ГЛАСНИК СРПСКОГ ГЕОГРАФСКОГ ДРУШТВА
BULLETIN OF THE SERBIAN GEOGRAPHICAL SOCIETY
ГОДИНА 2009. СВЕСКА LXXXIX - Бр. 4
YEAR 2009 TOME LXXXIX - N° 4

Original Scientific Paper UDC 911.2:551.7(497.11)

S. H. HOSSEINI[1]
S. FEIZNIA
H. R. PEYROVAN

ASSESSMENT OF MARL PROPERTIES EFFECT ON SEDIMENT AND RUNOFF RATE AT DIFFERENT RAINFALL INTENSITY UNDER FIELD RAINFALL SIMULATOR

Abstract: The objective of this study is to assess the effect of physical and chemical properties of Marl's formations on sediment and runoff rates at different rainfall intensities, based on using field rainfall simulator. For this purpose, first Marl's formations (Neocene's units) were separated to five units including Halite siltstone(NgSiH), Siltstone (NgSi), Mudstone (gy_1C), Gypsum mudstone (gy1CG) and Halite clay stone (gy2CH), based on physical and chemical properties. Then runoff and sediment rates were determined in each unit at two intensities (30 and 60 mm/h) using rainfall simulator. Analysis of variance and Duncan's tests showed that Halite siltstone unit has produced the highest amount of runoff and sediment rates and then the runoff and sediment rates of other subunits in decreasing order are as follows: Siltstone, gy2CH, gylCG and gy_1C are 5% significant level. The trend of induced runoff and sediment rates at different times showed that in Halite siltstone and Siltstone units the runoff amounts were fixed rapidly at 2nd ten minutes. And, on the other units, the runoff amounts were fixed at 3rd ten minutes and sediment yield was increased rapidly at 3rd ten minutes.

Key word: Sediment, Runoff, Rainfall Simulator, Neocene's units

Извод: Циљ ове студије је да процени утицај физичких и хемијских својстава формација лапорца на величину наноса приликом падавина различитог интензитета, а на основу коришћења симулатора терену. За ову намену формације лапорца (Неоцене старости) издвојене су у пет јединица, укључујући и NgSiH, NgSi, gy_1C, gy1CG, gy2CH различитих хемијских и физичких карактеристика. Том приликом стопе наноса и протицаја су утврђиване у свакој јединици на два интензитета (30 и 60 mm/h користећи симулатор падавина. Анализа варијансе и Данканов тест су показали да је највиши износ за NgSiH затим следе друге јединице у опадајућем реду: NgSi, gy2CH, gylCG и gy_1C, који су сигнификантни на нивоу вероватноће од 5%.

Кључне речи: седимент, протицај, симулатор падавина, Неоцен.

Introduction

In Iran, Marls formations (Neocene's units) are very sensitive to erosion due to Production of suspended sediment in the majority of watershed (Ahmadi, H., 1999). These formations locate between destructive sedimentary rocks and chemical sedimentary rocks that contain destructive particles (silt and clay) and in the chemical fraction involve carbonate calcium with one or some chemical minerals including gypsum and halite (Feyznia, S., 2003). Mathys et al (2005) in survey of 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, N., Klotz, S., Esteves, M., 2005). Amaeiz et al. (2006) studied

[1] **S. H. Hosseini,**Academic member, Islamic Azad University, Torbat -e- jam branch, Iranh-hosseini@ iautj.ac.ir, hhosseini2008@yahoo.com
S. Feiznia, Professor, Faculty of Natural Resource, University of Tehran, Iran
H. R. Peyrovan, Ass. Professor, Soil conservation & Watershed Management Research Institute, Iran

factors affecting run-off and erosion in Marls with rainfall simulator and concluded that there is an exponential relation between the rate of runoff and rainfall intensity and rate of soil loss is increased with intensity (Hassanzade, N., 2006). Hassanzadeh et al (2005) in a survey of credibility of marls (in Ivanaki-Iran) concluded that physical and chemical properties of Marls such as SAR, EC and K are main factors of erodibility of marls (Amaez, J., Lasanta, T., Ruize, F.P., 2006). In Taleghan watershed, despite similar conditions like climate, Marls formations (Neocene's units) contain different kinds of erosive shapes such as landslide, sulifluxion, rill erosion, gully and badland. Thus, survey of condition of runoff and sediment production in these units with respect to opening of Taleghan Dam can be more effective in understanding of process of runoff and sediment production in this region.

