

# Forecasting Sediment with Erosion Potential Method with Emphasis on Land Use Changes at Basin

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## ABSTRACT

Experimental methods have been developed during the past decades for studying the effects of changes in land use on soil erosion. These involve the measurement of sediment yield at the basin. Each method has its advantages and limitations for a particular application at different scale soil loss estimates using different techniques commonly vary by an order of magnitude by various EPM (erosion potential method) models, thus to chose a proper method for erosion measurement is very important for all erosion studies. A grid-based distributed model EPM model compatible with ArcView Geographic Information Systems (GIS), was applied to the 344.91 km<sup>2</sup> Upper Sezar River in DEZ basin. Model parameters were derived from a digital elevation model (DEM), land use and soil type map of the basin. These parameters and the observed daily meteorological data (1968-2006) were used (1) to test the performance of the EPM model to a large tropical basin for determined total sediment yield, (2) to identify the different erosion components. The use of yearly observations instead of monthly observations and the lack of other measurements of the hydrological processes. The deviations between the observed and simulated sediments may also be caused by the lack of a good representation of the meteorological conditions in the study area. The EPM model also provided insight into the main flow processes during the year.

**KEYWORDS:** EPM model, geographic information system, erosion rate, land use, sediment yield

## INTRODUCTION

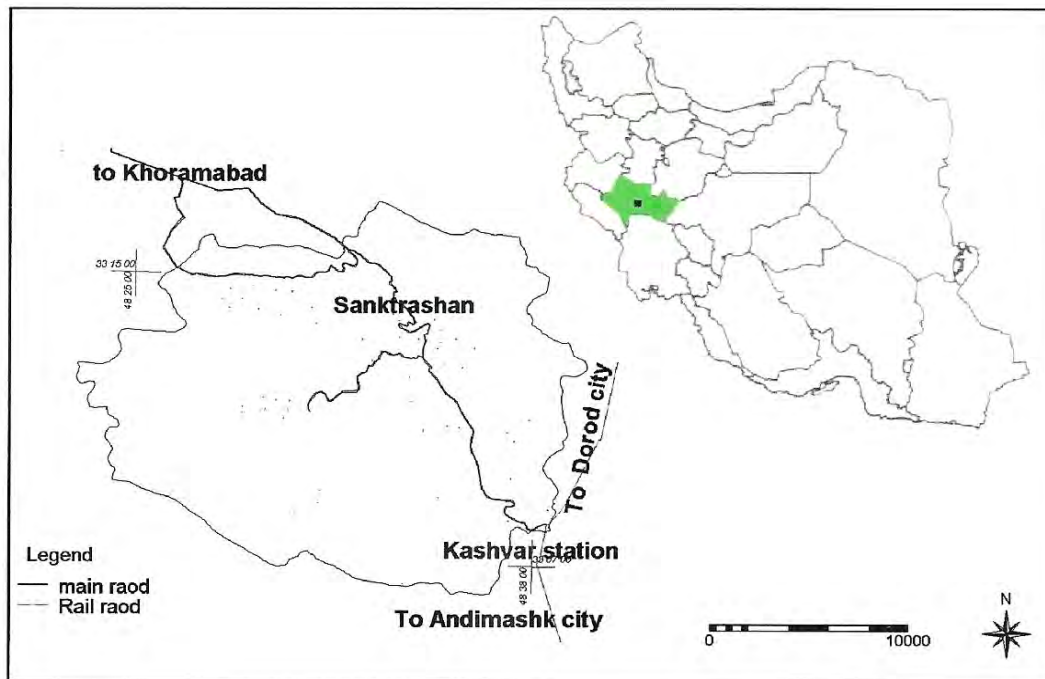
In studying soil erosion risk it is important to formulate effective soil conservation plans. Erosion causes serious consequences on economy as well as environment resulting in decreased productivity. Great influence is also evident in areas that are not directly exposed to erosion but suffer from its consequences in form of sediment deposition in watercourses and reservoirs, resulting in decreased water quality and flow rate. All these have negative impact on water regime. There are numerous classifications of erosion available in the literature. Since most significant problem in southwest Iran is soil erosion by water, this paper places an emphasis on estimation of potential and actual risk of soil erosion caused by water. Traditionally, the most common method used in western and central Balkan areas is quantitative analysis of erosion processes proposed by Gavrilovic (1970 *a* and *b*). There are also numerous cartographic methods available today to estimate risk of the soil erosion by water Husnjak et al. (2000). Various methodologies and procedures enable estimation of erosion and it is important to take into consideration all the influencing factors (such as scale, characteristics of the area etc.) when choosing the one appropriate.

