Combating erosion as the main effective factor in land degradation in arid and semi-arid regions of Iran

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ABSTRACT
Soil erosion is one of the most important environmental problems in the world including Iran. For decreasing the impacts of soil erosion, soil conservation measures are required. For successful soil conservation measures, obtaining information about the relative importance of sediment source and their shares in sediment production is required. There are different methods for determining the relative importance of sediment sources, among which tracing or source studies are emphasized in recent years due to their privileges. In this research, sediment sources were identified in Amrovan Drainage Basin, Semnan Province, Iran, using tracing method.
A small earth dam is constructed at the outlet of Amrovan Drainage Basin in 1993. Sediments are accumulated in the reservoir of dam. In this study, sediments were sampled from dam reservoir, different sources were also sampled. Fifteen tracers were first selected for tracing which are: the amounts of N, Carbon, Cr, Co, Mg, K, Na, smectite, cholorite, illite, kaolinite, PH and two magnetic properties consisting of X_{LF} and X_{FD}. The samples were analyzed in the laboratory for these parameters and different statistical methods were applied to the data including Nonparametric Kruskal Walis Test, Stepwise Differentiation Function Analysis. The results have shown that the main sediment source is Upper Red formation consisting of evaporitic marls.
Keywords: Erosion, Sedimentation, Small dams, Semnan Province, Iran, Tracing, Finger-printing, Source studies.

Keywords: land degradation, erosion, sediment control, sediment source, fingerprinting

INTRODUCTION

Soil erosion is one of the most important environmental problems in developing countries including Iran which has destructive effect on all natural ecosystems being managed by human. Erosion not only causes land degradation and lowering of fertility, but by producing and accumulation of sediments, lowers reservoirs dam capacity. For decrease of soil erosion effects, soil conservation and sediment control measures are needed. For execution of these plans, information about the relative importance of sediment sources is required. Sediment sources may be geological rocks and formations, land uses, soils or different erosions. There are different methods for determining the relative importance of different sources, among which tracing or sediment source identification is emphasized in recent years due to advantage it has.
In this method, physical, chemical and organic characteristics of sediments and sediment sources are determined. Here, by using suitable combination of the mentioned characteristics and multivariate models, the contribution of different sources is determined.
For determining source of sediments in Upper Torridge Catchment, United Kingdom, Nicholls (2001) used sediment yield data of hydrometric stations. Then by using different statistical methods, he determined the potential of each tracer in differentiating sediment source and then by using composite multivariate model, he determined the share of each source. Among 19 parameters which were first chosen, the optimal composition of tracers were: N, P,

Cs137, C, Cr, Fe, and Rd-226 which could completely differentiate sediment sources. According to composite multivariate model, the contribution of sediment from Woodland Pasture topsoil was (%47), cultivated topsoil(%28), Channel banks (%23), and Woodland topsoil (%2). Similar studies have been performed by Walling (2008), Pittarn, etal. (2006) and Moazami(2007).
The studied area is Amrovan Drainage Basin, located in Seman Province, Iran, (Figure1). A small earth dam is constructed in the outlet of the basin in 1993 for flood-control. In this research sediments accumulated in the reservoir of dam were sampled and analyzed for sediment source identification. Specific sediment yield of the drainage basin is high and is 3.57 t/h/y (Hashemi 2006). Mean annual rainfall is 174.5 mm, mean elevation is 1845m, mean annual temperature is 17^0C. Rangeland is the main land use in the area, a part of drainage is under badland erosion.

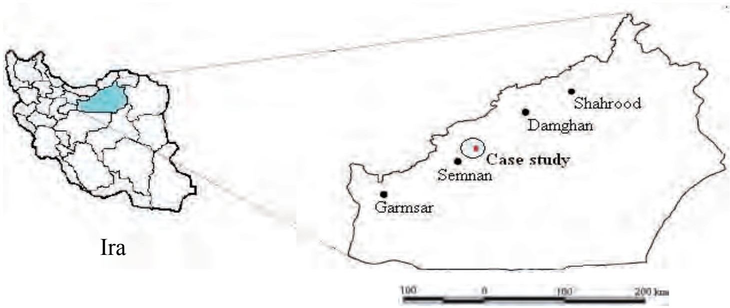

Figure1: The location of studied area

MATERIALS AND METHODS
Sediments were sampled from reservoir dam. Primary field studies showed that there are four sources of sediments in the drainage basin: Quaternary unit, Upper Red Formation, Hezar-Dareh Formation and Badland erosion. These sources were also sampled. The samples were analyzed in the libratory for tracers consisting of : N, C, Ca, Cr, Co, Mg, K, Na, PH, smectite, cholorite, illite, kaolinite and two magnetic characteristics of X_{LF} and $X_{FD.}$ The potential of tracers in differentiating sources of sediments was analyzed statistically using two steps statistical method proposed by Collins etal.(2001). To determine which tracers show meaningful differences between sources, non-parametric Kruskal-Wallis test was used. Then Stepwise differentiation function analysis was used for decreasing the number of parameters first used so that the parameters have the lowest amount of correlation and the highest amount of differentiation potential.

