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Categorization of Marl Units with New Method and Investigation of Sediment and Runoff under Field Rainfall Simulator:a case study of Taleghan watershed, Iran

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Abstract: The purpose of this study was the investigation of Marl units in sub-watersheds of Taleghan watershed, Surrounding Taleghan Dam Lake in northeast of Iran, with emphasis on natural properties of marls using field rainfall simulator ($1m^2$). On the basis of terrigenous material percentage (clay and silt) and chemical properties sampling with new method were separated to eight sub-units including gy2ma, gy1ma, gy1mu, Ngma, Ngs, Ngmu, Ngsc and Ngc, That mu, ma, s and sc are Mudstone, Marl, Siltstone and Silt clay stone respectively. Then with 48 rainfall simulations, runoff and sediment rates were determined in eight sub-units at two slopes (10% and 30%) with 60 mm/h intensities in three repetitions using rainfall simulator in natural field conditions. Data analysis was conducted in a factorial experiment in a complete randomized design with SAS software. Analysis of variance and Duncan's tests showed that gy2ma sub-unit produced the highest amount of sediment yield ($320g/m^2$) and then the sediment yield of other sub-units in decreasing order was as follows: gy1ma($317g/m^2$), gy1mu($169g/m^2$), Ngma($112g/m^2$), Ngs($61g/m^2$), Ngmu($60g/m^2$), Ngsc($57g/m^2$) and Ngc($34g/m^2$) were 1% significant level. Also, results showed that Ngc(12.2 L) sub-unit has produced the highest amount of runoff rate, and then the runoff rate of other sub-units in decreasing order was as follows: gy2ma(11.1 L), gy1ma(10 L), gy1mu(8.2 L), Ngma(7.1 L), Ngmu(6.5 L), Ngsc(5 L) and Ngs(3.4 L) are 1% significant level. There was a statistically significant difference between interactions of slope and marl units with sediment amount and runoff at probability levels of 1%, so that the highest sediment and runoff were related to gy2ma and Ngc sub-units at slope of 30% respectively, and the lowest sediment and runoff were related to Ngc and Ngs sub-units at slope of 10%.

Key words: Neocene's units, Sediment, Runoff, Rainfall Simulator, Marl

INTRODUCTION

Globally, soil erosion is one of the most important environmental problems, which threatens soil and water resources. One of such problems observed in lakes of the dams of Iran is erosion and sediment of the units of Neogene Marl, which has resulted in dams being filled with sediments. It has also shortened their useful life. Marls are mostly unconsolidated geological materials which outcrop in many drainage basin of Iran, including Taleghan Drainage Basin. They are erodible; in other words, they significantly contribute to erosion and sedimentation and lower quality of their water. Marls consist of terrigenous material and chemical particles which fall within terrigenous material sedimentary rocks and chemical sedimentary rock (Feiznia, 2009). Cerda(2002) investigated the effect of parent material and season on water erosion in east of Spain. Mathys *et al*. (2003) calibrated rainfall runoff erosion model in experimental catchment of Draix in France and quantified erosion of marls. Many studies have been conducted on runoff and sediment by using rainfall simulator. The results suggest that runoff is exponentially related to rainfall intensity, and soil loss amount also increases with rainfall intensity. Hosseini *et al*. (2007) study is a good example in which they used rainfall simulator to categorize the marls of the region of upper Taleghan and compared erodibility of different marl units, index factors of samples and runoff, and suspended sediment of marl units. They also provided multivariable regression models. In another study Arnaez *et al*. (2007) determined the effective factors on runoff and erosion by using rainfall simulator and they studied runoff and erosion at slope of 3.8° in loamy soil, using rainfall simulator. Cerda *et al*. (1997) also designed and used a portable rainfall simulator, which simply used a nozzle and a manual pump. However, in this simulator, terminal fall velocity was lower than the terminal velocity of natural rain. Mousavi *et al*. (1998) studied soil infiltration depth by double cylinder method, artificial rainfall simulator and spray in Eastern Azerbaijan's Research Center's station for matching different models against experimental observations. Heshmati (1996) studied formations of marls of Ghasr-e-Shirin and Somar in terms

