Asian Journal of Chemistry Vol. 22, No. 10 (2010), 7601-7614

Chemical Properties of Soil of Marly Lands with Different Erosion Types in Northern Iran

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In this investigation after field surveying, soil sampling were carried out from top soil of different erosional forms of marly lands including sheet, rill, gully and badlands (12 samples from 0-30 cm of each one) and from subsoil of gully and badlands (12 samples from the lowest depth of each one). These marly lands which located on the northern Iran have aridic moisture regime and thermic temperature regime. Comparing the average of chemical factors with different type of erosion by using Duncan test showed that amounts of EC (electrical conductivity), exchangeable and soluble sodium, SAR (sodium adsorption ratio) and ESP (exchangeable sodium per cent) had significant difference ($p < 0.05$) between all forms of erosion. While, $CaCO_3$, gypsum, calcium, magnesium, potassium, HCO_3^-, SO_4^{2-}, Cl^- had no significant effect in form and type of erosion. Also, the comparison of mean for CEC (cation exchange capacity), pH and organic carbon revealed that sheet erosion as well as rill erosion had significant difference ($p < 0.05$) with other forms of erosion (gully and badland erosion).

Key Words: Marly land, Figures of erosion, Soil chemical properties.

INTRODUCTION

Marly lands in arid regions are recognized as areas having high potential of erodiblilty and the main source of sediment production[1,2] believes that lots of factors are contributing in erosion variations of marly lands. He also pointed out that the erosion processes in theses kinds of lands have severe complexity. Therefore, he attributed the erosion processes in marly lands to the external factors such as the distribution of rainfall and internal factors such as soil characteristics. However, in areas that the chemical properties of geological formations are the main factors controlling the shape and form of erosion, the hydrological variables have lower importance in erosion processes[3].

High exchangeable sodium on the exchange complex promotes dispersion (deflocculating) of the clays. The exchangeable sodium percentage (ESP), sodium adsorption ratio (SAR), sodium percentage (PS) and total dissolved salts (TDS) are

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commonly used to measure the dispersive state[4,5]. According to Ben-Hur[6] as the EC decreases and the ESP increases, the clay dispersion is enhanced and the stability of the soil structure and this, in turn, could enhance the soil detachment and the soil loss. Zadeh[7] introduced the SAR as the most important soil chemical factor controlling the erodibility of marly soils and suggested that by increasing SAR level in marly lands, the erosion status may change from sheet to badland (from slight to severe) erosion. However, Battaglia *et al.*[8] found the SAR significantly higher in two different landforms, the difference alone did not seem to be able to distinguish the two features. Faulkner *et al.*[9] explored the effectiveness of the relationship between electrical conductivity (EC) and SAR, originally used by Rengasamy *et al.*[10].

Many studies revealed the importance of organic matter in aggregate stability and reduction of erosion[11,12]. However, the role of organic matter in stabilizing and reducing the erosion of dispersive soils has received less attention than that of non-dispersive soils, although a number of studies do exist. Greenland and Payne[13] expressed that organic matter (OM), iron and aluminum oxides are so important factors in stabilization of marly soils against erosion. Similarly, Robinson and Phillips[14] found that high organic matter (OM), iron and aluminum oxides can promote aggregate stabilization in the top horizons of badlands. The effective organic buffering content of surfaces in their study areas was found to be present when organic matter contents > 20 g kg^{-1}, this value being sufficient to stabilize aggregates. Mbagwu[15] believes that carbonates as well as iron and aluminum oxides are more important factors than organic carbon in aggregate stability against erosion caused by rain drops impact. He also introduced the titanium oxides and silica as two chemical important agents in aggregate stability. Similarly Mohamed[16] confirmed the role of carbonates in stabilization of marly soils. Poch *et al.*[17] introduced soils containing more than 25 % gypsum as so vulnerable to erosion due to having poor structure, lack of plastic behaviour and nonexistence of continuity.

Erosional processes in relation to marly soils especially in arid regions are very intensive, so that different figures of erosion particularly; badlands are the obvious characteristics at marly lands[18]. Therefore, it is essential to study some characteristics of marly soils to specify ways for control of erosion. The objective of this study is to determine the effect of some chemical properties of marly soils on erosion variations in arid regions of northern Iran. These changes may affect the rate and severeness of erosion and create different forms of erosion in this region.

EXPERIMENTAL

This study was accomplished in Gilevan region in south of Guilan province, in Iran, having aridic moisture regime and thermic temperature regime. This area is located between 49º26' and 49º31' E longitude and 36º25' and 36º46' N latitude. The mean annual precipitation is 2451.8 mm with an annual average rainfall (mean 24 h intensity) of 28.3 mm. the mean annual temperature is 17.4 ºC. These lands produce large amount of sediments that enter to Sefidroud dam. The soil profiles in the marly regolith materials are poorly developed. The maximum local relief of the badland area is about 90 m.

