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ESTIMATIVA DE EROSÃO E SEDIMENTAÇÃO USANDO DADOS SEDIMENTOLÓGICOS E CÁLCULO DA CARGA SUSPENSA DE SEDIMENTO EM BACIA DE GARMSAR

ESTIMACIÓN DE EROSIÓN Y SEDIMENTACIÓN MEDIANTE DATOS SEDIMENTOLÓGICOS Y CÁLCULO DE LA CARGA DE SEDIMENTOS SUSPENDIDOS EN LA CUENCA DE GARMSAR

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Abstract:

Erosion, sediment transport, sedimentation and water quality are very important issues in watershed management. Based on the initial study, it was found that the three factors of geological materials, slope, and climate are the most important factors in erosion. Therefore, these three factors were examined and combined to create work units. Then, the qualitative sensitivity of the rocks and pre-Quaternary formations was continually determined using the criteria of resistance method and hardness of the rock mass in a field method. Then, several statistical regression models were investigated by discharge classification and temporal separation of data; and by establishing a regression relation between flow discharge and sediment discharge data and its simulation, sedimentation rating curves along with FAO and USBR were presented based on the error least squares method according to statistical analysis methods, and annual long run suspended sediment load values were estimated by combining the proposed models and flow discharge methods such as flow continuity curve, daily mean discharge, and monthly mean discharge. In this regard, the statistics of a 13-year period of Bankooh hydrometric station on the HablehRood River were used. Finally, combination of the classes mean model with the mean daily discharge by FAO method was introduced as a suitable model.

Keywords: Erosion, Regression relation, Quality sensitivity, Rating curves.

Resumo:

Erosão, transporte de sedimentos, sedimentação e qualidade da água são questões muito importantes no manejo das bacias hidrográficas. Com base no estudo inicial, verificou-se que os três fatores de materiais geológicos, declividade e clima são os fatores mais importantes na erosão. Portanto, esses três fatores foram examinados e combinados para criar unidades de trabalho. Em seguida, a sensibilidade qualitativa das rochas e formações pré-quaternárias foi determinada continuamente, usando os critérios do método de resistência e dureza da massa rochosa em um método de campo. Em seguida, vários modelos de regressão estatística foram investigados pela classificação da descarga e separação temporal dos dados; e estabelecendo uma relação de regressão entre os dados de descarga de fluxo e descarga de sedimentos e sua simulação, as curvas de classificação de sedimentação juntamente com FAO e USBR foram apresentadas com base no método dos mínimos quadrados de erro de acordo com os métodos de análise estatística, e os valores anuais de carga suspensa de sedimentos suspensos a longo prazo foram estimados combinando os modelos propostos e os métodos de descarga de fluxo, como curva de continuidade de fluxo, descarga média diária e descarga média mensal. Nesse sentido, foram utilizadas as estatísticas de um período de 13 anos da estação hidrométrica Bankooh no rio HablehRood. Finalmente, a combinação do modelo médio de classes com a descarga média diária pelo método FAO foi introduzida como um modelo adequado.

Palavras-chave: Erosão, Relação de regressão, Sensibilidade de qualidade, Curvas de classificação.

Resumen:

La erosión, el transporte de sedimentos, la sedimentación y la calidad del agua son cuestiones muy importantes en el manejo de cuencas hidrográficas. Según el estudio inicial, se descubrió que los tres factores de los materiales geológicos, la pendiente y el clima son los factores más importantes en la erosión. Por lo tanto, estos tres factores fueron examinados y combinados para crear unidades de trabajo. Luego, la sensibilidad cualitativa de las rocas y las formaciones pre-cuaternarias se determinó continuamente utilizando los criterios del método de resistencia y la dureza de la masa rocosa en un método de campo. Luego, se investigaron varios modelos de regresión estadística mediante clasificación de alta y separación temporal de datos; y al establecer una relación de regresión entre la descarga de flujo y los datos de descarga de sedimentos y su simulación, se presentaron curvas de clasificación de sedimentación junto con FAO y USBR basadas en el método de mínimos cuadrados de error de acuerdo con los métodos de análisis estadístico, y se estimaron los valores anuales de carga de sedimentos suspendidos a largo plazo combinando los modelos propuestos y los métodos de descarga de flujo, como la curva de continuidad del flujo, la descarga media diaria y la descarga media mensual. En este sentido, se utilizaron las estadísticas de un período de 13 años de la estación hidrométrica de Bankooh en el río HablehRood. Finalmente, la combinación del modelo medio de las clases con la descarga diaria promedio por el método de la FAO se introdujo como un modelo adecuado.

Palabras clave: Erosión, Relación de regresión, Sensibilidad de calidad, Curvas de calificación.

