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ASSESSMENT OF SOIL EROSION, SEDIMENT YIELD AND MAXIMUM OUTFLOW, USING IntErO MODEL (CASE STUDY: S8-intA SHIRINDARREH WATERSHED, IRAN)

ABSTRACT

The complexity of hydrological processes, spatial and temporal variation of all effective factors and lack of essential measured filed data convinced researchers to use empirical models in various scales. The IntErO model was used to predict maximum outflow (Qmax), soil erosion intensity (W year) and sediment yield (G year) in one of the internal sub-watersheds of Shirindarreh watershed, northeast of Iran. The results showed that the peak flow was 13.51 m^3s^{-1} for a return period of 100 years. As an internal area, the peak flow of all upstream sub-watersheds should be also considered to be added to the predicted peak flow. The value of Z coefficient of 0.696 indicated that the river basin belongs to III destruction category and the strength of the erosion process was medium, and according to the erosion type, it was intrusive erosion. The predicted gross soil erosion in the study sub-watershed was 8.06 ton ha^{-1} $year^{-1}$. The coefficient of the deposit retention (Ru) or sediment delivery ratio (SDR) was 0.124 and therefore, the sediment yield was 1.00 ton ha^{-1} $year^{-1}$. According to Gavrilovic, the study sub-watershed is a region of very weak erosion.

Keywords: IntErO Model, Land Use, Runoff, Sediment Delivery Ratio.

INTRODUCTION

Soil erosion is one of the most important environmental issues worldwide and is a cause of various problems (Toy et al., 2002). Soil loss is a serious problem in developing countries (Wolancho, 2012) that cause in great concern (Gholami et al., 2013). For the appropriate watershed management, land use and landscape planning, which will more effectively meet national or local needs and assists in assessing the consequences of the alternatives the important issue is to

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quantify the sediments and to estimate sediment yield at the river basin scale (Chalise et al., 2019; Spalevic, 2019; Curovic et al, 2019; Parsipour et al, 2019, Fikfak et al, 2017; Popovic et al, 2018). On one hand, it is difficult to accurately measure the soil erosion generated in the field (Conoscenti, 2008; Rawat et al., 2011) and on the other hand, in many of the hydrometric stations, the sediment concentration are determined only in some severe storms without any evaluation of time distribution pattern of sediment (Khaledi Darvishan et al., 2010). Therefore, the modelling of the erosion process has progressed rapidly and a variety of models have been developed to predict both runoff and soil loss (Spalevic, 2017a; 2017b; Barovic et al., 2015). Soil erosion process models can be used for long as well as short periods (Sadeghi et al., 2013). Calculation of sediment yield is one of the basic necessities to achieve integrated land management and soil and water conservation (Khaledi Darvishan et al., 2014). Therefore, among the available soil erosion and sediment yield models, those which can predict both soil erosion and sediment yield can be more useful and more widely used. Because of the complexity of factors influencing sediment delivery ratio (SDR) as the ratio between soil erosion and sediment yield, it is very important to predict and use of this ratio correctly (Behzadfar et al., 2014; Khaledi Darvishan et al., 2012; Vujacic et al., 2017; Vujacic et al., 2015).

Among several empirical models, Erosion Potential Method – EPM, originally developed for Yugoslavia by Gavrilovic (1972), was in recent times repeatedly applied in several watersheds in the Balkan region (Blinkov and Kostadinov, 2010; Kostadinov et al., 2006, 2014; Milevski et al., 2008; Ristic et al., 2012; Spalevic et al. 2013, Spalevic et al. 2014; Spalevic et al. 2015; Spalevic et al. 2016; Stefanovic, 2004; Tazioli, 2009; Zorn and Komac, 2008; Tavares et al., 2019), and also in arid and semi-arid areas of the south-western USA (Gavrilovic Z., 1988), Saudi Arabia (Aburas Al-Ghamdi, 2010). The method was based on the factors affecting erosion in a watershed; its parameters were dependent on the temperature, the mean annual rainfall, the soil use, the geological properties and some other factors in the watershed scale (Khaledi Darvishan et al., 2016; 2017). The synergic influences of climate and human abandonment could have triggered erosion processes (Vitali et al., 2019).

