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Modelling the erosion in the Shahzadeh Abbas basin using HEC- HMS model

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Abstract: Erosion is process in which soil particles are separated from their bed and moved to another location with the help of transferor and deposited there. Today, erosion and sediment are of the major problems of different catchment basins in Iran and determining their extent is of the upmost importance. Empirical model of erosion has been developed for a specific area and it is necessary to calibrate it to use in the conditions except the place where it was provided. This study aimed to estimate the erosion and sediment of Shahzadeh Abbas catchment basin in Kerman Province. For this purpose, the hydrological model HEC-HMS (V.4) was used and the efficiency of Universal Soil Loss Equation (USLE) and Modified Universal Soil Loss Equation (MUSLE) was evaluated in the mentioned area. Finally, the results show that Modified Universal Soil Loss Equation (MUSLE) technique has good agreement to the observed data and reaches the overlap of 85%.
Key words: *erosion and sediment, Universal Soil Loss Equation (USLE)*

Introduction

Erosion and its effects are not very impressive in the short-term but they are tangible in the long-term, because it usually causes the reduction of products. To prevent its adverse effects, i.e. reduction of product, the land should be used in a way that no erosion is created. However, erosion is a permanent phenomenon and there will always be, but, if its amount is less than formed soil, it won't be critical. When the amount of soil erosion is less or equal to the amount of formed soil, the properties of soil such as texture, depth and fertility remain constant over time [3]. The other adverse effects of erosion are demolition of structures along the rivers, destruction of bridges and other buildings beside the river and also it deepens the river bed [2]. River sediments are moved in two ways: these materials are immersed in the water and moved with water that they are called suspended sediment load or they may move near the river bed in one of the three modes of slipping, slithering and jumping that they called bed load. Type of movement depends on the characteristics of sediments, flow conditions and characteristics of the river. In the rivers with steep slope and under the condition of high speed, sand particles may be suspended to move while in the river with gentle slope and low speed, fine-grained particles and sludge are suspended to move. The sedimentary particles can create the problems such as damaging to the turbines, pumps and piers of bridge, revetment of channels, etc. in movement. In the deposition process, eroded sediment particles may be deposited after a short or long distance. The sedimentation of particles intensifies when the factors causing the erosion and movement of particles are reduced. The main problems that sedimentation can cause are creation of islands in the river and thereby reducing the capacity of flood flows, sedimentation in the reservoirs behind the dams and thereby reducing reservoir storage capacity and finally, outage of the reservoir, sedimentation in the watercourses of rivers during flooding and thereby damaging buildings and farms, sedimentation in the riverbed and thereby making the river shallow and also, impossible for shipping [2]. Therefore, erosion damages the agricultural development program which is based on the facilities. If correcting this type of sedimentation isn't impossible, at least, it is difficult. For example, if the dam is filled with the sediments

caused by erosion, the only solution will be to release it and to search another place to construct the dam. For this reason, the investment must be used to prevent erosion instead of restoration of lost resources [3].
Given the consequences of erosion, as mentioned, erosion and sediment are now the major problems of the different catchment basins in Iran and determining the amount of them is very important. In this research, the mathematical model HEC-HMS and the MUSLE technique were used to model the movement of sediment mathematically that its outcome will lead to better design and soil conservation practices. Soil erosion is considered as an inseparable part of the soil. Till now, different ways have been identified to determine the causes of erosion directly (measurement) or indirectly (model). Despite proper accuracy, the direct methods are not noticed because of economic aspects. But, the use of models has become more developed every day. In USLE model, the soil erosion is measured based on texture, percentage of organic matter, structure and permeability of the soil profile [34].
Pongsai et al. (2010), with establishing experimental plots in 5 different slope (9, 16, 25, 30 and 35%) and measuring and recording the sediments caused by 17 storms in the period of July to October 2003, evaluated and calibrated Universal Soil Loss Equation and stated that both USLE model and MUSLS provided by Donald Mac Cole, estimated the amount of sediments more than its actual value in all slopes [32].
Miguel et al (2011) used Universal Soil Loss Equation to predict soil erosion in a small drainage basin (1895 hectares) located in south of Brazil that its terrains are very complex and announced that the factor LS is the main factor controlling the soil erosion potential and the factors CP and K are placed after it and finally concluded that the prediction of soil erosion in the small drainage basins using the USLE model has some acceptable restrictions [29].
Olivares et al. (2011) used USLE model to estimate the water erosion in Hapludalfs soils by using 3 experimental plots in 3 treatments of natural pasture, tilled soil and dry soil and concluded that USLE model can highlight the trend of data but the estimates are generally less than actual values [30].