Materials and methods

Study area

The study was carried out in Taleghan watershed and its outlet was located on the Glinak hydrometry Station. Climate, on the basis of modified Demartans method is Mediterranean and semi humid. The study area is between northern latitude 36° 5' 17" to 36° 20' 45.9" and eastern longitudes 50° 39'33" to 51° 11'26". Figure (I) shows location and limits of Neogens units in Taleghan watershed.

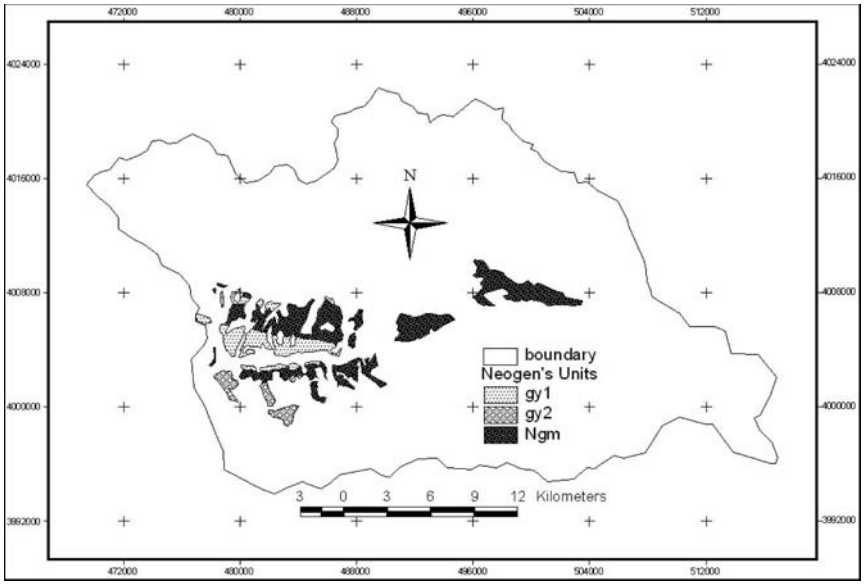

Figure 1. Location and limits of Neocene's units in The Taleghan watershed

Research procedure

In this research, to study rate of runoff and sediment in Neocene's units following steps were conducted:

Provision of geomorphology unit map

In order to prepare this map at first, topography map (scale 1:50000) was digitized in the R2V Software and then by providing DEM map in the Ilwis software, the maps of

slope and direction were prepared.. Then, the map of erosive shape (with aerial photos 1:40000 related to 2001 year and also field visits) were provided and at last, by integration of three mentioned maps, the geomorphology unit map was obtained. Figure (2) shows the geomorphology unit map in the limits of Marl's formation.

Sampling and determination of physical and chemical properties for separating the Marl's formation

After the provision of geomorphology unit map, during three samples of formation were obtained from work unit. Then, obtained samples were transported to the Soil & water lab. of Soil conservation & Watershed Management Research Institute and physical properties like soil texture(% silt and % clay) and chemical properties like anions, cations, calcium carbonate, plaster an salt, EC, etc were determined.

Simulation of precipitation

A rainfall simulator portable was used to measure runoff and sediment. It is necessary to mention in order to compare the rate of runoff and sediment produced in each Marl's unit, rainfall simulation in two intensities 30 and 60 mm/h and durations 0-10, 0-20 and 0-30 minutes have been done.

