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Erodibility and loss of marly drived soils

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Abstract

Considering to high distribution of the marly lands in west Azerbaijan province and high sediment yield of such lands, in this research, the relation among the form and the rate of erosion on marls with their erodibility properties were studied. Therefore, marly regions of province with the special properties were recognized and the soils samples were taken from 15 points of the topsoil of this area. Soil erodibility indices were determined and analyzed by statistical methods considering the form and rate of erosion. Also portable rain simulator were used to study of the runoff and sediment yield potential of such soils. Finally the factors affected the soil erodibility were determined by variance analysis. Results showed erosion rate could be classified as moderate. Gully erosion had highest number in Gare-Agaj and Gare-tappe areas whereas rill erosion had high number in all area of marly lands. Surface runoff volume ranged between 255 to 577 cm^3 in Shabanlu region and surface runoff coefficient varied from 0.23 to 0.53 in Gare-tappe. Maximum turbidity yield was determined 180 gr/lit in Gare-Agaj area. It was found that the clay ratio played the important role ($P \leq 0.05$) in creating the gully erosion and the volume of runoff in the surface and rill erosion.

Keywords: marl, clay ratio, erodibility, sediment, runoff.

Introduction

Marly soils are very sensitive to erosion and considered one of the most important sources of sedimentations in catchments (Bouma and Imeson, 2000; Jafari Ardekani, 2002). Marl is a mixture of clay and calcium carbonate. Its carbon content is between 35 to 65% and occurs during the weathering and erosion of other rocks. Marl also contains high amounts of the silt (Feiznia et al., 2007). The deposition of fine particles is become so dense by the erosion, and a new rock is created. The type of this new rock is depending on the material of eroded rock. The term of the Marl generally used to describe the marine sediments in North America (Schnurrenberger et al., 2003). One of the inhibitor factors of the environmental behavior of marl is its chemical properties (Abdi Nejad et al., 2011). Due to the great spread of the marl rock in many countries, the study of the characteristics of these formations is essential (Hooshmad et al., 2012). Feiznia et al. (2003) determined the resistance of different formations to erosion in semi-humid to humid and semi-arid to arid climates. They reported that the red upper and lower formations show the greatest sensitivity to erosion. The emergence of various forms of erosion is one of the characteristics of the marl areas (Ismail Nejad et al., 2007). The clay and the sand are effective parameters in determination of the sensitivity of the marly derived soils to erosion (Smaeilzadeh, 2002; Gadimi Aroose Mahaleh et al., 1999). Thoms et al., (2004) reported that marly lands with high erodibility, are the origin of sediment yield in arid areas. Cerda (2002) used a portable rainfall simulator and a double cylinder to determined runoff volume. He indicated that water runoff is occurred sooner on the marl with low permeability and high runoff coefficient. In the Clay and sandy soils, the start of the runoff is delayed and erosion and sediment yield will

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be in the lower than marl in such soils. Hamidzade (2000), determined sheet, rill and bad-land erosions as the erosion forms of marly soils of some areas of Iran. He repoted that the marly soils have high sodium adsorption ratio and the gully erosion has further development in such areas. According to Thoms et al. (2004), different forms of soil erosion, especially bad-land erosion is one of the outstanding features in the marly areas. Esteves et al. (2005) investigated the hydraulic properties of the gullies that were created on marly soils. He concluded that due to the structure and type of the clay minerals in the marl, the hydraulic conductivity coefficient is very low in such soils. In addition, when the marly soil is saturated with water the hydraulic conductivity coefficient will be negligible.

The erodibility of marly soils is different and these factors can influence the form and intensity of the erosion. Therefore, the sensitivity to erosion and sediment yield from Miocene and Neogene marls of northern areas of west Azerbaijan province was investigated in this study. The runoff and sedimentation were determined by using portable rainfall simulator. The erosion rate was measured by the Bureau of Land Management (BLM) of US method. The sensitivity to erosion determined by using the clay ratio and the erodibility indexes. The survey was conducted for the first time in this area.

