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Determining the Soil's Most Important Parameters Affecting the Water Erosion Intensity of Marl and Shale Formations of Sanganeh Region, Northeast of Khorasan Razavi Province of Iran

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ABSTRACT

Soil is one of the most important effective factors in the soil erosion. This is the similar soil from the same grade in the soil classification system with relatively identical origin but different physical specifications show dissimilar behaviors vs. erosion. Because the physical quality along with other soil properties directly affects the retention and controlling of the nutrients, assigning proper attention as controlling and improving such factors and parameters will produce direct positive influence on the economical status of a society. Especial petrology texture of the region (geological formations) and abundant faults and consequently limited lithologic variations in small scale in addition to dry to semi dry climatic conditions of the region makes it a good exceptional sample, representing other parts of the country with identical features, so that the results could be generalized to the other parts of the country. The parameters being investigated in this study are: the soil texture, saturated moisture and saturated extract of the soil, electrical conductivity of the soil, the sodium solution of the soil, calcium solution of the soil, the lime, and the soil organic materials. The attempt has been made, through determining the ratio of the mentioned materials, their influence in the erosion process of the area and the correlation among them is evaluated.

KEYWORDS: Physical Quality of the Soil, Erosion, Geological Formations, Faults.

1. INTRODUCTION

The area under study (Shekar Kalat Pastures) has been located on the east of Kopehdagh basin in Khorasan Razavi Province. The Kopehdagh sedimentary basin is located in the shape of a long strip on the northeast of Iran and comprises widespread portions of Turkmenistan and north of Afghanistan. The Iranian part of the basin, which is generally called "Kopehdagh region", lies between 35◦, 30' to 38◦, 15' of northern latitude and 61◦, 13' to 61◦, 54' of Eastern longitude. The area of Koppehdagh region is about 55000 Km^2. Severe erosion of the surface soil in the area has caused decreasing in the protective cover of the ground surface and thereby decline of the pasture performance. Consequently, in addition to serious economical loss, broad pollution of the surface and underground waters has been followed, endangering the health of the people in the area. The regional physiography causes exiting of all of the flows resulting from atmospheric precipitations into Turkmenistan territories. Considering the loess and semi-loess formations in the region, considerable amount of sediments and nutrients are entered into Turkmenistan lands along with the outflow waters.

Usually estimations of the soil losses resulting from the erosion are made from the qualitative perspective, and as a result, the priorities of the effective factors in the soil losses are not specified [1, 2]. In case the effective factors in the soil loss of the natural areas are determined, definitely it will greatly help in fundamentally proper investment in building soil protection facilities. On the other hand, implementing any kind of careful management in relation with protection of the soil and prevention from intensification of erosion and halting or decreasing the losses requires recognition of the effective factors in the soil erosion. Through determining such factors, it will be possible to assist the soil protection plans in the region and designing and implementing suitable control methods for this kind of erosion that has caused exiting of the valuable soil of the region.

Climatic and Geological Characteristics of the Region

Climatic specifications: Relatively various climatic conditions govern different parts of Koppehdagh. The altitudes of different areas of the region vary from 28m below the sea level to more than 3000m above the sea level. This altitude difference is one of the most important effective factors in diversity of the climatic conditions in the region. Water vapor penetration from the Caspian Sea is another factor that affects the climate of the region [3, 4, 5]. The precipitation rate is higher on the west areas. In some areas on the west of the meridian 55◦, 30", the mean annual rainfall is about 800ml, while on the east of the meridian 57◦, 30" the amount of rainfall drops to 200ml to 300ml.

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On the whole, temperating the cold climate is the dominant weather throughout most areas of the region. Sarakhs and Jajarm plains with mean annual rainfall of 250 and 200ml respectively have desertive climates. The weather on the south part of Gorgan plain is relatively Mediterranean. The northern part of the plain features has low rainfall and dry climate with a mean annual rainfall of about 250ml.

Geological, Strati graphical and Morphological Characteristics of the Region

The geology of the region belongs to the Koppehdagh area, located in the Sanganeh formation section. The Koppehdagh area has been formed from sedimentary rocks of the second geological era until now and the site under study is located in part of the anticline, called Chahchahe and comprises part of the anticline apex. The center of the anticline is consisted of older Marl sediments of Sarcheshmeh formation covered in most parts by loess depositions and in some parts by shale and marll shale depositions of Sanganeh formation. Sanganeh and Sarcheshmeh formations constitute the most important rock units of the region. These formations have been formed in late lower Cretaceous era and have been folded under the influence of the orogenic phases of Tertiary era. Loesses and water depositions are detached and un-hardened sediments formed in the Quaternary era that are seen scattered in some parts of the region.