Surface erosion and mass movements within a catchment area produce sediment which becomes available for transport. Changes in land use due to development strategies exposing erosion-sensitive geological formations consisting largely of shale and marl, and poor vegetation cover in the Zagros Mountains are the main factors in making millions of tons of sediment available annually for erosion and transport. Surface erosion and sediment yield are important factors that should be taken into account in planning renewable natural resource projects. Generation of erosion and sediment-yield maps for areas under soil conservation and vegetation improvement is controlled mainly by considering the extensive effects of soil-wasting processes. Methods for estimating sediment yield were first developed for the analysis of the effects of agricultural practices. The first model used was the Universal Soil Loss Equation—USLE (Wischmeier and Smith (1965) and Wischmeier and Smith (1978)). Several experimental models were used for predicting the erosion severity and sediment yield in a sub-catchment area for which hydrometric data is not available. The commonest models now being used are USLE Mati et al. (2000) and Erskine et al. (2002), MUSLE (Modified Universal Soil Loss Equation), WEPP (Water Erosion Prediction Project), RUSLE (Revised Universal Soil Loss Equation) (Millward and Mersey (1999), Raghunath (2002), PSIAC (Pacific Southwest Interagency Committee) (Nelson and Rbsele (1989), and Clark et al. (2004), and EPM (Erosion Potential Method). The EPM model was developed primarily for application in arid and semi-arid areas in the southwestern USA, and is believed to be appropriate for the same environmental conditions in Iran (Sadeghi and Isensee, 1997; Bagherzadeh *et al.*, 1993). The EPM model was originally developed for Yugoslavia by Gavrilovic (1988). The method has been tested in some catchment areas in Iran, and it is found that output results are compatible with field observation. Both the EPM and other models are factor-based, which means that a series of factors, each quantifying one or more processes and their interactions, are combined to yield an overall estimation of soil loss. Applications of Geographic Information Systems (GIS) and remote sensing techniques in erosion and sediment yield assessment have been developed recently (HILL et al. (1996), Mezosi and Mucsi (1993), Floras and Sgouras (1999), Tangestani and Moore (2001), Le Bissonnais et al. (2002), Yuliang and Yun (2002) and Martinez-Casasnovas and Ramos (2006)). Remote sensing techniques assist the evaluation of erosion processes and the generation of land use maps, while the integration of such data layers with the generation of erosion-severity and sediment-yield maps can readily be performed by the use of the analytical tools of a GIS. Because of

ambiguities in the validity of the results of EPM and PSIAC models for semi-arid regions, such as SW Iran, the objective of this study is to compare the output results of the models with field observations and a GLASOD (Global Assessment of Soil Degradation) map, used to verify the results. The Nojian sub-catchment area was taken as an example of the use of GIS techniques, spatial data management and modelling for assessing erosion severity and sediment yield A.Haghizadeh et al (2008). The paper shows application of the EPM model in assessing of land use change and estimating erosion in Nojian catchment, Lorestan in Iran. Since land cover (and land use) is an important factor in runoff and therefore erosional processes, authors analysed impact of the land cover/land use changes on erosional processes in the study area.

## MATERIALS AND METHODS

The study area is one of sub catchments of Dez watershed and includes 344.91 km<sup>2</sup> (figure 1). This sub watershed is located between latitudes 33° 04' , 33° 14' N and longitudes (UTM zone) 48° 23' , 48° 40' . It borders with Sezar catchment in north and northeast, DEZ dam basin in north and northwest, Nojian catchment in east and city of Khoram Abad in south. From these profiles shows the variation of altitude along the river path. The elevation in the catchment ranges from maximum 2900m to minimum 1100m at the outlet.