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of geology and erosion. The results indicated that the type of formation (especially percentage of clay and minerals content) has the largest effect on the occurrence of different forms of erosion. In another research, Khamehchian (1990) examined the physical and mechanical properties of marl-clay rocks. The research revealed that as the percentage of carbonate content of marl-clay rocks increases, their physical and mechanical properties also improve. Ghadimi Arousmahaleh (1999) studying physicochemical properties of marls and forms of the formed erosions found out that sheet erosion was prevalent among non-spreading marls, and gully and rill erosion were prevalent among spreading marls. Hassanzadeh Nafouti (2006) having studied average values of sediment yield of different marl units using rainfall simulator found out that evaporative Neogene marl units (M1, M2 and M3) were 27-100 times more sediment yielding than marine marls of Qom Formations and littoral marls of Kand Formation. In addition, plaster had a significant effect on decreasing erosion of sodium lands (25%-39%). Mathys *et al*. (2005) in a study on runoff rate in Marls with rainfall simulator concluded that in the moderate intensity and duration minutes, coefficient of runoff in marls is about 20 to 50% (Mathys *et al*. 2005). Hassanzadeh *et al*. (2005) in a study on credibility of marls (in Ivanaki-Iran) concluded that physical and chemical properties of Marls such as SAR, EC and K are the main factors of erodibility of marls. In Taleghan watershed, despite similar conditions like climate, Marls formations (Neocene's units) contain different kinds of erosive shapes such as landslide, rill erosion, stream erosion, gully and badland erosion. Thus, with respect to opening of Taleghan Dam, investigation of the condition of runoff and sediment production in these units can be more effective in understanding the process of runoff and sediment production in this region.

MATERIALS AND METHODS

Studied Area:

Taleghan Watershed, one of the subwatersheds of Sefidrood Basin, is located in southern hillside of Alborz Mountain Chain, 90 km northwest of Tehran. The studied area comprises a part of Taleghan Watershed (Lower Taleghan), which Surrounding Taleghan Dam Lake, and is extended from Glinak Station downstream to Mouchan, including Fashandak, Armout, Kashroud and Sangban subwatershed. The studied area is located at eastern longitudes 50° 35' 10" - 50° 45' 33" and northern latitudes 36° 6” - 36° 15”. As defined by modified Demartans method, the cimate is Mediterranean and semi humid. Mean annual rainfall in 14 existing stations, averaged over a 35-year-period is 672.3 mm. In 2005, reservoir dam was built downstream of Taleghan River which provides drinking water of Tehran. Around this dam and in Taleghan Drainage Basin, Neogene marly Formations are present. Due to their sensitivity to erosion and being saline and alkaline, these units play an important role in land degradation. (Zakikhani, 2009).

Research Procedure:

To investigate the Neocene's marl units and their effects on land degradation of the area as well as the rate of runoff and sediment, the following steps have been performed in the present study:

Provision Of The Map Of Geomorphology Homogenous Work Unit:

In order to prepare this map, at first the inventory map of units in Taleghan Drainage Basin was prepared, topography map (scale 1:50000) was digitized in the Arc GIS software, and the maps of slopes and directions were prepared by providing DEM map. Then the map of erosion features (with aerial photos 1:40000 related to 2001 year and also field visits) were provided and at last, by overlying geologic, erosion features, slope and direction maps of the area in GIS environment, the geomorphology homogenous work unit map was obtained.

Sampling And Determination Of Physical And Chemical Properties:

After the provision of geomorphology of homogenous unit map, samples in three depths (total=72 samples) were obtained from geomorphology work units during three replications. Then the obtained samples were transported to Soil Conservation and Watershed Management Research Institute to analyze the physical properties like soil texture (silt% and clay%) and chemical properties like anions, cations, TNV, EC, etc.

Samples Categorization And Provide The New Map Of Marl Units:

After physical and chemical analysis of samples and the determination of the terrigenous material percentage (clay and silt) and chemicals percentage (TNV, gypsum and salt) in each sample, on the basis of this new method, Marly samples were separated to five categories including: 1) terrigenous material stones 2) terrigenous material stones contacting chemical material 3)marl 4) chemical stone 5)chemical stone containing terrigenous material materials. Then terrigenous material stones & terrigenous material stones containing chemical material (1 and 2 categories) On the basis of dominant percentage of terrigenous material (clay and silt) were separated to five categories including: 1) Clay stone 2) Silt Clay stone 3) Mudstone 4) Clay Silt stone 5) silt stone. Fig. 1 shows the new method of categorization of the Marly unit samples. Finally, the geomorphology unites were named on the basis of dominant category and provided the new map of marl units, so that 8 new marl units were obtained.