Lithology of Sarcheshmeh in the study areas indicates differences in their type sections. Such differences can be attributed to the local developments of the basin in the region. Sarcheshmeh formation has outcrops in northern part of the under study project and includes two parts: the lower part which is formed from shale and marll shale depositions and the upper part which includes a sequence of dark shale and layers of thin limestone. In the meantime, a sandstone layer is seen in the sedimentary sequence. The Sanganeh formation in the region under study lies with almost slope concordance on the Sarcheshmeh formation. This formation includes dark gray uniform shale, having thin and minor layers of Siltstone. Eroded surfaces of Siltstone layers are seen in light brown color. A sandstone layer of about 1m thick is seen in the rule of Sanganeh formation. Study of thin sections of this sandstone layer show that about 30% of total volume of the sections is constituted from carbonated cement and the best part of them includes clastic particles. Quartz, chert, glaconite and feldspar constitute the most abundant clastic particles of these sections. Field studies show that erosion has removed the considerable part of shales covering the sandstone unit and this has caused broad outcrop of this sandstone layer.

The region’s morphology is often mound shaped hills with nearly even altitudes. Lithology of rock units, geological structures, and climatic conditions of the region are among the most important factors that seemingly played considerable role in shaping the regional morphology.

Different rocks show different strength versus weathering and erosion. Besides, the climatic conditions are definitely effective factors in rock units’ strength against erosion. In dry climatic conditions of the region, the carbonated units make rocks while the shale and marl show less strength against erosion and have shaped the lowland and valleys. This is obviously noticeable in the under study region.

In the northern part of the site, where parts of Sarcheshmeh formation have been formed by a sequence of shall and limestone, due to more erodibility of the shales in comparison with the limestone, differential weathering has caused the limestones to be formed as rocks amongst the stone units and the shales to form lowlands. Also the marl and shales of the lower part of this formation have low strength against the erosion and have undergone the erosion considerably. In the middle part of Sarchedhmeh formation, there is a sandstone layer with several meters thick. This sandstone unit has high strength against chemical and physical weathering, and for the same reason, it can be seen much highlighted in the sedimentary sequence. Sanganeh formation has been constituted from uniform shales having thin and minor layers of Siltstone. These shales constitute the best part of the Sanganeh formation and cover the lower part of the formation which is made of a sandstone layer.

A considerable portion of the shales lying on this sandstone layer has been vanished due to erosion, causing widespread outcrop of the sandstone layer. Law strength of the shale part of the Sanganeh formation against erosion has caused gully and rill erosions in different parts. The geological structure of the region has had great effect in topographical formation of the region. Numerous folds and faults are among the most important structural features of the region. Sarcheshmeh and Sanganeh constitute part of the sedimentary formation of the northern and southern crests of this folding (Syncline).

Specifications of the Study Region

In 1996 to investigate the effective parameters in sediment production in natural areas and through test plots, the 30 acre Sanganeh Soil Protection Site which is almost the typical representation of Khorasan Razavi dry region postures, comprising different geological, vegetation, soil depth, topography conditions and other effective potential factors in soil, erosion was established 100Km northeast of Mashhad. A number of 92 test plots for measuring the runoffs and sediments in various soil, vegetation and topography were built in the site. Figure 1 shows the geographical location of Sanganeh research site in Khorasan Razavi province.

The physiographic unit of the site is the round low altitude hills of the site with soil cover. These hills feature very shallow to shallow soil without evolution profile to evolved deep and very deep soil. The mean annual rainfall of the site based on the 10 years statistics of the site pluviometers is lower than 180ml. The dominant vegetation type of the site is Artemisia sieberi – Poa bulbosa (Rangavar, 2004).