**Figure 1:** Location map of Nojian catchment in Lorestan, Iran

EPM method gives a quantitative estimation of erosion intensity as well as the estimation of Sediment production and transportation. According to the method, average annual catchment Degradation  $W$  (average annual sediment production) is calculated using the following equation:

$$Wsp = T \times h \times \pi \times (aZ^3 \times F) \quad (\text{m}^3/\text{year}) \quad (1)$$

Where  $h$  (mm) denotes average annual rainfall,  $F$  is size of a catchment ( $\text{km}^2$ ) and  $T$  denotes the temperature coefficient defined as: with  $T_0$  being average annual air temperature ( $^{\circ}\text{C}$ ).

Erosion coefficient  $Z$  can be calculated as (Table 1)

$$T = \sqrt{\frac{t_0}{10} + 0.1} \quad (2)$$

$$Z = Y \times Xa \times (\phi + j) \quad (3)$$

where:

$Y$ - Coefficient of the soil resistance to erosion (function of geology and soil type)

$Xa$ - coefficient defining the level of resistance to erosion,

$X$ - Land use/land cover coefficient,

$a$ - conservation coefficient after an erosion measures (in this case  $a = 1$ ),

$\phi$ - Coefficient of the observed erosion process (takes into consideration clearly visible erosion processes)

$j$ - Average slope of the catchment.

**Table 1: Erosion coefficient  $Z$**

Erosion and torrent category	Qualitative name of erosion category	Range of values of coefficient $Z$	Mean value of coefficient $Z$
<b>I</b>	Excessive erosion - deep erosion process (gullies, rills rockslides and similar)	$Z > 1.0$	$Z=1.25$
<b>II</b>	Heavy erosion-milder forms of excessive erosion	$0.71 < Z < 1.0$	$Z=0.85$
<b>III</b>	Medium erosion	$0.41 < Z < 0.7$	$Z=0.55$
<b>IV</b>	Slight erosion	$0.20 < Z < 0.4$	$Z=0.30$
<b>V</b>	Very slight erosion	$Z < 0.19$	$Z=0.10$

Eq. 1 gives an estimate of the total production of erosion deposits in a catchment. However, not all the sediments that result from erosion processes reach the lowest point in the catchment. Instead, they are being deposited in the numerous depressions. Such a process is incorporated into the calculations with retention coefficient  $Ru$ :

$$Ru = \frac{(O \times D)^{0.5}}{0.25 \times (L + 10)} \quad (4)$$

where:

$O$ - Perimeter of the catchment (km)

*L*- Length of the catchment (km)  
*D*- Average altitude gradient (km)

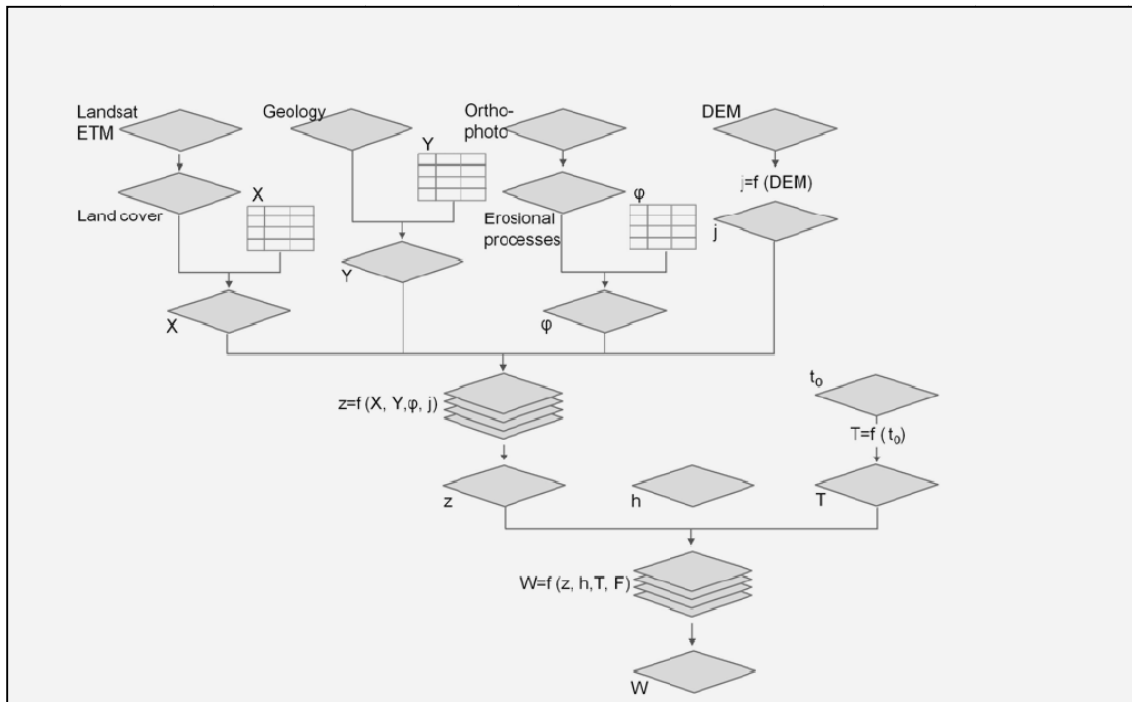
Finally, average annual sediment quantities that reach observed cross-section is estimated multiplying Equations (Eq. 1) and (Eq. 4) i.e.:

$$G_s = T \times h \times \sqrt{Z^3} \times F \times R_u \quad (\text{m}^3/\text{year}) \quad (5)$$

## RESULTS AND ANALYSIS

Erosion intensity maps as well as the estimation of sediment production/ transportation are done in GIS environment, as shown in Fig. 2. Definition of the coefficient maps (*Xa*, *Y*,  $\phi$  and *j*) was based on the spatial input data, namely land use/ land cover map, geology of the area (Fig. 3), DEM (Fig. 6) and ortho-photo of the area.

(1) *Y* map showing the soil resistance to erosion should be based on geology and soil data. However, data on soil characteristics is not sufficient enough to be used hence only geology map of Nojian basin.(Fig. 3) catchment that is part of the geological and tectonic study published by Iran Geological Survey and extracted litho-stratigraphic units were used.



**Figure 2:** Schematic overview of estimating sediment production using EPM method

(2) *Xa* maps are based on the land use/land cover (LU/LC) maps (Fig 3,8) in a way that each LU/LC unit was assigned with a different coefficient, depending on the LU/LC characteristics

(3)  $\phi$  map is a result of the expert estimation based on field and remote sensing (ortophoto) data.

Average value is defined for each sub-catchment in the area.

(4)  $j$  map (Fig. 8) was derived from DEM of the area. Spatial distribution of the coefficient  $Z$  (Fig.9) was estimated for three different LU/LC conditions using (Eq. 3). Accuracy of the calculations greatly depends upon the spatial resolution chosen for the analysis. In this case, spatial resolution of the input and hence the output data is 15 m.

