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Research Paper

Determination of Erosion Severity Using Quantitative and Qualitative Models in Case Study of Navroud Drainage Basin

Tahereh Fatolahzadeh[1] , Mohammadreza Servati[2]
1. * Department of Geography, Science and Research Branch,Islamic Azad University, Tehran, Iran.
fatolahzadeh4@gmail.com
2. Associate Professor of the Department of Natural Geography, Shahid Beheshti University, Tehran, Iran.

Abstract: Recognition of different areas of a drainage basin in terms of erosion occurrence and its severity has always been one of the most important goals of experts of natural resources. To achieve this goal , some models have been presented experimentally , each of which have strengths and weaknesses, including EPM and FAO which have been implemented with an area of 265,46 km2 in Navroud drainage basin , Guilan province. EPM model considers land utilization and drainage basin's erosion coefficients , coefficient of stone and soil sensitivity to erosion , and average slope of the basin ,all in percentages ; while FAO model includes seven lithological factors (formation type) , soil (structure and grading) , topographic factors and specially the slope , soil coverage (vegetation) , how to utilize areas of drainage basins and its erosion statutes. The present research using each of the models mentioned above aims at studying the erosion severity statutes in the area being studied and the results show about 88.12./. of the basin area with very low , 4.16/ with low , 7057/ with moderate and 0.08/ with sever erosion rates , while these amounts in qualitative FAO method are 0.002/ in II , 10.59/ in III , 78081/ in IV and 10.59/ in V erosion classes. Since the results of EPM method and statistics of sediments are very close, EPM model can be adapted to existing statistics of sediments to estimate erosions and sediments of Navroud drainage basin. As FAO model is a qualitative method, it is inadaptable to statistics of observational sediments , therefore this model is better utilized in basins where there's no hydrometric station in the area.

Keywords: Navroud Drainage Basin, Model, Erosion Severity, FAO, EPM.

Introduction

Erosion refers to the process during which the soil particles are separated from their main stream and different types of erosions namely water, wind and glacial erosions will take place via a transfer agent (Refahi, 2000). Also, it is mentionable that erosion has two important aspects that include decrease of product capacity of the land and the other is disturbance of the eroded materials (Ghadiri, 1993). So, compensation of the eroded soil is very difficult and long term for the nature. Therefore, more attention should be paid to soil preservation and erosion prevention (Kardovani, 1998). Thus, recognition of the areas susceptible to erosion and sedimentary areas and their zoning in different sections of a drainage basin is one of the basic factors in prioritization of the areas for soil preservation and watershed management executive works.

To measure the erosion severity in drainage basins, experimental methods or sediment samplings are applied (Lal, 1988). Generally, different factors are responsible for erosion and intensification some of which have managerial aspects and erosion can be prevented by adaptation and implementation of practical and scientific policies and strategies. To control water erosion, first the managerial factors should be recognized together with environmental factors and appropriate solutions should be presented via studying the roles of each one in erosion (Morgan, 1995). In order to fight and consequently get succeed in inhibition of soil erosion, it is necessary to recognize the factors influencing erosion and to gain information about them, their domain and influence severity and eventually prioritization of the areas in terms of erosion severity and sediment production. The first scientific researches on erosion took place between 1877-1895 by the German scientist Wollny (Wollny, 1938).

(Ahmadi .1999) has achieved erosion outcrops and has determined erosion severity using geological maps, slope, direction, altitude and also interpretation of the photographs, via the method he has presented as the geomorphology method. He has examined his method in Baba Ahmadi drainage basin in south zagros and has recognized the method appropriate for Iran. Salajeghe and Delfari (2007), comparing the geomorphological qualitative methods and EMP quantitative methods concluded that the geomorphological method presents better results in Khosban sub-watershed of Taleghan drainage basin.