Material and Methods

The study area is located in the northern part of West Azerbaijan province extends from the 38° 58' - 39° 47' north latitudes to the eastern 44° 14' - 46° 16' longitudes (Figure 1). Most of the area is mountainous at an altitude ranging from 800 to 4000 meters above the sea level. The marly lands within rock type were identified by using a digital geological map at 1: 100000 scale. After sampling the surface soil (0-30 cm) in 15 areas, the analysis consisted of determining the percentage of sand, silt, clay and very fine sand, organic matter, soil structure and permeability were conducted by the conventional methods of Soil and Water Research Institute (NSSH, 2006). The analyses were repeated in 3 replications and in total, 45 experiments were conducted on the rill, gully and surface erosion. The erosion rate of the selected marly soils was measured by the BLM method. The erosion class was determined by PSIAC method. Then the erodibility indexes (K) were determined by the global erosion formula (Wischmeier and Smith, 1978). The clay ratio was measured by Islami et al. (2007) method.

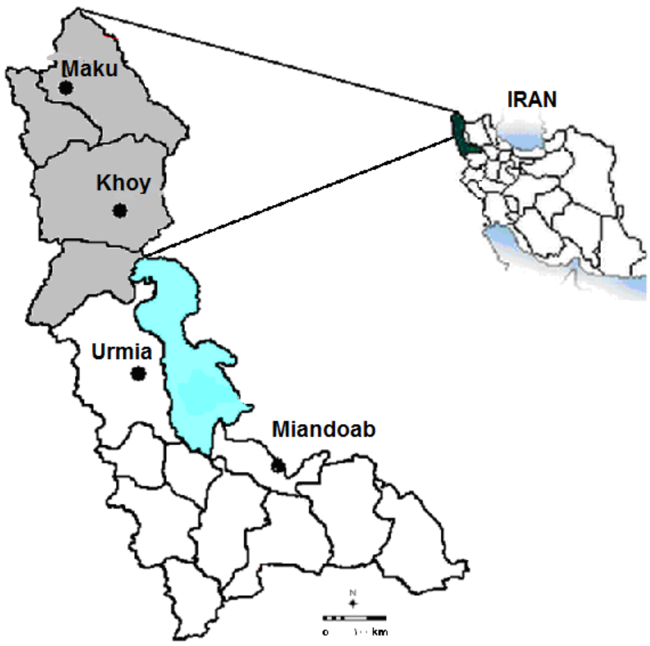
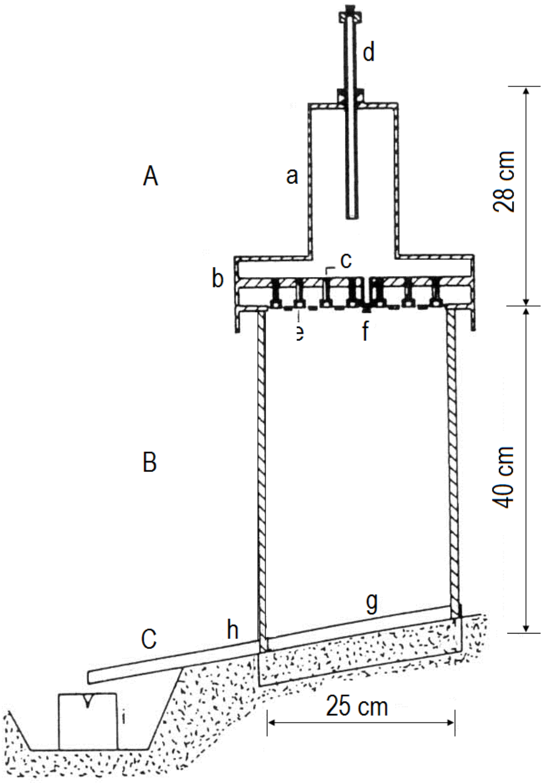


Figure1. The geographic location of the study area in West Azerbaijan province

The surface runoff, sediment and turbidity yield was measured by using the rainfall simulator. The rainfall simulator was made up of rain sprayer, body and metal frame (Figure 2). The capacity of the rainfall simulator tank was 1.2 liters with 49 pores. Its dimensions were 25 × 25 cm. The bottom of the body of the rainfall simulator had 20% vertical slope. This device sprayed 18 mm/3 min of water in on the plot. The rainfall intensity was 6 mm/min by this machine (Islam et al., 2007).



a: The water tank
b: The flat sheet of the tank
e ,f , c: The pores that water outflow
g, h, c: Sequential sections of the plates containing soil and runoff guide
v : The sedimentation and runoff collection tank
d : The movable tube to adjust the rainfall intensity

A: water sprayer
B: Body
C: the metal frame

Figure 2. Vertical sections of the rainfall simulator

The relationships between erodibility indices, the clay ratio, intensity and forms of erosion, runoff, and sedimentation yield of marly derived soils were determined by a correlation matrix of measured data. Then the erodibility index and clay ratio of marly soils were analyzed based on Duncan's method.