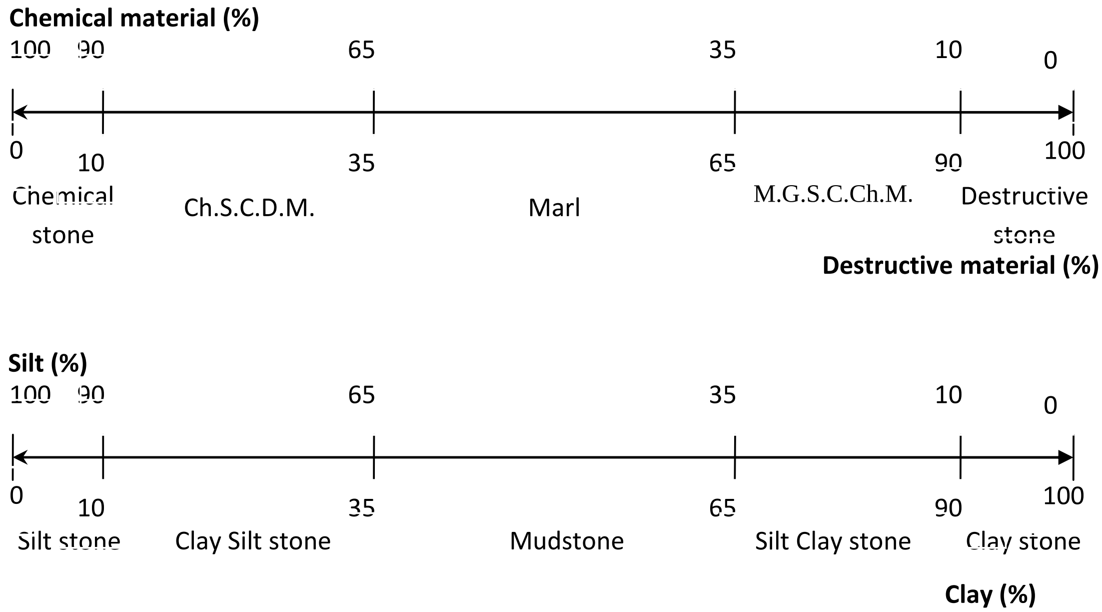


Fig. 1: Categorization with new method for samples of Marly formation**.** That M.G.S.C.Ch.M is Micro Granular terrigenous material stone containing chemical material and Ch.S.C.D.M. is chemical stone containing terrigenous material.

Simulation of Precipitation:

A portable rainfall simulator (1m^2) was used to compare the rate of runoff and sediment produced in each Marl unit. Forty-eight rainfall simulations in 8 new marl units at two 10% and 30% slopes, in three repetitions, and intensity of 60 ml/h in duration of 30 minutes were simulated in natural field conditions, and the rate of runoff and sediment were measured. Finally, the runoffs from the plots of rainfall simulators were collected by special containers and then were transported to the lab to measure the rate of runoff and sediment.

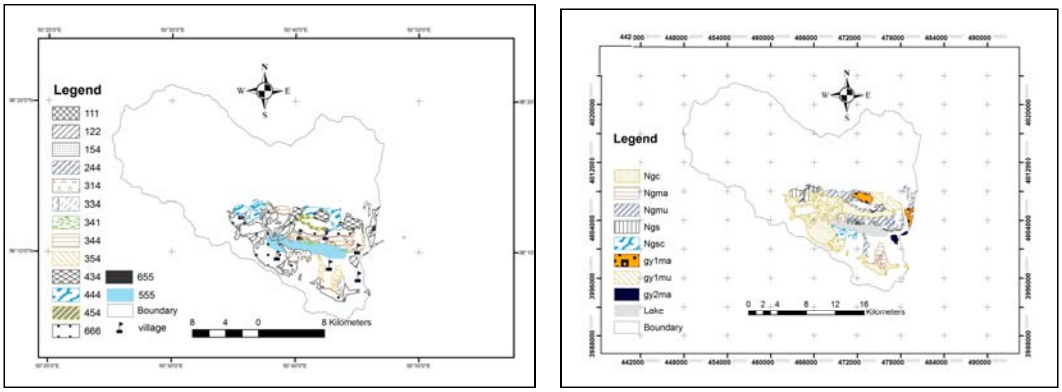
Statistical Analysis:

The data were obtained from rainfall simulator including runoff and sediment, in 8 new marl sub-units in three repetitions, at 10% and 30% slopes. Data analysis consisted of a factorial experiment in randomized complete design with SAS software to study the runoff, sediment, as well as interactions of slope and marl sub-unit with sediment amount. In addition, to compare the average, Duncan’s Multiple Range Test was used at probability levels of 1% and 5%.

Results:

Results of Categorization:

Regarding the samples of units of the study, marly units were categorized on the basis of geomorphology units and percentage of terrigenous material (clay and silt) and chemicals percentage (TNV, gypsum and salt) of samples. The results showed that the marl units separated to 8 sub-units including Ngmu, Ngma, Ngs, Ngsc, gy2ma, gy1mu, gy1ma and Ngc. That mu, ma, s and sc are Mudstone, Marl, Siltstone and Silt clay stone respectively. Table1 and Fig. 2 (a, b) show the results of the new categorization and maps of sub-units of marls respectively.



a) b)

Fig. 2: The geomorphology unit map (a) and new map of Marl unit (b)

Table 1: results of new categorization with new method in marl samples on the basis of physical and chemical properties.

Row	Chemical properties (%)				Physical properties (%)			New name (step 1)	Physical properties (%)		New name of sub units		
	Nacl	TNV	$CaSO_4$	Total	Clay	Silt	Total		Clay	Silt	New name (step 2)	sub unit	
1	0.29	16.7	0.01	17	47	36	83	M.G.S.C.Ch.M	56.7	43.3	Mudstone	gy1mu	
2	0.17	17.8	2.02	20	47	33	80	M.G.S.C.Ch.M	58.4	41.6	Mudstone	gy1mu	
3	0.11	14.2	0.29	14.6	29	56	85	M.G.S.C.Ch.M	41.5	58.5	clay Silt stone	gy1sc	
4	0.22	16.1	0.07	16.4	39	45	84	M.G.S.C.Ch.M	46.7	53.3	Mudstone	gy1mu	
5	0.14	15.9	1.14	17.2	38	45	83	M.G.S.C.Ch.M	45.7	54.3	Mudstone	gy1mu	gy1 mu
6	0.11	17.1	0.87	18.1	39	43	82	M.G.S.C.Ch.M	47.9	52.1	Mudstone	gy1mu	
7	0.24	20.4	0.02	20.7	28	51	79	M.G.S.C.Ch.M	35.6	64.4	Mudstone	gy1mu	
8	0.01	21.2	1.06	22.3	47	31	78	M.G.S.C.Ch.M	60	40	Mudstone	gy1mu	
9	0.05	21.3	0.38	21.7	47	32	78	M.G.S.C.Ch.M	59.5	40.5	Mudstone	gy1mu	
10	0.89	34.7	0.03	35.6	15	50	64	Marl	22.7	77.3	Marl	gy1ma	
11	0.03	21.4	0.01	21.5	18	61	79	M.G.S.C.Ch.M	22.9	77.1	clay Silt stone	gy1sc	
12	0.89	34.7	0.03	35.6	15	50	64	Marl	22.7	77.3	Marl	gy1ma	
13	0.06	38.5	0.03	38.6	21	40	61	Marl	34.8	65.2	Marl	gy1ma	gy1 ma
14	0.31	22.6	0.02	22.9	47	30	77	M.G.S.C.Ch.M	61.1	38.9	Mudstone	gy1mu	
15	0.23	27.2	0.02	27.5	42	30	73	M.G.S.C.Ch.M	58.3	41.7	Mudstone	gy1mu	
16	0.31	35.6	0.02	35.9	24	40	64	Marl	37.5	62.5	Marl	gy2ma	
17	0.73	15.6	0.03	16.3	43	41	84	M.G.S.C.Ch.M	51.2	48.8	Mudstone	gy2mu	
18	0.58	13.7	0.05	14.4	33	53	86	M.G.S.C.Ch.M	38.3	61.7	Mudstone	gy2mu	gy2 ma
19	0.21	33	1.83	35	40	24	64	Marl	62.4	37.6	Silt clay stone	gy2cs	
20	0.06	42	0.04	42.1	15	43	58	Marl	25.8	74.2	Marl	gy2ma	
21	0.33	35.7	0.02	36	32	32	64	Marl	49.5	50.5	Marl	gy2ma	
22	0.01	19.8	0.01	19.8	22	38	60	M.G.S.C.Ch.M	36.7	63.3	Mudstone	Ngmu	
23	0.01	22.5	0.03	22.5	39	39	77	M.G.S.C.Ch.M	50	50	Mudstone	Ngmu	Ng mu
24	0.02	18.5	0.01	18.6	29	53	81	M.G.S.C.Ch.M	35.2	64.8	Mudstone	Ngmu	
25	0.03	21.8	0.01	21.8	35	43	78	M.G.S.C.Ch.M	44.6	55.4	Mudstone	Ngmu	Ng mu