INTRODUCTION

Erosion and sedimentation are of the most important environmental issues in the world causing great damage to life and ecosystem (MOHAMMADI, 2007). Surface lithology is one of the most influential factors on erosion and sedimentation. In most models and experimental methods, estimation of watershed sedimentation is considered as an important factor. Therefore, rock sensitivity is of great importance in estimating watershed basin sedimentation (EINI et al., 2013). HablehRood River is one of the most important rivers in the salt desert watershed basin. The watershed basin of this river includes areas of Tehran province (including Firoozkooh and Damavand) and Semnan province (the city of Garmsar) (Map 1). This basin is located in the northwest of the Dasht-e Kavir and belongs to the Semnan and Garmsar sub-basins. The geological formations of the basin range from the Cambrian to Quaternary times. Elika, Shemshak, Lar, Delichai, Tizkuh, Kand, Karaj, Fajan, Ziarat, Lower Red, Qom, Upper Red, Hezar Dareh, Old and Young Alluvial are indicated in Map 2 (AGHANABATI, 2010; DARVISHZADEH, 1993). The mean annual rainfall in the highlands and lowlands is estimated to be 200.9 mm and 81.4 mm, respectively. The amount of evaporation from the pan in the plain and the highlands of the study area were calculated to be 2903 mm and 2030.1 mm, respectively. Various studies have shown the relationship between watershed sedimentation and climatic, hydrological and geomorphological factors (WALLING, 1996). The ratio of erodible formations as the source of suspended load was investigated by Nolan et al.

(1986) in the state of California. The event of erosion is one of the prominent phenomena of sediment transport in rivers. Transport of suspended load in rivers is one of the major problems of surface water resources (GERICKE; VENOHRE 2012). Sedimentation in the rivers when flooding causes damage to buildings, farms; it also makes the river shallow leading to difficult navigation (SHAFAEIAN BOJESTAN, 2008). Various methods have been introduced for estimating suspended load, including the measurement of suspended load. Suspended load measurement method and suspended load concentration measurement and flow discharge are reliable methods but they need continuous measurement that is usually only possible for important and permanent rivers (DEHGHANI et al., 2009). So many studies have been carried out on the suspended load using the suspended load rating curve.

Classifying the data to improve the accuracy of the methods, Zoratipour (2007) showed that the mean data and FAO method for general data and dry seasons, and the linear method for classifying the data of flood seasons, are suitable for estimating suspended load of Taleqan Watershed. Seasonal classification of suspended load data and hydrograph analysis of basin outputs are effective in increasing the accuracy of suspended load rating curve and estimating suspended load of the river. Pour Aghniaei et al. (2007) compared single-line, two-line, seasonal, and FAO (sedimentary load adjustment methods) rating curve methods on the Sidon River in Khuzestan province, and showed that the FAO method is appropriate for this river. Showed that the equations of suspended load rating curve in the inlet stations of Dez and Karaj dams' basins estimate sedimentation rate for these two dams around 70% and 97% lower than the actual value, respectively.

The accuracy of the current methods in estimation of the suspended load in rivers varies, and their performance depends on the status of the data and the characteristics of each region. Therefore, the development of surface water containment programs requires accurate access to flow behavior and sediment content. Measurement of rivers' suspended sediment in Iran started on a regular basis since the 1960s and there are currently about 500 sedimentation stations nationwide.

In most cases, organizations do not continuously measure the discharge data. Concentration data are also measured less frequently due to the high cost of sampling and laboratory analyzes. Therefore, researchers use estimation methods to obtain long-term suspended concentration or load. The error of sediment estimation through the rating equation can be eliminated by applying the correction coefficients).

MATERIALS AND METHODS

According to the geological maps of 1:250000 Tehran and Semnan and 1:100,000 Garmsar and Kohanabad and Firoozkooh, topographic maps and field visits, and according to the geology of the area, type of erosion, results of XRD, Harvested, XRF sample rocks analysis, Harajchi (2018), Mohammad Reza Khamoshi (1996), slope, stratigraphic type, and lithology based on Feiznia division, and information collected from adjacent basins by Feiznia et al, (2002) and River slope (Map 3) were provided in ArcGis software (Map 4). Then, the map of alluvial fan and erodible formations was prepared in 5 categories of very sensitive, sensitive, relatively sensitive, resistant and very resistant (Map 5).

In reviewing available statistics and reports on erosion and sedimentation, and the information recorded, the sediment loads of rivers are generally reported as suspended loads; these statistics are recorded as daily sediment rates for the flow discharge at Bankooh Hydrometric Stations. We used the sediment statistics of the HablehRood River at Bankooh Hydrometric Station located at the upstream of the

Garmsar diversion dam as the river yield to the study area.

The purpose of this study is to evaluate stratigraphic units in terms of erosion and investigate different statistical models and determine the most appropriate equation and best method of data classification to more accurately estimate the amount of sediment transported based on the use of flow discharge in long-term annual suspended sediment estimation at Bankooh station. Prior to any attempt to analyze the Bankooh dat a, which consists of 138 pairs of simultaneous daily flow-sediment discharge data, in order to form various models with respect to discharge and measurement time, the relationship of suspended sediment discharge was firstly calculated (2). Calibrated and validation data were used to fit the power curve and simulate the sediment, respectively.

RESULTS

Evaluation of erodibility and sediment transport potential and the studies on the geological layers in the studied basin and their material show that the western part of the basin includes alternating silt and clay shales, basalt, lime sand, marl lime, green marl; east of the basin includes alternating silt and clay shales, sandy lime, marl lime and green marl; northwest of the basin includes shale, sandstone and dark marl, thick-layer dolomites, thin lime layers with abundant black chert veins; northeast part of the basin includes alternating layers of conglomerate layers, shale, lime, siltstone and sandstone, dolomite, sandy lime, marl lime and green marl; north of basin includes dolomite, thin layers of lime and alternating shale and sandstone and tuff shale and green marls; and southern part of the basin includes shale, marl, sandstone and chalk. There are also layers of shale, sandstone, and marl, and thin layers of lime and marl below, and thick lime layers at the top with a relatively large extent extending from north to south.