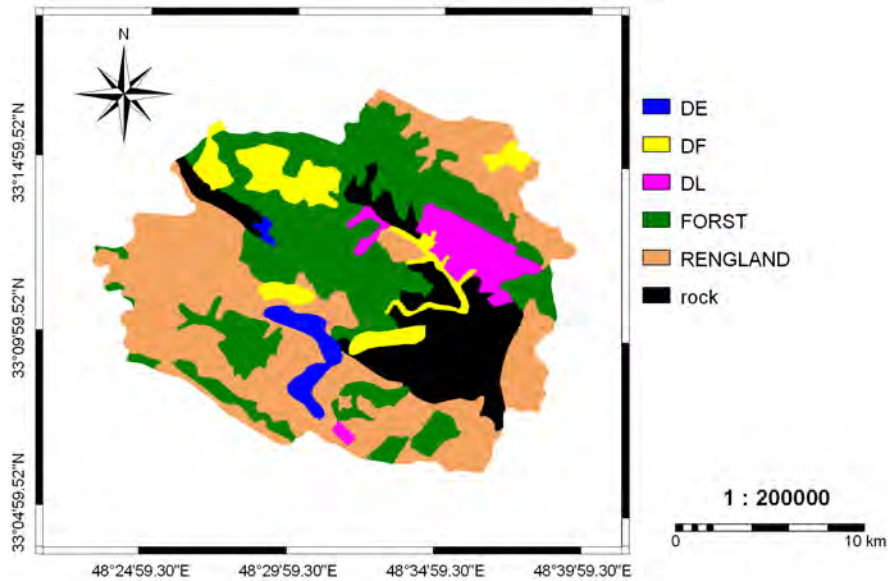


Figure 3: land use map of Nojian catchment

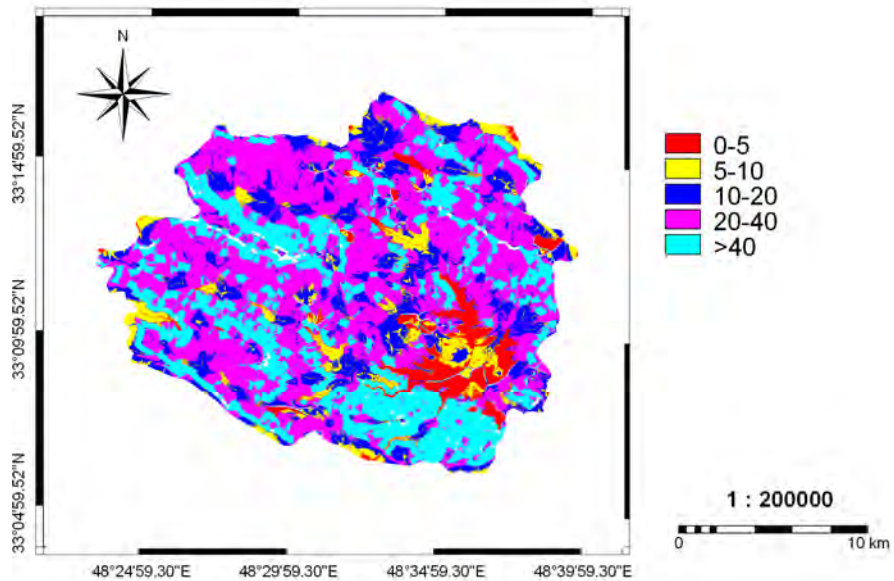


Figure 4: Slope map of Nojian catchment

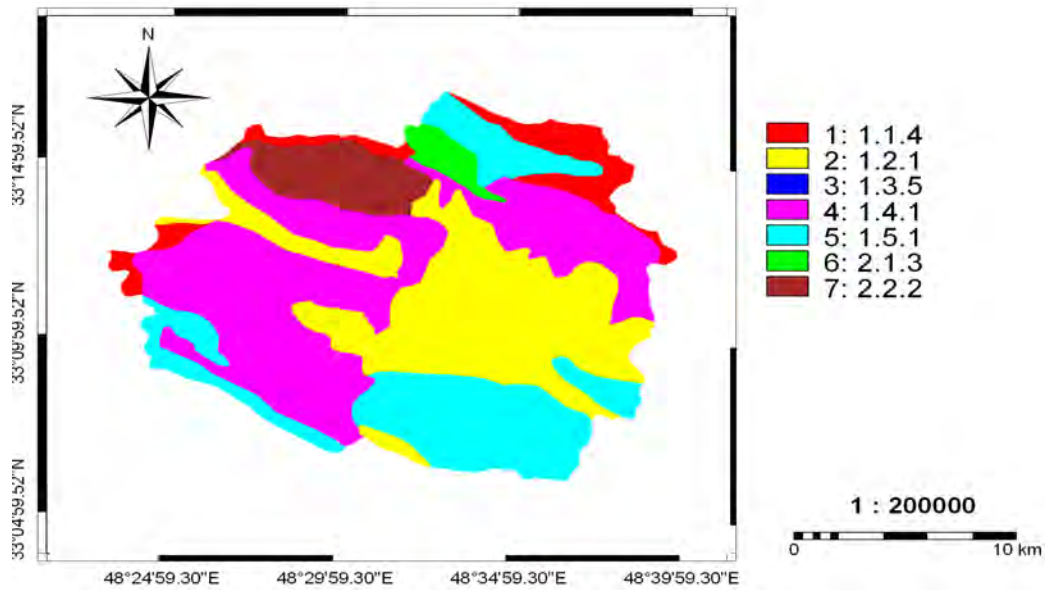


Figure 5: Soil DEM map of Nojian catchment