According to results from the research by Hoseinzade et al (2011), the decisive influence of vegetation type on drainage density with slope, altitude level and amplitude direction shows a significant relationship between them and has considered the relation as exponential type. Jalalian (1992), during his assessment of sedimentation rate, using PSIAC model in north Karoun drainage basin has concluded that, the model has a good correlation with sediments from the sediment survey station. Bagherzade and Karimi (1993), during a research in Ozon sub-watershed of Ghazal Ozen drainage basins, has concluded that, PSIAC has had a good correspondence with the measured amounts. Servati (2011), considering his findings about using the experimental models and multivariate methods in assessment of water erosion severity in Baghere drainage basin, distiguishes MPSIAC model appropriate for determination of erosion severity. Ahmadi and Mohammadi (2010), regarding implementation of PSIAC and EPM models have concluded that, inorder to achieve an accurate and reliable work when using experimental model, first the drainage basins should be divided into units, brigades, outcrops and work units. The findings from Servati's and Fatollahzade's (2003) research in Masoule drainage basin showed that the stone nature in terms of resistance to erosion has been the most significant

factor in the scope of each work unit and this applies to almost all of the outcrops. Fargas et al (1997) have presented a method in which there has been attempted to recognize sedimentary regional resources (erosion severity) at the regional level using two factors of stone type erodibility and drainage density which had 78.5 percents of likelihood.

EPM model was used to study the soil erosion rate in former Yugoslavia in 1952 and it led to invention of special classification method for erosion called (M.Q.C.E) (Gavrilovich 1988). Using this model, we can calculate the erosion rate in a drainage basin plus the sediment amount in different parts of a river. In FAO method, qualitative estimation of soil erosion, based on assessment of 6 factors influencing soil erosion and sediment production in a drainage basin is implemented. In this method, each mentioned factor is assessed and scored by a specialist based on how and how intensively they affect the soil erosion and sediment production in each hydrology unit or each unit of drainage basin's lands (Ahmadi, 1999).

Martial mad Methods

Navrod drainage basin with an area of 265.46 square kilometers, located in west of Guilan and adjacent to Talesh County, between eastern longitudes of 48 degrees and 35 minutes to 48 degrees and 54 minutes and northern latitudes of 37 degrees and 36 minutes to 37 degrees and 45 minutes (figure1). This part of the basin is mainly mountainous and its maximum and minimum altitudes are respectively 3016 and 118 meters above sea level. The average height of this area is 1567.45 meters above sea level. The length of the river to Kharajil station is about 33.28 kilometers. For a detailed review, the research area has been divided into 11 sub-watersheds. From lithological point of view, the study area is consisted of the units belonged to Paleozoic, Mesozoic and Cenozoic periods (Darvishzade, 2001). The lithological characteristics show that how this drainage basin is lithologically diverse and how the existing stones resist one of the important factors that cause stone erosion namely the weathering factor (Feiznia, 1995). This area is consisted of mountainous land type and upper plains type. The study area is considered as a part of humid Iranian forests in terms of its vegetations and its pasture coverage (up-country) in the heights. The soil texture class in this area is mostly sandy loam, loam, clayey loam, silt clayey loam, silt clay and clay.

Navroud drainage basin is rectangular shaped and the river flows in the middle and parallel with its length. The river regime is snowy-rainy and it has two courses of high water with more or less equal periods and severities. The weighted average slope of the whole area is 47.20. The average annual precipitation in the whole area is 983 mm and the climate is humid and cold in the heights and very humid in downstream by Domartin's modified method and it is humid in upper heights and very humid in low levels by Ambreje's method.