EVALUATING THE BEHAVIOR OF GEOLOGICAL UNITS AGAINST EROSION

The lithology units of the HableRood River watershed area were studied in terms of material and extent of outcrop development, but evaluation of the behavior of these units against erosive factors will depend on features such as the extent of the seam and crevice system development, the geomorphologic position of the outcrops, and the factors affecting the erosion and transport of worn materials in addition to lithological features (rock type, type of minerals, texture, etc.). Therefore, not only the behaviors of different geomorphological units differ against erosive factors, but also the behavior of a particular unit is not necessarily the same across the basin and can be different in different parts.

Investigation of topographic status and geomorphologic features of different parts of HableRood River watershed with special attention to the geological-tectonic characteristics of this area and considering the climatic features of the area suggest that one can classify the stratigraphic outcrops at the watershed in terms of sensitivity to erosion in different groups. (Tables 1 and 2)

DISCUSSION AND CONCLUSION

According to the maps and tables presented, it can be said that the Quaternary Formations and the Lower Red Formation are erodible and have the highest sedimentation. Hydrologists use rating curves to predict and estimate the flows' suspended sediment concentration in the absence of suspended sediment concentration data (HOROWITZ, 2002). Sediment estimation methods are categorized into single-line, multi-line, and classes mean curves in terms of the type of rating curve and use of flow discharge (SAGHAFIAN et al., 2005), all of which follow the revival management relationship. This relationship is as follows: (USBR) American lands Qs = aQw b. Qw is the flow discharge and Qs is the sediment discharge in mg or ton per day where the coefficients are constant. Lemeck (1) states that the simplest form of regression equations that requires the logarithmic transformation of concentration and discharge data is as C=aQb where C is the suspended sediment concentration in runoff, Q is the water flow discharge, and a and b are regression parameters. a is an indicator of erosion severity, and the high values of the above coefficient indicate high erosion of watershed geological formations that are easily transmitted. b is the river erosion coefficient; slight increase in the discharge leads to severe increase in the erosion.

In the rating curve model (monthly, yearly, and seasonally), the estimation of sediment discharge is studied on the basis of data breakdown on monthly, yearly and seasonally basis, and a separate relationship is fitted for each of them. Since the number of samples collected from the sediment discharge is very low during floods and high in dehydration periods of rivers, in the fitting of curve by considering the total statistics, the relation determined for the low discharge has the best estimation, but it has trouble when estimating the high discharges. Therefore, to increase the share of high discharges, one method is to classify the discharges, determine the average of each class, and establish a correlation between the categories of mean flow discharge and mean sediment discharge.

In the single-line rating curve method, the best correlation is established between the discharge (cubic meters per second) and the sediment discharge (ton per day), the result of which is shown in Figure (1). According to daily statistics at the location of hydrometric stations and using the selected relation, sediment load values have been estimated. Specific sediment estimated using the above relationship for the study area is 326 ton per year in a Km2, if the data distribution condition requires, instead of a curve based on river discharge classification, several rating curves are passed through the measured data. It is necessary that the given fitted lines have an acceptable regression correlation coefficient.

In the two-linear rating curve method, according to the distribution of suspended load measured at the hydrometric station location to the flow discharge, two separate relations are fitted for the discharge values. The result is shown in Figure (2). Based on the above equations and daily discharge statistics, the specific suspended load for the area was estimated to be 708 tons per year in a km2.

In the FAO Sediment Load Adjustment Method, a relation is first fitted between all measured sediment load data at the hydrometric station location; the relation obtained is as follows:

Qs=a'Qwbd

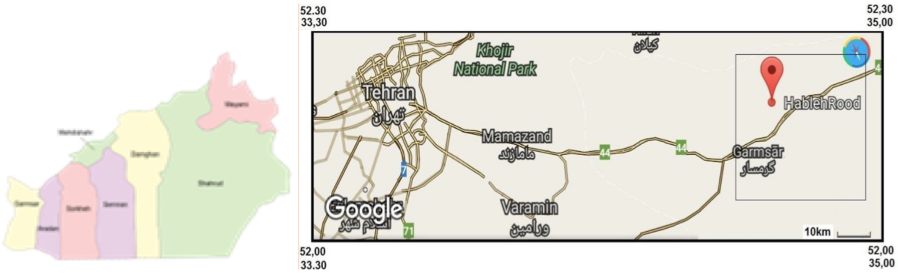
QS = sediment suspended load in terms of ton per day

QW = Discharge in terms of cubic meters per second

b and d are the coefficients of the relation. a' is the y-intercept resulted from dividing the sediment by the river discharge. In this method, the FAO[1] recommends the following relationship to adjust the figures and bring the estimated values of the sediment rating curve closer to the observed values. Applying the above modified coefficient in the single-line curve method, the FAO adjustment coefficient changed to 46.39 from 1.927, while in the two-line rating curve method, the coefficients of 0.4796 and 2.6 changed to 9.8 and 24.28, respectively. Based on the above relation, the amount of suspended sediment load for the study area was estimated to be 1312 and 851 ton /day In a km2 using single-line and two-line rating curves, respectively.

