57 | 74.57 | 17.32 | 17.32 |
| 19 | 71.93 | 71.93 | 19.82 | 19.82 |
| 20 | 66.62 | 66.85 | 25.42 | 25.19 |
| 21 | 66.00 | 66.51 | 26.16 | 25.57 |
| 22 | 60.54 | 60.69 | 33.11 | 32.90 |
| 23 | 70.38 | 70.38 | 21.37 | 21.37 |
| 24 | 66.77 | 67.24 | 25.28 | 24.75 |
| 25 | 66.10 | 66.10 | 26.05 | 26.05 |
| 26 | 60.00 | 60.00 | 33.86 | 33.86 |
| 27 | 65.80 | 66.80 | 26.40 | 25.24 |
| 28 | 62.20 | 62.20 | 30.87 | 30.87 |
| 29 | 63.66 | 63.66 | 28.99 | 28.99 |
| 30 | 67.47 | 67.56 | 24.49 | 24.39 |
| 31 | 70.43 | 70.43 | 21.32 | 21.32 |
| 32 | 66.58 | 66.71 | 25.49 | 25.35 |

Table 2: Impervious land percent changes on the sub-basin areas of Kasilian watershed during the last forty years

| Sub-basin | Area ($km^2$) | 1967 | 1995 | 2002 | 2007 |
|---|---|---|---|---|---|
| 1 | 2.220 | 0.45 | 0.65 | 1.30 | 1.35 |
| 2 | 1.110 | 1.80 | 2.00 | 2.50 | 3.68 |
| 3 | 1.620 | 0.37 | 0.38 | 1.23 | 1.23 |
| 4 | 0.910 | 2.30 | 2.30 | 2.30 | 8.80 |
| 5 | 2.480 | 7.50 | 10.10 | 15.12 | 19.00 |
| 6 | 1.640 | 1.20 | 1.25 | 1.40 | 2.00 |
| 7 | 2.670 | 0.93 | 0.93 | 1.53 | 2.45 |
| 8 | 5.920 | 1.87 | 2.63 | 3.40 | 4.55 |
| 9 | 2.070 | 1.60 | 1.64 | 1.64 | 3.96 |
| 10 | 1.690 | 6.45 | 7.68 | 8.90 | 11.98 |
| 11 | 1.520 | 11.10 | 12.57 | 13.09 | 13.50 |
| 12 | 0.200 | 0.90 | 2.52 | 23.50 | 47.93 |
| 13 | 2.590 | 3.20 | 3.80 | 5.88 | 12.11 |
| 14 | 0.609 | 1.10 | 1.15 | 3.55 | 3.80 |
| 15 | 1.690 | 1.04 | 1.04 | 1.07 | 4.64 |
| 16 | 1.250 | 16.30 | 18.50 | 23.49 | 33.22 |
| 17 | 1.630 | - | 0.64 | 1.07 | 1.97 |
| 18 | 2.050 | 1.30 | 1.78 | 3.32 | 9.50 |
| 19 | 0.901 | 0.45 | 0.46 | 1.30 | 1.89 |
| 20 | 3.700 | - | 0.11 | 0.24 | 0.48 |
| 21 | 2.050 | 0.35 | 0.35 | 1.00 | 1.12 |
| 22 | 1.850 | 0.20 | 0.23 | 0.64 | 0.81 |
| 23 | 2.240 | 0.84 | 1.23 | 1.63 | 2.13 |
| 24 | 2.530 | 0.26 | 0.68 | 0.76 | 0.76 |
| 25 | 3.920 | 0.18 | 0.18 | 0.20 | 0.64 |
| 26 | 1.800 | - | - | - | 1.58 |
| 27 | 2.190 | - | - | - | 0.77 |
| 28 | 1.010 | - | - | - | 1.49 |
| 29 | 1.380 | - | - | - | 1.06 |
| 30 | 1.760 | - | - | - | - |
| 31 | 4.880 | - | - | - | - |
| 32 | 3.230 | - | - | - | 0.37 |

rain intensity of Sangdeh rain recorder station and the flood hydrograph of Valic ben hydrometric station and six rainfall events in 1991-1994 are applied in the model. The SCS method, curve number and lag methods are used for presentation of the runoff-rainfall model, for estimation of the runoff high and for the flood routing in channels, respectively. Curve number determination are made with respect to land use and soil hydrological groups maps in different antecedent moisture conditions (dry, average and moist) and hydrological conditions. It is the whole interception, infiltration, transmission in the soil and surface (mm). Run off calculation is given below:

