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# CALCULATION OF SOIL LOSS FROM THE S7-3 CATCHMENT OF THE SHIRINDAREH WATERSHED, IRAN USING THE RIVER BASIN MODEL

## SUMMARY

Soil erosion is one of the major environmental problems in Iran. Factors such as soil erodibility, density of the river network of the river basin and its asymmetry, slope length and steepness, agricultural practices and the other physical-geographical characteristics, were surveyed and soil loss rate were calculated using an empirical River Basin Model (RBM). The objective of this research was to introduce a new method based on Erosion Potential Method (EPM) for the estimation of soil erosion on the catchment scale. Calculated peak discharge from the river basin was 35 $m^3s^{-1}$ for the incidence of 100 years and the net soil loss was 3182 $m^3yr^{-1}$, specific 164 $m^3km^{-2}yr^{-1}$. Supplementary research is needed to address model limitations regarding the further development in relation to the GIS adaptations.

**Key words:** Soil erosion, River Basin Model, Sediment yield, Shirindareh watershed.

## INTRODUCTION

Soil degradation caused by erosion, as one of the most important environmental problems in the world (Stoffel and Huggel, 2012) and sediment transport is not only the cause of an imbalance of natural rivers and streams, but also the cause of change in the river channel and sediment accumulation behind dams reducing their storage volumes (Sadeghi *et al.*, 2014).

Soil loss is a serious ecological concern in various environments worldwide (Kisic *et al.*, 2016; Ballesteros-Cánovas *et al.*, 2015; Ristic *et al.*, 2001, Curovic *et al.*, 1999). Sediments are responsible for transporting a significant fraction of nutrients and contaminants. Large suspended sediment fluxes in river catchments, which result from soil loss due to water erosion, constitute a major environmental issue (Louvat *et al.*, 2008), heavily affecting

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sustainable land management in various environments (Ballesteros - Cánovas *et al*, 2015; Stoffel *et al*, 2013).

Study of soil erosion and sediment yield is one of the basic necessities to achieve integrated land management and soil and water conservation (Khaledi Darvishan *et al*., 2014).

Direct measurements of erosion in the catchment are valid for a number of year's measurements of solid transport in the closing-section (Behzadfar *et al*., 2014a and Behzadfar *et al*., 2014b). The water and sediment sampling in given intervals need a lot of time and is costly (Khaledi Darvishan *et al*., 2010) and the assessment of sediment yield using soil erosion models have been used more and more (Spalevic *et al*., 2013a, 2013b, 2013c).

The modelling of the erosion process has progressed rapidly and a variety of models have been developed to predict both runoff and soil loss. We used the computer-graphic "River Basin" model (Spalevic, 2011; Spalevic *et al*., 2000; Spalevic, 1999) for prediction of soil erosion intensity from the watershed area.

The objectives of this research were to quantify the sediment yield in the studied S7-3 Watershed of the Shirindareh River Basin testing the possibility of application of the River Basin model in the conditions of the Caspian Sea Watersheds.

## MATERIAL AND METHODS

We calculated soil loss from the S7-3 Catchment (19 km$^2$), of the Shirindareh Watershed, a tributary of the river Atrak (Caspian Sea Watershed), located in the north eastern parts of the mountainous area of Iran (Figure 1).


Figure 1. Study area of the S7-3 Catchment of the Shirindareh River Basin

Morphometric methods were used to determine the slope, the specific lengths, the exposition and form of the slopes, the depth of the erosion base and the density of erosion rills. Google Earth and Google Maps were used for further studying of the morphology of the features.

We used available data on Soils and of Geology of North Khorasan province, based on the research of the National Geological Survey Organization (Bolourchi, 1987).

Climatological data were received from the meteorological stations located in North Khorasan province of Iran. We analysed torrential rains, annual air temperatures, and average annual precipitations.

