CALCULATION OF SEDIMENT YIELD USING THE INTERO MODEL IN THE S1-3 WATERSHED OF THE SHIRINDAREH RIVER BASIN, IRAN

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ABSTRACT

Soil erosion is a natural process caused generally by the force of water (running water and raindrops) or wind. The process involves not only the detachment of soil particles (on-site), but also their transfer and deposition elsewhere in the river basin and out of the catchment (off-site). The assessment of soil erosion may be performed using and analyzing measurements data (sediment discharge series and soil erosion measurements) or applying various analytical models. It is well known fact that the measurements results are available only in a few experimental catchments in most of the countries all over the World and as a consequence the researchers are frequently using the analytical models. For calculation of the Sediment yield in the S1-3 Watershed of Iran we used the IntErO model (Spalevic, 2011) based on EPM method (Gavrilovic, 1972). Calculated peak discharge from the S1-3 Watershed was 87 m^3s^{-1} for the incidence of 100 years and the net soil loss was 5,574 m^3km^{-2}, specific 194 m^3 km^{-2} per year. Taking into consideration the results of this study and previous experiences of the other researchers, it was concluded that the IntErO Model may be applied to the other regions similar to Shirindareh basin for calculation of sediment yield and identification of critical areas in watersheds.

Keywords: *soil erosion, IntErO Model, sediment yield, ShirinDareh watershed*

INTRODUCTION

Soil degradation and desertification risk is a globally acknowledged issue with ecological, socioeconomic, cultural and political implications at both the regional and local scales. Those processes occur in both developed and emerging countries and affect arid, dry and even sub-humid areas (Strijker, 2005; Koulouri and Giourga, 2007; Helming *et al.*, 2011).

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Soil degradation caused by erosion, together with rapid population increase, are ranked as the most important environmental problems in the world (Stoffel and Huggel, 2012; Ristic *et al.*, 2001) where the erosion is a key driver of land degradation heavily affecting sustainable land management in various environments worldwide (Ballesteros-Cánovas *et al.*, 2015; Stoffel *et al.*, 2013; Verheijen *et al.*, 2009). Every year, soil erosion leads to the loss of about ten million hectares of cropland, which reduces the limited amount of arable land available for food production, thereby contributing to malnourishment in millions of people (Pimentel, 2006). In addition, the accumulation of large volumes of sediment can cause severe sedimentation in reservoirs and channel beds, resulting in the loss of various functions in these hydraulic projects. Thus, it is important to determine the sediment yield rates in watersheds, which can provide a good basis to facilitate soil erosion control and river basin management (Zhao *et al.*, 2015).

Soil erosion is a growing problem globally and is serious problem in Iran. Quantitative information on soil loss is needed for erosion risk assessment. The modelling of the erosion process has progressed rapidly, and a variety of models have been developed to predict both runoff and soil loss. The authors of this study used the computer - graphic models (Spalevic, 2011; Spalevic, 1999a) for prediction of soil erosion intensity from the catchment area – IntErO model (Spalevic, 2011).

The objectives of the present study were: (1) to quantify the sediment yield in the studied S1-3 Watershed of the Shirindareh River Basin on the north-eastern part of Iran; (2) testing the possibility of application of the IntErO model in the conditions of the Caspian Sea Watersheds.

MATERIAL AND METHODS

The study was conducted in the area of the S1-3 watershed of the Shirindareh River Basin of the Caspian Sea Watershed (Figure 1).

Figure 1. Study area of the S1-3 watershed, the Shirindareh River Basin, Iran

The studied river basin of the S1-3 watershed is located in the north-eastern part of Iran and encompasses an area of 28.6 km^2. In terms of geomorphology and climate, it is part of the natural entity of the Shirindareh River Basin of the Razavi Khorasan that lies between steep slopes and plains bordering with Turkmenistan on Chaat region, draining to the Caspian Sea Watershed in the Gulf of Hasan Ghuly.

Shirindareh river basin area has the important strategic values for North Khorasan province. Because of quality and quantity of surface runoff and need to supply of drinking water and agriculture a rock fill dam has been constructed on the main river. The management of upland areas is very important to increase performance of the dam (Behzadfar *et al.*, 2015).

The shortest distance between the fountainhead and the mouth, lv, is 7 km; and the total length of the main watercourse with tributaries is 47.7 km. The average slope gradient in the river basin, Isr, is calculated on 23.50% what indicates that in the river basin prevailing steep slopes. The average river basin altitude Hsr, is calculated on 1,798 m.

Figure 2. Details from the filed visit: Problem with overgrazing (February 2015)

Fieldwork was undertaken to collect detailed information on the intensity and the forms of the soil erosion, the status of the plant cover, the type of land use, and the measures in place contributing to the reduction or alleviation of the erosion processes. Morphometric methods were used to determine the slope, the specific lengths, the exposition and form of the slopes, the depth of the erosion base, the density of the erosion rills, the degree of the rills, and other relevant parameters. Different forms: the shape of the slope, the depth of the erosion base and the density of erosion rills were determined.