26	0.01	36.7	0.01	36.7	27	36	63	Marl	42.4	57.6	Marl	Ngma	
27	0.61	20.1	0.02	20.8	35	45	79	M.G.S.C.Ch.M	43.8	56.3	Mudstone	Ngmu	
28	0.02	25.7	0.03	25.8	33	41	74	M.G.S.C.Ch.M	45	55	Mudstone	Ngmu	
29	0.15	17.7	0.01	17.9	36	47	82	M.G.S.C.Ch.M	43.2	56.8	Mudstone	Ngmu	
30	0.01	27	0.01	27.1	36	36	73	M.G.S.C.Ch.M	50	50	Mudstone	Ngmu	
31	0.13	18.9	0.02	19.1	39	42	81	M.G.S.C.Ch.M	48.6	51.4	Mudstone	Ngmu	
32	0.04	17.9	0.01	18	32	50	82	M.G.S.C.Ch.M	38.6	61.4	Mudstone	Ngmu	
33	0.02	11.8	0.01	11.9	55	33	88	M.G.S.C.Ch.M	62.2	37.8	Mudstone	Ngmu	
34	0.07	22.3	0.01	22.4	31	47	78	M.G.S.C.Ch.M	39.6	60.4	Mudstone	Ngmu	
35	0.01	24.8	0.04	24.8	38	37	75	M.G.S.C.Ch.M	50.7	49.3	Mudstone	Ngmu	Ngmu
36	0.05	45.7	0.04	45.8	17	38	54	Marl	30.8	69.2	Marl	Ngma	
37	0.13	36.1	0.01	36.3	28	36	64	Marl	44.2	55.8	Marl	Ngma	
38	0.01	34.4	0.01	34.4	35	31	66	M.G.S.C.Ch.M	53.1	46.9	Mudstone	Ngmu	Ngma
39	0.02	75.1	0.01	75.1	13	12	25	M.G.S.C.Ch.M	52.1	47.9	Calcite stone	Ngch	
40	0.03	44.4	0.02	44.4	19	37	56	Marl	33.3	66.7	Marl	Ngma	
41	0.03	51	0.03	51.1	20	28	49	Marl	41.8	58.2	Marl	Ngma	

Continuance of Table1 - results of new categorization in marl samples on the basis of physical and chemical properties