Results and Discussion

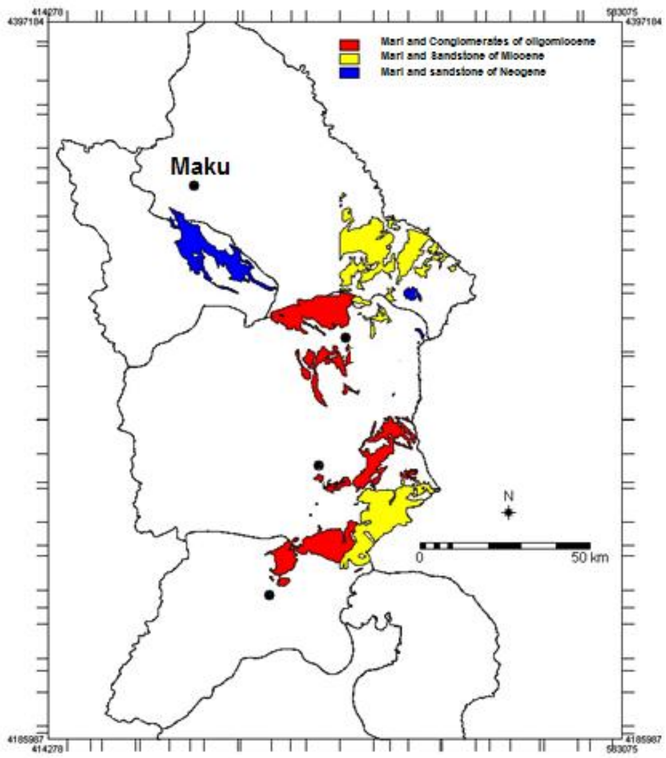


Figure 3. The distribution of marls in the study area

According to the results of field studies, three types of marls were identified in study area. They are the Oligomiocene marls with conglomerate, sandstone, marl and shale, Neogene marls with red sandstone and red marl with conglomerate layers, and sandstones alternating with red to gray marls known as Upper Red Formation. The distribution of marls in study area is given in Figure 3.

Some of the physical, chemical and geological properties of the soils are given in Table 1. According to the results of the soil analyzes, the texture of the most of the soils was silty clay loam that contain relatively high amounts of silt. However, the clay content of the samples was high (19 to 41 %). The Lime and salinity contents of the soils were determined ranging 3-23% and 0.3- 4.3 dS/m, respectively (Table 1).

Table 1. Some of the physical, chemical and geological properties of the marley soils in study area

Study area	Lithology	Erosion Form	Sand (%)	Silt (%)	Clay (%)	Texture Class	Org. C. (%)	SAR	pH	EC (dS/m)	Lime (%)
Chupanlu (CL) 1	MS3	Surface	25	40	35	CL	0.39	1.0	7.6	2.60	14.0
Chupanlu (CL) 2	MS3	Rill	25	42	33	CL	0.19	0.7	7.5	2.80	15.0
Chupanlu (CL) 3	MS3	Gully	24	42	35	CL	0.58	0.4	8.1	2.40	15.5
Gare Tappe (GT) 4	OMS	Surface	8	56	36	SiCL	0.70	0.6	8.1	0.61	3.0
Gare Tappe (GT) 5	OMS	Rill	11	49	40	SiCL	0.39	0.7	8.0	0.34	13.0
Gare Tappe (GT) 6	OMS	Gully	9	50	41	SiCL	0.87	0.8	8.4	0.37	4.0
Shabanlu (SL) 7	OMS	Surface	12	48	40	SiCL	0.78	0.5	7.7	1.20	11.0
Shabanlu (SL) 8	OMS	Rill	9	52	39	SiCL	0.39	0.8	7.5	3.00	12.0
Shabanlu (SL) 9	OMS	Gully	9	52	39	SiCL	0.70	0.9	7.5	4.00	16.0
Gare Agach (GA)11	OMS	Surface	15	65	25	SiCL	0.48	1.8	8.2	0.87	8.0
Gare Agach (GA)12	OMS	Rill	9	63	28	SiCL	0.78	0.8	8.2	0.55	18.0
Gare Agach (GA)13	OMS	Gully	12	69	19	SiCL	0.80	0.5	7.9	1.41	9.5
Gare Agach (GA)13	M	Surface	11	60	29	SiCL	<0.1	3.2	8.2	0.63	15.0
Gare Agach (GA)14	M	Rill	16	59	25	SiCL	0.58	0.6	8.5	1.20	15.0
Gare Agach (GA)15	M	Gully	9	61	30	SiCL	0.20	0.1	8.3	1.30	13.0