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

and the discharge calculation as:

$$Q = \frac{(P - 0.25)^2}{P + 0.85} \tag{2}$$

Where:

Q = Run off (mm)
S = Losses (mm)
P = Maximum precipitation in 24 h (mm)

After calculation of runoff due to rain storm the maximum flood discharge calculation is achieved by:

$$Q_{max} = \frac{2.083AQ}{t_p} \tag{3}$$

Where:

$Q_{max}$ = Maximum flood discharge ($m^3 sec^{-1}$)
A = Basic area ($km^2$)
Q = Run off (mm)
$t_p$ = Time of flood crest, which is evaluated by time of concentration (tc) in minute

Rainfall is simulated in the ways of incremental or even speed on the watershed surface. The model is optimized by the initial loss and lag time parameters of the sub-basin areas (SCS-Lag).

In the next step, the efficiency of the optimized hydrologic model is confirmed by comparison results from the model for simulation of the hydrograph of the other six flood events with the recorded flood hydrographs.

In the final step, after evaluating the hydrologic model of Kasilian watershed, changes in land use (with the curve number criterion) and impervious surface growth are applied for a rainfall event during the last forty years. It is noted that the model is implemented only by entering the changes and even rainfall on the whole watershed surface. The influence of man's activities and environmental changes resulted from them in intensifying runoff generation and flood hazard are investigated quantitatively during the recent forty years.

## RESULTS

A rainfall-runoff model is presented for simulating the hydrologic behavior in Kasilian watershed by using statistics and the information of the six previous flood events. Comparison of the simulated hydrograph by the model with the recorded hydrograph in Valicben hydrometric station for one of the six events before and after optimizing the model are shown in the Fig. 6 and 7. The results prove model efficiency in simulating. The efficiency of the model is evaluated and confirmed after optimization for simulation of the outlet hydrograph in Kasilian watershed for the six flood events. The comparison the simulated hydrograph with the observed hydrograph of one of the events using for evaluation of the model is shown in Fig. 8. The simulated hydrographs of Kasilian watershed with the rainfall 24 May 1994 in land use conditions and road network and residential areas, in 1967 and 2007 years (all of the model factors except land use and impervious land percent were considered constantly) are shown in Fig. 9 and 10. By using the GIS and RS abilities, the land use changes are investigated during the last forty years and their results are shown in Table 3. According to the results, land use changes occur from forest to farming and also urban development is observed. The rainfall of one of the previous events is considered for evaluating the influence of man's activities on the runoff generation potential and flood hazard. The model is implemented only by changing

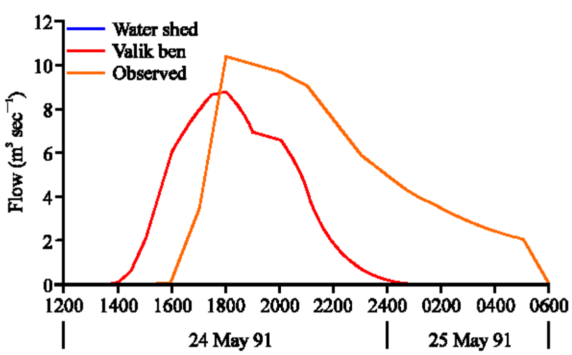


Fig. 6: Comparison the simulated hydrograph by the model with the observed hydrograph. Flood event: 24 May 1991

