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CALCULATION OF SEDIMENT YIELD IN THE S1-1 WATERSHED, SHIRINDAREH WATERSHED, IRAN

SUMMARY

Soil erosion and sediment redistribution are natural processes of paramount importance. They are causing environmental concerns such as land degradation, soil and habitat loss, water pollution, desertification, ecosystem alteration. They may also have severe consequences on human infrastructures, such as bridges, road and rail network; sedimentation and deposition on reservoirs. The integrated management of soil erosion at the catchment scale has always been of a great importance for agriculture and other fields such as ecology and water science. For this reason, the assessment of soil erosion and sediment transport is a key component of integrated catchment management. It is generally accepted fact that both sediment discharge series and soil erosion measurements are only available in a few and small to medium-size experimental catchments. The most useful tool available to catchment managers for soil erosion and sediment yield assessment is use of analytical models of these processes. In order to carry out this task, the IntErO model was tested in 48 catchments of Shirindareh watershed in Iran with different sediment data availability. One of the studied regions was S1-1 watershed where we studied soil erosion processes using this analytical and computer-graphic method. Calculated maximal outflow from the river basin was 41 m^3s^{-1} for the incidence of 100 years and the net soil loss was 3355 m^3km^{-2}, specific 224 m^3km^{-2} per year. It was concluded that this model can be applied to this Region and may be applied to the other areas similar to Shirindareh watershed for simple, reliable identification of critical areas of soil erosion in watersheds. Nevertheless, further research is needed to address model limitations and to reduce model results uncertainty.

Keywords: Erosion, Soil erosion assessment, watershed, Land use, IntErO model

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INTRODUCTION

Erosion and soil loss are of great interest in Europe because of their effects on the environment, especially at the scale of hydrographic basin. The environmental impact is a widespread problem often not enough faced by the Governments and Public territorial Authorities. The problem of soil loss and land degradation, with their huge impact on the environment such as desertification, ecosystem alteration, human works damaging, siltation of reservoir is a key point for agriculture, ecology, hydrology and hydrogeology.

Watersheds are in fact often affected by natural disasters, above all floods, overflows, inundations, erosion problems, landslides and pollution (Tazioli*et al.*, 2015).

The estimation of the erosion in a watershed is therefore essential to encompass a lot of environmental problems and to evaluate the amount of sediment moved, transported and deposited in and out of the basin. Direct measurements of erosion in a watershed are possible with multi-years measurement of solid transport in the closing-section (Tazioli, 2009).

Sediment transport is a process yielded by soil erosion; it produces some consequences on the watershed and on the surrounding environment. The suspended load can be measured through different techniques (Edwards and Glysson 1999; International Atomic Energy Agency 2005), for instance tracing techniques, nuclear probes, optical and acoustic probes, digital imaging analysis and direct sampling (IAEA, 2005).

Some authors (Tazioli*et al.*, 2005; and Tazioli, 2009; Spalevic, 2011) indicate that sediment load measurements are useful to calibrate erosion predicting models, necessary to estimate the erosion in a watershed on multi-annual basis.

Modelling, in fact, is a good, often necessary and proven tool useful to evaluate the amount of discharge and erosion in a watershed, especially when hydrometric and discharge data are not available. For these reasons, mathematical erosion models were developed to forecast the erosion severity and the sediment yield in a sub-catchment area, based on a simple mathematical equation such as Universal Soil Loss Equation – USLE, or with the modified and updated RUSLE, MUSLE (Wischmeier and Smith, 1965, 1978).

Among several models, Erosion Potential Method – EPM, originally developed for Yugoslavia by Gavrilovic (1972), was in recent times repeatedly applied in the watersheds of Apennine and in the Balkan Peninsula (Blinkov and Kostadinov, 2010; Kostadinov*et al.*, 2014, 2006; Lenaerts, 2014; Milevski*et al.*, 2008;Ristic*et al.*, 2012; Sekularac, 2000, 2013; Spalevic *et al*. 2014a, 2014b, 2014c, 2013a, 2013b, 2013c, 2013d, 2013e, 2013f, 2012a, 2012b;Stefanovic, 2004; Tazioli, 2009, Zorn and Komac, 2008), but also in the other regions in the world, for example in arid and semi-arid areas of the south-western USA (Gavrilovic Z., 1988), Saudi Arabia (Aburas Al-Ghamdi, 2010)... The method is based on the factors affecting erosion in a catchment; its parameters dependent on the temperature, the mean annual rainfall, the soil use, the geological properties and some other features of the catchment.