Materials and methods

Total area of Shahzadeh Abbas catchment basin is 473.9 km^2 and it is placed between two longitudes of 56° 21’ 52” and 56° 53’ 27” and two latitudes of 29° 23’ 28” and 29° 45’ 41”.
Physiographic characteristics of Shahzadeh Abbas catchment basin
The height of highest point of Shahzadeh Abbas catchment basin is 3310 m and the height of its outlet is 2030m. Its area is 473.9 km^2 and its perimeter is 128.36m. Using partial area between contours, its average height is calculated equal to 2611.4 m above sea level. Its average slope is 5.88% and the weighted average slope of the main drainage is 3.5%. All characteristics of case study are shown in table 1-2.

Table1-2. Physiological characteristics of Shahzadeh Abbas catchment basin

Name		Shahzadeh Abbas
Area(km^2)		473.97
Perimeter (km)		128.36
Height	Minimum	2030
	maximum	3310
Height difference (m)		1280
Weighted average height (m)		2611.43
Length km)	Basin	34.16
	Stream	43.24
Weighted average slope (%)	Stream	3.50
	basin	5.88
Coefficient	Shape	2.96
	Compaction	0.03
	Length of equivalent rectangle	1.65
	Width of equivalent rectangle	55.67
	Length to width ratio	8.51
Time of concentration (h)	Chow	4.37
	Kirpich	4.68
	Bransby Williams	11.38
	SCS	11.52

The most important river of this basin is Shahzadeh Abbas River which is formed by several rivers: Galuzard river, Kankarij river, Dareh gol shiron river and Rahmat abad river. In this research, the first stage is to model the basin and to analyze the physiographic characteristics of it by HEC-Geo HMS software. First, the studied basin was imported with a form of Shape File in Arc GIS software. Then, its digital elevation model (DEM) was prepared by using contour layers and the analysis was started by importing DEM map in HEC-Geo HMS software. Mapping the direction of flow and cumulative flow, defining and classifying the streams, forming sub-basins and defining the main stream are the items done at this stage.

