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EFFICIENCY OF INTERO MODEL TO PREDICT SOIL EROSION INTENSITY AND SEDIMENT YIELD IN KHAMSAN REPRESENTATIVE WATERSHED (WEST OF IRAN)

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ABSTRACT

Application of empirical models is inevitable because of the complexity of process, features, spatial and temporal variation of soil erosion and non-existence or lack of associated data. In the present study, maximum outflow and soil erosion intensity were predicted for Khamsan representative watershed in West of Iran, using IntEro model. The results of production of erosion material in the river basin (W year), coefficient of the deposit retention (Ru) and real soil losses (G year) were then compared with the measured soil erosion, SDR and sediment yield data in Khamsan watershed. The intensity of the erosion process were medium in studied watershed. The predicted data were compared with the measured sediment yield of studied watershed and verified the acceptable results of the IntEro model in Khamsan representative watershed. The results showed that the peak flow is 27.50 m^3s^{-1} for a return period of 100 years. The value of Z coefficient of 0.876 indicates that the river basin belongs to the second destruction category out of five. The calculated net soil loss from the river basin was 12263.44 m^3 per year, specific 282.81 m^3km^{-2} per year. The strength of the erosion process is strong, and according to the erosion type, it is surface erosion.

Keywords: *IntErO Model, land use, runoff, sediment delivery ratio, soil degradation*.

INTRODUCTION

Soil erosion is one of important issues of environmental in the world, that it cause the various problems (Toy et al., 2002). The population increase and growing demand for agricultural products (Prokop and Poręba, 2012; Zhao et al., 2013) or intensive dry land (Biro et al., 2013) has generated changes in land use and resulted in erosion and land degradation. Water erosion has several types of water erosion, including splash, sheet, interrill, rill, gully and stream bank erosion (Khaledi Darvishan et al., 2012; Khaledi Darvishan et al., 2014 and 2015, Gholami et al., 2016). Knowing or estimating the accurate quantity of soil erosion in a watershed is therefore essential and one of the basic steps of all studies to encompass lots of environmental problems and to evaluate the amount of sediment moved, transported and deposited in and out of the basin. On the other hand, direct measurements of erosion in a watershed are possible with multi-years measurement of solid transport in the closing-section (Tazioli, 2009).

The models use and modeling processes modeling, especially watersheds of without hydrometric stations, are the useful and essential tools to evaluate the amount of sediment and soil erosion (Wischmeier and Smith, 1965, 1978) for this purpose the various models have been developed (Zhang et al., 1996).

Evaluation of the applicability of soil erosion models to a watershed is not easy, as it is difficult to accurately measure soil erosion in the field (Conoscenti et al. 2008, Rawat et al. 2011). In contrast, sediment yield models are easier to apply, because the data for these models can be measured at the watershed outlet (Kinnell and Riss 1998; Erskine et al. 2002; Kinnell, 2010).

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., 2006, 2014; Lenaerts, 2014; Milevski et al., 2008; Ristic et al., 2012; Sekularac, 2000, 2013; Spalevic et al. 2012a, 2012b, 2013a, 2013b, 2013c, 2013d, 2013e, 2013f, 2014a, 2014b, 2014c; 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 intensity of soil erosion and the runoff peak discharge in a watershed, is a computer-graphic method based on the Erosion Potential Method - EPM, which is embedded in its algorithm.

This present study, the IntErO model was verified and tested in Khamsan watershed in Kurdistan province and west of Iran.

MATERIAL AND METHODS

Study area

The Khamsan watershed with the area 43.37 km^2 has two sub-watersheds with exclosure treatment and under grazing, respectively. The main river length, total river length, average elevation, maximum elevation, minimum elevation, average annual temperature and average annual rainfall are 5.18 km, 198.85 km, 1936.27

m, 2378 m, 1580 m, 12.86 °C and 308.04 mm, respectively. Figure. 1 shows the location of Khamsan Representative and treated and control sub-watershed