Sampling: After preliminary studies of geological (1:100000, 1:250000) and topographic maps and identification of marly lands, using GPS, studying locations were appointed. Then, in some dominant marly land forms (with uniform shape, direction and slope) 12 soil samples were taken from surface layer of sheet, rill, gully and badland erosion (total of 48 samples) and from underlying layer of gullies and badlands (total of 24 samples). Samples were air dried then ground and sift (2 mm sieve) and prepared for physical and mineralogical experiments.

Physico-chemical analyses: Organic carbon was determined by Walkley-Black method[19]; carbonate and bicarbonate were determined by Bernard's calcimetric method; pH in aqueous suspensions and 1 M KCl[20]; CEC (cation exchange capacity in cmole kg^{-1} soil) by the method of Chapman[21]; electrical conductivity of the saturated extract by the Bower and Wilcox method[22]. Also, soluble (meq L^{-1}) and exchangeable basic cations (Na, K, Ca, Mg in meq 100 g^{-1} soil), $CaCO_3$ (%), gypsum (%), SAR (sodium adsorption ratio) and ESP (exchangeable sodium percentage) were measured with respect to standard methods[23]. Particle-size distribution was determined by the pipette method[24]. The total clay content and fine clay were determined by Kittrick and Hope[25]. The ratio of fine clay to total clay was measured by excavation method, the percentages of fine sand by volumetric method and MWD (mean weight diameter in mm) by dry sieving method[26]. Other soil characteristics such as soil colour in wet and dry conditions were determined with respect to standard methods[26]. For measuring of aggregate consistency used rain drops technique[27].

Experimental design and statistical analyses: Soil samplings were collected randomly from four types of erosion as a completely randomized design. Correlation coefficients comparison of mean values was done using Duncan multiple range test by SAS software.

RESULTS AND DISCUSSION

Analysis of variance for chemical properties: Table-1 presents the analysis of variance for some chemical properties of studied soils that were taken from different erosional forms. As shown (Table-1) among all of the chemical properties, the levels of EC, pH, ESP, SAR, Cl^-, soluble sodium (Na^+_s), soluble magnesium (Mg^{2+}_s), exchangeable sodium (Na^+_{ex}), exchangeable calcium (Ca^{2+}_{ex}), CEC and organic carbon have significant difference ($p < 0.05$) between various erosional forms using Duncan test.

Electrical conductivity (EC): Mean rate of EC for marly soils with sheet, rill, gully and badland erosion are 11.7, 14.6, 16.7 and 20.2 dS/m, respectively. The least (8.1 dS/m) and the most (24.9 dS/m) rate are related to sheet and badland erosion respectively (Table-2). The increasing trend from sheet to badland erosion is observed (Fig. 1). In addition, comparison of mean rates of different types of

TABLE-1
ANALYSIS OF VARIANCE FOR SOME CHEMICAL PROPERTIES OF STUDIED SOILS

S.O.V.		Treatment	Error	Total
df		3	44	47
Gypsum	Mean square	9.21	13.89	
	F	0.66ns		
$CaCO_3$	Mean square	2.98	4.39	
	F	0.68ns		
EC_e	Mean square	155.8	5.6	
	F	27.79*		
pH	Mean square	0.519	0.077	
	F	6.74*		
ESP	Mean square	1293.39	40.37	
	F	32.04*		
SAR	Mean square	24112	1392	
	F	17.31*		
Cl^-	Mean square	154	17.21	
	F	8.99*		
SO_4^{2-}	Mean square	2.94	4.16	
	F	0.71ns		
HCO_3^-	Mean square	5.93	5.31	
	F	1.12ns		
K^+_S	Mean square	0.018	0.046	
	F	0.39ns		
Na^+_s	Mean square	154726	8129	
	F	19*		
Ca^{2+}_s	Mean square	0.222	1.14	
	F	0.19ns		
Mg^{2+}_s	Mean square	7.83	2.21	
	F	3.54*		
K^+_{ex}	Mean square	0.18	0.34	
	F	0.52ns		
Na^+_{ex}	Mean square	403.75	7.75	
	F	52.06*		
Ca^{2+}_{ex}	Mean square	23.89	5.32	
	F	4.49*		
Mg^{2+}_{ex}	Mean square	6.55	4.18	
	F	1.57ns		
CEC	Mean square	66.33	12.87	
	F	5.15*		
OC	Mean square	2.73	0.28	
	F	9.75*		

*Significant at 5 % and ns: Non significant.

erosion, implies the significant difference between all of erosional forms ($p < 0.05$). The amount of EC, that has a direct relationship with salts, is presented as an index for erodibility of marly soils. This parameter has a strong relationship with erodibility of badlands, especially, low rates of EC in soil solution lead to swelling of soil and its dispersion[28].