The Intensity of Erosion and Outflow - IntErO program package (Spalevic, 2011), developed to predict the soil erosion intensity and the extreme runoff in a watershed, is a computer-graphic method based on the Erosion Potential Method - EPM, which is embedded in its algorithm.

In the present research, the IntErO model was verified and tested in 48 catchments of Shinindareh watershed in Iran; one of the studied regions was S1-1 watershed and here applied to a small sub-catchment of the Shirindareh River Basin, one of the main tributary of the River Atrak, having an area of around 15 $km^2$and average altitude of about 1600 m. Here, soil erosion processes, soil erosion intensity and runoff of the Shinindareh River were calculated using the IntErO model, thus confirming the compliance of this model to the Iranian watersheds.

MATERIAL AND METHODS

Study area. The north eastern parts of Iran are mountainous, with the presence of deep incised valleys (in Limestone Mountains) but also hilly. Rivers in this region drain to the Caspian Sea.

The study was conducted in the area of the Shirindareh River Basin, one of the main tributary of the river Atrak. Atrak originates from Hezar-Masjed Mountains in the region of Razavi Khorasan and lies between steep slopes and plains till to enter the territory of Turkmenistan on Chaat region and finally drain to Caspian Sea in the Gulf of Hasan Ghuly. Shirindareh river basin area has the important strategic values for North Khorasan province. Because of good 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 of the basin. So, the management of upland areas is very important to increase performance of the dam.

The river basin (S1-1) encompasses an area of 14.96 km^2 and is categorized in the group of the small watersheds of the natural entity of the Shirindareh region. The average slope gradient in the river basin, Isr, is calculated on 8.9%, indicating that in the river basin prevail gentle slopes. The average river basin altitude, Hsr, is calculated on 1617.82 m; the average elevation difference of the river basin, D, is 256.82 m. The natural length of the main watercourse, Lv, is 7.06 km. The shortest distance between the fountainhead and the mouth, Lm, is 6.72 km (source: original).

Fieldwork & laboratory analysis. During the field work, using a morphometric methods, various data on intensity and forms of soil erosion, land use, and the measures taken to reduce or mitigate erosion were recorded. Different forms: the shape of the slope, the depth of the erosion base and the density of erosion rills were determined.

Figure 1. Study Area location in Iran and Shirindareh region

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 S1-1 Basin.

Soil loss model application. We used the Intensity of Erosion and Outflow - IntErO program package (Spalevic, 2011) to obtain data on forecasts of maximum runoff from the basin and soil erosion intensity, with the Erosion Potential Method – EPM (Gavrilovic, 1972) embedded in the algorithm of this computer-graphic method.

This methodology is in use in: Bosnia & Herzegovina, Bulgaria, Croatia, Czech Republic, Italy, Iran, Montenegro, Macedonia, Serbia and Slovenia (Kostadinov*et al*., 2014); in Iran have been successfully used previously in the Regions of Chamgardalan; Kasilian (Yousefi*et al*., 2014; Zia Abadi&Ahmadi, 2011; Amiri, 2010) and many other regions.

Figure 2.Details from the studied river basin of Shirindareh

RESULTS AND DISCUSSION

Climatic characteristics.

The climate in the studied area is continental, i.e. with cold winters and warm, dry summers. The absolute maximum air temperature is 34.6°C; the negative temperatures can fall to a minimum of -24.4°C. The average annual air temperature, t0, is 10.2°C. The average annual precipitation, Hyear, is 328.4mm (Source: Data from the North Khorasan Meteorological stations of Iran).

The temperature coefficient of the region, T, is calculated on 1.06; the amount of torrential rain, hb, on 35.61 mm.

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 structure of the river basin, according to bedrock permeability, is the following: f0, poor water permeability rocks, 36%; fpp, medium permeable rocks, 52%; fp, very permeable products from rocks: 12%. The coefficient of the region's permeability, S1, is calculated on 0.77 (source: original).The most common soil type in the studied area is Inceptisols with Calcic horizon.

Vegetation and land use.

The studied area is located in Middle- East of the Kope-Dagh geographical region. According to our analysis, portion of the river basin totally under mountain pastures (100%).The coefficient of the river basin planning, Xa, is calculated on 0.6. 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 mixed erosion and has taken place in all the soils on the slopes. This erosion is the most pronounced on the steep slopes with scarce vegetation cover.

Using software IntErO we calculated the coefficient of the river basin form, A, on 0.5. Coefficient of the watershed development, m, is 0.51 and average river basin width, B, is 1.75 km. (A)symmetry of the river basin, a, is calculated on 0.48 and indicates that there is a possibility for large flood waves to appear in the river basin.