Row	Chemical properties (%)				Physical properties (%)			New name (step 1)	Physical properties (%)		New name of sub units		
	NaCl	TNV	$CaSO_4$	Total	Clay	Silt	Total		Clay	Silt	New name (step 2)	sub unit	
42	1.27	24	0.03	25.3	11	64	75	M.G.S.C.Ch.M	14.8	85.2	clay Silt stone	Ngsc	
43	0.08	29	0.02	29.1	19	52	71	M.G.S.C.Ch.M	26.2	73.8	clay Silt stone	Ngsc	
44	0.02	30.3	0.02	30.3	12	58	70	M.G.S.C.Ch.M	16.7	83.3	clay Silt stone	Ngsc	
45	0.07	21.6	0.01	21.7	22	56	78	M.G.S.C.Ch.M	28.3	71.7	clay Silt stone	Ngsc	
46	0.06	19.3	0.01	19.3	23	58	81	M.G.S.C.Ch.M	28.6	71.4	clay Silt stone	Ngsc	
47	0.14	24	0.01	24.2	37	39	76	M.G.S.C.Ch.M	48.6	51.4	Mudstone	Ngmu	
48	0.03	24.8	0.02	24.9	15	60	75	M.G.S.C.Ch.M	20.4	79.6	clay Silt stone	Ngsc	
49	0.15	21.5	0.01	21.6	18	61	78	M.G.S.C.Ch.M	22.5	77.5	clay Silt stone	Ngsc	
50	0.3	25.9	0.02	26.2	21	52	74	M.G.S.C.Ch.M	29	71	clay Silt stone	Ngsc	Ngsc
51	0.38	18.2	0.02	18.6	20	61	81	M.G.S.C.Ch.M	25	75	clay Silt stone	Ngsc	
52	0.22	16.8	0.02	17	23	60	83	M.G.S.C.Ch.M	27.3	72.7	clay Silt stone	Ngsc	
53	0.06	19.3	0.01	19.4	27	54	81	M.G.S.C.Ch.M	33.3	66.7	clay Silt stone	Ngsc	
54	0.02	21.1	0.02	21.2	31	48	79	M.G.S.C.Ch.M	39.5	60.5	Mudstone	Ngmu	
55	0.05	20	0.02	20.1	19	61	80	M.G.S.C.Ch.M	23.3	76.7	clay Silt stone	Ngsc	
56	0.05	31.5	0.02	31.6	11	58	68	M.G.S.C.Ch.M	15.9	84.1	clay Silt stone	Ngsc	
57	0.03	17.8	0.01	17.8	27	55	82	M.G.S.C.Ch.M	33.3	66.7	clay Silt stone	Ngsc	
58	0.12	20.2	0.01	20.3	13	67	80	M.G.S.C.Ch.M	16.2	83.8	clay Silt stone	Ngsc	
59	0.0	22.1	0.01	22.2	20	58	78	M.G.S.C.Ch.	25.9	74.1	clay Silt stone	Ngs	

	3							M				c	
60	0.09	29.4	0.02	29.5	8	63	70	M.G.S.C.Ch.M	11.1	88.9	clay Silt stone	Ngsc	
61	0.14	18.8	0.01	19	23	58	81	M.G.S.C.Ch.M	28.2	71.8	clay Silt stone	Ngsc	
62	0.46	29	0.03	29.5	7	63	70	M.G.S.C.Ch.M	10	90	Silt stone	Ngs	
63	0	23.1	0.01	23.1	23	54	77	M.G.S.C.Ch.M	29.6	70.4	clay Silt stone	Ngsc	
64	0.06	20.8	0.02	20.9	22	57	79	M.G.S.C.Ch.M	28.1	71.9	clay Silt stone	Ngsc	
65	0.24	23	0.02	23.3	8	69	77	M.G.S.C.Ch.M	10.3	89.7	Silt stone	Ngs	Ngs
66	0.03	25.2	0.01	25.3	29	46	75	M.G.S.C.Ch.M	38.9	61.1	Mudstone	Ngmu	
67	0.32	24	0.02	24.3	22	54	76	M.G.S.C.Ch.M	28.6	71.4	clay Silt stone	Ngsc	
68	0	11.9	0.01	11.9	10	16	26	Conglomerate	38.5	61.5	Conglomerate	ngc	
69	0.02	12.6	0.01	12.6	13	23	36	Conglomerate	36.1	63.9	Conglomerate	ngc	
70	0.01	12.4	0.01	12.4	6	25	31	Conglomerate	20	80	Conglomerate	ngc	
71	0.03	42	0.03	42.1	11	47	58	Conglomerate	18.2	81.8	Conglomerate	ngc	ngc
72	0.14	43.4	0.02	43.6	7	50	56	Conglomerate	12.2	87.8	Conglomerate	ngc	
73	0.06	44.5	0.02	44.6	11	45	55	Conglomerate	19	81	Conglomerate	ngc	

That M.G.S.C.Ch.M is Micro granular terrigenous material stone containing chemical material and mu, ma, s and sc are Mudstone, Marl, Siltstone and Silt clay stone respectively

Table 2: Results of variance analysis of rainfall simulation data in marl sub-units