In the flow continuity curve method, sediment load estimation is based on daily discharge flow continuity curve. For this purpose, the daily discharge of different years at the hydrometric station site is arranged in descending order and then, based on the Weibull relation, the percentage of probability of occurrence of each daily discharge is calculated. Then, according to the instructions of the US Army Bureau of Investigation, the discharge of certain probabilities percentage is determined, and based on the best fitted relationships among the measured samples, the suspended sediment load values are calculated. The results of this method are shown in Tables (3) and (4). Based on the above relationship, the specific sediment yield in the study area was estimated to be 1112 and 1138 ton / km, respectively, using single- and two-line rating curves.

Bed sediment load was measured at the stations under study. In such conditions, an average of 10-35% of the suspended sediment load is usually considered as bed load depending on the physiographic conditions of the basins. In this study, 15% of suspended sediment load is considered as bed load. Based on total sediment load for the study area, it is estimated to be 1507, 852 for single- and two-line curves, respectively the continuity of the single-flow current 1282 and the two-flow current are estimated to be 1303 ton / km2.



Map 1 - Location of Study Area

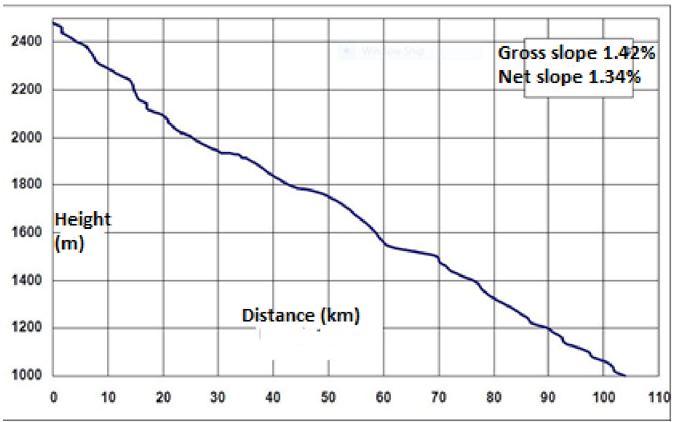


Figure 1 - HableRood River Slope

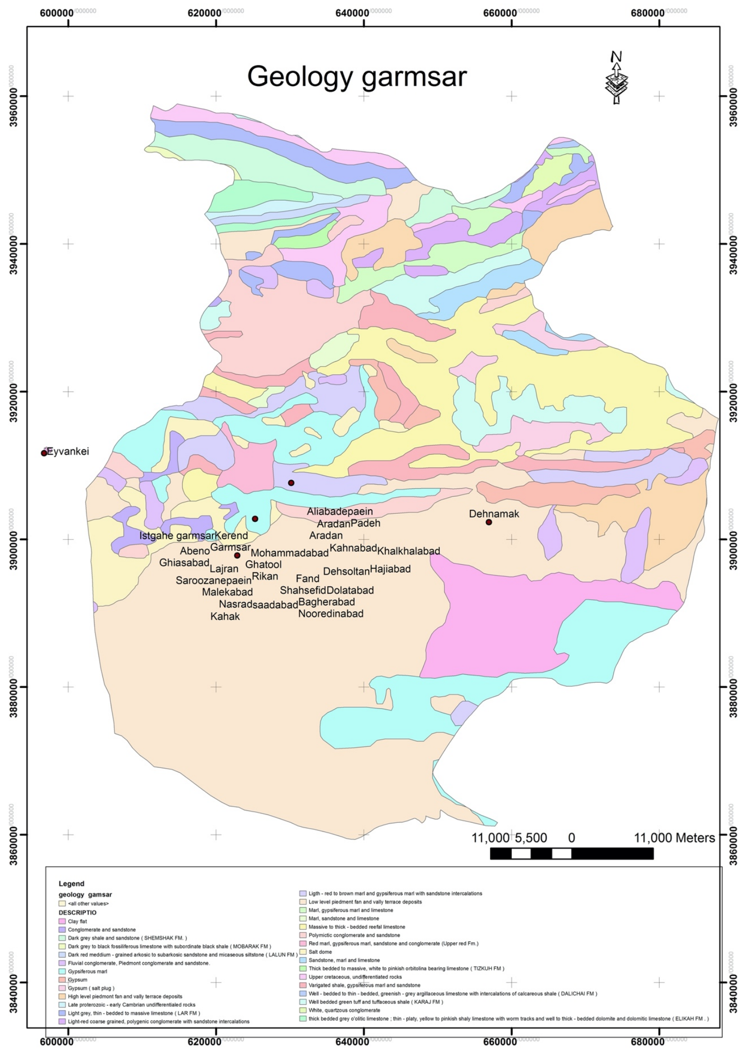
Erosion Classification	Output percentage	Outcrop Area (km2)	Stratigraphic unit	Row
Very resistant	1/22	38/9	b	1
Sensitive	0/04	1/33	C1m	2
Very resistant	0/1	3/23	Cm	3
Resistant	0/05	1/56	E bt	4
Resistant	0/01	0/24	E g2	5
Resistant	11/13	355/64	E k	6
Resistant	6/42	205/25	E m	7
Resistant	0/03	1/05	E mt	8
Resistant	2/57	82/18	E t2	9
Very resistant	0/01	0/4	E v	10
Resistant	0/85	27/22	E z	11
Resistant	0/42	13/46	E f	12
Resistant	0/43	13/63	EL	13
Resistant	0/31	9/89	EO g	14
Resistant	0/12	3/79	EO mt	15
Very resistant	0/84	26/74	g	16
Resistant	9/1	290/62	J L	17
Resistant	0/72	23/06	Jd	18
Sensitive	3/27	104/54	Js	19
Resistant	1/98	63/28	K2	20
Resistant	0/03	1	Kc	21
Resistant	0/24	7.78	K 12	22
Resistant	2/22	71/03	K 1-m	23
Resistant	1/16	36/93	K m	24
Resistant	0/69	21/91	K s	25
Resistant	3/94	125/78	K t	26
Resistant	0/26	8/3	I	27
Sensitive	0/45	14/22	M	28
Resistant	4/46	142/64	M pl	29
Sensitive	2/81	89/79	M1	30
Fairly sensitive	3/21	102/67	M2	31
Fairly sensitive	3/27	104/4	M3	32
Sensitive	0/75	23/81	M1-2	33
Very resistant	0/07	2/2	O v 1	34
Resistant	0/52	16/7	OI g	35
Fairly sensitive	3/35	106/88	OM q	36
Resistant	0/18	5/87	Pd	37
Resistant	0/13	4/11	P l-Q	38
Resistant	0/02	0/6	P r	39
Resistant	0/16	4/99	PE Bt	40
Resistant	2/82	90/04	PE cf	41
Resistant	0/19	6/13	PE s	42
Resistant	1/12	35/84	PE sc f	43
Resistant	0/55	17/55	PLc	44
Very sensitive	2/52	80/6	Q al	45
Very sensitive	21/1	674/13	Q t1	46
Very sensitive	1	32/1	Q t2	47
Very sensitive	0/44	13/91	qc	48
Fairly sensitive	0/45	14/38	Sa	49
Sensitive	0/05	1/63	sh	50
Fairly sensitive	1/27	40/49	sm	51
Very resistant	0/71	22/64	TR 2e	52
Very resistant	0/12	3/85	TR 3e	53
Very resistant	0/13	4/08	TR 1E	54
	100	3195	Total	