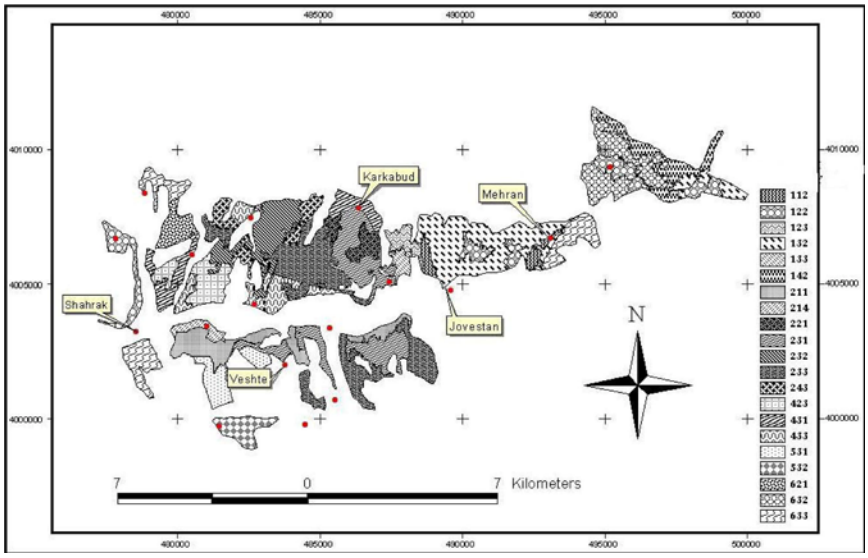

Figure 2. The geomorphology unit map in the limits of Marl's formation

Also, to survey the trend of runoff and sediment changes, two intensities of 30 and 60 mm/h in duration 30 minute were simulated and the rate of runoff and sediment in time 0-10 minute(the first 10 minute), 10-20minute(the second 10 minute) and 20-30 min-ute(the third 10 minute) were measured. So that in each intensity and each time interval, the runoff from the plot of rainfall simulator was collected by special containers and then were transported to the lab to measure the rate of runoff and sediment.

Results

The separation of Marl's units

After physical and chemical analysis of samples and the determination of percentage destructives (% clay and silt) and chemicals percentage (calcium carbonate, gypsum and salt) in each sample, on the basis of dominant chemicals. Marl's formation were separated. Results are shown in table 1 and figure 2.

In this research, Marl's formation were separated to five units including Halite silt-stone (NgSiH), Siltstone (NgSi), Mudstone (gyiC), Gypsum mudstone (gy_1CG) and Halite clay stone (gy2CH), based on physical and chemical properties.

Table 1. The physical and chemical properties of soil samples

Sample	Unit	Chemical properties				Physical properties			Subunit
		%NaCl	$\%CaCO_3$	$\%CaSO_4$	total	%silt	%clay	total	
1	gy1	0.04	31.13	1.03	32.20	28.82	39.80	68.61	gy1C
2	gy1	0.09	30.76	1.03	31.88	27.01	37.82	64.83	gy1C
3	gy1	0.07	29.09	1.40	30.56	22.61	48.04	70.64	gy1CG
4	gy1	0.06	28.90	1.32	30.28	29.63	40.92	70.56	gy1CG
5	gy1	0.02	33.90	1.11	35.03	30.31	35.58	65.89	gy1C
6	gy1	0.04	32.24	1.01	33.29	31.80	32.00	63.60	gy1C
7	gy1	0.11	27.80	1.03	28.94	25.00	41.66	66.66	gy1C
8	gy1	0.03	29.83	1.66	31.52	25.06	44.56	69.62	gy1CG
9	gy1	0.07	29.09	1.40	30.56	22.61	48.04	70.64	gy1CG
10	gy1	0.07	27.61	1.60	29.28	28.17	38.02	66.19	gy1CG
11	gy2	0.20	29.09	1.54	30.83	23.06	42.05	65.11	gy2CH
12	gy2	0.64	29.28	1.50	31.42	23.10	46.00	69.10	gy2CH
13	gy2	0.55	29.46	1.44	31.45	26.99	44.03	71.02	gy2CH
14	gy2	0.45	25.00	1.32	26.77	23.06	42.05	65.11	gy2CH
15	gy1	0.06	28.90	1.32	30.28	29.63	40.92	70.56	gy1CG
16	Ngm	0.01	31.31	0.01	31.33	37.57	26.84	64.41	NgSi
17	Ngm	0.02	31.87	0.01	31.90	36.50	23.47	59.97	NgSi
18	Ngm	0.02	31.13	0.01	31.16	28.52	38.03	66.55	NgSi
19	Ngm	0.50	31.13	0.00	31.63	30.96	33.66	64.62	NgSiH
20	Ngm	0.42	30.00	0.00	30.42	43.20	26.48	69.68	NgSiH
21	Ngm	0.49	32.00	0.00	32.49	39.09	26.96	66.05	NgSiH
22	Ngm	0.55	29.83	0.00	30.38	38.64	28.98	67.63	NgSiH
23	Ngm	0.02	31.68	0.02	31.72	45.01	25.32	70.33	NgSi
24	Ngm	0.02	30.02	0.02	30.05	34.28	34.28	68.56	NgSi
25	Ngm	0.03	29.28	0.05	29.35	41.72	25.57	67.28	NgSi
26	Ngm	0.42	31.13	0.00	31.55	35.32	32.60	67.92	NgSiH
27	Ngm	0.02	32.61	0.01	32.64	39.74	28.78	68.52	NgSi
28	Ngm	0.03	31.87	0.01	31.91	38.03	28.52	66.55	NgSi
29	Ngm	0.03	31.31	0.00	31.35	33.66	30.96	64.62	NgSi
30	Ngm	1.30	31.87	0.01	33.18	36.10	29.10	65.20	NgSiH
31	gy2	0.64	29.28	1.50	31.42	23.10	46.00	69.10	gy2CH
32	gy2	0.55	29.46	1.44	31.45	26.99	44.03	71.02	gy2CH
33	gy2	0.45	25.00	1.32	26.77	23.06	42.05	65.11	gy2CH