Climatological data were received from the North Khorasan Meteorological stations of Iran. Pedological survey was based on the research of the National Geological Survey

Organization (NGS) led by Bolourchi *et al*. (1987), who analysed the physical and chemical properties of all geological formations of North Khorasan province, including those in the study area of the S1-3 Basin.

For the obtaining data on forecasts of peak discharge from the basin and the intensity of the soil erosion we used the program package Intensity of Erosion and Outflow - IntErO (Spalevic, 2011) that is an integrated, second-generation version of the program "Surface and Distance Measuring" (Spalević, 1999) and the program "River basins" (Spalević, 2000). The Erosion Potential Method – EPM (Gavrilovic, 1972) is embedded in the algorithm of this computer-graphic method.

The model is currently in use in all the countries of Western Balkans, but also used by some researchers from Czech Republic and Italy (Gazdic *et al.*, 2015; Spalevic *et al.*, 2015a, 2015b, 2015c, 2015d, 2015e, 2015f, 2015g, 2015h, 2015i, 2015k; Kostadinov *et al.*, 2014, Curovic *et al.*, 1999). The EPM and/or the IntErO model have been successfully used in some regions of Iran: Chamgardalan, Kasilian, Kermanshah, Razavi Khorasan (Barovic *et al.*, 2015; Behzadfar *et al.*, 2015; Behzadfar *et al.*, 2014a; Behzadfar *et al.*, 2014b; Sadeghi, 1993; Amiri, 2010).

RESULTS AND DISCUSSION

The geological structure and soil characteristics of the area. Our analysis, extracting the geological data from the Geological map of Iran (Bolourchi *et al*., 1987), shown that the poor water permeability rocks prevails. The geological structure of the studied river basin is presented at the Table 1.

Table 1. The geological structure of the S1-3 watershed of the Shirindareh River Basin

A part consisted of a very permeable products from rocks	fp	0.07
Apart of the river basin area consisted of medium permeable rocks	fpp	0.42
A part of the river basin consisted of poor water permeability rocks	fo	0.51

The coefficient of the region's permeability, S1, is calculated on 0.83. The most common soil type in the studied area is Inceptisols with Calcic horizon.

There is a highly variable climate and human pressure on the land in the studied area of the S1-3 Watershed of the Shirindareh River Basin. The climate is continental, with cold winters and warm, dry summers. The Basic climatological data needed for calculation of Soil erosion intensity are presented at the Table 2.

Table 2. Basic climatological data needed for calculation of Soil erosion intensity

The absolute maximum air temperature	34.6 [°C]
The absolute negative air temperature	-24.4 [°C]
The average annual air temperature (t0)	10.2 [°C]
The average annual precipitation (H_{year})	328.4 [mm]

Source: The North Khorasan Meteorological stations of Iran

The temperature coefficient of the region, T, is calculated on 1.01; the amount of torrential rain, hb, on 36.84 mm.

Vegetation and land use. Good vegetation cover reduces overland flow velocity and increases infiltration by protecting the soil against rain drop impact and reducing the erosive capacity of the rain (Asfaha *et al.,* 2015; Molina *et al*., 2007) whereas deforestation leads to increased peak discharge (Bonan *et al*., 2004).The studied area is located in Middle-East of the Kope-Dagh geographical region. According to the available literature and the analysis using the Google maps and Google Earth, including the records from the field visits almost all the studied area is used for the pastures and meadows (Table 3).

Table 3. Land use structure at the S1-3 watershed of the Shirindareh River Basin

A part of the river basin under forests	fs	0
A part of the river basin under grass, meadows, pastures and orchards	ft	0.98
A part under bare land, plough-land and ground without vegetation	fg	0.02

The coefficient of the river basin planning, Xa, is calculated on 0.61. The coefficient of the vegetation cover, S2, is calculated on 0.8.

Soil erosion and runoff characteristics. The dominant erosion form in this area is surface erosion. Problems with overgrazing and livestock traces are recorded also all over the studied area.

The coefficient of the river basin form, A, is calculated on 0.81. Coefficient of the watershed development, m, is 0.37 and average river basin width, B, is 3.63 km. (A)symmetry of the river basin, a, is calculated on 1.1 and that indicates that there is a possibility for large flood waves to appear in the studied river basin. The value of G coefficient of 1.66 indicates there is very high density of the hydrographic network.

The height of the local erosion base of the river basin, Hleb, is 578 m. Coefficient of the erosion energy of the river basin's relief, Er, is calculated on 79.5. According to the erosion type, the dominant process is surface erosion.