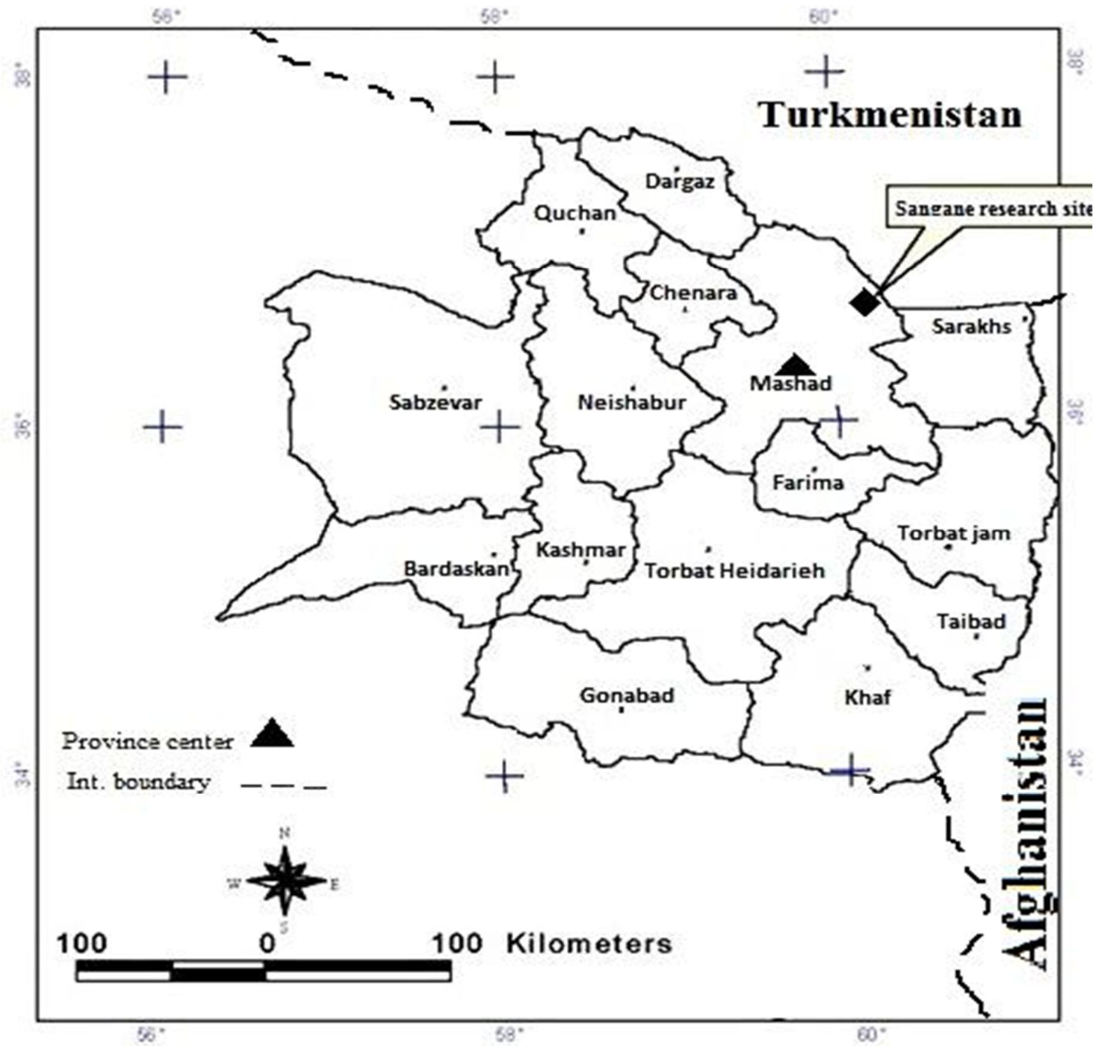

Figure 1. Sanganeh research site in Khorasan Razavi Province

2. MATERIALS AND METHODS

Sanganeh research site has diverse vegetation cover, soil and topographical features. The study was undertaken the following steps: Basin was divided into 6 smaller basins based on the natural drainage locations. Measuring the runoffs and sediments was necessary in selected basins. Creating the required basins on outflows of selected basins was predicted for collecting the runoff and sediments. For this purpose, careful hydrological studies for estimating the runoff volume and peak were performed on outflow of basins. The suitable method for measuring the runoff and sediments is collecting and storing of the basins. Complementary studies showed that due to low flow rate and depth at the divider, especially with flows lower than the design flow, no possibility exists for designing a capable system of uniform dividing of flow with the desirable precision. Ultimately, the interconnected small reservoirs system was designed and implemented; so that the overflow of a reservoir will flow to the next one. Each one of these reservoirs has an independent bottom output, so that it will be possible to discharge them after filling up and sampling and making them ready for the next collecting runoff and sediments. Thus, the sediment and runoff volume was measured and determined through this method.