Table 1 - Classification of stratigraphic units based on outcrop percentage and sensitivity to erosion

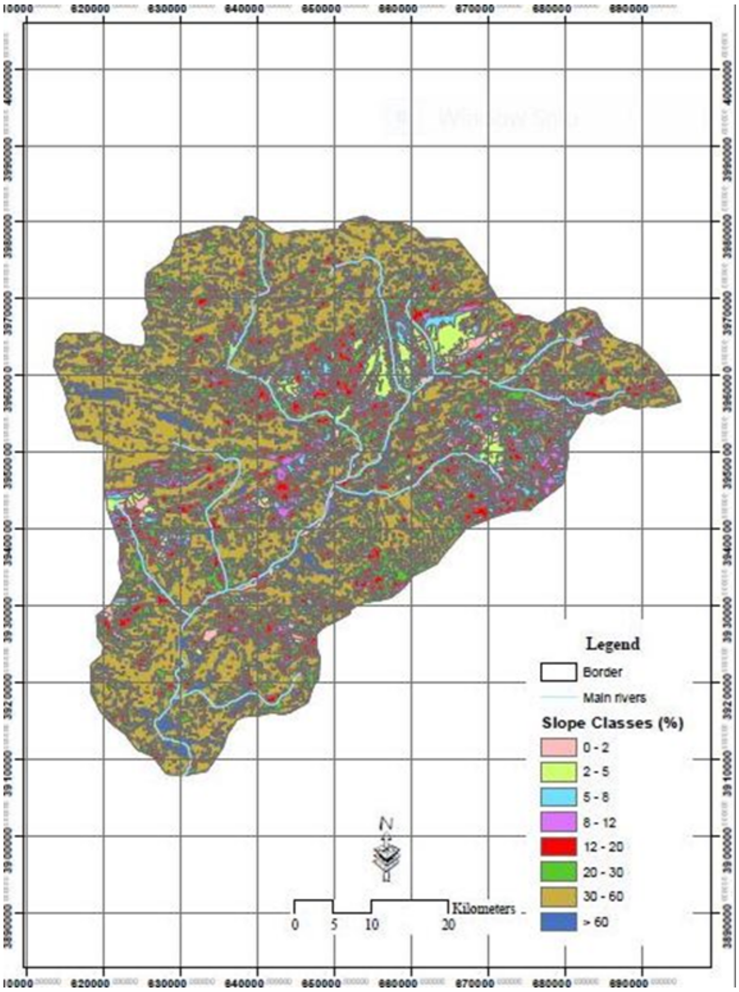
Table 2 - Classification of erosion sensitive units