Figure1-2. Digital elevation model (DEM) of Shahzadeh Abbas catchment basin

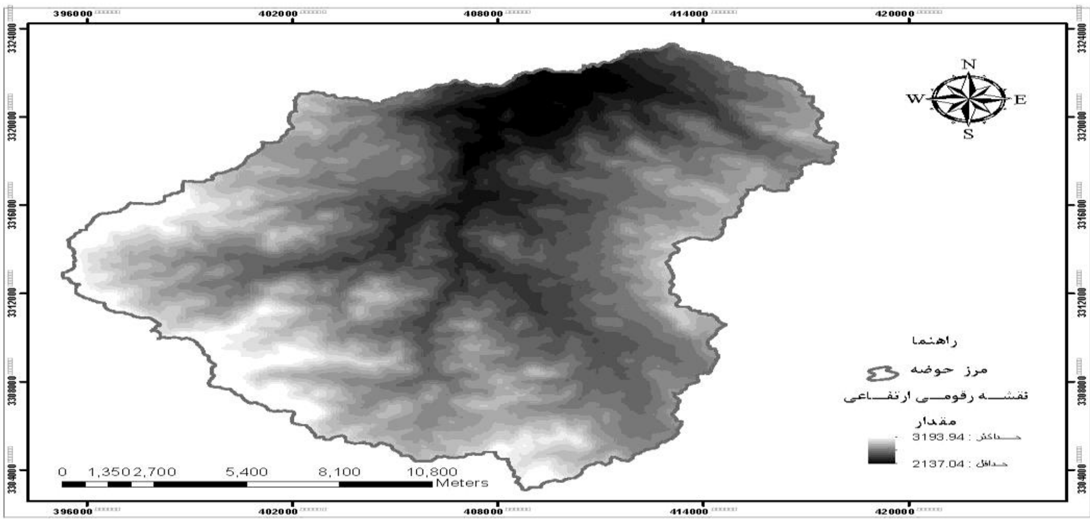
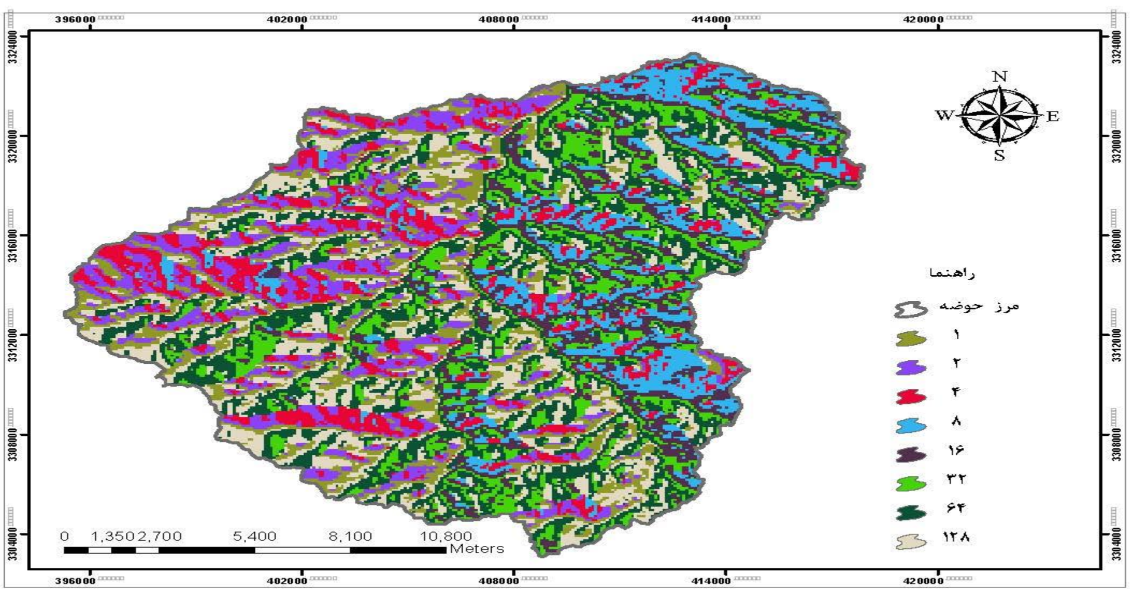
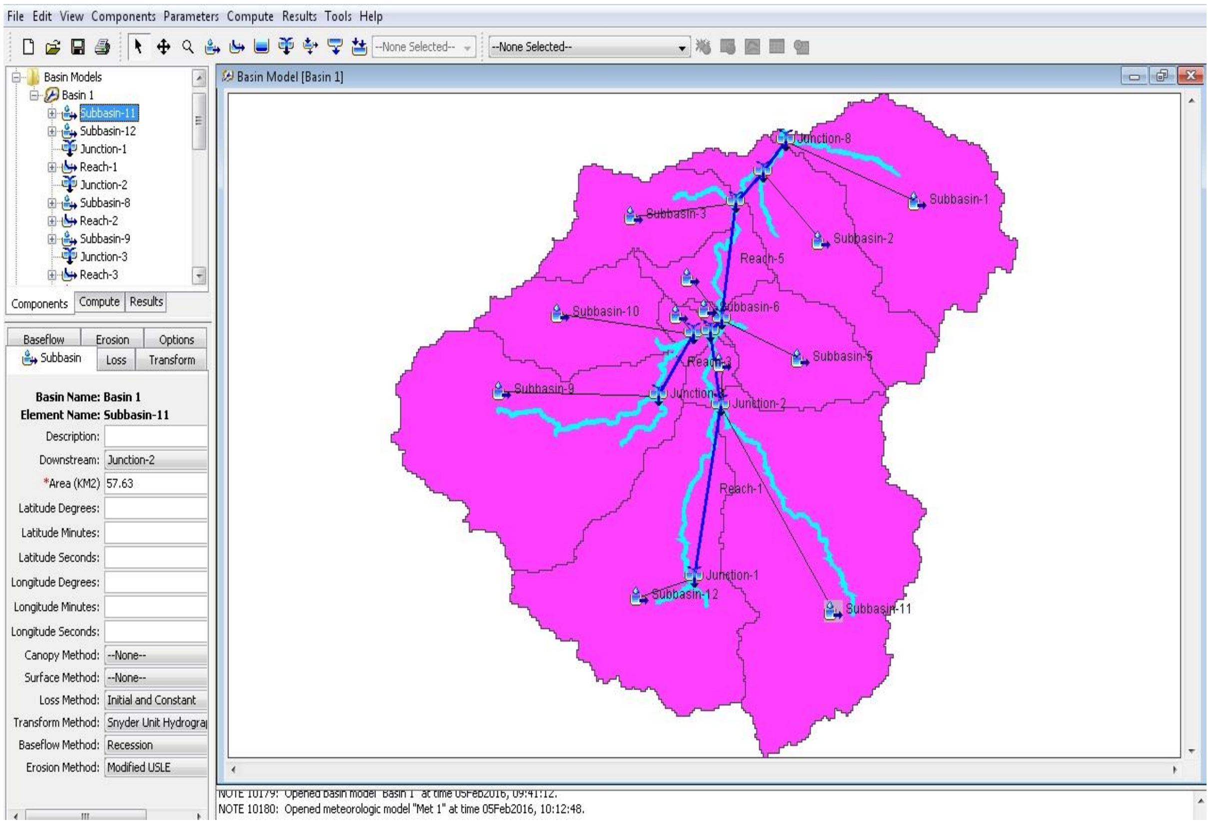