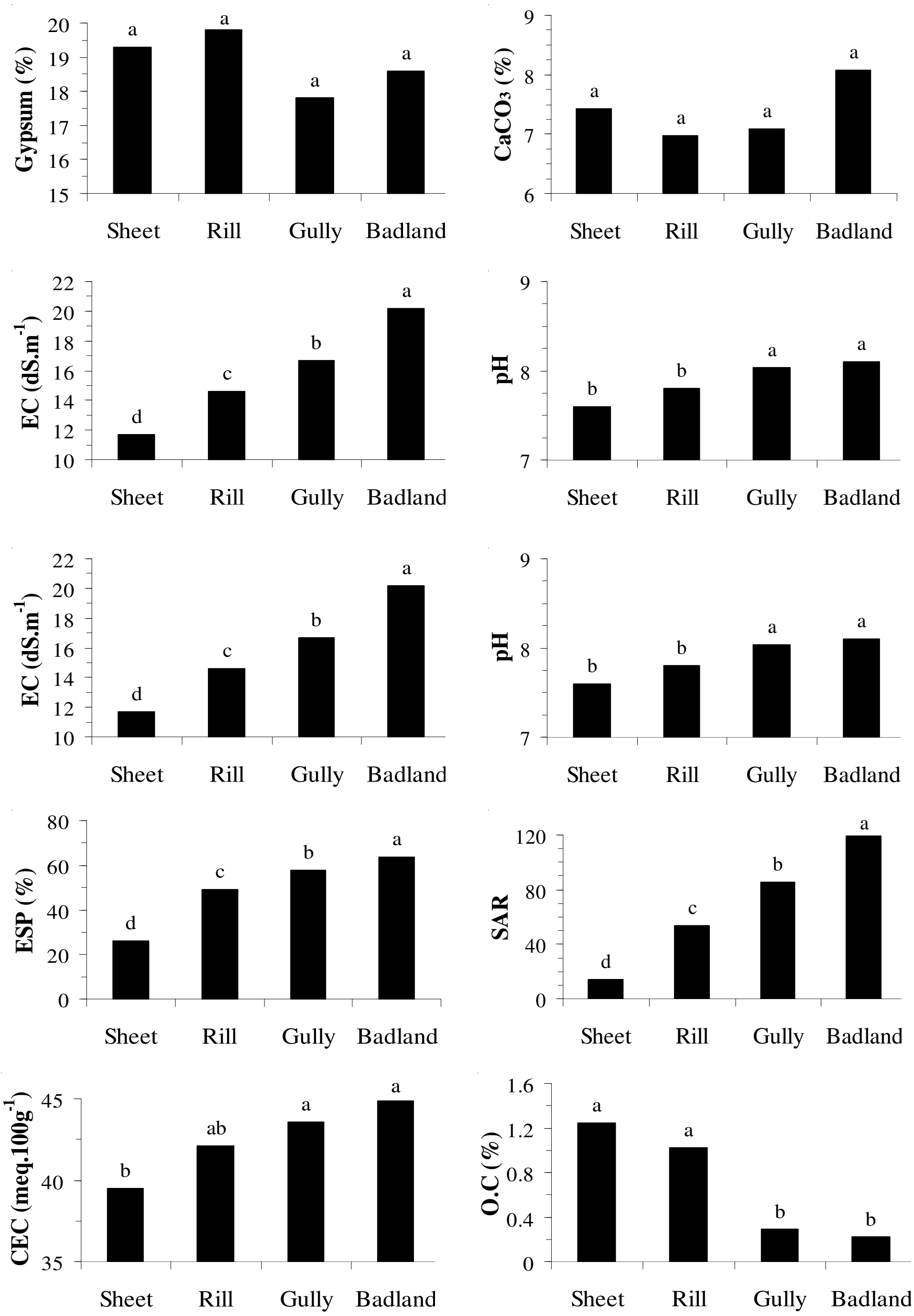

Fig. 1. Mean values of some soil chemical properties for different forms of erosion (the same alphabets means no significant differences between forms of erosion and related soil property using Duncan test)

With increasing in salinity, electrical conductivity increases, too. The manifest characteristic of marly lands is existence of much amount of salt in them. In studying soils, soil salinity is high that causes to produce of small granular structure in dry state but, as soon as they become wet, their structure destroys. In other hand, they have pseudo structure[29]. Increasing in salt amount in soil profile, in addition to impact on soil solution concentration, leads to change in exchangeable complex content. This change causes adding exchangeable sodium to complex, because, sodic salts are the most solvable salts in nature and their solution leads to releasing of sodium. Then, sodium ions occupy exchangeable sites and soil disperses[30].