The Intensity of Erosion and Outflow - IntErO program package (Spalevic, 2011) with the Erosion Potential Method – EPM (Gavrilovic, 1972) embedded in the algorithm of this computer-graphic method, was developed to predict the runoff peak discharge and the intensity of soil erosion in a watershed scale. This model is a computer-graphic method based on the Erosion Potential Method - EPM, which is embedded in its algorithm. The use of this model has been reported in various countries all around the world including Bosnia & Herzegovina, Bulgaria, Croatia, Czech Republic, Italy, Iran, Montenegro, Macedonia, Serbia, Slovenia, Morocco, Brazil, Nepal and Japan. The efficiency of IntErO model to predict peak outflow, soil erosion and sediment yield was also assessed in some cases and the results showed that this model can be use in variety of watershed sizes with various land uses (Spalevic, 2011).

The present study was therefore conducted to use the IntErO model to predict peak outflow, soil erosion and sediment yield for S8-intA sub-watershed in Shirindarreh watershed located in the northeast of Iran.

MATERIALS AND METHODS

Study area. The study area is an internal sub-watershed located in the north part of Shirindarreh watershed, northeast of Iran (Figure 1).

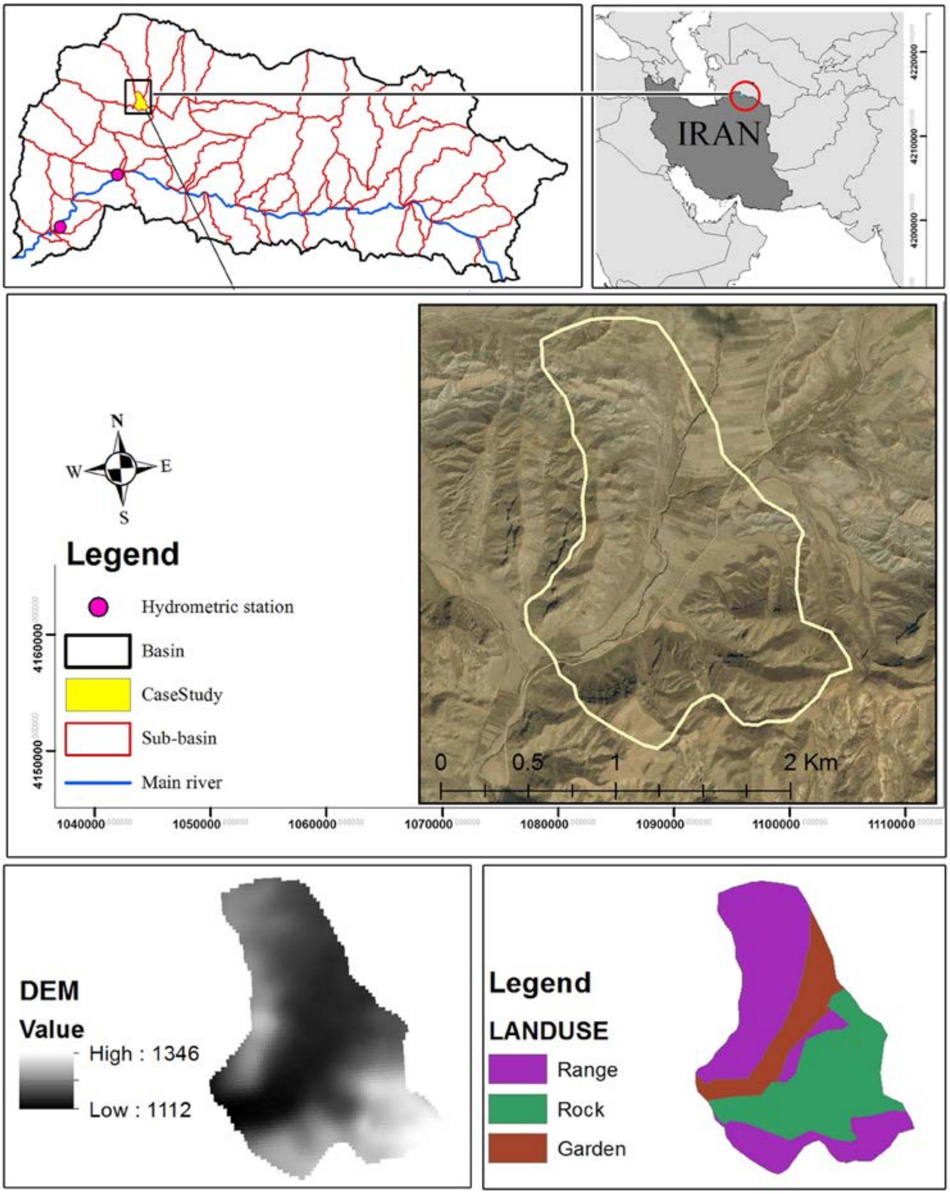

Figure 1. Location of the S8-intA basin of the Shirindarreh watershed, Iran

The name of the study area is S8-intA which means that a series of sub-watersheds drain into it. In other words, three upstream sub-watersheds (S8-1, S8-2 and S8-3) drain in a small inter-basin area. The location of the study area in Shirindarreh watershed, northeast of Iran is shown in.

Application of IntERO model. The Intensity of Erosion and Outflow - IntErO program package was used to estimate maximum peak outflow, the intensity of soil erosion and sediment yield for the study sub-watershed. All the input data required for the model can be extracted from some simple available maps including topography or Digital Elevation Model (DEM), geology map, land use/land cover map and also some easy obtained climatic variables such as temperature and precipitation.