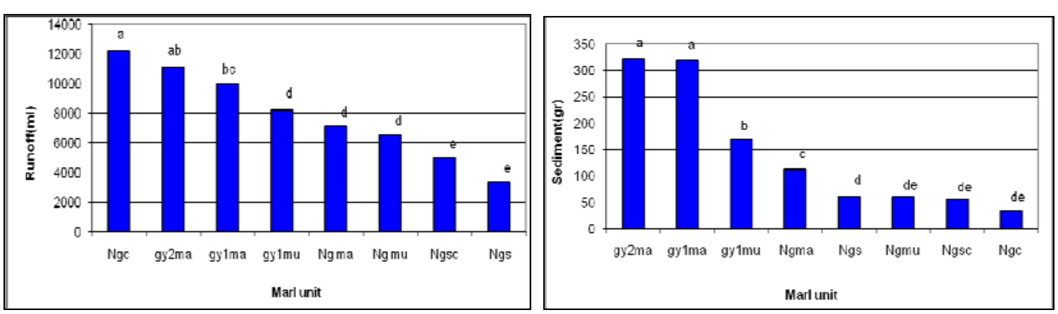
Source of variation	D. F.	Sediment amount (g)	Runoff (ml)
Slope	1	1268.3**	418591662**
Sub unit	7	1223.4**	56942632.4**
Slope * Sub unit	7	258.0*	18706226.5**
Error	32	4	688158
Variation coefficient	-	17.1	7417.1

* And ** do note significance level at probability level of 0.05 and 0.01, respectively

Results Of Rainfall Simulations (Runoff rate and Sediment Yield):

The results of variance analysis as shown in table 2 suggest a statistically significant difference between different sub-units in rate of runoff and Sediment Yield at probability level of 1%. Comparison of the results, using Duncan's Test, showed that Ngc and gy2ma had the highest runoff rate, and Ngsc and Ngs units had the lowest runoff rate.

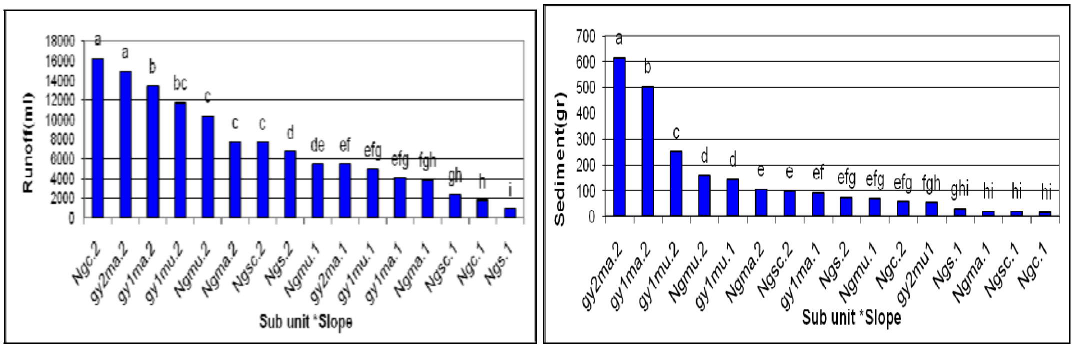
gy2ma and gy1ma Marl sub-units had the highest sediment yield, in a way that they both were placed in the first group. Gy1mu and Ngma sub-units were placed in the next rank of sediment yield following gy2ma and gy1ma. The lowest sediment yield was related to Ngc unit. The results of the average of runoff and sediment yield in Marl sub-units in 60 mm/h intensity in duration 0-30 minute are shown in Fig. 3.



a) b)

Fig. 3: Comparison of average runoff rate (a) and sediment (a) in Marl subunits. a, b, c, etc.: if one of these letters is common, there is no significant difference between them (statistical level is one percent).

Based on variance analysis, interactions of marl sub-unit and slope with sediment yield and runoff yield were significant. The results of the comparison of the averages of sediment yield and runoff rate of studied marl subu-nits at two 10 percent (S1) and 30 percent (S2) are presented in Fig. 4. According to average comparison conducted, Ngc at large slope (30%) has the highest sediment amount, followed by gy2ma at large slope (30%). However, gy2ma and gy1ma, although having the high value at large slope, had the lowest sediment amount at small slope (10%) than Ngmu.



a) b)

Fig. 4: Comparison of interactions of marl subunit and slope in runoff (a) and sediment (b)

Discussion:

The present research investigated the different marl sub-units of Taleghan watershed directly facing Taleghan Dam Lake. It also focused on samples of marl units separated to 8 sub-units including Ngmu, Ngma, Ngs, Ngsc, gy2ma, gy1mu, gy1ma and Ngc. Mu, ma, s and sc are Mudstone, Marl, Siltstone and Silt clay stone respectively. Their runoff rate potential and sediment yield were studied.