Figure2-2. Flow direction map. Shahzadeh Abbas catchment basin



Schematic shape of catchment basin created by model HEC-Geo HMS was entered in HEC.

Figure3-2. Schematic shape of catchment basin created by model HEC-Geo HMS



Then, the process of precipitation and runoff was modelled to model the erosion and finally, the modified soil loss equation of erosion was performed by activating the element of erosion in this mathematical model and choosing the Modified USLE.

Universal Soil Loss Equation

Universal Soil Loss Equation (USLE) is a technique which is extensively used to predict the amount of rill and interrill erosions in the fields or the units with the size of fields with different management operations around the world [30].

$A = R\times K\times L\times S\times C\times P$

A: Average annual soil loss caused by sheet and rill erosion in mass unit per area unit and per time unit that in English system it is calculated in tons per acre per year and in metric system, it is calculated in tons per hectare per year.

R: it is rainfall erosivity index which depends on the kinetic energy of rain and is closely correlated with the maximum intensity of 30-minute rain. It is calculated by multiplying the total kinetic energy of the rain (E) by the maximum intensity of 30-minute rain and then dividing the result by 100 (its unit is MJ/mm ha h) [12].

K: it is a soil erodibility factor, it specifies the inherent sensitivity of the soil. It calculate the amount of inherent erosion. It is equal to the erosion rate per unit of soil erosion index for any special soil in farm and plowed lands that it is right up to the slope of 9% and slope length of 22.1m. In America, Wischmeier and Smith determined the most accurate coefficient k for each type of soil by averaging these coefficients (its unit is tons per hectare per R) [6, 7].