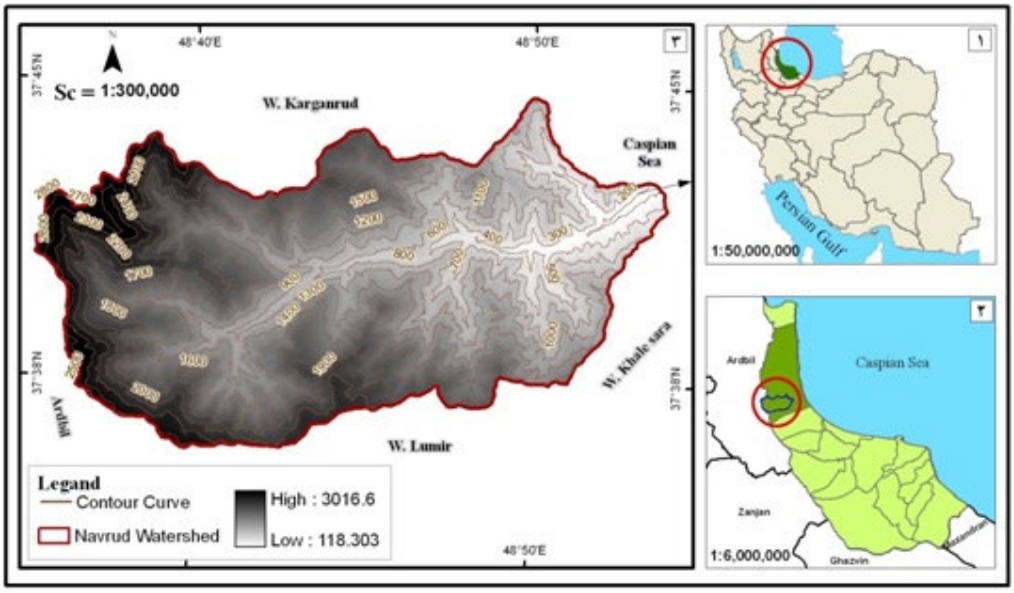

Figure 1. The Map of Navroud Drainage Basin Status

1. To provide the geological map of Khalkhal-Rezvanshahr sheet of National Iranian Oil Company with the scale of 1:100000, which has been used in the models.

2. To provide the topograghical map of Asalam-Khalkhal sheet of geological organization of the Armed Forces of Islamic Republic of Iran with the scale of 1:50000, which have been elicited for being applied in the models and borders of the area.

3. To provide aerial photographs of National Mapping Agency of 2002 which were used for preparing the geomorphological map.

4. The EPM model of the factors applied in this model for estimation of erosion in a drainage basin are: topographical status, lithology, soil, how to use the lands and climatic factors for estimation of erosion and sedimentation, using this method in the study area. Different levels of implementation of this model are as follows:

1-4 Determination of Erodibility Severity Index of the Basin

Z: Erossion severity coefficient, Xa: Land utilization coefficient Y: Stone and soil sensitivity to erosion coefficient, φ: Coefficient of drainage basin's erosion and I: Percental average slope of the basin. Then, erosion severity in the study area was determined using the following equation.

After determination of erosion severity, the erosion condition in drainage basin can be classified quantitatively, using table1.

Table 1. Erosion severity classification in EPM model

Classification of Erosion	The value	The average value	The rate of erosion
1	1 >Z	1. 25	Very severe
2	0.71 >Z > 1	0.85	severe
3	0.41> Z >0.7	0.55	Average
4	0.2> Z >0.4	0. 2	Low
5	Z > 0.19	0.1	Very low

Source: Ahmadi (1999)

2-4 Calculation of Quantitative Rate of Erosion and Basin Sedimentation of the Study Area Using EPM Method

The special erosion was calculated using isohyetal and isothermal maps, in precipitation and temperature average software environment in each sub-watershed. The rate of special erosion was calculated in terms of cubic meters per square kilometers each year, applying special erosion equity and the special erosion rate was calculated from their total for the whole drainage basin. Calculation of the deposition coefficient in each sub-watershed, calculation of deposition coefficient of the basin using drainage basin's length factors, calculation of drainage basin's premier and average height difference and the height of the output of drainage basin were implemented. Special sediment discharge, special sediment rate, is obtained through multiplying the special erosion and sedimentation coefficient and the total sedimentation was calculated by multiplying the special sediment rate and the area of each sub-watershed and from their total for the whole area (figure3)(Tables).

5. In FAO model of FAO method, estimation of soil erosion is implemented qualitatively and based on assessment of 6 effective factors in soil erosion and sediment production in a drainage basin. The maximum of total score is 100 (Ahmadi, 1999).

The score of erosion class can be determined using table2.

Table 2. Domain of the Factors of the Scores in FAO Method

Domain Experience	Factor
1-20	1 – Covering the soil surface
1-18	2 – Lithology (type of formation)
1-16	3– Slope
1-16	4 – Soil structure
0-15	5 – Use of content
0-15	6 – Current erosion
4-100	Domain Experience

Table 3. Classification of Erosion, Using FAO Method

Class erosion	Qualitative classification of erosion	The sum of the numbers obtained from the 6 factors affecting erosion (sedimentation rate)	Corrective Actions
1	VI	86>	Land use based on their potential use in short-term instruments to manage pasture as a principle to be considered.
2	V	85-66	The land is suitable for agriculture, land tenure is characterized by a specific government can act as observers in sensitive areas in the short term, in addition to combating biological structures to be built.
3	IV	40-65	Fundamental changes occurred in agriculture and soil conservation biology and the rise. Pasture management appeal.
4	III	21-40	Review of agricultural management, soil conservation and watershed management to pay more attention to administrative tasks.
5	II	20<	Agriculture and natural resource management in the region to appeal.