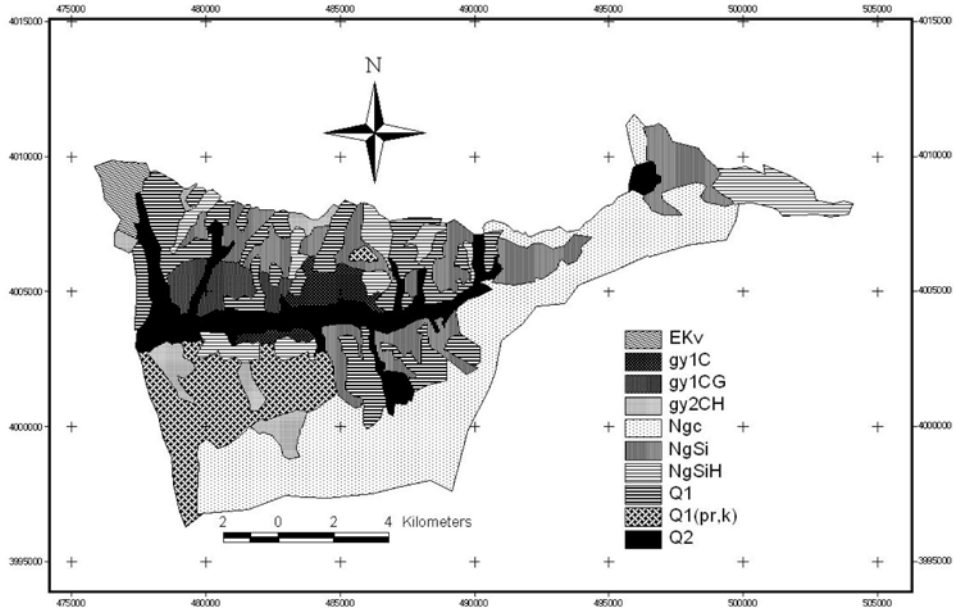

Figure 2. The subunits map of Marl`s formation.

Runoff

The Marl's units due to different integrity of physical and chemical properties produce different rates ofrunoff. Result related to the rate ofrunoffin two intensities 30 and 60 mm/h and in duration 0-10 min, 0-20 min and 0-30 min in different Marl's units are shown in table 2.

Figures 3 also show diagrams related to runoff height (mm) in different Marl's units in two intensities 30 and 60 mm/h, respectively.

Table 2. Comparison of mean rates of runoff (mm) in Marl's units inintensities30and60mm/h(Duncan'smethod)

Intensity (mm/h)	Duration (Minute)	Confidence	Marl's units				
			gy_2CH	gy_1CG	gy_1C	NgSi	NgSiH
30	0–10	0.95	15.5^{b}	12.2^{bc}	10.56^{c}	20.5^{ab}	24.8^{a}
	0–20	0.95	32.5^{c}	28.4^{cd}	25.1^{d}	42.5^{b}	54.6^{a}
	0–30	0.95	49.9^{c}	45.4^{cd}	41.4^{d}	68.4^{b}	89.7^{a}
60	0–10	0.95	32.4^{b}	27.5^{cd}	24.8^{d}	40.2^{ab}	49.6^{a}
	0–20	0.95	71.5^{c}	59.2^{d}	52.8^{d}	85.6^{b}	99.7^{a}
	0–30	0.95	111.9^{c}	92.3^{d}	81.9^{d}	131.8^{b}	152.2^{a}