L: It is the length of slope. It is defined as a distance from the starting point of surface runoff to the point in which the slope reduces that the moved materials sediment by water or to the point where surface runoff enters to a natural or artificial watercourses such as terrace stream or Circulating water system (it is the

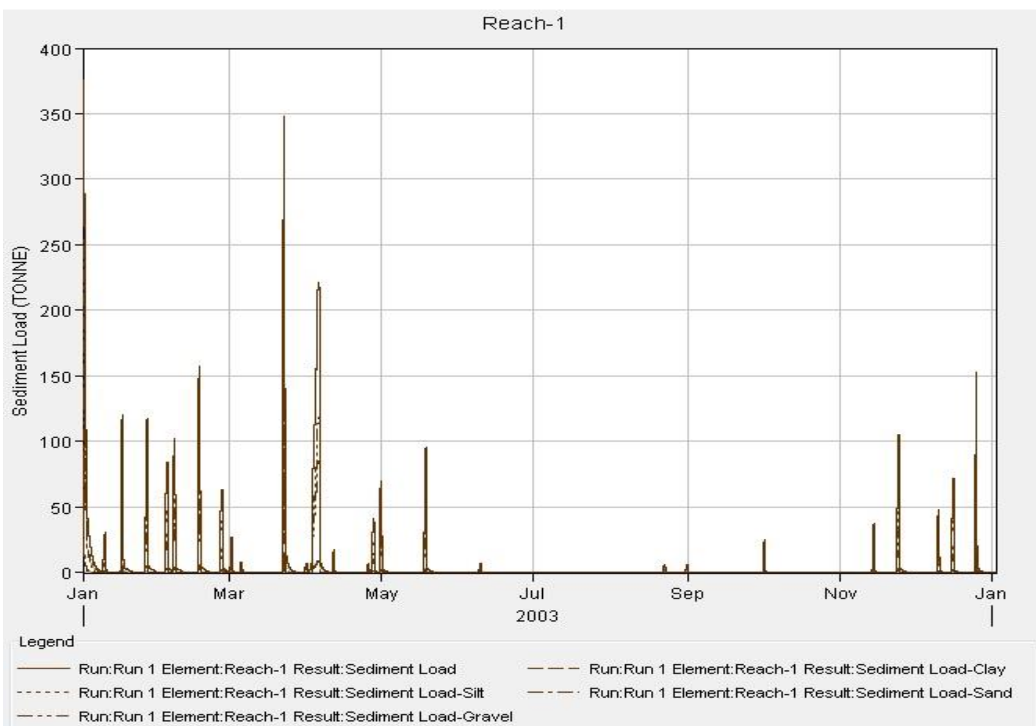
ratio of erosion of the slope length to the erosion of the land with the same slope but with the length of 72.6 feet (22.1 m)).
S: it is the slope of land and it is a ratio of the erosion of the slope of land to the erosion of the same land with the same length but with slope of 9% (or 5 degrees)
(Effects of the length and the amount of slope is usually calculated as a one factor LS (LS has no unit)) [3, 10].
C: it is a crop management factor. This factor is the ratio of soil loss from land cropped under specified conditions to corresponding loss under tilled, continuous fallow conditions (standard plot is uncovered plot which is plowed in line with the aspect and it is permanent fallow) [2,6].
P – It is the conservation practice factor. It is the ratio of the erosion of conserved land to the erosion of the same land which is fallow and no conservation practices were done on it, i.e. cultivation on a given slope established on the contour. Practices included in this term are contouring, strip cropping (alternate crops on a given slope established on the contour), and terracing. If no conservation practices are done, P=1, if the practices are contouring, P=0.5, if the practices are terracing, P=0.8 and if the practices are strip cropping, P=0.4 (in a permanent fallow land, C and P are equal to 1).

Results

The results of the sediment load obtained by running the model for the end of the analyzed streams

One of the items that refers to the sediment load of basin is to analyze the sediment load in the river and the streams of the basin. The results are presented as the total sediment load, sediment load of bed and suspended sediment load. The results of total sediment load are presented in the forms of graph. For example, the sediment load at the end of the stream 1 was estimated by USLE and volume sediment rate and presented in following figure.