In this model, considering different factors influencing erosion in homogeneous units including stone type, outcrops, slope and erosion status, soil and how to use the lands and vegetation are determined. In the next level, the lithological map is provided using geological maps and geomorphological outcrops' map was provided using aerial photographs and their interpretations

together with operations and field visits and maps of geomorphological outcrops and the work unit map (Homogeneos units) is prepared through their combination. In order to estimate erosion and sedimentation, using FAO method the work unit map is provided first. Then, topographic factors specially slope, vegetation, soil type, stone type, type of erosional outcrops and how to use the drainage basin lands have been studied in each unit and the condition of each unit is separately determined considering the mentioned factors and based on the principles of FAO method. Inorder to provide the soil severity map using FAO method, via study of the resulting data from erosion severity status in each work unit, the whole area was divided into 5 classes including: VI, II, III, IV, V (table3). After determination of erosion severity status in each level of the units located in one erosion class, they were integrated and erosion severity map of the area was prepared using FAO method (figure4).

Results

1. Results of geomorphological studies show that the basin is consisted of 15 morphological outcrops types and 104 work units. In each work unit, the coefficients influencing the erosion were calculated and erodibility severity map of the basin was drawn (figure2). Result of the calculations related to special erosion estimation, sedimentation coefficient, special sediment discharge and total sediment discharge of Navroud drainage basins are presented in table5 (figure3).

The results from application of EPM method for estimating the erosion and sedimentation rate show that, 88.12 percents of the basin has very low sensitivity to erosion, 4.16 percents has low sensitivity, 7.57 percents has average sensitivity and 0.08 percents has severe sensitivity (table4).

Table 4. Area and Percentage of Each Erosion Severity Class, Using EPM method

The rate of erosion	Erosion classes	Area - hectares	Percent of area
Severe	0.71 >Z > 1	22.2	0.08
Average	0.41> Z >0.7	2010.69	7.57
Low	0.2> Z >0.4	1104.17	4.16
Very little	Z > 0.19	23408.98	88.12

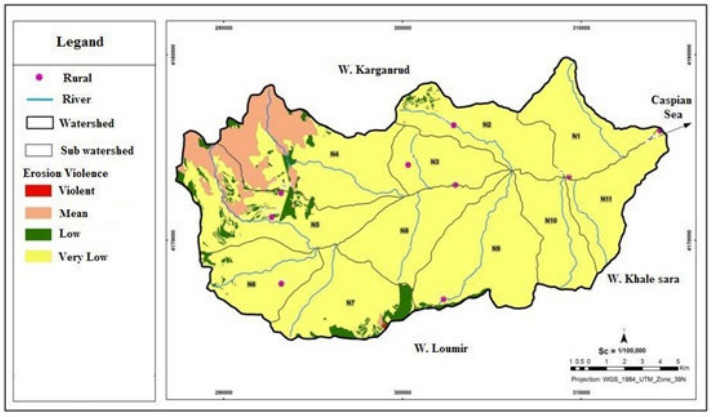

Figure 2. Results from Implementation of EPM Model

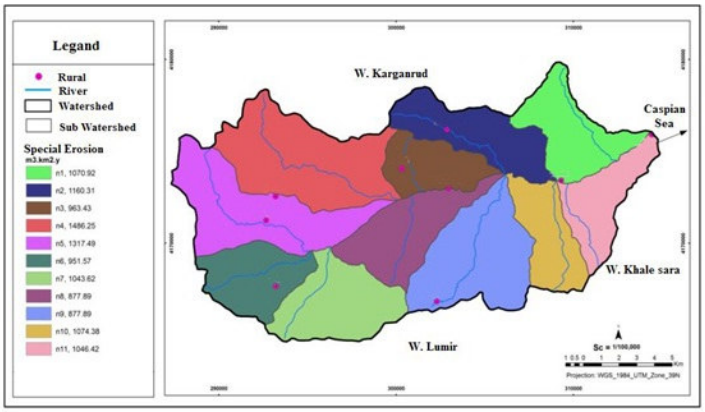

Figure 3. Special Erosion Map Using EPM Method of Navroud Drainage Basin

Table 5. The calculated amounts of erosion severity coefficient, special erosion, special sediment and total sediment, using EPM model in sub-watersheds of the study area.