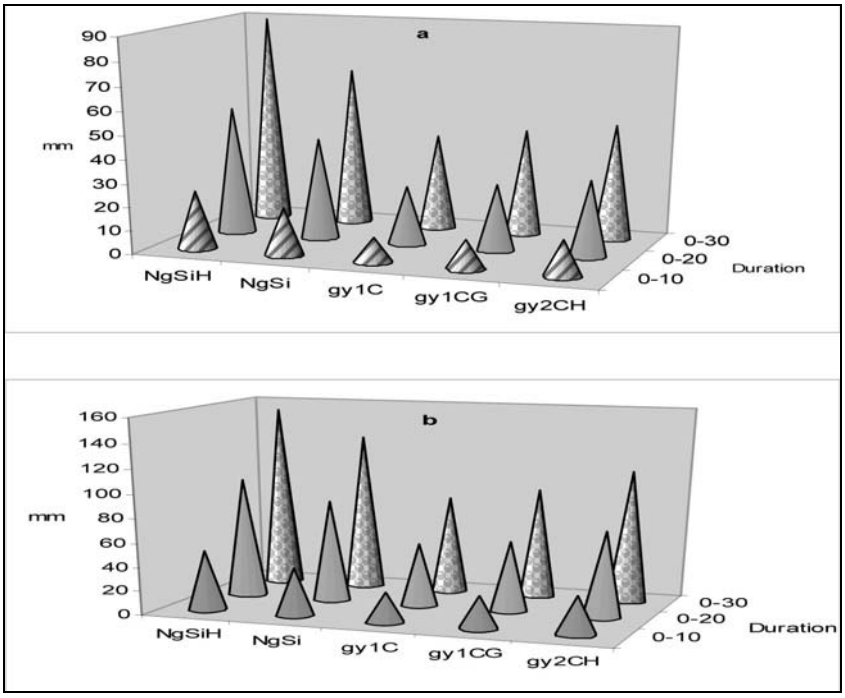

Figure 3. The rate of Runoff in Marl's units in two intensities 30 mm/h (a) and 60 mm/h (b)

Sediment

Results related to the rate of sediment in Marl's units in two intensities 30 and 60 mm/h and in duration 0-10 min, 0-20 min and 0-30 min are shown in table 3.

Table 3. Comparison of mean rates of sediment (gr/lit) in subunits in intensities30 and 60 mm/h with Duncan's method

Intensity (mm/h)	Duration (Minute)	Confidence	Marl's units				
			gy_2CH	gy_1CG	gy_1C	NgSi	NgSiH
30	0-10	0.95	14.5^{b}	10.4^{bc}	6.7^{c}	18.2^{ab}	23.2^{a}
	0-20	0.95	25.3^{b}	17.2^{c}	13.4^{c}	37.2^{ab}	45.1^{a}
	0-30	0.95	45.3^{b}	30.2^{c}	23.9^{c}	56.1^{ab}	67.6^{a}
60	0-10	0.95	36.2^{b}	25.3^{c}	32.2^{c}	40.5^{ab}	40.5^{a}
	0-20	0.95	56.1^{c}	40.3^{d}	41.4^{d}	75.4^{b}	100.8^{a}
	0-30	0.95	88.3^{c}	71.3^{d}	67.1^{d}	105.7^{b}	140.5^{a}

Figure 4 also show diagrams related to the rate of sediment in Marl's units in two intensities 30 and 60 mm/h, respectively.