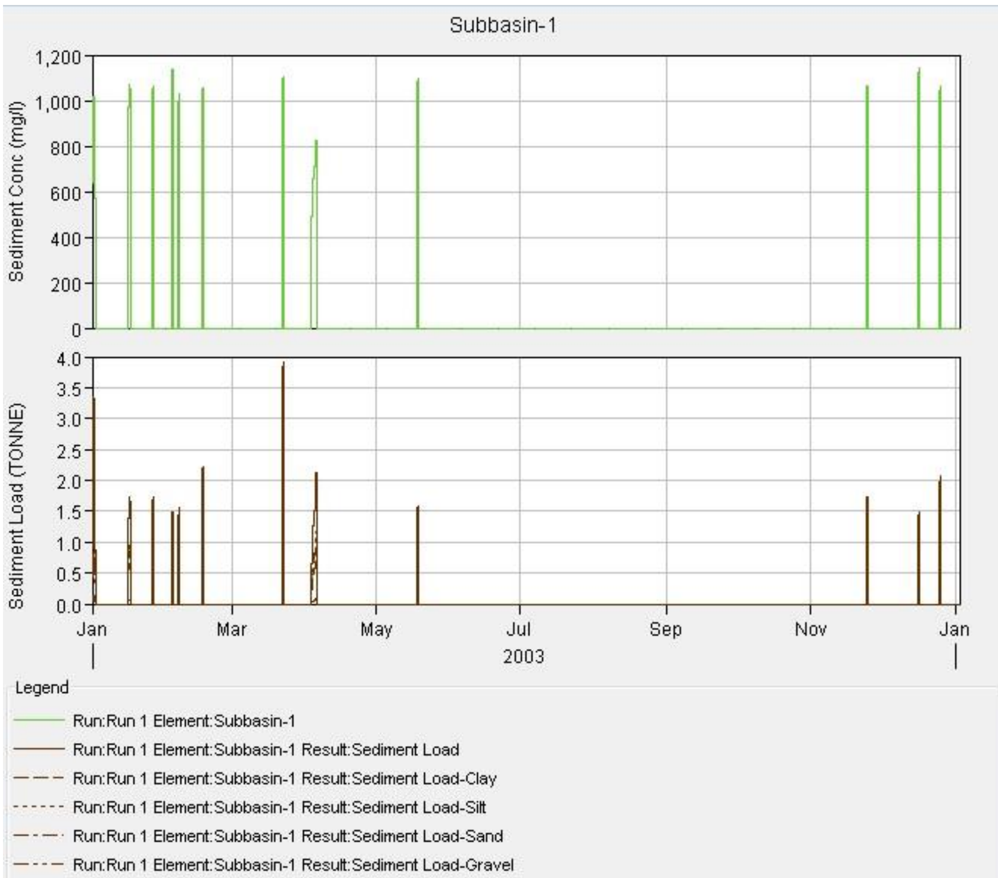
Figure1-3. The sediment load at the end of the stream 1 estimated by USLE and volume sediment rate



The results of the sediment load obtained by running the model for sub-basins

The results of the sediment in each sub-basin include the time series of the final load of sediments removed from each sub-basin. Final sediments are the sum of the classification of particle size. Also, time series of the sediment load for each particle are specified with size (grain size). For example, the graph and interpretation related to sub-basin 1 is shown in figure 2-3.

Figure2-3. The final load of the sediments removed from the sub-basin1 based on USLE