Directly observing of large-scale hydrological processes is difficult. Modelling has become a key research tool at the basin scale studies (Fu *et al*., 2011).

The “River Basin[2]” physically-based model (Spalevic *et al*., 2000) as a computer-graphic catchment-scale hydrological model, with the Erosion Potential Method – EPM (Gavrilovic, 1972) rooted in the procedure of this model, was used for soil loss calculation from the studied watershed.

According to the method sediment yield is calculated using the following calculation:

$$W_{yr} = T \cdot H_{yr} \cdot \pi \cdot \sqrt{Z^3} \cdot F$$

where $W_{yr}$ is the annual erosion in $m^3yr^{-1}$; T, the temperature coefficient; $H_{yr,}$ the average yearly precipitation in mm; Z, the erosion coefficient.

The erosion coefficient, Z, was calculated as follows:

$$Z = Y \cdot X \cdot (\phi + \sqrt{I})$$

where, Y is Soil erodibility coefficient; X is Soil protection coefficient; $\phi$ is Erosion development coefficient (tables for Y, X and $\phi$ coefficients available at Gavrilovic, 1972). F is the watershed area in $km^2$.

The actual sediment yield was calculated as follows:

$$G_{yr} = W_{yr} \cdot R_u$$

where, $G_{yr}$ is the sediment yield in $m^3yr^{-1}$; $W_{yr}$, the total annual erosion in $m^3yr^{-1}$; $R_u$ is sediment delivery ratio.

The actual sediment yield was calculated as follows:

$$R_u = \frac{\left(\sqrt{O \cdot D}\right)}{0.2 \cdot (L + 10)}$$

where, O is perimeter of the watershed in km; D is the average difference of elevation of the watershed in km; L is length of the catchment in km.

## RESULTS AND DISCUSSION

The climate of the studied area is continental, with the absolute maximum temperature of 34.6°C and the negative of -24.4°C, respectively. Average annual air temperature, t0, is 11.8°C and the Temperature coefficient of the region, T, is calculated on 1.13; The amount of torrential rain, hb, on 33.53 mm. The average annual precipitation, $H_{yr}$, is 303.2 mm (Source: Data from the North Khorasan Meteorological stations of Iran).

The coefficient of the river basin planning is calculated on 0.7. The coefficient of the vegetation cover is calculated on 0.8.

(A)symmetry coefficient indicates that there is a possibility for large flood waves to appear in the river basin. The value of G coefficient of 1.85 indicates

[2] Link to the “River Basin” exe file: www.agricultforest.ac.me/Spalevic/River

there is high density of the hydrographic network. The value of 23.51% indicates that in the river basin prevail steep slopes.

According to the erosion type, it is mixed erosion. Surface erosion is the most pronounced on the steep slopes without vegetation cover. In the studied river basin some problems of overgrazing and livestock traces are recorded also.

Calculation of Sediment yield of the S7-3 Watershed of the Shirindareh River Basin of Iran is presented at the "River Basin" Report 1.

**Report 1.** The "River Basin" report for the S7-3 Watershed

***Inputs:*** *River basin area,* ***F****, 19.33 km²; The length of the watershed,* ***O,*** *24.76, km; Natural length of the main watercourse,* ***Lv,*** *12 km; The shortest distance between the fountainhead and mouth,* ***Lm****, 10.96 km; The total length of the main watercourse with tributaries of I and II class,* ***ΣL****, 35.67 km; The area of the bigger river basin part,* ***Fv****, 10.58 km²; The area of the smaller river basin part,* ***Fm****, 8.75 km²; Altitude of the first contour line,* ***h0****, 1200 m; The lowest river basin elevation,* ***Hmin****, 1119 m; The highest river basin elevation,* $H_{max}$*, 1758 m; A part of the river basin consisted of a very permeable products from rocks (limestone, sand, gravel),* ***fp****, 0.08; A part of the river basin area consisted of medium permeable rocks (slates, marls, brownstone),* ***fpp****, 0.25; A part of the river basin consisted of poor water permeability rocks (heavy clay, compact eruptive),* ***fo****, 0.67; A part of the river basin under forests,* ***fs****, 0; A part of the river basin under grass, meadows, pastures and orchards,* ***ft****, 1; A part of the river basin under bare land, plough-land and ground without grass vegetation,* ***fg****, 0; The volume of the torrent rain,* ***hb****, 33.53 mm; Incidence,* ***Up****, 100 years; Average annual air temperature,* ***t0****, 11.8 °C; Average annual precipitation,* $H_{yr}$*, 303.2 mm; Types of soil products and related types,* ***Y****, 1.1; River basin planning, coefficient of the river basin planning,* ***Xa****, 0.7; Numeral equivalents of visible and clearly exposed erosion process,* ***φ****, 0.64.*