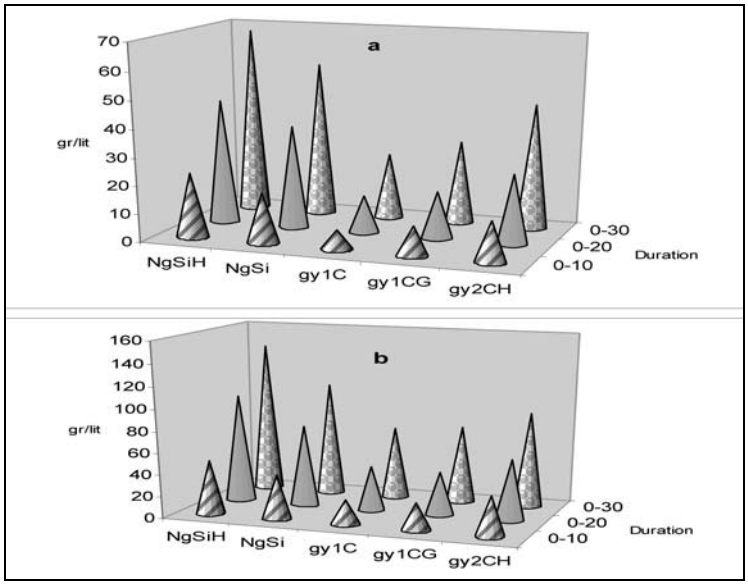

Figure 4. The rate of sediment in Marl's units in two intensities 30 mm/h (a) and 60 mm/h (b)

The trend of runoff and sediment changes

In this survey, in duration 0-30 minute, the rate of runoff and sediment in two intensities 30 and 60 mm/h and in time series 0-10 min, 10-20 min and 20-30 min were measured. The trend of runoff changes in Marl's units in two intensities are shown in table 4.

Table 4. The trend of runoff changes (mm) in Marl's units in two intensities 30 and 60 mm/h

Intensity (mm/h)	Duration (Minute)	Marl's units				
		gy_2CH	gy_1CG	gy_1C	NgSi	NgSiH
30	0–10	15.2	12.2	10.6	20.5	24.8
	10–20	17.3	16.2	14.5	23	30
	20–30	17.4	17	16	24	32
60	0–10	32.2	27.2	24.8	40.2	49.8
	10–20	39	32	28	45	50
	20–30	40	33	29	46	53

The trend of sediment changes in Marl's units in two intensities 30 and 60 mm/h are also shown in table 5.

Table 5. The trend of sediment changes (gr/lit) in subunits ofNeogen in two intensities 30 and 60 mm/h

Intensity (mm/h)	Duration (Minute)	Marl's units				
		gy_2CH	gy_1CG	gy_1C	NgSi	NgSiH
30	0–10	15.2	12.2	10.6	20.5	24.8
	10–20	17.3	16.2	14.5	23	30
	20–30	17.4	17	16	24	32
60	0–10	32.2	27.2	24.8	40.2	49.8
	10–20	39	32	28	45	50
	20–30	40	33	29	46	53