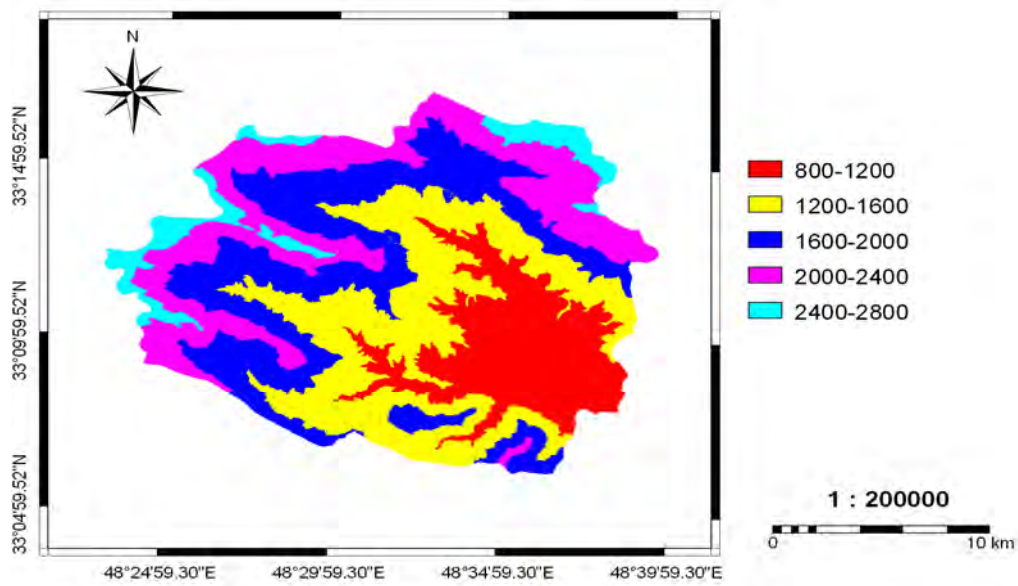


Figure 6: DEM map Nojian catchment

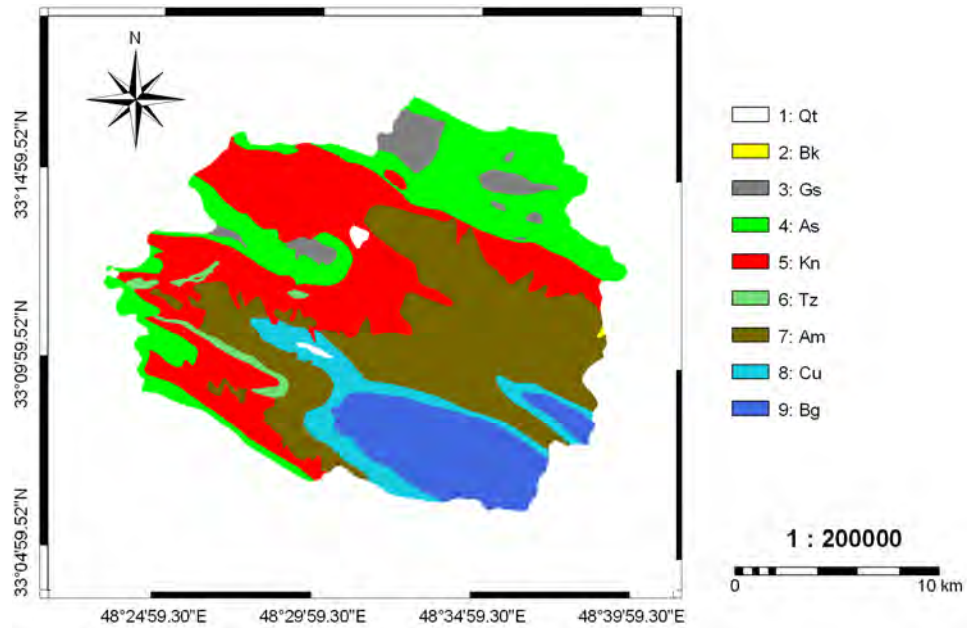


Figure 7: Geological map of Nojian catchment

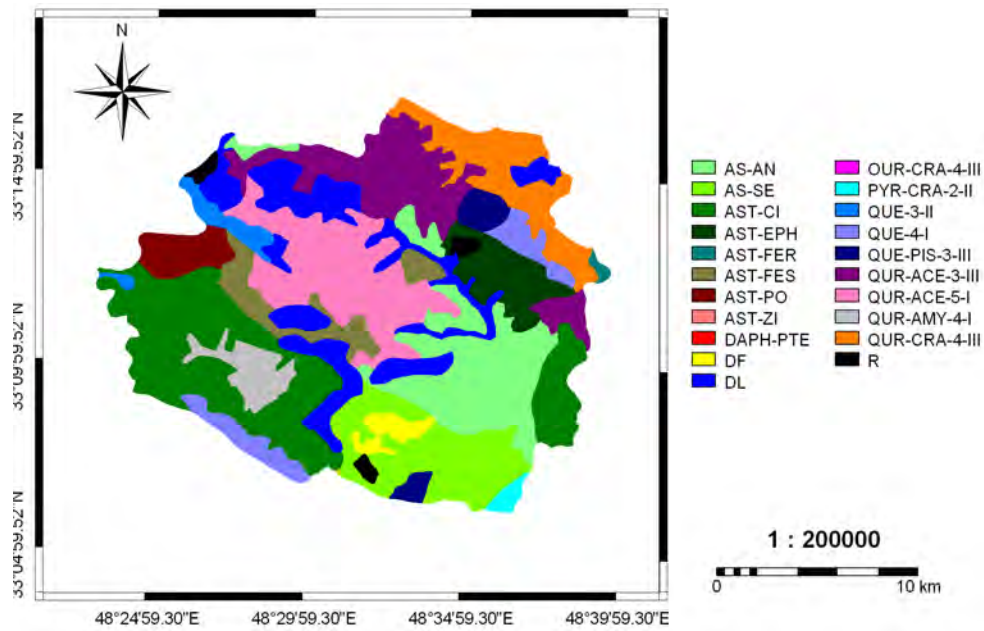