Drainage density, G, is calculated as 1.89 km km^{-2} which corresponds to high density of the hydrographic network. The height of the local erosion base of the river basin, Hleb, is 602 m. Coefficient of the erosion energy of the river basin's relief, Er, is calculated on 97.43.

The value of Z coefficient of 0.86 indicates that the river basin belongs to the second destruction category out of five. The strength of the erosion process is strong, and according to the erosion type, it is mixed erosion.

For the current state of land use, calculated peak flow is 40.9m^{3}s^{-1} for a return period of 100 years.

The production of sediments in the basin, W_{year}, is calculated as 13235 m^3 year^{-1}; and the Coefficient of the intra-basin deposition, Ru, at 0.254.

Sediment yield at catchment outlet (G_{year}) was calculated as 3355 m^{3}year^{-1}; and specific sediment yield at 224 m^{3}km^{-2}year^{-1}.

Part of the detailed report for the S1-1 watershed presented in the Table 1.

Table.1. Part of the IntErO report for the S1-1 watershed river basin

Input data			
River basin area	F	14.96	km^2
The length of the watershed	O	18.21	km
Natural length of the main watercourse	Lv	7.06	km
The shortest distance between the fountainhead and mouth	Lm	6.72	km
The total length of the main watercourse with tributaries I&II class	ΣL	28.33	km
River basin length measured by a series of parallel lines	Lb	8.56	km
The area of the bigger river basin part	Fv	9.27	km^2
The area of the smaller river basin part	Fm	5.68	km^2
Altitude of the first contour line	h0	1400	m
Equidistance	Δh	100	m
The lowest river basin elevation	Hmin	1361	m
The highest river basin elevation	Hmax	1963	m
Part of the basin consisted of a very permeable rocks	fp	0.12	
Part of the river basin area consisted of medium permeable rocks	fpp	0.52	
Part of the river basin consisted of poor water permeability rocks	fo	0.36	
Part of the river basin under forests	fš	0	
Part of the river basin under meadows, pastures and orchards	ft	1	
Part under plough-land and ground without grass vegetation	fg	0	
The volume of the torrent rain	hb	35.61	mm
Incidence	Up	100	years
Average annual air temperature	t0	10.2	°C
Average annual precipitation	H year	328.4	mm
Types of soil products and related types	Y	1.1	
River basin planning, coefficient of the river basin planning	Xa	0.6	
Numeral equivalents of clearly exposed erosion process	φ	0.8	
Results:			
Coefficient of the river basin form	A	0.5	
Coefficient of the watershed development	m	0.51	
Average river basin width	B	1.75	km
(A)symmetry of the river basin	a	0.48	
Density of the river network of the basin	G	1.89	km km^{-2}
Coefficient of the river basin tortuousness	K	1.05	
Average river basin altitude	Hsr	1617.8	m
Average elevation difference of the river basin	D	256.82	m
Average river basin decline	Isr	25.15	%
The height of the local erosion base of the river basin	Hleb	602	m
Coefficient of the erosion energy of the river basin's relief	Er	97.43	
Coefficient of the region's permeability	S1	0.77	
Coefficient of the vegetation cover	S2	0.8	
Analytical presentation of the water retention in inflow	W	0.4779	m
Energetic potential of water flow during torrent rains	2gDF^½	274.55	m km s
Maximal outflow from the river basin	Qmax	40.9	m^3s^{-1}
Temperature coefficient of the region	T	1.06	
Coefficient of the river basin erosion	Z	0.869	
Production of erosion material in the river basin	W year	13235	m^3year^{-1}
Coefficient of the deposit retention	Ru	0.254	
Real soil losses	G year	3355.6	m^3year^{-1}
Real soil losses per km^2	Gyear km^{-2}	224.3	$m^3km^{-2}year$

CONCLUSIONS

The study was conducted in the area of the S1-1 Basin of Shirindareh region, the main tributary of the river Atrakin Iran. 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 S1-1river basin.

Calculated peak flow is 40.9 $m^3s^{-1}$for a return period of 100 years. The value of Z coefficient of 0.869 indicates that the river basin belongs to the second destruction category out of five. The calculated net soil loss from the river basin was 3355 m^3 per year, specific 224 m^3km^{-2} per year. The strength of the erosion process is strong, and according to the erosion type, it is mixed erosion.

This study further confirmed the findings of Yousefi *et al*. (2014); Zia Abadi & Ahmadi, (2011); as well as Amiri (2010) in successful implementation of the Erosion Potential Method – EPM in Iran, what leads to the conclusion that the IntErO model may be a useful tool for researchers in calculation of runoff and sediment yield at the level of the river basins draining to the Caspian Sea.

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