Erosion

The erosion rate in field experiments was estimated according to BLM method. The results are given in Table 2. The results showed that the erosion rates are between 31 and 54 and classified in moderate level. The gully erosion has higher rate in GT and GA. However, the surface erosion also has higher rate in GA and SL2 areas. High rates of rill erosion were observed in all areas. According to Table 2, all forms of soil erosion with different intensity are obvious in study area. The surface erosion with moderate intensity, the rill erosion with linear shape and generally high intensity and the gully erosion frequently occurred in claw form (Figure 4). The rill and gully erosion were the dominant erosion forms of the Oligomiocene and Upper Red Formation marls, respectively. All forms of erosions were observed on Neogene marls (Table 2).

Table 2. The determination of the erosion rate by BLM method

Study area/ Lithology	The rate of the soil erosion								The dominant erosion form	Erosion rate
	Soil movement	Surface litter	Flagstone	Erosion barriers	Rill	Flow pattern	Gully	Total		
CL / MS3*	3	2	9	10	13	12	3	52	Rill	Moderate
GT / OMS**	5	3	6	3	11	4	7	39	Gully	low
SL1 / OMS**	3	2	3	3	13	4	3	31	Rill	low
SL2 / OMS**	12	2	5	5	10	4	3	41	Surface	Moderate
GA / M***	11	3	5	3	14	11	7	54	Gully	Moderate

SM* The Oligomiocene marls with conglomerate, sandstone, marl and shale

SMO** Neogene marls with red sandstone and red marl with conglomerate layers

M*** Sandstones alternating with red to gray marls known as Upper Red Formation

The Soil Loss

The runoff volume, sediment and runoff coefficient of each treatment and replicates and the mean of these values are given in Table 3 Table 4, respectively. The surface runoff volume values varied from 255 to 577 cm^3 by using the rainfall simulator, in Shabanlu (SL) and Gare Tappe (GT), respectively (Table 3). The runoff coefficient was calculated by subtracting the volume of water in the tank of the rainfall simulator and the volume of water by surface runoff. These values were rated between 0.23 and 0.53 in the same areas, respectively (Table 3). The highest and lowest tubidity yield values were determined 180 and 10 gr/lit in the GA and GT regions respectively (Table 3).