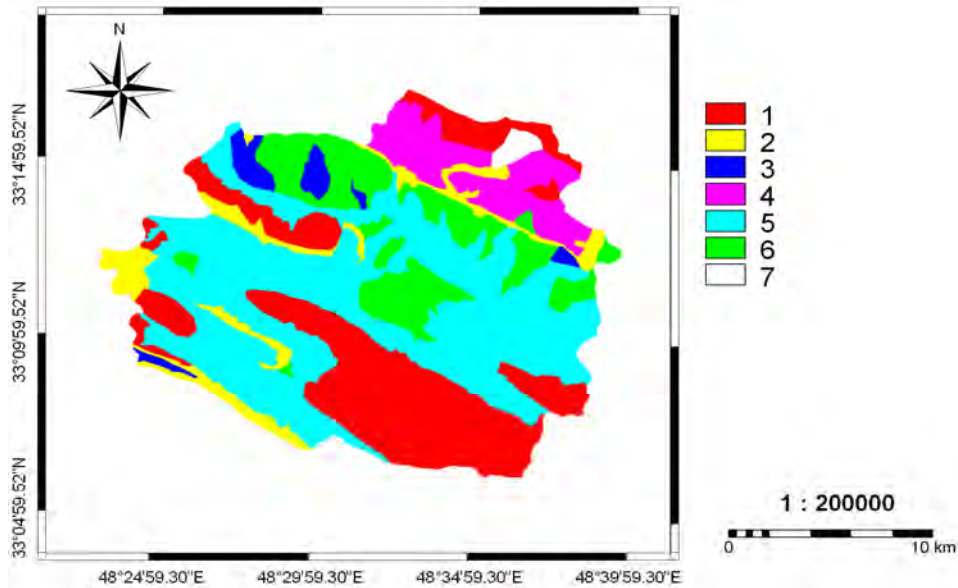


Figure 8: Land cover map Nojian catchment



**Figure 9:** Z map of Nojian catchment

Production (Eq.1) and transportation of the sediments are calculated as average values for each sub-catchment (Table 2).