The relationship between salinity and concentration of soluble salts is linear, the distinguished characteristics of marly soils is the existence of abundant salts in that soils. It should be said that, EC depends on the number of soluble ions and not on weight of them. However, dispersion is usually related to high SAR values, but may be inhibited by too high soluble salt contents (*i.e.*, EC values)[31]. In these studied soils the mean EC is high but the most part of soluble ions are sodium and cause to aggregate dispersion. Vandekerckhove *et al.*[31], measured the minimum and maximum values of EC in gullies of southeast Spain between 0.12-13.09 mS cm^{-1}, respectively. The mean of EC in these areas was measured about 3.78 mS cm^{-1}. They also reported that EC values were greatly variable with, but not systematically related to the depth at which the sample was taken. Moreover, their chemical analysis showed that piping occurred in soil layers with a higher electrical conductivity.

Na^+ and Cl^- have the most correlation coefficient with soil salinity and the relationship between these two soil chemical parameters with EC is given by following equation:

$$EC = 0.013\ Na^+ + 0.295\ Cl^- + 7.6 \qquad R^2_{adj} = 0.656 \qquad (2)$$

On the other hand, soil salinity in marly lands is mainly affected by sodium and chloride ions. Hovever, sodium have the most correlation coeficient with soil salinity. Rate of EC, that has direct relation with salts, is selected as an indicator for marly soils erodi-bility. This parameter has a strong communication with badlands erodibility[9]. Rienks *et al.*[32] demonstrated a very strong correlation with EC and SAR of the saturated paste extract and ESP values in a gully of Southern Africa. They suggested that dispersion plays an important role in the erodibility of the materials under conditions of short duration and turbulent water flow due to this high correlation with ESP and EC. These findings also confirm the role of Na^+ ions in increasing EC value.

pH: All samples have pH > 7.5. The mean rate of pH in marly soils with sheet, rill, gully and badland are 7.6, 7.8, 8.0 and 8.1, respectively (Fig. 1). In addition, with regard to this figure and analysis of variance (Table-1), is a significant difference between all forms of erosion except sheet with rill and gully with badlands. Also, with regard to increasing trend of pH from sheet to badland erosion, it can be concluded that high pH implies its effect on the increase of severeness and type of erosion, especially badland. In these soils because of high concentration of electrolytes, pH is usually less than 8.5 and soil is flocculated but, if soluble salts wash away, soil pH because of existence of sodium ions, increasing up to 8.5 and soil disperses. Solution of ions and consistency of minerals, specially, silicate minerals, depend on pH. In marly soils as a bed for formation of alkaline and saline soils, pH is about 8.5 and more. This amount of acidity causes to solve elements such Si, Al and Fe and then structure of minerals decomposed[33]. In a definite concentration of soil salts, soil fluculates that is named critical flocculation concentration (CFC). On the other hand, in lower concentration than CFC, aggregates destroy and upper than CFC, minerals coagulate. Increasing in pH, leads to increasing negative charge in soil colloids and cause to increase of CFC rate and whereas, needed concentration of salts not be supplied, aggregation not be done successfully[34].

$CaCO_3$: The amount of $CaCO_3$ in studied samples with regard to carbonatic marly soils is low. With respecting to Fig. 1, mean amount of $CaCO_3$ in all samples is lower than 6.97 %. The maximum and minimum rate of $CaCO_3$ is 12 and 4.1 %, respectively that are related to marly soils with badland erosion (Table-2). Statistical analyses shows that there is no significant difference ($p < 0.05$) between all forms of erosion, from view of calcium carbonate (Fig. 1). Thus, it is not possible to choose $CaCO_3$ amount as an index for determining erosion forms. Calcium carbonate present in cement increases the stability of marly soils and other clayey soils[33,35]. Because, it improves aggregating and consequently, permeability increases and run off decreases[36]. Permeability has a positive correlation with amount of calcium carbonate and soils with high vulnerability levels contain low amounts of carbonate compounds[37]. The source of calcium carbonate in marly soils is from the processes of soil formation or secondary reactions[38]. The role of $CaCO_3$ in soil is important from two point of views *i.e.*, texture and structure, because from one direction, with aggregate formation causes that moisture be released at low suctions and from other direction, with creating the fine porous medium, distribute the moisture at high suctions, even. The solubility of $CaCO_3$ is 0.013 g L^{-1} and if it be fine crystallized and has coarse particles, it has a few effect on flocculation of soil particles and *vice versa*. The work done by Ouhadi and Yong[33] in marly regions indicated that using from calcium carbonate for increasing of consistency, aggregate consistency might be improved at first, but, after a definite time, with formation of clay minerals such ettringite, thamasite and palygorskite, soil consistency becomes worthless. Calcium carbonate provides a favourable condition for these expansible minerals formation.