Discussion

The Marl's units have different physical, chemical and mechanical properties produce different runoffand sediment. Surveys show that by increasing precipitation duration from 10 min to 20 and 30 min in a fixed intensity, subunit NgSiH produce more runoff related to other subunits and after that, locate subunits NgSi, gy2CH, and gylCG and gylC respectively. Statistical surveys with Duncan's method show that subunit NgSiH in all intensities and duration has the highest rate of runoff and after that locates subunit NgSi. It is due to the fast saturation of these subunits. So that subunits NgSiH and NgSi reach the saturation faster than other subunits, while subunits gylC, gylCG, gy2CH due to clay particles absorb more water and this condition is very considerable for gylC that has less chemical particle and more clay. By increasing intensity from 30 to 60 mm/h, the condition of runoff for subunits is similar to intensity 30 mm/h, but with this difference that the rate of runoff increases, particularly in gylCthat causes a rate of runoff that is nearer to gylCG and gy2CH. Condition of sediment is almost to condition of runoff production. So that in two intensities 30 and 60 mm/h in all states subunit NgSiH has highest rate of sediment and after that locate subunits NgSi, gy2CH, gylCG and gylC respectively. Studying the trend of runoff changes in the first 10 minute (0-lOmin), the second 10 minute (10-20 min) and the third 10 minute (20-30 min) in a 0-30 minute duration and in two intensities 30 and 60 mm/h also show that at the beginning of the precipitation due to the moisture deficit and also unblocking of soil pores, the rate of intensity of water percolation is high and as a result, in the first 10 min, less runoff is produced. By passing time due to the impact of rain droplets, soil structure is degraded and because of formation impermeable layer and blocking pores and with respect to fine texture of subunits, percolation intensity is reduced and runoff is increased. However, due to the fine texture of formations from the second 10 min, runoff reaches a fixed rate. In 30 mm/h intensity and in the first 10 min, curves trend of runoff production in all subunits has a fixed trend and is increasing. But the rate of runoff in NgSiH and then NgSi is higher than other subunits. In the second 10 min, curves of trend of runoff production for the mentioned subunits have a mild slope and in the third 10 min, reach a relatively fixed rate. Trend of runoff changes (mm) in subunits ofNeogen in two intensities 30 and 60 mm/h are shown in figure 5. The trend of sediment production also shows that in the most case, sediment is different in any subunits. So that since the beginning of the runoff (the first 10 min) that gradually is confronted by increasing power of transportation, rate of sediment is increased but this increase for subunit NgSiH and then NgSi is considerably higher than other units. In the second 10 min, due to going particles out of soil surface in the first 10 min and remaining clays with high adhesiveness and resistant to detachment because of adhesiveness, rate of sediment in subunits gylC and gylCG is gradually decreased, because clay particles due to high adhesiveness against detachment are resistant and this condition for subunit gy2CH has less intensity. Because in this sub-unit there are higher chemical particles compared to subunits gylCG and gylC. In subunits NgSiH and NgSi, due to high silt and with respect to high sensitivity of these particles to erosion, means non-resistant against transportation due to the size of particles and non- resistant against detachment because of non- adhesiveness specially at the presence of chemicals(halite and gypsum) rate of sediment is being increased at the second 10 min. in the third 10 min , by saturation of clay particles in subunits gylC, gylCG and gylCH and start of Love flows , rate of sediment is increased intensely. However, these curves of trend have a less slope for intensity 30 mm/h compared to 60 mm/h, but in subunits NgSiH and NgSi, rate of sediment will be fixed rate. The rate of sediment in NgSi subunit (due to fewer chemicals) is less in compare with NgSiH subunit. The trend of sediment changes (gr/lit) in subunits of Neogen in two intensities 30 and 60 mm/h are shown in figure 6.

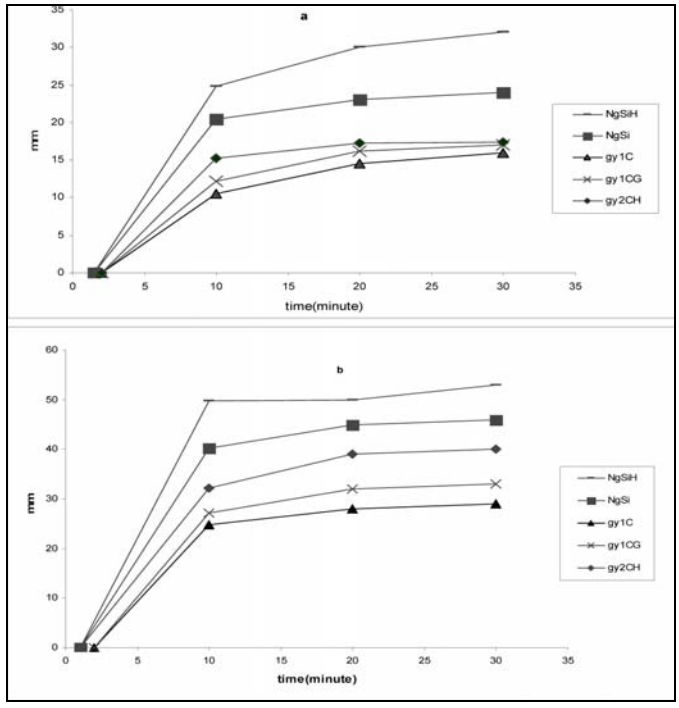

Figure 5. Trend of nmoff changes (nun) in subunits of Neogen in two intensities 30 and 60 mm/h