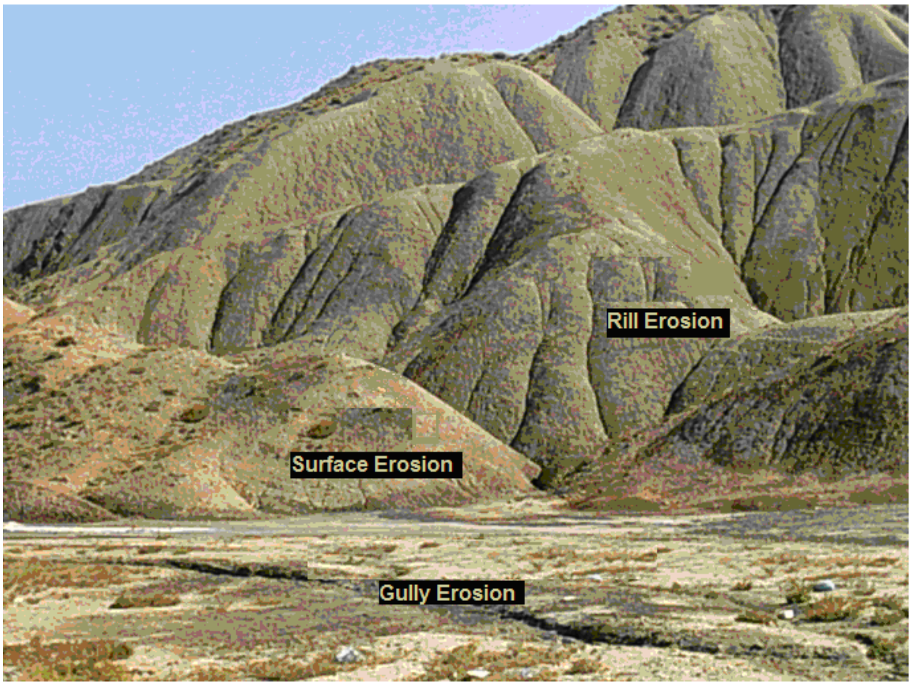


Figure 4- The erosion forms of the SL area with the Neogene marls with red sandstone and red marl with conglomerate layers lithology

Table 3. The Results of the runoff volume, sediment and runoff coefficient of each treatments and replicates by using the rainfall simulator

Study area	Lithology	Erosion form	Slope (%)	Runoff coefficient	Runoff volume (cm^3)	Sediment (gr)	Turbidity yield (gr/l)	Bulk density (gr/cm^3)
Chupanlu (CL) 1	MS3	Sheet	21	0.46	505	27.11	0.05	1.25
Chupanlu (CL) 2	MS3	Rill	47	0.48	503	60.92	0.12	1.12
Chupanlu (CL) 3	MS3	Gully	7	0.5	541.7	60.13	0.11	1.12
Gare Tappe (GT) 4	OMS	Sheet	24	0.53	577	3.3	0.01	1.38
Gare Tappe (GT) 5	OMS	Rill	45	0.41	453	6.9	0.02	1.37
Gare Tappe (GT) 6	OMS	Gully	17	0.5	543	2.97	0.01	1.55
Shabanlu (SL) 7	OMS	Sheet	17	0.43	417	50.2	0.12	1.08
Shabanlu (SL) 8	OMS	Rill	24	0.44	483	24.8	0.05	0.93
Shabanlu (SL) 9	OMS	Gully	18	0.23	255	34.9	0.14	1.21
Gare Agach (GA)11	OMS	Sheet	23	0.51	460	8.97	0.02	1.56
Gare Agach (GA)12	OMS	Rill	58	0.38	376.7	15.67	0.04	1.38
Gare Agach (GA)13	OMS	Gully	16	0.48	510	20.73	0.04	1.25
Gare Agach (GA)13	M	Sheet	21	0.48	325	21.41	0.07	1.26
Gare Agach (GA)14	M	Rill	42	0.29	490	37.61	0.08	1.26
Gare Agach (GA)15	M	Gully	5	0.44	465	84.23	0.18	1.11

MS3 : The Oligomiocene marls with conglomerate, sandstone, marl and shale
OMS : Neogene marls with red sandstone and red marl with conglomerate layers
M : Sandstones alternating with red to gray marls known as Upper Red Formation

Table 4. The Mean values of the coefficient and volume of the runoff and sediment yield with the rainfall simulator in different places of the study area

Study area / Lithology	Sediment (gr)	Tubidity yield (gr/l)	Runoff coefficient	Runoff volume (cm^3)
CL / (MS3)	49.39	0.09	0.48	516/57
GT / (OMS)	4.39	0.01	0.48	524.33
SL1 /(OMS)	36.63	0.10	0.37	385
SL2 / (OMS)	15.12	0.03	0.46	448.9
GA / (M)	47.75	0.11	0.40	426.67

The Clay Ratio and Erodibility Index

The clay ratio was calculated by the division of the sum of the percentages of silt and sand values to clay in soil texture class. These values varied between 9.6 and 26.3 in the GT and CL, respectively (Table 5). The mean of the clay ratio of these soils was determined 15.4.