***Results:*** *Coefficient of the river basin form,* ***A****, 0.4; Coefficient of the watershed development,* ***m****, 0.77; Average river basin width,* ***B****, 2,41, km; (A)symmetry of the river basin,* ***a****, 0.19; Density of the river network of the basin,* ***G****, 1,85; Coefficient of the river basin tortuousness,* ***K****, 1,09; Average river basin altitude,* $H_{sr}$*, 1316.28 m; Average elevation difference of the river basin,* ***D****, 197.28 m; Average river basin decline,* $I_{sr}$*, 23.51%; Coefficient of the region's permeability,* $S_1$*, 0.88; Coefficient of the vegetation cover,* $S_2$*, 0.8; Maximal outflow from the river basin,* $Q_{max}$*, 34* $m^3s^{-1}$*; Production of erosion material in the river basin,* $W_{yr}$*, 15842* $m^3\ yr^{-1}$*; Coefficient of the deposit retention,* ***Ru****, 0.201; Real soil losses,* $G_{yr}$*, 3182,* $m^3\ yr^{-1}$*; Real soil losses per* $km^2$*, 164* $m^3\ yr^{-1}\ km^{-2}$*.*

This approach is also in use: Bosnia and Herzegovina, Brazil, Bulgaria, Croatia, Czech Republic, Italy, Macedonia, Montenegro, Morocco, Saudi Arabia, Serbia, South Africa and Slovenia (Al-Turki *et al*., 2015; Gazdic *et al*., 2015; Spalevic *et al.*, 2015a, 2015b, 2015c, 2015d, 2015e, 2015f, 2015g, 2015h, 2015i, 2015k; Vujacic & Spalevic, 2016; Kostadinov *et al.,* 2014; Spalevic *et al*., 2014a, 2014b, 2014c). The provided methodology have been successfully used in Iran in the regions of Chamgardalan, Kasilian, Kermanshah, Razavi Khorasan (Spalevic *et al.*, 2016; Draganic *et al*., 2015a; Draganic *et al*., 2015b; Behzadfar *et al.*, 2015; Barovic & Spalevic, 2015; Sadeghi, 2005) and other regions.

## CONCLUSIONS

Based on the calculation of sediment yield it can be revealed that:

- Production of erosion material in the river basin, $\mathbf{W_{yr}}$, was 15842 $m^3$ $yr^{-1}$;
- Calculated soil losses are 3182 $m^3yr^{-1}$ and specific soil losses were 164.66 $m^3$ $yr^{-1}$ $km^{-2}$;
- The peak discharge was calculated on 34 $m^3s^{-1}$ (incidence 100 yr).

This study confirmed the findings of Barovic *et al.* (2015); Behzadfar *et al.,* 2015, Zia Abadi & Ahmadi (2011); as well as Amiri (2010) in possibility of implementing the "River Basin Model" for the other river basins similar to the the Shirindareh Watershed of Iran, when hydrological stations are missing. The model is a good tool for rapid assessment of erosion risk to support decision-making and policy development.

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