Gypsum: It is found that maximum (28.5 %) and minimum (10.54 %) amount of gypsum is pertaining to marly soils with rill and gully erosion respectively (Table-2). Also, statistical analyzing shows that is not any significant difference between gypsum rates with different types of erosion (Fig. 1 and Table-1). Thus, it is not possible to select gypsum per cent as an index for determining erosion forms. Also the mean of gypsum in study area among all of the erosional forms is ranging between 17.8-

19.8 and according to FAO[39] classification system calcify as gipsyferrous soil. According to Martin-Penela[40], the most decisive factors for piping and gulling are the presence of poorly indurated silty-clayey materials containing cracks, fractures or other discontinuities, such as (gypsum-filled) joints and faults.

TABLE-2
MAXIMUM AND MINIMUM VALUES OF SOME SOIL CHEMICAL PROPERTIES IN DIFFERENT FORMS OF EROSION

Variables	Sheet erosion		Rill erosion		Gully erosion		Badland erosion	
	Min	Max	Min	Max	Min	Max	Min	Max
Gypsum (%)	11.9	28.1	10.8	28.5	10.5	21.4	14.9	21.7
$CaCO_3$ (%)	5.3	11.5	5.5	9.5	4.2	11	4.1	12
EC_e (dS m^{-1})	8.1	1.2	11.3	17.8	12.3	20.2	16.4	24.9
pH	7.5	8.2	7.6	8.3	7.6	8.3	7.5	8.7
ESP (%)	16	30	44	59	47	66	42	75
SAR (meq $L^{-1})^{0.5}$	13.5	14.9	28.1	95.9	51.7	190.9	59.9	220.9
Cl^- (meq L^{-1})	1.3	7.1	3	17.6	1.5	17.2	2	19.1
SO_4^{-2} (meq L^{-1})	1.5	9.3	1.2	11	1.5	8.5	1.5	7.5
HCO_3^- (meq L^{-1})	0.8	9.7	1.7	9.3	1.7	9.2	1.5	6.7
K^+_S (meq L^{-1})	0.09	1.18	0.32	0.65	0.13	0.7	0.16	1
Na^+_s (meq L^{-1})	36.1	23.9	32.6	436.3	44.3	461.9	139	530.7
Ca^{2+}_s (meq L^{-1})	4.5	9.2	6.2	9.1	4.5	9.1	5.2	9.9
Mg^{2+}_s (meq L^{-1})	1.5	5.64	6.6	2.15	2.1	8.5	3.35	9
K^+_{ex} (meq 100 g^{-1})	0.1	2.3	0.35	1.86	0.57	1.6	0.1	2.98
Na^+_{ex} (meq 100 g^{-1})	7.5	19	19.7	24.6	20.1	29.3	21.6	34.3
Ca^{2+}_{ex} (meq 100 g^{-1}	4.8	15.4	4.9	9.2	9.2	4.2	4.6	16
Mg^{2+}_{ex} (meq 100 g^{-1})	4	9.3	4	9.2	2	9	3.5	10.1
CEC (meq 100 g^{-1})	30.5	45.5	31.5	46.7	35.6	48	40	48.5
OC (%)	0.85	1.6	0.64	1.4	0.21	0.35	0.2	0.31

Organic carbon: Fig. 1 shows that mean percentage of organic carbon of marly soils is between 0.22-1.25 %. The minimum rate is related to badlands and the maximum rate is related to marly soils with sheet erosion (Table-2). In addition, with comparison of the means of organic carbon percentage at different forms of erosion it was determined that there is no significant difference between sheet with rill erosion and gully with badland erosion. But other erosional forms have significant difference (Fig. 1). Organic carbon cause to aggregates is stable. Because bonds with clays and creates durable complexes with them and protect aggregates *versus* high amount of pH and SAR. In marly soils, with high concentration of salts, condition for growing vegetation is not accommodated, thus, marly soils have lack of organic matter and aggregating is low. Consequently, such soils are prone to erode extremely[34]. It must be said that the decreasing trend of organic carbon % from sheet to badland is considerable. Therefore, the amount of organic carbon can be viewed as the other index for separating erosion forms in marly soils. Bissonais[36] showed that soil structural stability is a relevant indicator, related to soil organic matter (SOM) content and soil erodibility. Piccarreta *et al.*[4], found that all the aggregates which were taken from badlands of Basilicata of Southern Italy had organic matter contents below the critical threshold of 20 g/kg. Similarly Conde *et al.*[37], explained that soils with high vulnerability levels contain low amounts of organic carbon and are not deep.

Cations: Exchangeable and soluble sodium have a increasing trend from sheet to badland erosion and between all erosional forms observed statistically significant difference. As discussed already, sodium ions are the most important factor in marly soils durability, because high percentage of sodium leads to increasing in soil particles diffusion. Other cations haven't important amount and differences between erosional forms are not such significant.