The value of Z coefficient of 0.748 indicates that the river basin belongs to II destruction category. The strength of the erosion process is high, and according to the erosion type, it is intrusive erosion. We calculated the soil losses from the S1-3 catchment on 5574 m^3 yr^{-1} and the peak discharge on 87 m^3s^{-1} (for the incidence of 100 years).

Processing the input data using the IntErO model we received the results in relation to the sediment yield for the S1-3 Watershed of the Shirindareh River Basin of Iran (Table 4).

Table 4. Part of the IntErO report for the S1-3 Watershed River Basin

Input data			
River basin area	F	28.68	km²
The length of the watershed	O	29.16	km
Natural length of the main watercourse	Lv	7.03	km
The shortest distance between the fountainhead and mouth	Lm	6.43	km
The total length of main watercourse with tributaries of I & II class	ΣL	47.7	km
River basin length measured by a series of parallel lines	Lb	7.91	km
The area of the bigger river basin part	Fv	22.22	km²
The area of the smaller river basin part	Fm	6.46	km²
Altitude of the first contour line	h0	1700	m
The lowest river basin elevation	Hmin	1611	m
The highest river basin elevation	Hmax	2189	m
The volume of the torrent rain	hb	36.84	mm
Incidence	Up	100	years
Average annual air temperature	t0	9.3	°C
Average annual precipitation	Hyr	343	mm
Types of soil products and related types	Y	1.1	
River basin planning, coefficient of the river basin planning	Xa	0.61	

Results			
Numeral equivalents of visible and clearly exposed erosion process	φ	0.64	
Coefficient of the river basin form	A	0.81	
Coefficient of the watershed development	m	0.37	
Average river basin width	B	3.63	km
(A)symmetry of the river basin	a	1.1	
Density of the river network of the basin	G	1.66	

Results			
Coefficient of the river basin tortuousness	K	1.09	
Average river basin altitude	Hsr	1798.79	m
Average elevation difference of the river basin	D	187.79	m
Average river basin decline	Isr	23.5	%
The height of the local erosion base of the river basin	Hleb	578	m
Coefficient of the erosion energy of the river basin's relief	Er	79.5	
Coefficient of the region's permeability	S1	0.83	
Coefficient of the vegetation cover	S2	0.8	
Analytical presentation of the water retention in inflow	W	0.4934	m
Energetic potential of water flow during torrent rains	2gDF^½	325.07	m km s
Maximal outflow from the river basin	Qmax	86.79	$m^3 s^{-1}$
Temperature coefficient of the region	T	1.01	
Coefficient of the river basin erosion	Z	0.748	
Production of erosion material in the river basin	Wyr	20284.32	$m^3 yr^{-1}$
Coefficient of the deposit retention	Ru	0.275	
Real soil losses	Gyr	5574.57	$m^3 yr^{-1}$
Real soil losses per km2	Gyr km^2	194.37	$m^3 km^2 yr^{-1}$

CONCLUSIONS

The study was conducted in the area of the S1-3 Basin of Shirindareh region, the main tributary of the river Atrakin Iran. Many factors have influenced the development of erosion processes in the studied territory. The most significant factors are the area’s climate, relief, geological substrate and pedological composition, as well as the condition of the vegetation cover and the land use.

We calculated the soil erosion intensity and runoff using the IntErO model. According to our findings, it can be concluded that there is a possibility for large flood waves to appear in the studied S1-3 river basin.

Calculated peak discharge was 87 $m^3s^{-1}$for a return period of 100 years. The value of Z coefficient of 0.748 indicates that the river basin belongs to the second destruction category out of five. The calculated net soil loss from the river basin was 5574 m^3 per year, specific 194 m^3km^{-2} per year.

This study further confirmed the findings of Barovic *et al.*, 2015; Behzadfar *et al.*, 2015, 2014a, 2014b; Amini *et al.*, 2014; Moradi *et al.*, 2015; as well as Amiri, 2010; Khaleghi, 2005; Maleki, 2003; Nadjafi, 2003; Sadeghi 1993 in possibility of implementing the

Erosion Potential Method in Iran. That leads to the conclusion that the IntErO model may be a useful tool for researchers in calculation of runoff and sediment yield for the river basins of the Caspian Sea Watershed with the similar physical-geographical characteristics like the Shirindareh River Basins. The team of authors have the same good experience about the simplicity in operation and practicality in use of the IntErO also in Saudi Arabia (Al-Turki *et al.*, 2015) and in the Western Balkans (Barovic & Spalevic, 2015; Vujacic & Spalevic, 2015; Spalevic *et al.*, 2014a, 2014b, 2014c, 2014d, 2013a, 2013b, 2013c, 2013d, 2013e, 2003a, 2003b, 1999b, 1999c).

Because of high erosion rate, complex measures must be taken for soil conservation and environmental protection in the studied area. That is key requirement for better socio-economic growth in the future.

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