Sub-basin	Moderate amount of slope	The mean annual temperature	Above average rainfall in mm	The catchment basin	Main channel length km	The height difference Basin km	The rate of erosion z	Special Qrsaysh	The temperature coefficient	Basin sedimentation coefficient	Km2 area.	Special discharge	The total discharge
1	37.56	13.1	1122	24.42	6.9	1.12	0.07	74.96	1.15	1.24	20.71	93/4	1926.77
2	58.89	12.6	1093	26.05	8.06	1.62	0.09	104.43	1.13	1.44	22.27	150.58	3353.51
3	34.79	11.3	1016	18.31	3.54	1.47	0.08	77.07	1.07	1.53	15.8	118.21	1867.71
4	64.28	10.2	952	32.54	12.6	20.1	0.24	356.7	1.01	1.43	39.57	511.39	20235.83
5	96.62	9.5	913	35.16	10.68	2.23	0.22	289.85	0.98	1.72	34.3	497.09	17050.33
6	64.81	9.7	923	19.44	7.29	1.68	0.11	104.67	0.99	1.32	18.95	138.45	2623.61
7	36.2	10.1	950	22.63	6.061	1.48	0.12	125.33	1.01	1.44	24.82	180.66	4483.93
8	39.34	11	1003	26.33	5.26	1.68	0.07	61.45	1.05	1.75	22.52	107.24	2415.01
9	5.69	11	1003	23.37	9.86	1.69	0.07	61.45	1.05	1.34	32.91	82.63	2719.25
10	55.97	12.4	1082	20.32	6.89	1.42	0.08	85.95	1.12	1.27	16.96	109.44	1854
11	40.87	12.8	1109	22.26	5.42	1.31	0.07	73.25	1.14	1.40	17.42	102.63	1787.88
The total catchment	**47.20**	**10**	**960**	**83.74**	**0.033**	**2.89**	**0.13**	**142**	**1**	**6.21**	**265.46**	**881.93**	**60317.84**

2. Also, the results of FAO method application in recent research show that, 0.002 percents of the total area of drainage basin have little sensitivity to erosion, 10.592 percents have low sensitivity, 78.811 percents have average sensitivity and 10.595 percents have high sensitivity (table6).

Table 6. Area and Percentage of each class of erosion severity, using FAO method

The rate of erosion	Erosion classes	Area - hectares	Percent of area
Negligible	>20	0.62	0.002
Low	20 –40	2811.57	10.592
Medium	40 –60	20920.24	78.811
Large	60–80	2812.30	10.595

The resulting map of the study of essential factors for erosion severity determination in FAO method has been shown in figure4.