Classification of stratigraphic units based on erosion sensitivity

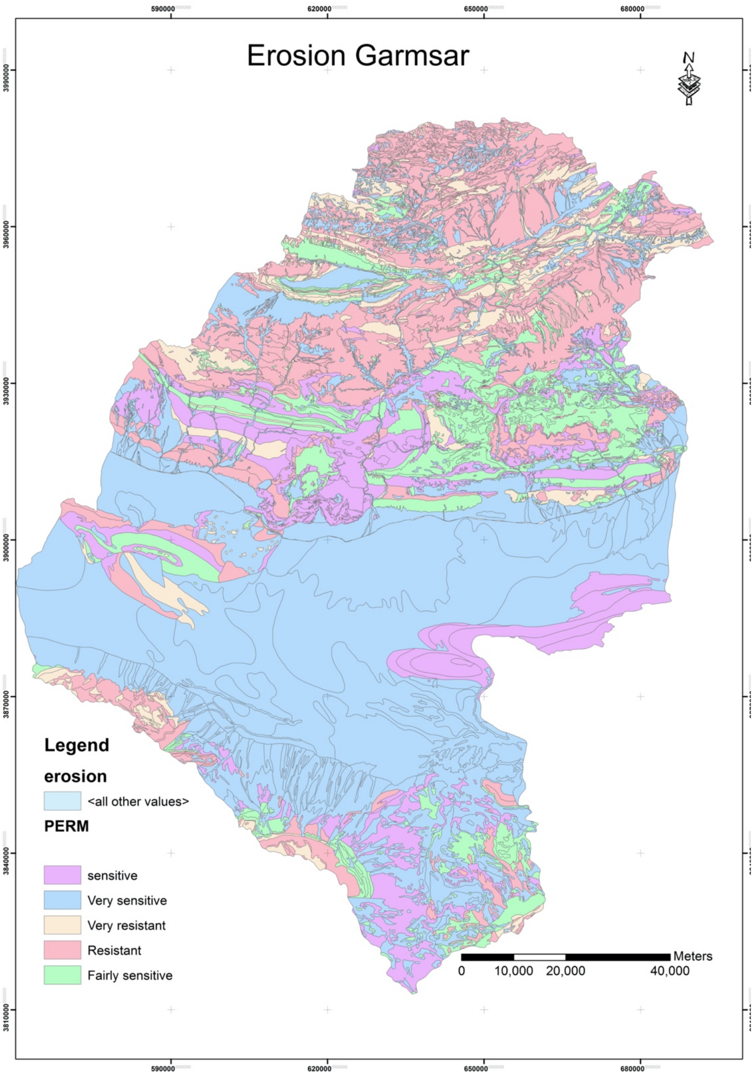
Lithology composition	Resistance against erosion	Map marks provided
Gypsum, marl, sand marl, chalk marl	Severe erodibility	Very sensitive
Shale, marl shale, sand shale	Erodible	Sensitive
Mal lime, shale marl, shale sandstone, marl sandstone, tuff	Fairly resistant	Fairly sensitive
Marl, sandstone, sandy conglomerate	Resistant	Resistant
Lime, dolomite, dolomite lime, lime dolomite, acidic igneous rocks	Very resistant	Very resistant