Table 5. The erosion forms and intensity by modified MPSIAC method and erodibility index of the studied soils

Study area	The dominant erosion form	Index		Erosion Intensity	Erosion intensity Ton/ha/yr.	The sediment yield from the rain fall simulator (gr)
		Erodibility	Clay ratio			
CL	Rill	0.5	14.83	Moderate	13.5	49.39
GT	Gully	0.33	25.86	low	10.1	4.39
SL1	Rill	0.33	12.23	low	8.1	15.12
SL2	Surface	0.36	10.73	moderate	10.7	36.63
GA	Gully	0.46	14.15	moderate	14	47.75

Wischmeier erodibility index were determined with the silt plus very fine sand, organic matter, sand percent, soil structure and permeability factors by using Wischmeier nemograph. Wischmeier erodibility index varied between 0.33 and 0.54. These values were obtained in CL, GA and SL, respectively (Table 5).

The Relationship between the K (Erosion Index) and Clay Ratio with the Erosion Forms

According to the correlation matrix results, the relationship between K (erosion index) and silt and clay, and the relationship between clay ratio and sand and silt, values was significant ($P \leq 0.05$). On the other hand, The significant difference ($P \leq 0.05$) were observed between sand, silt, runoff volume and the clay ratio with erosion forms. But there were no significant difference between surface and gully erosion and between rill and gully erosion forms. The results of the correlation matrix also showed the significant difference between the clay ratio and erosion forms ($P \leq 0.05$). There was no significant difference between K (erosion index) and erosion forms. This might be related to the functional nature of the rainfall simulator that is designed primarily for surface erosion size but it can be used in the calculation of runoff and sediment yield.

The Relationships between the Erodibility Index, Soil Loss and Clay Ratio

Comparing the results of the assessment of soil loss by BLM (Table 2) with K (the erodibility index) and clay ratio indicated that, there was the significant difference ($P \leq 0.05$), between the clay content and K (the erodibility index) with soil loss. According to Table (3) there was a significant relationship (with correlation coefficient: 0.97 and SE: 0.028) between the clay ratio and the runoff volume (Equation 1).

$$Wv = 0.609(CR) \quad \text{(Equation 1)}$$

Where

Wv= The runoff volume

CR= The clay ratio

Based on the results, according to erodibility index, the marls can be classified in the three groups with significantly different between them.

The first group was appointed to the Neogene marl soils, includes the erosion values to 41 points, by BLM method. The Second and third groups are belongs to the Oligomiocene marl soils and the Upper Red Formation with the erosion values points to 50 and more than 54, respectively (Table 3).

The erosion rates significantly increased with increasing erodibility index (listed in columns 1, 2 and 3 of Table 6). Likewise, according to clay ratio the marls can be classified in the two main groups (Table 4). The first group includes the erosion values to 50 points and the second includes the erosion values more than 50 points by BLM method. The erosion rates significantly increased with increasing the clay ratio (listed in columns 1, 2 and 3 of Table 6).

Table 6 – The Classification of the homogenous groups of the marl soils according to the index k by Duncan

Study area	The erosion rate by BLM method	The homogenous groups of the marl soils according to the index k		
		1	2	3
SL1	28	0.33		
GT	39	0.34		
SL2	41	0.35		
CL	50		0.46	
GA	54			0.55
	The Significance level	0.173	1	1

Conclusion

In this study, the mean of the sediment yield of the marly soils was 4.96 ton/ha, by using the rainfall simulator. This result corresponded to the results of the investigation of Feiznia et al. (2003), Ismailnajad et al. (2007), Creda (2002) and Hamidzade (2002) on the erosion intensity and forms of the marly soils. The runoff coefficient (to 0.53) in this research showed that the runoff intensity is high in the study area. These outcomes are expectable according to the results of the investigation of Creda (2002) and Hassanzadeh et al. (2008) reported that the same results in runoff coefficient of the marly soils. In this investigation, the Wischmeier erodibility indices and the clay ratio varied from 0.33-0.54 and 0.09-0.26, respectively. These result showed that the erosion intensity of the marly soils is moderate to high in study area. Meanwhile, in this study the marly soils were studied in relation to the type of geological formation and erodibilty which were not studied in previous researches. The Upper Red Formation marly soils had the highest erosion rate and Oligomiocene and Neogene formations, were in the later stages in the erodobility.