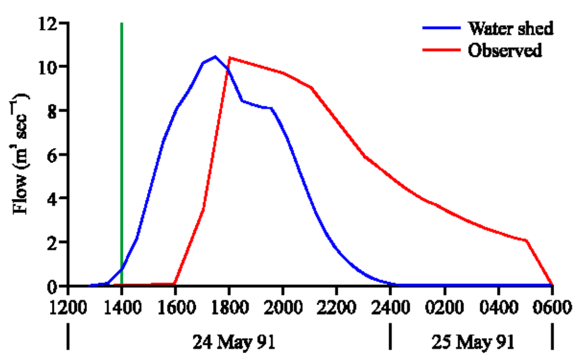


Fig. 7: Comparison the simulated hydrograph by the model with the observed hydrograph. Flood event: 24 May 1991 after optimizing the model

Table 3: Land use changes on the surface of Kasilian watershed during the last forty years

| Year | Road (km) | Residental (ha) | Forest (ha) | Range (ha) | Farming (ha) |
|---|---|---|---|---|---|
| 1967 | 50.20 | 74.99 | 5396.1 | 346.8 | 1235.0 |
| 2007 | 127.38 | 86.98 | 4537.9 | 346.8 | 2143.6 |

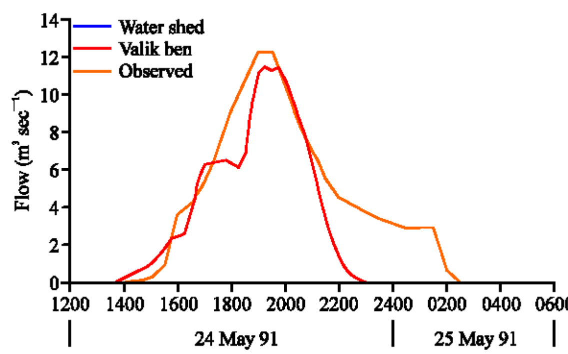


Fig. 8: Evaluating the hydrologic model of Kasilian watershed with comparison the simulated hydrograph by the model and the recorded hydrograph in hydrometric station. The event: 23 October 1994

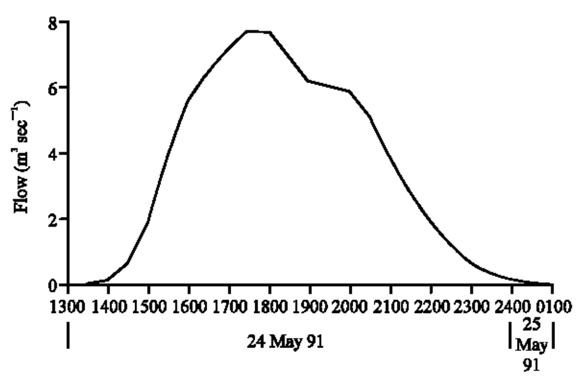


Fig. 9: The outlet hydrograph of Kasilian watershed with the rainfall 24 May 1994 in land use conditions and road network and residential areas, 1967

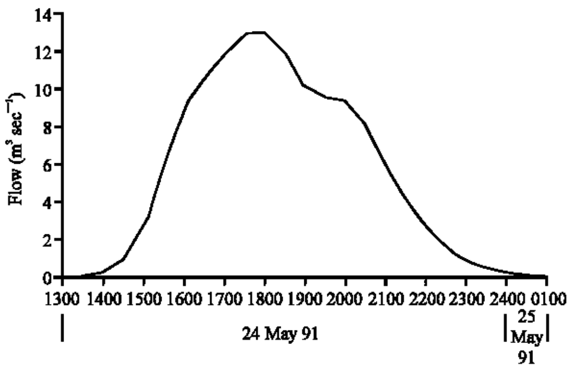


Fig. 10: The outlet hydrograph of Kasilian watershed with the rainfall 24 May 1994 in land use conditions and road network and residential areas, 2007 (all of the model factors except land use and impervious land percent were considered constantly)