Discussion and conclusion

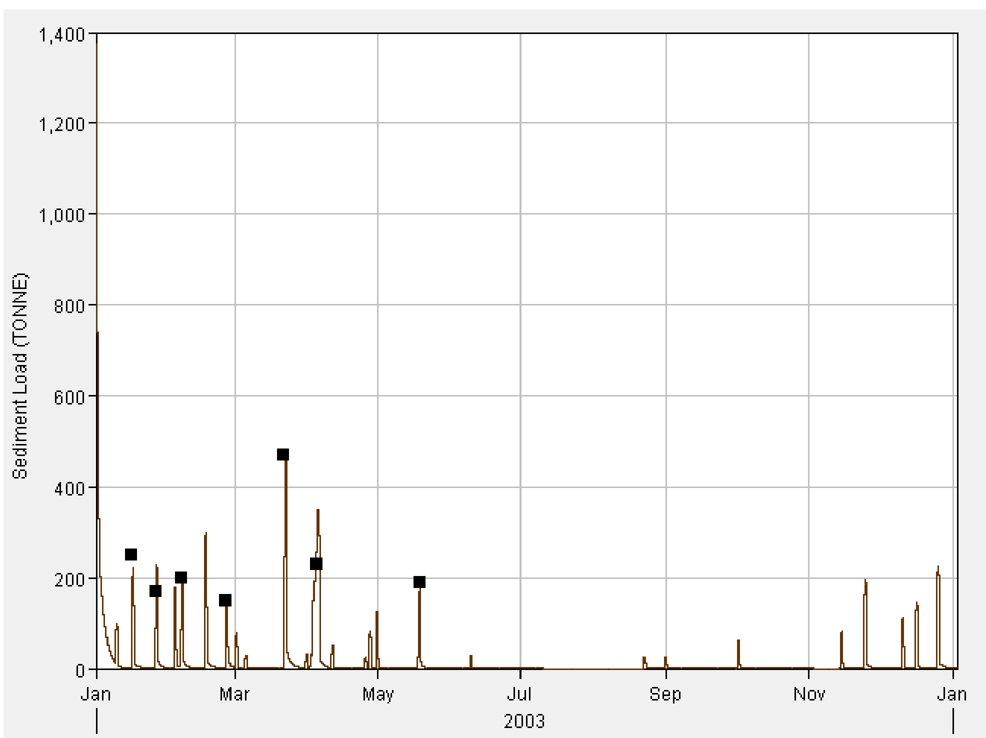
The performance of MUSLE was examined in the hydrological model HEC-HMS. This analysis was evaluated on a scale of cloudburst. Firstly, the amount of erosion caused by each cloudburst was estimated and the estimated erosion was considered equal to the sediments. Finally, the results of this model were compared with the measured sediments caused by the cloudburst and the accuracy of the technique was evaluated.

Sediment load has been studied by MUSLE and the results were presented in figures 1-3 and 2-3. The results of the MUSLE were compared with the measured sediment load and the results of this comparison are shown in figure 1-4 1nd table 1-4.

Table1-4. Comparison between the observed and estimated amount of sediment in Shahzadeh Abbas catchment basin

No	Date of cloudburst	Amount of observed sediments (gr/m^2)	Amount of estimated sediments (gr/m^2)		The average absolute percentage of the difference between the value estimated by MUSLE and observed data
			MUSLE	Percentage of difference between columns 3 and 4	
1	17.01.2003	0.53	0.463	-12.64%	14.176%
2	26.01.2003	0.306	0.4599	33.46%	
3	07.02.2003	0.364	0.326	-10.43%	
4	25.02.2003	0.296	0.312	5.1%	
5	23.03.2003	1.07	1.04	-2.80%	
6	04.04.2003	0.486	0.694	29.97%	
7	18.05.2003	0.372	0.39	4.83%	

Figure1-4. Comparison between the observed and estimated amount of sediment in Shahzadeh Abbas catchment basin



■ Observed amount of sediment
—— Amount of sediment estimated by MUSLE

According to the research, the movement of the sediments was modelled by the use of MUSLE and mathematical model HEC-HMS. The results showed that the average absolute percentage of the difference between the sediment load estimated by MUSLE and observed sediment load is equal to 14.176%. The amount of sediments obtained by MUSLE has significant correlation with observed data, the correlation is equal to 0.85 in terms of R^2. The amount of sediment load was calculated equal to 430 tons. In model HEC-HMS and MUSLE, the factors of soil properties and vegetation, as the pre-calculated coefficients, have special effects on erosion and sedimentation in the catchment basins.
In model HEC-HMS, there is the greatest correlation between the soil erosion and distribution percentage of particle size. These values were considered completely and the smallest change in them causes the biggest change in the amount of soil erosion.

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