References

Abdi Nejad, P., Feiznia, S., Peyrovan, H.R., 2011, Study of characterization, mechanical erodible marl formations Zanjan. Zanjan Agricultural and Natural Resources Research Center, 92 p. (In Persian)

Bouma, N.A., Imeson. A.C., 2000. Investigation of relationships between measured field indicators and erosion processes on badland surfaces at Petrer, Spain. *Catena* 40: 147-171.

Cerda, A., 2002. The effect of season and parent material on water erosion on highly eroded soils in eastern Spain. *Journal of Arid Environments* 52: 319-337.

Clarke, M.L., Helen, M.R., 2005. Process–form relationships in Southern Italian badlands: erosion rates and implications for landform evolution. *Earth Surface Proceses and Landforms* 31: 15-29.

Schnurrenberger, D., Russell D., Kelts, K., 2003. Classification of lacustrine sediments based on sedimentary components. *Journal of Paleolimnology* 29: 141-154.

Esteves, M., Descroix, L., Mathys, N., Lapetite, J.M., 2005. Soil hydraulic properties in a marly gully catchment (Draix, France). *Catena* 63: 282-298.

Feiznia, S., Heshmat, M., Ahmadi, H., Ghodousi. J., 2007. Study marl gully erosion Aghajari formation in Qasr-e Shirin. *Journal of Construction Research* 74: 40-33. (In Persian)

Feiznia, S., Sharifi, F., Zare, M., 2003. Sensibility of geological formation to erosion in the basin of Chandab Varamin. *Journal of Construction Research* 61: 33-38. (In Persian)

Gadimi Aroose Mahaleh, F., Pourmatin, A., Ghoddousi, J., 1999. Investigation the relationship between physical characteristics of erosion forms. *Chemical, Marl, Research and Development* 40,41,42: 99-95. (In Persian)

Hassanzadeh, T., Feiznia, M, Ahmadi, H., Peyrovan, H.R., Ghayoumian, C., 2008. Explore the impact of physical and chemical properties of marl deposition rate using a physical model of Rainfall. *Iranian Journal of Engineering Geology Society* 1(1): 35- 48. (In Persian)

Hooshmad, A,. Aminfar, M,. Asghari, E., Ahmadi, H., 2012. Mechanical and physical characterization of Tabriz marls. *Geotechnical and Geological Engineering* 30: 219-232.

Islami, M., Jafari Ardekani, A., Kamali, K., 2007. To examine the relationship between measured soil erodibility factor using a rain simulator, Bysal and nomograph Vishmayr. Fourth National Conference on Science and Engineering, watershed management. Abstract Book. Tehran, Iran. p 104. (In Persian)

Ismail Nejad, L., Ramazanpour, H., Shabanpour, M., Bakhshipour, R., 2007. Physical and chemical factors affecting the development of the gully and badlands of southern part of Gilan province. Proceedings of the Tenth Congress of Soil Science, Tehran University, Iran. pp. 1213- 1215. (In Persian)

Jafari Ardekani, A., 2002. Effect of gypsum on different slopes on unstable soils, runoff and erosion marl. Research project reports. Soil Conservation and Watershed Management Research Institute. 85 pages. (In Persian)

National Soil Survey Handbook. 2006. Soil properties and qualities, Particle Size Part 618 (42-55) United States Department of Agriculture - Natural Resource Conservation Service.

Rey, F., 2003. Influence of vegetation distribution on sediment yield in forested marly gullies. *Catena* 50: 549-562.

Smaeil Zadeh, H., 2002. Marl soils and different types of erosion in Iran. 17th World Congress of Soil Science on"Soil Science: Confronting New Realities in the 21st Century". Bangkok, Thailand. 2235:1-8.

Thoms, M., Hill, S. Spry, M., Chen, X.Y., Mount, T., Sheldon, F., 2004. The geomorphology of the Barwon-Darling Basin. In: Breckwoldt, R., Boden, R., Andrew, J., (eds.) The Darling. Murray-Darling Basin Commission, pp. 68-103.

Wischmeier, W.H., Smith, D.D., 1978. Predicting Rainfall Erosion Losses: A Guide to Conservation Planning. Agriculture Handbook No. 537. USDA/Science and Education Administration, US. Govt. Printing Office, Washington, DC. 58pp.