Table 4: The changes of peak discharge and runoff volume due to the development of impervious surfaces and residential areas in four different time frames for a constant conditions from all the model parameters except impervious land percent of the sub-basin areas (rainfall 24 May 1994)

| Year | Peak discharge ($m^3 sec^{-1}$) | Runoff volume ($m^3$) | Runoff increasing (%) |
|---|---|---|---|
| 1967 | 9.01 | 167920 | - |
| 1995 | 9.57 | 178430 | 6.25 |
| 2002 | 10.05 | 188710 | 12.38 |
| 2007 | 11.29 | 212310 | 26.43 |

Table 5: Peak discharge changes and runoff volume because of land use changes (rainfall 24 May 1994)

| Year | Pick discharge ($m^3 sec^{-1}$) | Runoff volume ($m^3$) | Runoff increasing (%) |
|---|---|---|---|
| 1967 | 8.04 | 153850 | - |
| 2007 | 11.11 | 197190 | 28.1 |

Table 6: The changes of peak discharge and runoff volume in Kasilian watershed because of land use changes and impervious surface development.(rainfall 24 May 1994)

| Year | Pick discharge ($m^3 sec^{-1}$) | Runoff volume ($m^3$) | Runoff increasing (%) |
|---|---|---|---|
| 1967 | 7.67 | 147440 | - |
| 2007 | 12.92 | 233310 | 58.2 |

the impervious land percent, the curve number changes (land use and vegetation) and initial loss in different time frames and the influence of impervious land development, destroy of forests and changing them into agricultural lands on runoff generation, the peak discharge increase and flood volume are investigated. In fact, a rainfall is considered for the model in different time frames and only the changes from man's activities are applied in the model and their effects are investigated. The results from impervious surface development in the rate of volume and peak discharge of flood in Kasilian watershed are shown in Table 4 and the influence of land use changes on runoff generation, peak discharge and flood volume in Table 5. Finally, the influence of the set of activities such as making road network, urban development, destroy of forests and changing them into agricultural areas are investigated and the results are presented in Table 6.

The development of residential area and impervious surfaces in Kasilian watershed during the recent forty years.

## CONCLUSIONS

Man's activities have been accompanied by land use changes, destroy of natural resources and urban development. Cosmopolitan area development on the surface of the watershed will cause increase in peak discharge and runoff volumes (Brilly *et al*., 2006; Pappas *et al*., 2007). Kasilian watershed is a forest area, which in comparison with other places of Iran is less exposed to destroy and land use changes. Forests cause reduction in the runoff generation and flood hazard by increasing permeability of soil and water-holding capacity of the watershed area (Wahl *et al*., 2005). Now, runoff generation potential on the surface of the watershed has remarkably been increased due to destroy of forests.

Man's activities in the form of urban development and land use changes have caused to increase in the hazard of flood events and watershed sensitivity against rainfalls and rain storms with respect to runoff generation and peak discharge that are more in cases of heavier rainfalls (Camorani *et al*., 2005). Urban development, impervious surface increase, destroy of forest lands and changing them into agricultural lands have remarkable affects on the potential runoff generation and flood hazard in Kasilian watershed. The influence of urban development has much more effect on the surface of the sub-basin areas, which have considerable impervious surface development (based on comparison between Table 5, 6). Land use changes took place in the Northern part of the watershed where there are local situation of the land use changes on the surface of the watershed, their influence rate on the peak discharge and the outlet runoff volume of the watershed has more influence than the impervious surface development. The research results have indicated more influence of urban development on the volume and peak discharge of the sub-basin areas or in surface units. Past studies confirmed the more influence of urban development in surface unit (Riley, 1998). According to the results from research, the runoff generation potential has increased approximately 60% for a rainfall event in Kasilian watershed because of man's activities during forty years on the surface of the watershed. The purpose of this study (the effects of man's activities in runoff generation and flood hazard) has been achieved by use of GIS, RS and HEC-HMS model quantitatively. It is noted that the study area is a forest area with low population density, which in comparison with other areas is less exposed to man's activities and whereas the rate of runoff volume, peak discharge and finally intensifying flood hazard are expected to increase during heavy rainfalls and this process of the urban development and destroy of forest lands are in continuous progress. Finally, the authors suggest investigation of the soil compaction effect due to man's activities in runoff generation potential.

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