The Soil Parameters

Test results showed that in the mentioned research site, none of the soil samples contained Cobble which based on three classification systems of USDA, CSSC, ASTM has a diameter of 3 inches or 7.62cm or above. Among the basins, the highest, lowest and average volume of the Coarse gravel (with a diameter of 0.5-3 inch based on USDA) is 17.07%, zero and 2.71% respectively. The minimum, maximum and average percentages of the fine gravel (with a diameter of 2 to 13 mm based on USDA) were zero, 40.44% and 11.7% respectively and in total, the overall percentage of the gravels contained in the basins lies between the range 2-40 percent.

In mound shaped hills and mountainous lands, the erosion usually eliminates the fine coarse materials resulting from destruction of the rocks. The existing gravel and Cobble on the ground surface decrease the collision energy of the rain drops and thereby decreases the soil erosion potential of the lands. Taking notice of the gravel component percentage of the surface soils is necessary. The soil parameters were measured for the continuation of study as follows:

Soil Texture

Results from analysis of the basins' soils showed that the sand, the silt and the clay components of the soil in the 6 basins constitute a range between 16.9 to 42.04%, 46.02 to 67.43% and 8.46 and 16.48% respectively. Using these results and the soil texture triangle, it can be concluded that the major soil of the research sites' basins belongs to the Silt loam texture class.

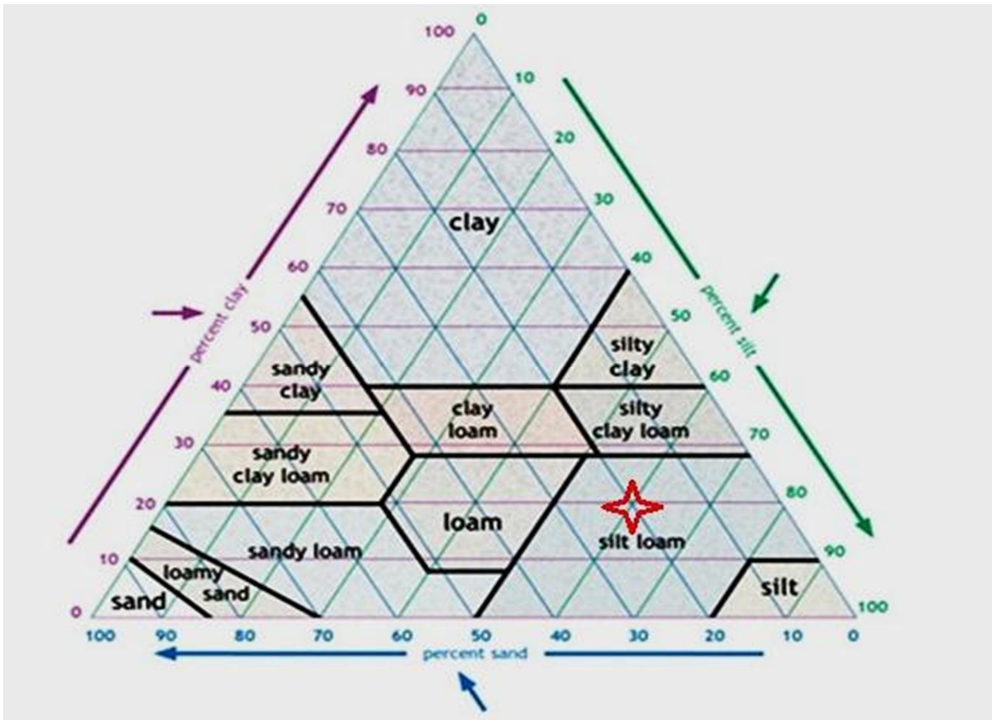

Figure 2. Triangle diagram of the soil texture segregation

The silt component in the site soils has the highest ratio in comparison with the other two components, the sand and the clay. Studies have shown that by increasing the soil silt content, the erodibility of the soil will also increase [6]. Wishmiyer and Mannring study results showed that partial change in the silt percentage often considerably affects the erodibility of the soil (K) [6].

Results of the sand analysis to its components show that from between the 5 sand components that are very fine sand, fine sand, medium coarse sand, coarse sand and very coarse sand, the very fine coarse sand portion with a range between 6.48 and 16.8% has assigned the highest rate to itself which is close to the silt component of the soli in size.