Exchangeable cations: The mean amount of Ca is variable between 6.35-9.65 meq 100 g^{-1} soil (Fig. 2), that maximum and minimum rate (16, 4.2) is related to badland erosion (Table-2). Also, mean of Mg is between 5.85-6.76 (Fig. 2), that maximum and minimum rate of Mg (10.1 and 3.2 meq 100 g^{-1} soil) is related to badland and gully erosion, respectively (Table-2). The results of statistical methods show that is a significant difference only between sheet with gully and sheet with badland erosion at both Ca and Mg. While in other cases there is not significant difference between both Ca and Mg with forms of erosion. Minimum amount of K (0.1) is related to sheet and badland erosion and maximum rate (2.98) is pertaining to badlands (Table-2). Fig. 2 shows there is not any difference between K and types of erosion. The average amount of sodium is between 15.5-29.04 meq 100 g^{-1} soils (Fig. 2), the minimum rate (13.5) is related to sheet and maximum rate (34.3) is related to badlands. There is an increasing trend of exchangeable sodium from sheet to badland erosion. The result (Fig. 2) shows that there is a significant difference between amount of exchangeable Na and forms of erosion. So that, we can determine exchangeable sodium as an index of erosion.

Soluble cations: The most important cations of the marly soils of these areas include sodium, magnesium and calcium ions. The average concentration of sodium is between 33.17-299.7 meq L^{-1} (Fig. 2). Maximum rate of sodium, magnesium and calcium are 530.7, 9.0, 9.9 meq L^{-1}, which are pertaining to marly soils with badlands (Table-2). There is an increasing trend in sodium ions from sheet to badland erosion and statistical analyzing shows a significant difference between Na and forms of erosion (Fig. 2). Also, some forms of erosions such sheet with rill and sheet with gully and sheet with badland erosion in terms of Mg have significant difference. While, soluble calcium has not any significant difference between different forms of erosion (Fig. 2). So, according to Heed[41], Mg and specially, Na are the most important soluble ions in marly soils undurability. Because, high percentage of sodium leads to increase in soil diffusion, that itself contribute in the variety of erosion forms. Also, soluble Mg ions create toxicity for vegetation and consequently, erosion activities.