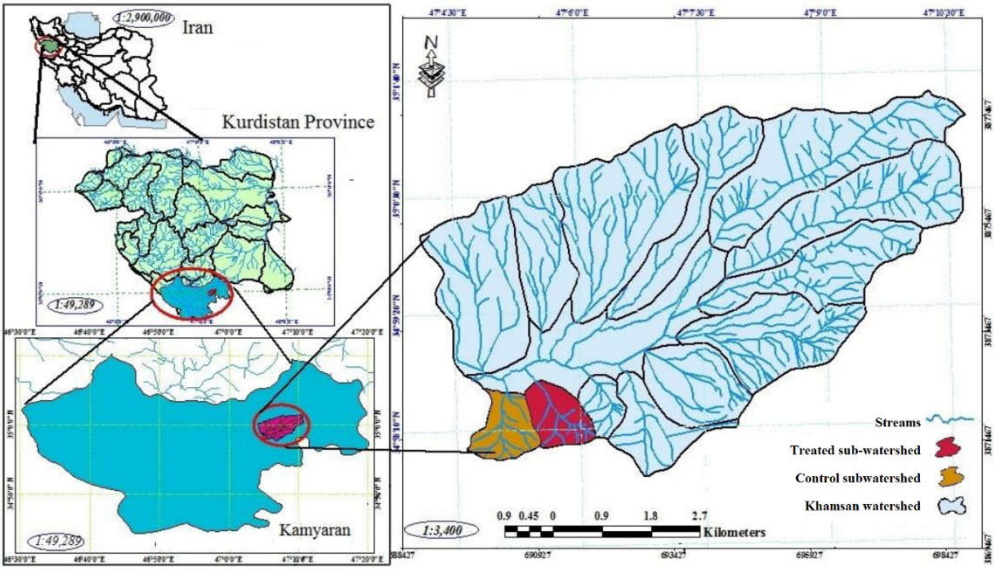

Fig. 1. Location of Khamsan Representative and treated and control sub-watersheds in Iran

IntERO model application

The Intensity of Erosion and Outflow - IntErO program package (Spalevic, 2011) was used to estimate maximum runoff discharge from the basin and the intensity of soil erosion, with the Erosion Potential Method – EPM (Gavrilovic, 1972) embedded in the algorithm of this computer-graphic method.

The above methodology was used in Bosnia & Herzegovina, Bulgaria, Croatia, Czech Republic, Italy, Iran, Montenegro, Macedonia, Serbia and Slovenia (Kostadinov et al., 2014). In Iran, the IntERO have been successfully used previously in the Regions of Chamgardalan; Kasilian (Amiri, 2010; Zia Abadi & Ahmadi, 2011; Yousefi et al., 2014) and some other sub-catchments (Behzadfar et al., 2014 and 2015; Barovic et al., 2015).

RESULTS AND DISCUSSION

Climatic characteristics

The average annual temperature is 12.86 °C, the average annual air temperature (t0) and the average annual precipitation (Hyear) are 12.5 °C and 428 mm, respectively, based on the data from the Khamsan meteorological station. The temperature coefficient of the region (T) was calculated equal to 1.16.

The geological structure and soil characteristics of the area

To calculate some inputs of IntERO, the geological data was extracting from the geological map of Iran (Bolourchi et al., 1987). The geological data showed that the structure of the river basin, according to bedrock permeability, is the following: poor water permeability rocks (f0), medium permeable rocks (fpp) and very permeable products from rocks (fp) were 6%, 51% and 35%, respectively. The coefficient of the region's permeability, S1, was calculated about 0.61 (source: original).

Vegetation and land use

According to the analysis, the main portion of the river basin is totally under grass, meadows, pastures and orchards (60%). The coefficient of the river basin planning (Xa) and the coefficient of the vegetation cover (S2) were calculated about 0.73 and 0.88, respectively.

Soil erosion and runoff characteristics

According to the results, surface erosion has taken place in all the soils on the slopes as the dominant erosion form in the studied area which is the most pronounced on the steep slopes with scarce vegetation cover.

The coefficient of the river basin form, A, calculated as 0.55 using IntErO software. Coefficient of the watershed development, m, was 0.47 and the average river basin width, B, was 4.23 km. (A)symmetry of the river basin, a, which indicates that there is a possibility for large flood waves to appear in the river basin, was calculated as 0.17.

Drainage density, G, was calculated as 3.53 km km^{-2} which corresponds to high density of the hydrographic network. The height of the local erosion base of the river basin, Hleb, was 700 m and also the coefficient of the erosion energy of the river basin's relief, Er, was calculated as 86.63.

The value of Z coefficient as 0.876 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 surface erosion, the second destruction category out of five.

For the current state of land use, calculated peak flow is 27.50 m^3s^{-1} for a return period of 100 years.