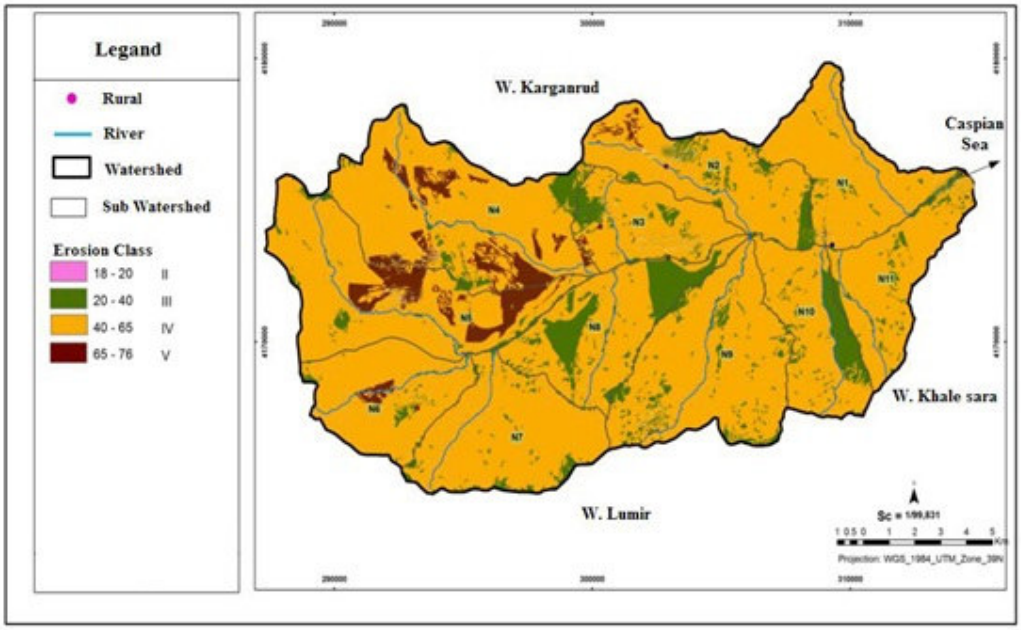

Figure 4. Map of Navroud Drainage Basin's Erosion Severity Using FAO Method

Conclusion

In this research, EPM and FAO models were presented for erosion severity determination. After determination of drainage basin's erosion severity status by applying the two mentioned methods, amount of relative difference of levels of each erosion class was obtained. Considering the resulting statistics, in EPM method, about 88.12 percents of the basin area has very low erosion rate, 4.16 percents have low erosion rate, 7.57 percents have average erosion rate and 0.08 percents have severe erosion rate, while this amount in FAO method is 0.002 percents in II erosion class, 10.59 percents in III erosion class, 78.81 percents in IV erosion class and 10.59 percents in V erosion class. To estimate the erosion and sedimentation of Navroud drainage basin, EMP model can be adapted to statistics of the existing sediments because the results from EPM method and the statistics of sediments are very close. The estimation obtained from the sediment rates of EPM method has been 78413.20 tones each year and the figure obtained from Kharajil station's sedimentation statistics is 80552 tons per year. We can accept the resulted figure but FAO model being a qualitative method, does not have the capability to adapt with observational sedimentary statistics and this model is applied better in basins in which there's no hydrometry stations in the basin. Sadeghi (1993), during his research about Ozondare sub-watershed which aimed at determination of erosion and sedimentation rate using PSIAC, EPM, Douglasof Fournier and krikby, conluded that EPM model has had an acceptable accuracy too.

In Navroud basin, we observe appearance and emergence of special erosion types including surface erosion with no vegetation, channel erosion, spot surface erosion, dissolution erosion, surface erosion with semi-intensive vegetation, mass movements and river erosion that show the influence of different factors with various intensities and weaknesses together with the impact of human factors. Among the natural factors, soil, climate, topography and in the next levels, geological factor and the coverage have the greatest impact on erosion and sediment production severity and this is emphasisable under a condition that other unnatural factors provide erosion conditions in the basin. The unnatural factors in Navroud basin include how to utilize the land, utilization change and land conversions, free and traditional ranching in forests and pastures of the area, deforestations for

various purposes, feeding the livestock and in some cases, illegal loggings, conversion of forest lands to residential areas and agricultural lands and in some cases, development of rural communicational paths and utilization of the forests.

The most important unnatural active phenomena that have caused acute erosive conditions in the area and should be managed and planned include:

- Organization of the foresters and ranchers and prevention of extensive and vast utilization without preservation of the principles of utilization of forest resources which is one of the factors influencing destruction and emergence of active erosion phenomena.
- Prevention of the concentration and aggregation of residential population centers temporarily and permanently that have occupied and destroyed a wide range of forest lands.
- Prevention and inhibition of construction and development of forest roads and rural communicational paths that have destroyed a wide range of foresed lands and have a great influence on occurrence of erosion phenomena.
- Prevention and inhibition of development of agricultural lands in different parts of gardening and agriculture of grains, crops etc. that cause a change in the hydrological regime and basin discharge while destructing the forest ecosystem and on the other hand, making production and emergence of mass movement and erosion phenomena possible.
- Prevention and inhibition of wide and extensive utilization of forested slope lands that considering the rates and volumes of rainfall, cause erosion intensification.
- Revival and reconstruction of the degraded forest areas by planting native species both to keep the forest types unchanged in terms of the genetic resources and to reconstruct the areas being demolished.

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