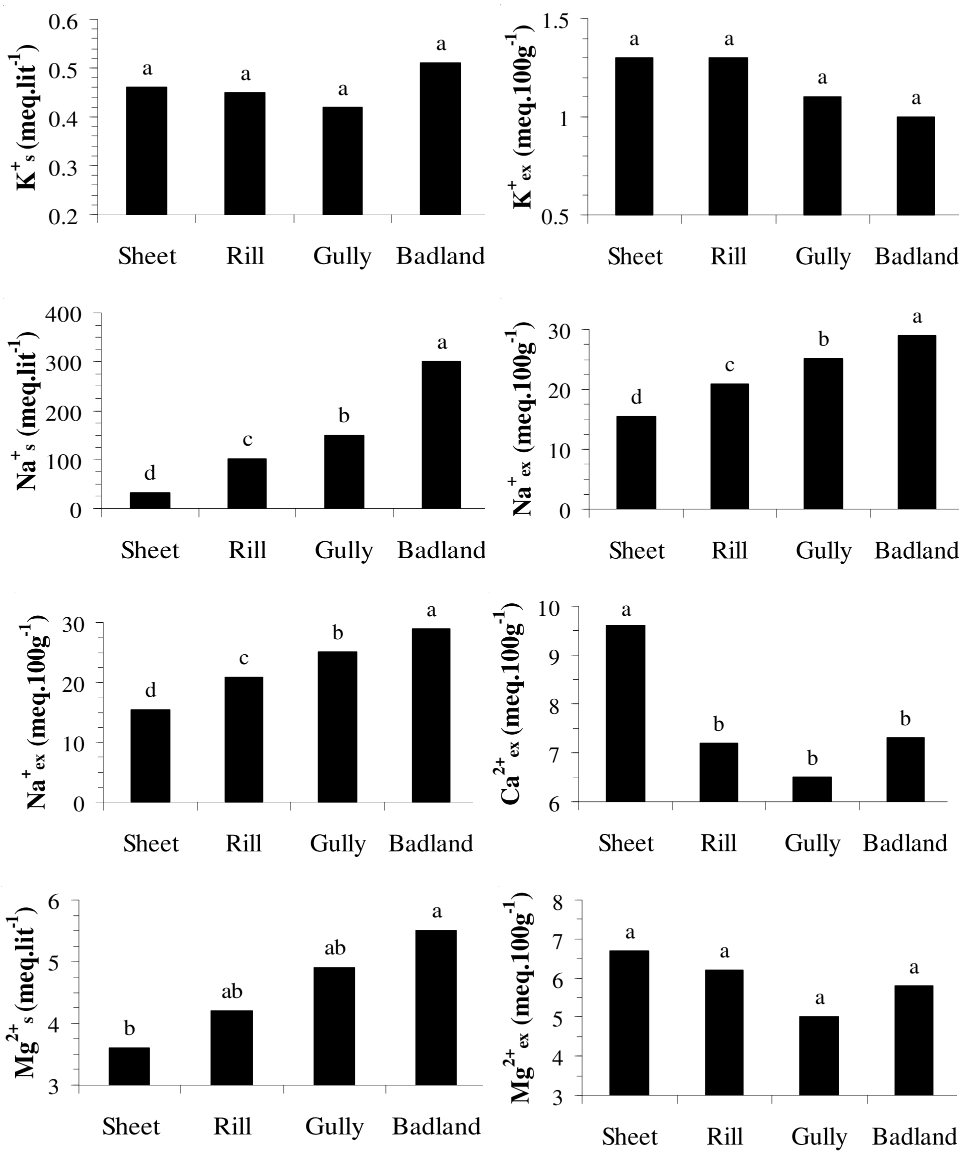

Fig. 2. Mean values of soluble and exchangeable cations for different forms of erosion (the same alphabets means no significant differences between forms of erosion using Duncan test)

Anions: The most important anions of the marly soils of this area include SO_4^{2-}, Cl^- and HCO_3^-, which show a wide spectrum in erosion forms. Average rate of Cl^- in badlands, gully, rill and sheet erosion are 12.23, 10.07, 8.58 and 3.76 meq L^{-1}, respectively (Fig. 3). Maximum rate of Cl^- (19.1 meq L^{-1}) is pertaining to badlands and minimum rate (1.3 meq L^{-1}) is pertaining to sheet erosion (Table-2). Cl^- ions have an ascending trend from sheet erosion to badlands. The amount of SO_4^{2-} ions in sheet, rill, gully and badland erosions are 5.3, 5.15, 5 and 4.19 meq L^{-1} and of HCO_3^- are 5.60, 5.81, 4.54 and 4.45 meq L^{-1}, respectively. The least (1.2 meq L^{-1}) and the most (11 meq L^{-1}) rate of SO_4^{2-} ions are related to gully erosion and of HCO_3^- is related to badlands (0.8 and 9.7 meq L^{-1}, respectively). In different forms of erosion, significant difference of Cl^- is only observed between sheet erosion and badlands, but, significant difference is not observed in instance of SO_4^{2-} and HCO_3^- (Fig. 3) Totally, increase in Cl^- ions can contribute to forms compounds associated with sodium, calcium and magnesium such as NaCl, $MgCl_2$ and $CaCl_2$ that lead to in durability and erodibility of marly soils. Also, these compounds are toxic for plants and prevent from vegetation cover existence.

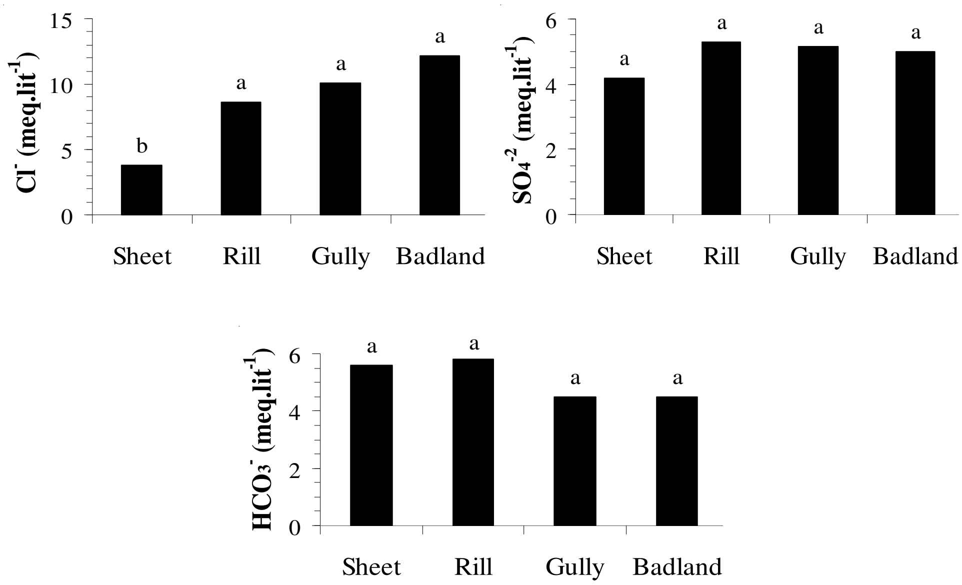

Fig. 3. Mean values of soluble anions for different forms of erosion (the same alphabets means no significant differences between forms of erosion using Duncan test)

Cation exchange capacity (CEC): The mean rates of CEC have a progressive trend from sheet erosion to badlands and are 39.48, 42.1, 43.6 and 44.96 meq 100 g^{-1} soils, respectively (Fig. 1). Minimum rate is 30.5 meq 100 g^{-1} soil related to sheet erosion and maximum rate is 48.5 meq 100 g^{-1} soil related to badland erosion (Table-2) and only, sheet with badland erosion and sheet with gully erosion have significant difference, in the case of CEC (Fig. 1). With regard to high percentage of clay in marly samples specially in gullies and badlands and low rate of organic matters in them, it can concluded that high CEC in these soils is related to clay portion (amount and type of clays).