The results of this categorization in comparison to previous studies (Ahmadi, 1999) showed that the amount of chemical materials in these marl subunits decreased. Seventy-two samples (except 2% of samples) were not in the chemical stone category, but more samples (80% of samples) were on the micro terrigenous material granular stone containing low chemical material and marl (18% of samples) category due to chemical material leaching leading to the derangement of these layers, transporting and depositing the materials in down layers (Hosseini, 1999).

The Marl units have different physical, chemical and mechanical properties and produce different runoff and sediment. The results of the study show that runoff and sediment amounts of different marl units are not similar. This is in conformity with the results obtained by Ahmadi (1999), Both & Rienks (2000), Komphorst (1987), Ghazanfarpour *et al* (2006), Hasanzadeh Nafouti *et al* (2006) as well as with the results obtained by Hosseini *et al* (2007) suggesting that there is a significant difference between runoff amounts and sediment of different marl units. Ngc unit has the lowest sediment yield and the highest runoff among the sub-units of the study. This is probably due to its lower clay content, high rock and pebble content of the unit (table 1). The existence of rock in surface soil and the low depth of soil resulted in decreased infiltration depth and increased runoff. The results are in conformity with Hosseni (2007), suggesting that there is a high correlation between soil properties and runoff and sediment amount. Comparing runoff and sediment of two Ngc and gy2ma sub-units revealed that Ngc unit does not have the highest sediment amount, with gy2ma having the highest sediment amount, although it may have the highest runoff. This indicates that the highest runoff amount does not necessarily lead to having the highest sediment. However, the latter also depends on susceptibility of the unit of erosion and sedimentation. On the other hand, it was revealed that gy2ma was the most susceptible to erosion and sedimentation among the studied marl units because it had the highest sediment yield. Ahmadi (1999) also stated that gy2 and gy1 are among marls units with high erosion and sedimentation susceptibility. According to the results of the sediment yield, gy2ma, gy1ma, gy1mu, Ngma, Ngs, Ngmu, Ngsc and Ngc had the highest erosion and sedimentation susceptibility, in descending order respectively. gy2ma and gy1ma subunits were much more susceptible to erosion than Ngc subunit, due to their high detritus content (clay and silt) and chemical minerals content (lime and plaster) (table 1).

Subunits such as gy2ma, gy1ma, gy1mu and Ngma that have more chemical materials and micro terrigenous material granular materials, high sediment yield, and consequently more sensitive to erosion. In this study, four sub-units including Ngmu, Ngma, Ngs, Ngsc derived from Ngm units have different behavior in sediment and runoff rate. Ngma and Ngmu produced more runoff related to other subunits such as Ngs and Ngsc due to the fast saturation of these subunits. Sub-units of Ngma and Ngmu reached the saturation faster than Ngs and Ngsc subunits, and due to more infiltration of silt particles. The condition was very considerable for Ngs and Ngsc that had less chemical particle and more silt.

Interactions of slope and marl units showed that different subunits had different sediment yield behaviors at different slopes when gy2ma had a high sediment yield at large slope and Ngma had a high sediment yield at small slope.

Conclusion:

The results of the present study showed that in comparison to the previous studies, marl sub-units of the study had less chemical particles and more micro granular terrigenous material particles (clay and silt). On the basis of the percentage of terrigenous material (clay and silt) and chemical properties, Marl formations (Neocene's units) were separated to eight sub-units including gy2ma, gy1ma, gy1mu, Ngma, Ngs, Ngmu, Ngsc and Ngc subunits. Mu, ma, s and sc are Mudstone, Marl, Siltstone and Silt clay stone respectively. The sub-units such as gy2ma, gy1ma, gy1mu and Ngma that have more chemical materials and micro-terrigenous material granular materials produced more sediment and Ngc sub-unit produced less runoff related to other sub-units because Ngc sub-unit had less micro granular terrigenous material and chemical particles.

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