Determination of the share of sediment sources
For obtaining the optimum results for determining the share of sediment sources optimization methods were used.(Walling and Collins 2000). By using equation 1 which is proposed and used by Collins etal.(1997) and by using the method of minimizing the sum squares of remaining in Solver software, the optimal share of sediment sources was estimated

$$R_{es} = \sum_{i=1}^{n} \left(\frac{C_{ssi} - \left(\sum_{s=1}^{m} c_{si} \cdot p_s \right)}{C_{ssi}} \right)^2 \qquad (1)$$

In which:
Cssi : The amount of tracer i in reservoir sediments   Csi : The amount of same tracer in sediment source S
Ps : The share of each S source in sediment production   S : The name of homogenous unit
n : The number of tracer parameters   Rse : Minimum of sum square of remaining

RESULTS

Table 1 shows the results of Kruskal-Wallis Test for determining the parameters that can differentiate sediment sources. These parameters are the one that are meaningful at %5 level. These parameters are shown in Table3 as *. According to this Table, exept N, Cr and Co all variables are meaningful at %5 level. In other words, the mean concentration of each parameter is different at least in one of sediment sources relative to other sources.

Table 1: The results of Kruskal-Walis Test for determining suitable tracer

Tracer parameter	P valu	Tracer parameter	P valu
N	0.35	Na	0.00*
PH	0.00*	smectite	0.00*
C	0.00*	Cholorite	0.00*
Ca	0.00*	Illite	0.00*
Cr	0.19	Kaolinite	0.01*
Co	0.06	X_{LF}	0.03*
Mg	0.00*	X_{FD}	0.00*
K	0.00*		

Table 2 shows the different steps in addition of tracer parameters in differentiation function by Stepwise method and its effect on differential power of sediment sources. Wilks Lambda is a criteria of the ratio of inttragroup differences to intergroup differences.

Table 2: Different steps of entering tracers and their effect on differentiation of sediment sources.

step	The characteristic of entered tracer	Willks Lambda	Cumulative percentage of correct classification of samples
1	C	0.162	66.7
2	PH	0.063	91.7
3	kaolinite	0.025	90.5
4	K	0.002	100

Figure 2 shows the spread of function 1 against function 2. According to this figure, the differentiation of sediment sources, especially for badland erosion and Hezar-Dareh Formation has been performed perfectly by functions one and two. Table 3 shows the relative importance of sediment sources in Amrovan Drainage Basin. According to this Table, Quaternary Unit, Upper Red Formation, badland erosion and Hezar-Dareh Formation have the highest relative importance, respectively. The relative error of the multivariate model which is used for the estimation of the share of sediment sources for each sediment sample is from 3 to 6.7 and its mean is 4.3. The mean efficiency coefficient of the model is 0.98.

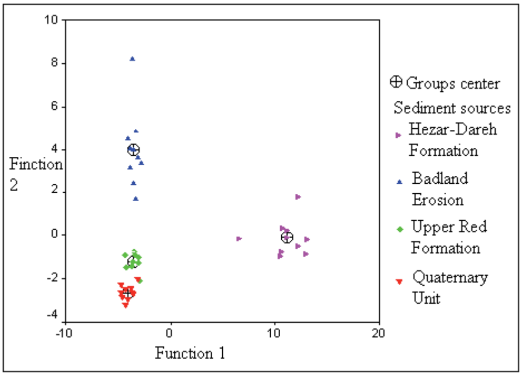

Figure 2: The spread of function 1 against function2

Table 3: The relative importance of sediment sources in Amrovan Drainage Basin

Sediment sources	Total share (%)	Area (he)	Relative importance
Quaternary unit	15.38	7.79	1.97
Hezar-Dareh Formation	28.21	65.23	0.43
Upper Red Formation	35.9	31.33	1.15
Babland Erosion	20.51	31.71	0.65

DISCUSSION AND CONCLUSION

The relative error of the multivariate model which is used for the estimation of the share of sediment sources for each sediment sample is from % 3 to % 6.7 and its mean is % 4.3. The mean efficiency coefficient of the model is 0.98. The low relative error and the high efficiency coefficient represents accuracy and efficiency of the model. Field evidences confirm the results: Quaternary Unit is located downstream and along the main drainage and its sediments enter the drainage directly and are not trapped in the way. So it is the main sediment source. Upper Red Formation consists of evaporitic (haliferous and gypsiferous) marls. It is hilly, deprived of vegetation and is under surface, rill and badland erosion. Hezar-Dareh Formation consists of conglomerate with sandstone and little claystone, it has medium erodibility and has lower share in produced sediments. Yair, etal.(1980) and Bryan and Yair (1982) believe that sediment yield of badland marly slopes are much higher than clayey and sandy slopes. They say that erosion rate on marls are very high and they produce the highest amount of sediment concentration and runoff coefficient. Erosion rate of clay and sand is 10 to 15 times lower than that of marls. Results shows that Quaternary unit and Upper Red Formation are two more important sources. Quaternary unit is not widespread in Amrovan Drainage Basin, but Upper Red Formation is widespread. Therefore it is proposed that for preventing land degradation due to the presence of marly formations in the studied area and similar areas, Preparation of inventory map of marly formations is essential.

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