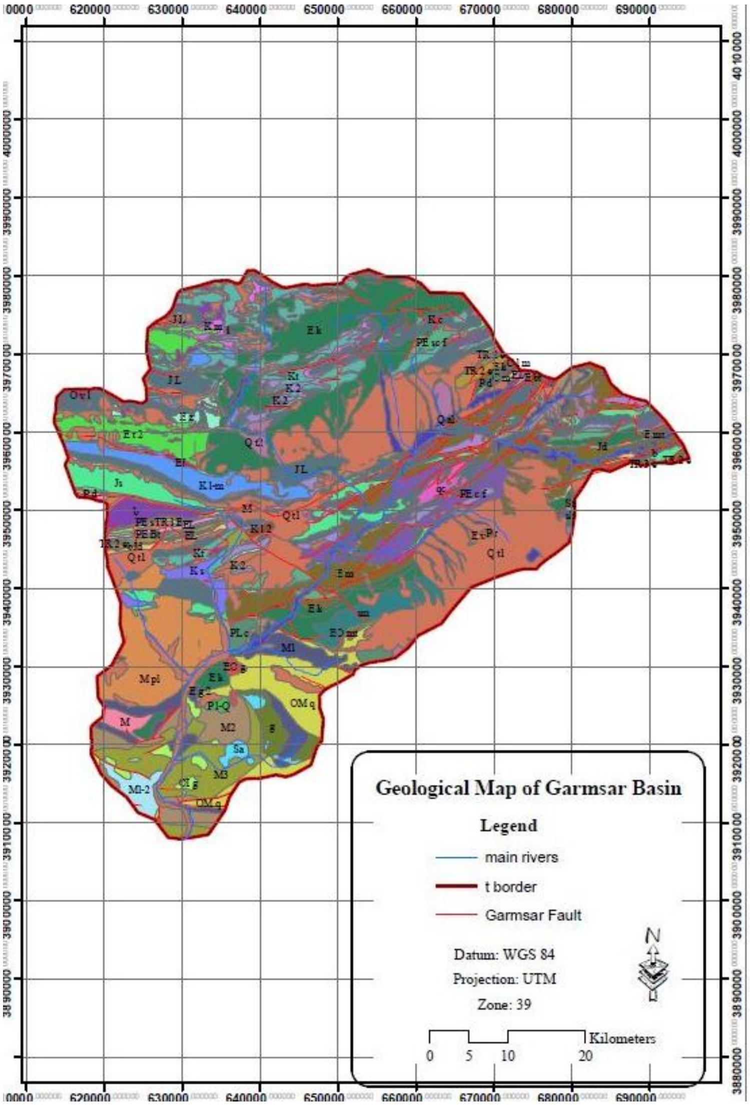
Map 2 - Geology of Garmsar Study Area



Map 3 - Slope of Garmsar watershed



Map 4 - Erosion of watershed area and alluvial fan



Map 5 - Geological map of Garmsar basin

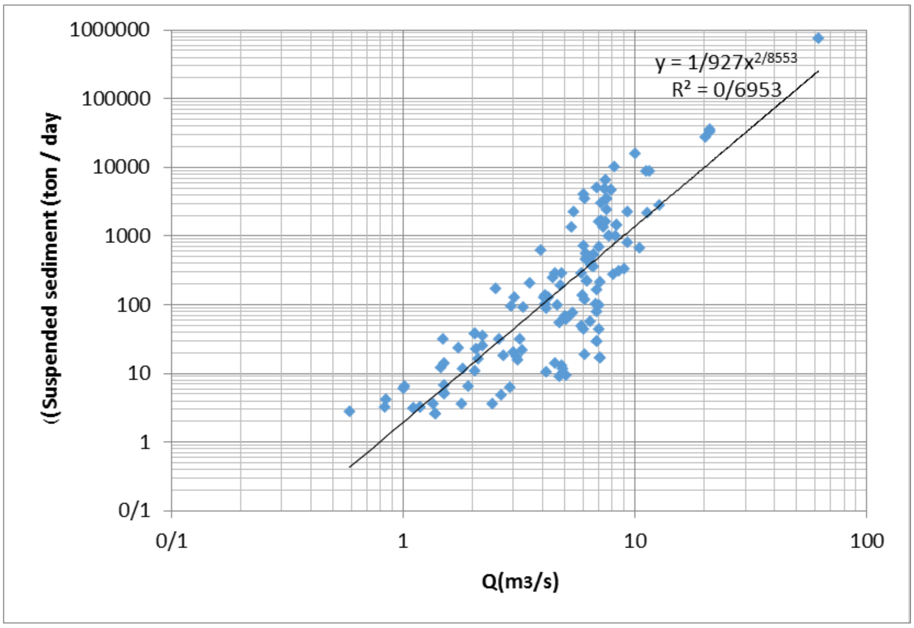


Figure 2 - Single-line rating equation

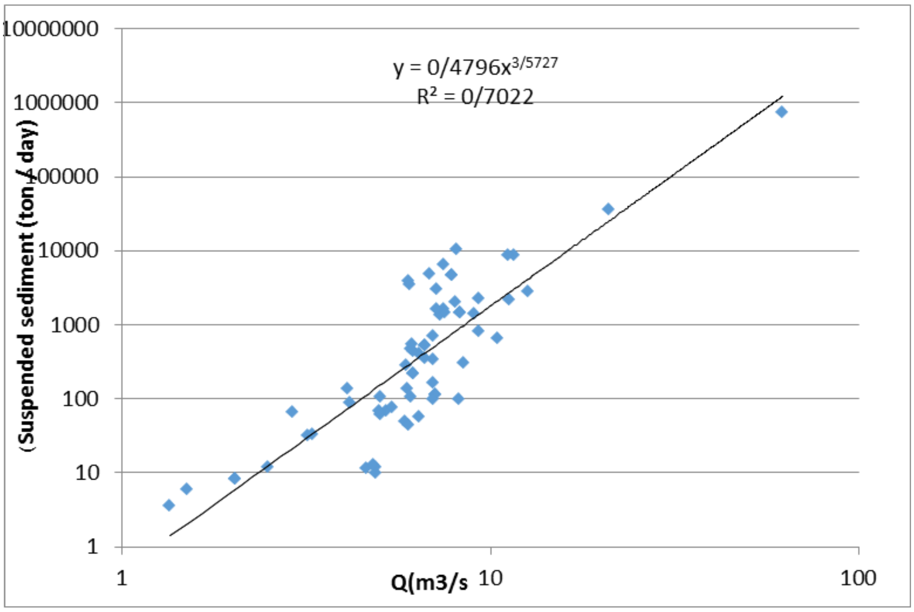


Figure 3 - Two-line rating equation

Category boundaries		Handle distance	The middle of the handle	Dubai	Suspended load	Discharge * Distance	Suspended load * distance
Low limit (percent)	Upper limit (percent)	(Percentage)	(Percentage)	(m3/se)	Ton/day	(m3/se)	Ton/day
0	0/01	0/01	0/005	0/05	0	0/000	0/0
0/01	5	4/99	0/4	0/2	0	0/010	0/0
5	10	5/00	7/5	0/3	0	0/015	0/0
10	20	10/00	15	0/5	0	0/050	0/0
20	30	10/00	25	0/8	1	0/080	0/1
30	40	10/00	35	1/5	6	0/150	0/6
40	50	10/00	45	2	14	0/200	1/39
50	60	10/00	55	3	44	0/300	4/44
60	70	10/00	65	6/5	404	0/650	40/36
70	80	10/00	75	10	1381	1/000	138/10
80	90	10/00	85	18	7397	1/800	739/71
90	95	5/00	92/5	27	23543	1/350	1177/13
95	98	3/00	96/5	40	72318	1/200	2169/53
98	99/99	1/99	98/8	62	252754	1/234	5029/8008
99/99	99/999	0/01	96/925	180	5301043	0/016	477/0938
						Average load per tonne	9778
						Annual Suspended loac	3569079
							535361/905
						Bed load	4104441
						Special deposition	1282