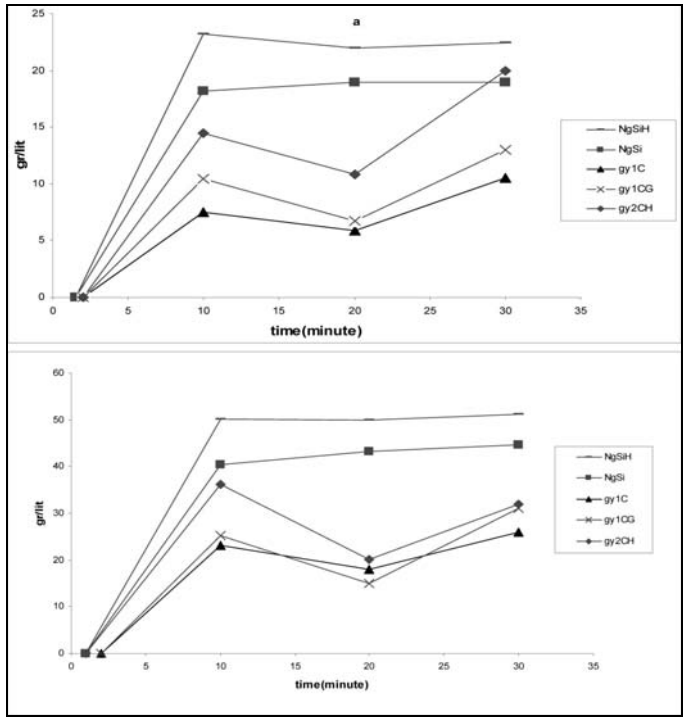

Figure 6. The trend of sediment changes (gr/lit) in subunits ofNeogen in two intensities 30 and 60 mm/h

Conclusions

Surveys show that by increasing precipitation duration from 10 min to 20 and 30 min in a fixed intensity, subunit NgSiH produce more runoff related to other subunits and after that, locate subunits NgSi, gy2CH, and gylCG and gylC respectively. By increasing intensity from 30 to 60 mm/h, the condition of runoff for subunits is similar to intensity 30 mm/h, but with this difference that the rate of runoff increases, particularly in gylCthat causes a rate of runoff that is nearer to gylCG and gy2CH. The Study of the trend of runoff changes show due to fine texture of formations from the second 10 min, runoff reaches a fixed rate. The trend of sediment production also shows that since the beginning of the runoff (the first 10 min) that gradually is confronted by increasing power of transportation, the rate of sediment is increased but this increase for subunit NgSiH and then NgSi is considerably higher than other units.

Reference

Ahmadi, H. (1999). *Applied geomorphology*. Tehran: University Press, Vol. 1 (Water erosion). 2nd edition..

Amaez, J., Lasanta, T., Ruize, F, P. (2006). Factors affecting runoff and erosion under simulated rainfall in Mediterranean vineyards. *Journal of Soil &Tillage Research;* Vol.93; pp. 324 - 334.

Feyznia, S. (2003). The erodibility of sedimentary rocks. Tehran: University Press.

Hassanzade, N. (2006). Survey of characteristics affecting Marl's erodibility. Ph.D. Thesis. IAU - Science and Research branch.

Mathys, N., Klotz, S., Esteves, M. (2005). Runoff and erosion in the Black Marls of the French, Alps: observation and measurement at the plot scale. *Journal of Catena.* Vol. 63; pp. 261-281.

Oldman, L.R. (1994). *The global extent of soil degradation.* Wallingford: CAB International, UK

S. H. HOSSEINI
S. FEIZNIA
H. R. PEYROVAN

Р е з и м е

ПРОЦЕНА ЕФЕКТА ЛАПОРЦА НА ИНТЕНЗИТЕТ СЕДИМЕНТАЦИЈЕ И ПРОТИЦАЈА У УСЛОВИМА СИМУЛИРАНЕ РАЗЛИЧИТЕ КОЛИЧИНЕ ПАДАВИНА

Истраживања показују да је повећање падавина трајању од 10 минута, 20 и 30 минута фиксног интензитета, субјединица NgSiH бележи већи протицај у односу на друге субјединице. Повећавајући интензитет од 30 до 60 mm/h, вредност протицаја је слична оној на 30 mm/h. Анализа тренда показала је да услед текстуре формација након 10 mm падавина, протицај достиже фиксну вредност. Тренд производње наноса такође показује да се од почетка протицаја (првих 10 mm) који постепено је суочен са повећањем снаге транспорта, стопа седимената повећава, али је то повећање за NgSiH и NgSi веће него што је то случај са осталим јединицама.