**Table 2:** Average values of erosion coefficient Z for each sub-catchment

Sub catchment	Z
N1	1.01
N2	0.87
N3	0.99
N4	0.77
N5	1.052
N6	1.173

**Table 3:** Sediment retention efficient (RU) for sub catchments

sub-catchment	H (m)	HO (m)	D (km)	P (km)	L(km)	RU
N1	1795	1078	0.716	46.83	13.84	0.9515
N2	1939.7	1078	0.861	37.14	8.39	1.2299
N3	1448.2	880	0.568	32.75	9.19	0.899
N4	1276.4	890	0.386	43.98	9.75	0.8348
N5	1772	1081	0.691	33.26	13.146	0.8284
N6	1741.8	1085	0.756	42.07	14.98	0.9035

Average erosion coefficient for all the area (sub-catchment is between 0.77 and 1.173 conditions of LU/ LC (Table 2). Accordingly, Fig. 9 shows heavy to excessive erosion in most of

the area (I, II category erosion) while excessive and heavy erosion (I and II category) occur on steep slopes (with high  $j$  values) in NE parts of the study area. High values of erosion coefficient and annual production (areas with I and II erosion category) are calculated for the sub-catchments of (number 1 and 6 in Table 2, but with average values for the whole sub-catchment area). It was already mentioned that in those tributaries of Nojian, the most severe erosion processes in combination with land sliding, are present. The most significant factors influencing high values of erosion coefficient and annual production are mentioned above: steep slopes (that are characteristic for the zone of marl and cliffs) and geologic composition that is prone to erosion (flysh slopes in the area of N1 and N6 Nojian). Average specific annual production (WSP) in the area is  $12434 \text{ m}^3/\text{year}/\text{km}$  and (GS)  $631748 \text{ m}^3/\text{year}$ . Considering the amount of the observed sediment yield of the watershed, which is about  $673675 \text{ t/y}$  the bed load generally constitutes between 10 and 40 percent total load of a stream. Bed load in case study by Assessing river discharge consider 20% mean is  $134735 \text{ t/y}$  we can calculate observed total sediment as  $808410 \text{ tons/y}$  model total sediment  $821272 \text{ tons/year}$ .

## CONCLUSION

Prediction amount of total sediment is near observed sediment in stations at basin outlet. We can develop erosion potential method for other sub-basins which are missing hydrological stations because cost of erosion modeling and watershed management are less than making of hydrological station. Since land cover (and land use) is an important factor in runoff and therefore erosion process, authors analyzed the impact of the land cover/land use (LC/LU) changes on erosion processes in the study area. Sediment production was estimated for the following land use changes: existing, planned and factious LC/LU conditions. On the base of performed analysis it can be concluded that there is an impact of the land cover/land use (LC/LU) changes on erosion processes in the study area. This impact is especially significant for the areas that already have some preconditions for erosion processes (like steep slope or geologic composition prone to erosion). This fact should be taken into account in the future urban planning.

**Table 4:** Special erosion and special sediment and total sediment by using model

Sub-catchment	WSP $\text{m}^3/\text{km}^2/\text{y}$	RU	GSP $(\text{m}^3/\text{km}^2)$	Area $(\text{km}^2)$	GS $(\text{m}^3/\text{y})$
N1	2714.89	0.9715	3726.51	71.35	188186.74
N2	2221.78	1.2299	2730.56	51.06	139422.2
N3	2474.23	0.899	2224.33	40.8	90752.66
N4	1611.44	0.8348	1345.23	73.28	98578.45
N5	2865.65	0.8284	2373.9	39.4	93531.66
N6	3411.85	0.9035	3082.6	69.0	21276.05
N				344.9	631747.76

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