Saturated Moisture (SP)

The test results of saturated moisture percentage measurement for the soil samples show that this parameter is variable from 32.35% to 43.11% in the basins' samples. As can be seen, the results from these measurements are consistent with the soil texture of the region which is mainly Silt loam.

Saturated Extract of the Soil

The obtained PH of the basins' soils was between7.67 and 7.85. Given that the best part of the soil in the site is shallow and young, the obtained PH value seems rational; because the young soil inherit their chemical properties from their parent material. Since many of the parent materials are calcareous material and contain considerable amounts of $CaCO_3$ and lover amounts of other salts, the PH of the under study sample soils lies within the mentioned range [2,3].

The Soil Electric Conduction (EC)

The test results of determining the electric conduction (EC) of saturated extract of the soil samples show that the EC of the saturated extract of this soil is within the range of 0.64 $^{dS/m}$ to 3.21 $^{dS/m}$ and the average EC of 1.48 $^{dS/m}$ was obtained for the site soils. The results are indicative of relatively suitable situation concerning salinity ration.

Sodium Solution of the Soil (Na_s)

The Sodium solution content of the saturated extract of the soil of the sextet basins, which is one of the most important influential factors on other soil specifications, was obtained to lie within the range $0.03^{cmolc/kg}$ and $0.51^{cmolc/kg}$. This element due to its special chemical properties causes scattering of the clay particles and distribution of the soil aggregates and decreasing the stability of the soil structure. The Sodium solution content in the sample soils is low.

This element's content in the saturated extract of the under study soils was obtained in $2.25^{mmol/l}$ to $20^{mmol/l}$ range. This element contrary to the sodium causes cohesion of the clay particles and aggregation of them and improvement of the soil aggregate structure.

The Soil Lime ($CaCo_3$)

The measured lime content of the 6 basins' soils of the site showed that the Lime percentages of the site soils are between 1.86% and 8.71%. In surface or near to surface horizons of dry regions' soils, the calcium carbonate accumulates to a considerable volume. This accumulation may appear as thin scattered strings in the soil or in shape of small and large calcium carbonate grains like in the site soils. The lime soils are found abundant in areas constituting from lime parent material [2]. These soils are typically observable in dry and semi-dry regions, because scouring of the carbonated salts is limited in such areas, and the calcium released from the weathering takes the form of carbonate [7]. This is exactly the situation with the Sanganeh research site.

The Soil Organic Material (OM)

The organic materials content in the basins' soil samples are included in the range of 0.75 and 1.76%. Organic materials are among the most important parameters in the soil's structure stability and thereby in the erodibility of the soil. Refahi [7] believes that the soils with less than 2% organic carbon are erodible. Considering this issue and the results from the experimental analysis of the soil texture and organic materials can be concluded that the soils of the site are subject to severe erosion. Table 1 represents a summary of the experimental analysis of the soil samples prepared from the sextet basins of the Sanganeh research site.

3. RESULTS

Considering the climatic, geological and topographical specifications of the region and based on the parameters' values of the regional soils, there is a significant relationship between a number of parameters including the total content of sand, very coarse sand, coarse sand, electrical conductivity, and the Calcium solution of the soil from the one hand and the soil losses and the produced sediments from the others. Given the above mentioned cases, one description that can be provided, is that the coarse and medium coarse sands cause turbulence in the runoff running on the soil surfaces of the basins and separation of more particles. Consequently, the soil losses and sediment production are increased. The positive correlation between the produced sediments ratio and the soil electrical conduction (EC) can be attributed to the relationship between this parameter and the other parameters of the soil.

The correlation results of the soil parameters with each other and between the soil parameters and the percentage of vegetation density shows that the electrical conductivity has negative meaningful correlation with the clay ratio, percentage of the organic material and the vegetation percentage. Also it was observed that there was a positive meaningful correlation between the EC and the Silt, very fine coarse sand from the one hand and the sodium solution content ratio of the soil from the other.