Table 3 - Estimation of suspended load by flow continuity curve method at Bankooh station (single-line rating curve)

Category boundaries		Handle distance	The middle of the handle	Dubai	Suspended load	Discharge * Distance	Suspended load * distance
Low limit (percent)	Upper limit (percent)	(Percentage)	(Percentage)	(m3/se)	Ton/day	(m3/se)	Ton/day
0	0/01	0/010	0/05	0/05	0/0	0/000	0/0
0/01	5	4/990	2/5	0/2	0/0	0/010	0/0
5	10	5/000	7/5	0/3	0/1	0/015	0/0
10	20	10/000	15	0/5	0/4	0/050	0/0
20	30	10/000	25	0/8	1/4	0/080	0/1
30	40	10/000	35	1/5	8/1	0/150	0/8
40	50	10/000	45	2	17/9	0/200	1/8
50	60	10/000	55	3	55/4	0/300	5/5
60	70	10/000	65	6/5	476/5	0/650	47/6
70	80	10/000	75	10	1580/1	1/000	158/0
80	90	10/000	85	18	8111/3	1/800	811/1
90	95	5/000	92/5	27	25068/8	1/350	1253/4
95	98	3/000	80	40	74845/2	1/200	2245/36
98	99/99	1/990	90	62	253418/3	1/234	5043/02
99/99	99/999	0/009	96/75	180	4920269/7	0/016	442/8243
						Average load per tonne	10010
						Annual Suspended load	3653560
							548033/9343
						Bed load	4201593
						Special deposition	1309/315518

Table 4 - Estimation of suspended load by flow continuity curve method at Bankooh station (two-line rating curve)

References

AGHANABATI, A. **Geology of Iran.** Geological Survey and Mineral Exploration of Iran, 2010. 583 p.

DARVISHZADEH, A. **Geology of Iran.** Amir Kabir Publications, 1993, 900 p.

DEHGHANI A.; ZANGANEH M.A.; MOSAEDI A.; KUHESTANI N. Comparison of suspended load estimation with two methods of sediment rating curve and artificial neural network in Dough River of Golestan Province. 2009. **Agriculture and Natural Resources Science.** 16(1): 276–266.

EINI, N; HAJI KARIMI; MARZBAN FARAMARZI; MAMIZADEH, J. Methodology of Underground Dam Locating, **First National Conference on Water Crisis**, Isfahan, Islamic Azad University of Khorasgan Branch, 2013.

FEIZNIA, S.; MAJDABADI FARAHANI, F.; MOHSENI SARAVI M.; ARAB KHADRI M. Proper statistical period for estimating annual sedimentation average and its relationship with area, annual sedimentation changes, climatic characteristics, geology and vegetation of the area, 2002. GORGAN Agricultural Sciences and Natural Resources Journal.

GERICKE A.; VENOHRE M. Improving the estimation of erosion-related suspended solid yields in mountainous, non-alpine river catchments. 2012. **Environmental Modelling and Software.** 37: 30-40.

HOROWITZ, A. J. **The use of rating (transport) curves to predict suspended sediment concentration:** a matter of temporal resolution. Turbidity and other sediment surrogates Workshop. U.S. Geological Survey. 2002, 3 p.

HARAJCHI, M. **Investigation of Physicochemical Factors Affecting Erosion of Marls in Northeast of Garmsar.** M. A. thesis, Kharazmi University, Tehran, 2018.

KHAMOSHI M.R. **Study of Sedimentology:** Geomorphology and Sedimentary of Quaternary Deposits of Garmsar Plain, M.A. Thesis, Tehran University of Teacher Education, p. 107 .1996

MOHAMMADI A.; MOSEADI A.; HESHMATPUR A. Determine the best method for estimating the suspended sediment in the river gauging stations Qazzaqli in Gorgan. 2007. **Agricultural Sciences and Natural Resources.** 14 (4): 232–246

NOLAN, K. M.; JANDA, R. J.; GALTON, J.H. **Sediment sources and sediment-transport curves:** in Proceeding of the Fourth Federal Interagency Sedimentation Conference, v. 1, Las Vegas, p. 4-70 to 4-79, 1976.

POUR AGHNIAEI M. J.; DOMIRI GANJI M.; YOUSEF POUR A.; GHERMEZCHESHMEH B. A review on estimation methods for suspended load (Case study: Seydon Basin). 2007. **Water Resources Research.** 3(3): 73–85.

SHAFAEI BOJESTAN, M. **Sediment Hydraulic Press**, Shahid Chamran University Third Edition: 2008. 470p.

SAGHAFIAN, B. *et al.* Analysis and Analysis of Suspended Sediment Areas Based on Image Processing GIS Satellites and Analyzes, **Third National Conference on Erosion and Sedimentology**, Tehran: Soil Conservation Research Center and sanitation, 2005.

WALLING, D. E. Suspended sediment transport by rivers: a geomorphological and hydrological perspectives. 1996. **Arc. Hydrobiol. Spec. Issues advance Limnol.** 47, p. 1-27.

ZORATIPOUR, **A. Comparison of Some Statistical Methods for Estimating Suspended River Load (Case Study: Taleghan River).** Thesis Master of Watershed Management, University of Tehran, 2007.

Notes

[1] Food and Agriculture Organization of the United Nations.