The average annual air temperature (t0) and the average annual precipitation (Hyear) were 12.4 °C and 293.3 mm, respectively. The geological required data was extracted from the geological map of Iran (Bolourchi et al., 1987). According to the analysis, the total area of the study sub-watershed was totally under grass, meadows, pastures and orchards (100%). The coefficient of the river basin planning (Xa) was calculated about 0.7. All the model inputs calculated using the maps and data provided by Natural Resources and Watershed Management Office, North Khorasan province are shown in Table 1.

Table 1. IntErO model inputs for the study area of the S8-intA basin

Input		Value	Unit
River basin area	F	2.62	km²
The length of the watershed	O	7.44	km
Natural length of the main watercourse	Lv	1.93	km
The shortest distance between the fountainhead and mouth	Lm	1.5	km
The total length of the watercourse with tributaries of I&II class	ΣL	4.07	km
River basin length measured by a series of parallel lines	Lb	10.9	km
The area of the bigger river basin part	Fv	1.55	km²
The area of the smaller river basin part	Fm	1.07	km²
Contour line length	Liz	4.8	km
		2.79	km
The area between the two neighboring contour lines	fiz	1.65	km²
		0.96	km²
		0.01	km²
Altitude of the first contour line	h0	1200	m
Equidistance	Δh	100	m
The lowest river basin elevation	Hmin	1120	m
The highest river basin elevation	Hmax	1363	m
A part of the river basin with very permeable rocks	fp	0.15	
A part of the basin area consisted of medium permeable rocks	fpp	0.35	
A part of the basin consisted of poor water permeability rocks	fo	0.5	
A part of the river basin under forests	ff	0	
A part of the basin under grass, meadows, pastures and orchards	ft	1	
A part of the basin under plough-land and without grass	fg	0	
The volume of the torrent rain	hb	32.71	mm

Incidence	Up	100	years
Average annual air temperature	t0	12.4	°C
Average annual precipitation	Hgod	293.3	mm
Types of soil products and related types	Y	0.9	
River basin planning, coefficient of the river basin planning	Xa	0.7	
Numeral equivalents of clearly exposed erosion process	φ	0.54	

RESULTS AND DISCUSSIONS

After preparing the inputs required for IntErO model, the model was ran and all the model outputs were obtained and shown in Table 2.