4. DISCUSSION AND CONCLUSION

In other words, the increasing in the EC of the site soil, the percentage of the very fine coarse and the sodium solution content will be increased and the percentage of clay and the organic material of the soil will be decreased, ultimately causing increasing in the sediment production rate. Also there is a positive and significant correlation between the calcium and sediment production at ($P<0.05$) level. Other researchers like Refahi [6] and Duiker et al. [8] in their studies have achieved reverse results and believe that the calcium solution volume has a positive effect on making the aggregate and consequently decreasing the soil losses. This contradiction can be described in that by increasing in the calcium solution content in the site and region soils, the soil's EC is significantly increased and by increasing in EC, the vegetation density percentage is significantly decreased, resulting in increase in the sediment production.

The clay particles are resistant to the water erosion due to their cohesion property; on the other hand, the high volume of clay causes increasing size and stability of the soil aggregates, because the clay usually acts as the cement in soil aggregates [6]. Attou et al. [9], and Zhang et al [10] and Refahi [6] believe that the clay component can assist the soil aggregate making process, meanwhile increasing the soil structure stability and decreasing its losses.

Table 1. Analysis results of the soil samples prepared from the sextet basins of the research site.

No	PH	EC (ds/m)	SP (%)	CEC (cmolc /kg)	Na(s) (cmol c/kg)	Ca(s) (cmol c/l)	CaCo3 (%)	O.M (%)	Clay% <0.002 (mm)	Silt% 0.002-0.05 (mm)	0.05-0.1 sand	0.1-0.25 sand	0.25-0.5 sand	0.5-1 sand	1.-2 sand	Total sand
E1	7.85	2.07	32.35	8.06	0.04	9.64	8.71	0.75	11.93	46.02	15.8	10.94	6.2	4.98	4.13	42.04
E2	7.67	0.71	37.6	11.3	0.03	3.57	2.36	1.22	13.91	64.41	6.48	3.28	3.11	5.32	3.49	21.68
E3	7.77	2.89	40.03	12.26	0.037	18.65	1.87	0.83	8.46	61.82	10.22	7.08	5025	4.87	1.97	29.72
E4	7.85	1.81	38.3	10.6	0.03	8.13	5.98	1.57	10.6	54.72	16.24	6.46	3.76	4.68	3.53	34.65
E5	7.8	0.64	43.11	12.7	0.04	2.55	1.86	1.76	16.48	67.43	8.98	3.06	2.02	1.45	0.58	16.09
E6	7.33	3.21	42.85	12	0.51	20	6.61	1.67	11	49.3	16.8	9.9	5.4	4	3.5	39.7

Negative correlation between the clay volume and the soil loss and sediment production can be described through considering the relationship between this parameter with other soil parameters; it means a negative and significant relationship ($P<0.01$) between the clay and the very fine coarse percentages, and also there is a positive and significant relationship ($P<0.01$) between this parameter and the soil's organic materials percentage. Structural stability is one of the important factors of the soil strength against water erosion. Another factor enhancing the soil structural stability is the existence of cement materials including the lime in the soil. The lime can bind the soil aggregate particles to each other like a mortar, making larger sized aggregates and more stabilized soil structure and thereby decreasing the soil erosion. The negative correlation between this parameter and the sediment volume confirms the above results. Other researchers like Al-Ani and Dudas [7], Cerda [11] and Refahi [6] also believe that the presence of lime in the soil can help in aggregate making and decreasing the soil loss.

Data analysis shows that there is a negative significant correlation between the vegetation density and the soil loss and sediment production in the basins. In other words, by increasing the vegetation density percentage in the basins' level, the soil loss and ultimately the sediment production will significantly decrease. Various researchers from around the globe including Hartanto et al. [2] Lopez-Bermudez et al. [12], and Dunjo et al. [13] believe that increasing the percentage of the vegetation density in the soil surface will significantly decrease the soil loss and sediment production.

This negative relationship can be described through the existing correlation between the vegetation density percentage parameter and other effective parameters in the soil erosion. The results of correlation between the mentioned parameter and the soil parameters show that there is a positive and significant correlation between this parameter and the soil organic materials, percentage of the lime and the clay percent which decrease the soil erosion rate; also there is a negative and significant correlation between the above mentioned parameter and the calcium content, EC, the percentage of very fine coarse sand and the total percentage of sand which increase the erosion rate of the soil surface. The results of the present study, along with identification of the effective factors in sediment production due to the soil erosion of the region, showed that considering the impossibility of modeling in precipitating specifications, the most practical and suitable method of controlling and decreasing the soil loss in the boundary region under study and the similar places is maintaining appropriate management, rehabilitation and improvement of the vegetation cover.

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