The production of sediments in the basin, Wyear, is calculated as 55552.22 m^3 $year^{-1}$; and the Coefficient of the intra-basin deposition, Ru, at 0.221 which indicates that 21% of the eroded materials will deposit and remain in the watershed.

Sediment yield at catchment outlet (Gyear) was calculated as 12263.44 m^3year^{-1}; and specific sediment yield at 282.81 m^3 km^{-2} $year^{-1}$.

Part of the detailed report for the Khamsan watershed is shown in Table 1.

Table.1. Part of the IntErO report (inputs and outputs of the model) for Khamsan watershed

Inputs	Amount and Unit
River basin areas (F)	43.36 km^2
The length of the watershed (O)	31.28 km
The area of the bigger river basin part (Fv)	23.57 km^2
The area of the smaller river basin part (Fm)	19.79 km^2
Natural length of the main watercourse (Lv)	11.08 km
Length of the contours / isohypses (liz)	223.57 km
Areas / surfaces between neighbouring contours / isohyets (fiz)	43.36 km^2
Altitude of the first contour line	1690 m
Incidence (Up)	100 years
Equidistance (Δh)	100 m
The lowest river basin elevation	1687 m
The highest river basin ele`vation	2387 m
A part of the river basin consisted of a very permeable products from rocks(fp)	35 %
A part of the river basin area consisted of medium permeable rocks (fpp)	59 %
A part of the river basin consisted of poor water permeability rocks (f0)	6 %
A part of the river basin under forests (fs)	0 %
A part of the river basin under grass, meadows, pastures and orchards (ft)	60 %
A part of the river basin under bare land, plough-land and ground without grass vegetation (fg)	40 %
The total length of the main watercourse with tributaries of I and II class	152.86 km
The shortest distance between the fountainhead and mouth(Lm)	1.34 km
The volume of the torrent rain (hb)	44.4 mm
Average annual air temperature (t0)	12.5 C
Average annual precipitation (H year)	428 mm
Types of soil products and related types (Y)	1
River basin planning, coefficient of the river basin planning (Xa)	0.73
Numeral equivalents of visible and clearly exposed erosion process(φ)	0.49
Outputs	
Coefficient of the river basin form (A)	0.55
Coefficient of the watershed development (m)	0.47
Average river basin width (B)	4.23 km
(A)symmetry of the river basin (a)	0.17
Coefficient of the river basin tortuousness (K)	8.25
Average river basin altitude (Hsr)	1860.04 m
Average elevation difference of the river basin (D)	173.04 m
Average river basin decline (Isr)	51.56%
The height of the local erosion base of the river basin (Hleb)	700 m
Density of the river network of the basin (G)	3.53
Coefficient of the erosion energy of the river basin's relief (Er)	86.83

Coefficient of the region's permeability (S1)	0.61
Coefficient of the vegetation cover (S2)	0.88
Analytical presentation of the water retention in inflow (W)	0.24
Energetic potential of water flow during torrent rains (2gDF^½)	383.69 m km s^{-1}
Maximal outflow from the river basin (Qmax)	27.50 m^3 s^{-1}
Temperature coefficient of the region (T)	1.16
Coefficient of the river basin erosion (Z)	0.876
Production of erosion material in the river basin (Wyr)	55552.22 m^3 $year^{-1}$
Coefficient of the deposit retention (Ru)	0.221
Real soil losses (Gyr)	12263.44 m^3 $year^{-1}$
Real soil losses per km^2 (Gyr/km²)	282.81 m^3 km^{-2} $year^{-1}$

CONCLUSION

The study was conducted in the Khamsan watershed of Kurdistan province in west of Iran. The soil erosion intensity and runoff were calculated using the IntErO model. According to the findings, it can be concluded that there is a possibility for large flood waves to appear in the studied Khamsan river basin.
Calculated peak flow is 27.50 m^3s^{-1} for a return period of 100 years. The value of Z coefficient of 0.876 indicates that the river basin belongs to the second destruction category out of five. The calculated net soil loss from the river basin was 12263.44 m^3 per year, specific 282.81 m^3km^{-2} per year. The strength of the erosion process is strong, and according to the erosion type, it is surface erosion.
This study further confirmed the findings of Amiri (2010), Zia Abadi & Ahmadi, (2011), Yousefi et al. (2014), Behzadfar et al. (2014 and 2015) as well as Gholami et al. (2016) in successful implementation of the Erosion Potential Method – EPM and/or IntERO model 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.

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