Table 2. The IntErO model outputs for the study area of S8-intA basin

Output		Value	Unit
Coefficient of the river basin form	A	0.75	
Coefficient of the watershed development	m	0.34	
Average river basin width	B	0.24	km
(A)symmetry of the river basin	a	0.37	
Density of the river network of the basin	G	1.55	
Coefficient of the river basin tortuousness	K	1.29	
Average river basin altitude	Hsr	1193.63	m
Average elevation difference of the river basin	D	73.63	m
Average river basin decline	Isr	28.97	%
The height of the local erosion base of the river basin	Hleb	243	m
Coefficient of the erosion energy of the river basin's relief	Er	60.8	
Coefficient of the region's permeability	S1	0.81	
Coefficient of the vegetation cover	S2	0.8	
Analytical presentation of the water retention in inflow	W	0.4535	m
Energetic potential of water flow during torrent rains	2gDF^½	61.52	m km s
Maximal outflow from the river basin	Qmax	13.51	m^3/s
Temperature coefficient of the region	T	1.16	
Coefficient of the river basin erosion	Z	0.696	
Production of erosion material in the river basin	Wgod	1624.361	m^3/god
Coefficient of the deposit retention	Ru	0.124	
Real soil losses	Ggod	201.55	m^3/god
Real soil losses per km^2	Ggod/km^2	76.93	m^3/km^2 god

The coefficient of the river basin form, A, calculated as 0.75 using IntErO software. Coefficient of the watershed development, m, was 0.34 and the average river basin width, B, was 0.24 km. (A)symmetry of the river basin, a, which indicates that there is a possibility for large flood waves to appear in the outlet of the study area, was calculated as 0.37. In addition as mentioned before, the study area in a kind of inter basin which three more upstream sub-watersheds (S8-1, S8-2 and S8-3) drain into it. It means that it is possible to receive large amounts of peak flows.

Drainage density, G, was calculated as 1.55 km km^{-2} which corresponds to low density of the hydrographic network. Because of the location of the study area as a low slope inter basin in the middle of high slopes surrounded, the drainage density was not high.

The value of Z coefficient as 0.696 indicated that the strength of the erosion process in the study sub-watershed is low and according to the erosion type, it is surface erosion.

For the current state of land use, calculated peak flow was 13.51 m^{3}s^{-1} for a return period of 100 years. It is very important to emphasize again the location of the study area in downstream of three other sub-watersheds. So that the total peak flow of the river in the outlet of the study area can be calculated by adding 13.51 m^{3}s^{-1} with other three peaks (58.34, 75.53 and 89.47 m^{3}s^{-1}). Therefore, the total peak flow of 236.85 m^{3}s^{-1} is expected to be seen at the outlet of the study area for a return period of 100 years.

The total production of sediments, or total soil erosion occurred in the study area, Wyear, was predicted as 1624.361 m^3 year^{-1} (8.06 ton ha^{-1} year^{-1}); and the coefficient of the deposit retention, Ru, was 0.124 which indicated that about 12.4% of the eroded materials will reach to the river network of the studied sub-watershed. Therefore, the sediment yield, or real/net soil loss at sub-watershed outlet (Gyear) was predicted as 76.93 m^3 km^{-2} year^{-1} (1.00 ton ha^{-1} year^{-1}).

According to the results shown in Table 2, it seems that the study sub-watershed is a region of very weak erosion and the surface erosion has taken place in all the soils on the slopes as the dominant erosion form in the studied sub-watershed which is the most pronounced on the steep slopes with scarce vegetation cover especially in meadow land use.

CONCLUSION

The Isr value of 28.97% indicates that in the river basin prevails steep slopes. The value of Z coefficient of 0.696 indicates that the river basin belongs to III destruction category. The strength of the erosion process is medium, and according. The value of 76.93 m^3 km^{-2} year^{-1} (about 1.00 ton ha^{-1} year^{-1}) indicates, according to Gavrilovic, that the river basin belongs to V category; region of very weak erosion.

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