Sodium adsorption ratio (SAR): The average of SAR value changes between 14.1-123.4 which shows increasing trend from sheet to badland erosion (Fig. 1). Minimum rate of SAR is related to sheet erosion (13.5) and maximum amount (220.6) is pertaining to badlands (Table-2). As shows in Fig. 1, SAR rate shows significant difference ($p < 0.01$) between different forms of erosion. So, it is considered that SAR rate as a parameter that definite forms and types of erosion. Increasing of this parameter leads to increasing of soil dispersion and erosion begins. With regard to sherard diagram[42] and using of total amount of calcium, magnesium, sodium and potassium and percentage of soluble sodium in saturated extract, it can say that all marly samples, are in dispersible soil limit. Thus, with respect to sherard diagram, the ratio of soluble sodium to total soluble cations has an important role in marly soils erodibility. Also, by using of sherard diagram and statistics results, SAR can be one of the most important alternatives, in controlling undurability and erosion severeness at the marly soils of this area. Heed[41] demonstrated that SAR is the main index for erodibility of marly soils and says, with increasing in SAR amount, erosion, from light state (sheet) inclined to extreme state (badland). Piccarreta *et al.*[4], reported that SAR values exceeding the threshold of 15 in badlands areas.

Exchangeable sodium percentage (ESP): The mean rate of ESP is between 39.9-63.65 that this rate increases from sheet to badland erosion (Fig. 1). The minimum rate of ESP (30 %) is related to sheet erosion and maximum rate (75 %) is related to badland erosion (Table-2). Statistics analyzing shows that, there is significant difference between different forms of erosion with ESP (Fig. 1). This progressive trend from sheet to badland erosion suggest that ESP as an important factor for determining type and severeness of erosion. With increasing of exchangeable sodium per cent to more than 15 %, consistency of aggregates becomes low and if, percentage of exchangeable sodium becomes more than 20 %, the consistency reached to zero[43]. Low electrolyte concentration in the soil solution and high ESP enhance clay swelling and dispersion, leading to easier breakdown of the surface aggregates and to the formation of a less permeable seal having low infiltration rate[6].

Conclusion

Sheet erosion is the most important form of erosion at this area. While, severeness of this type of erosion is less than other type of erosion (rill, gully, badland) but at the diffusive marly soils of this area gully and rill erosions are observable with high condensation that the severeness of erosion in them are too high. Field examinations imply existence of badland field in marly soils with high sodium and concentration of total cations. Consequently, because of sodium role in calculating SAR, so some marly soils of this area with high-solved sodium ion and SAR, has a high index of diffusion. With analyzing and comparing means, it seems that, solved sodium and SAR, salinity, Cl^-, Mg^{2+} and ESP make badlands more endurable because of making limitation in growing vegetation. While, calcium carbonate, gypsum Ca, K, HCO_3^-,

SO_4^{2-}, clay, silt and sand, haven't important effect in form and type of erosion. But high percentage of organic carbon in marl under the effect of sheet erosion in proportion with badlands shows the role of organic carbon in increasing the stability of marly soils. So, it can be concluded that sodium ions, SAR and the rate of organic carbon can be figured out as important indices in separating erosion forms in marly soils. Corresponding to results of the experiments, marly soils of south of Guilan province, have the characteristics of evaporating marly soils. Soil of these areas has the needed conditions for being saline-sodic soils. These conditions are EC > 4 dS m^{-1} and SAR > 13, that all of samples have these parameters. In regard to effects of chemical compounds in form and severeness of erosion it must be say that chemical factors such as ESP, SAR and EC are the most important properties in severeness of erosion. Therefore, between physical and chemical parameters only chemical factors have effects on erosion, so, amendatory efforts for reducing sediments must be done to improve chemical conditions of marly soils.

ACKNOWLEDGEMENTS

The authors thank the University of Guilan for supporting field studies and samplings. Thanks are also due to all the members of the Soil Science Laboratory of Faculty of Agriculture, University of Guilan, for providing the facilities to carry out this work and their suggestions.

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(*Received*: 31 December 2009; *Accepted*: 20 July 2010) AJC-8880