Study of relationship between different type of erosion and soil properties of marls in Southern Guilan Province, Iran.

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1. Abstract

Erosional processes in relation to marls are very intensive, so that different forms of erosion particularly, badlands are the obvious characteristics at marly lands. This paper focuses attention on the some basic aspects of the role of soil characteristics upon marls behaviour(erosional forms) in the regions of 756 km^2. Soil sampling were carried out from 48 surface sites of the marls which located in Gilevan area in south of Guilan province, having aridic moisture regime and thermic temperature regime with different forms of erosion including sheet, rill,gully and badland.

Statistical analysis with Duncan test showed that only exchangeable(Na_{ex}) and soluble sodium(Na_s),SAR(sodium adsorption ratio), ESP(exchangeable sodium percentage) and EC(electrical conductivity) have significant difference ($P<0.05$) between different erosional forms. These parameters were increased from sheet to badland erosion;while,other parameters had no significant difference. More investigation showed the positive effect of soluble sodium ($r=0.947^{**}$), SAR($r=0.949^{**}$) and ratio of fine clay(f.c) to total(t) clay($r=0.640^{*}$) on the depth of different gullies in badland extension . Moreover, results of x-ray diffraction showed the presence of dominant expansible 2:1clay minerals(smectite) in badland and gully erosion while area with rill and sheet erosion had no expansible clays. Hence, with respect to statistical analysis, sodium ion content and mineralogical properties control the intensity and forms of erosion in these regions. *: $p<0.05$, **: $p<0.01$

2. Introduction

Marls are unstable sedimentary formations including chemical materials and destructive particles(Benito,et al.,1991 . The amount of chemical materials and destructive particles in marls may be ranged between %35-%65 (Mashhadi,2001).Chemical materials in marls including gypsum , anhydrate, calcium carbonate, sodium chloride,etc. Thickness of surface soil of the marls is few and because of existence of deleterious elements and salinity,it is not possible to grow natural vegetative cover on marls which form saline and sodic soils (Shinberg,et al.,2000).

Erosion processes in marls are very severe , because of negligible amount of permeability and lack of vegetative cover ;however,different forms of erosion particularly badlands are of obvious characteristics at marly lands(Thornes, 1980). Erosion in marls depends on external factors such as the distribution of rainfall and internal factors such as soil properties (bryan,1987, Ouhadi,et al.,2003, Mohamed,2000).Previous studies showed that the presence of enough amount of organic matter, iron and aluminum oxides causes to make marls durable(Greenland, et al.,1975) while, sodium ions cause more erosion associated with dispersed clay particles. So, the ratio of exchangeable sodium ion in marls can be a good index of clay dispersion (Heed,1971, Bouma ,et al.,2000, Roth,1984).

The objective of this study was to determine the role of physical, chemical and mineralogical properties in the rate and severeness of different forms of erosion.

3. Materials

Marl formations in Gilevan region(Fig 1) covers a small area which located in south of Guilan province, produce large amount of sediments that enter to Sefidroud dam. Gully and badland erosion are the most obvious erosional forms in this region that leads to considerable soil losses from marly lands. The study area is located between 49^o, 26' and 49^o,31' E longitude and 36^o ,25'and 36^o ,46' N latitude with a mean annual precipitation of 160 mm and mean 24 hours intensity of 28.3 mm (aridic soil moisture regime) and mean annual temperature of 17.4^o C (thermic soil temperature regime) After preliminary studies on maps of geology and topography and field surveying on marly lands, study area were specified on land forms with uniform shape, aspect and slope with different surface morphology and colours.**O**n some marly hillslopes, accumulation of salts were observed. In the area,plant growth is very low and only special specieses of plants such as Salsola sp., Stipa sp., are present .

Twelve soil samples were taken from surface layer of sheet, rills, gullies and badlands (total of 48 samples) and from underlying layer of gullies and badlands (total of 24 samples) Parent material samples were air dried, then ground , seived (2mm) and prepared for physical, chemical and mineralogical analyses.Soil characteristics including total clay (t.c), fine clay(f.c), silt, sand and fine sand (in percent) , MWD(mean weight diameter in mm),Liq.li (liquid limit in percent) CEC(cation exchange capacity in cmolc kg-1 soil), EC (Electrical Conductivity in dS m-1), pH(1:1 water), soluble (meq lit-1) and exchangeable basic cations (Na, K, Ca, Mg in meq 100g-1 soil), CaCO3 (%), gypsum (%), SAR (sodium adsorption ratio) and ESP (exchangeable sodium percentage) were measured with respect to standard methods (Klute, 1986; Page, 1982, Kittrick,1971). Soil sampling were collected randomly from four types of erosion as a completely randomized design. Comparison of mean values was done using Duncan Multiple Range Test by SAS software and correlation coeficients using SPSS software in the way of step by step . For comparison of topsoil and subsoil in gullies and badlands ,T-test was used.

4. Results

The mean values of clay content in sheet, rill, gully and badland erosions are 32, 34.08, 37.85 and 41.43 respectively. The least amount was 18% related to rill erosion and the most value was 48% related to badlands and there was a significant difference between sheet and badland erosion. Clay particles have an important role in soil aggregating.If clay content is over 40%, small aggregates formand erode easily. This content(clay>40%) was present in some samples with gullyerosion and specially in badlands . In soils with clay contents of less than 10%,soil structure can not be formed,approximately,have a little adhesiveness and will destroy on exposure of rainfall.Moreover, type of clays influence in type and severeness of erosion, too.In gully and badlands, expansible 2:1 clay minerals was present (data not shownand). Fine clay to total clay from badland to sheet erosion was 0.37, 0.35,0 .29 and 0.26 respectively and has a descending trend from badland to sheet erosion and it confirms existence of expansible clays in areas withfurther erosion and conforms with XRD analyses.

Mean Weight Diameter (MWD) calculated by dry sieve method and for badland, gully,rill and sheet erosions are 0.23, 0.25, 0.33 and 0.52 mm,respectively. All forms of erosions have significant difference,except gully with badland erosion. With increasing in MWD,proportional resistance of aggregate stability and percentage of resistant aggregates increase. One reason for decreasing of this parameter from sheet to badland erosion, is increasing the silt. Silty soils, usually aggregates well, but will breakdown easily and soil particles transfer with wind and water as follows: MWD=0.04 O.C – 0.003 clay – 0.04 (silt+f.sand) – 0.006ESP+0.88 with a $R2=0.68$.

Disresistance of aggregates, causes diminishing water permeability, soil surface sealing, runoff and soil erosion. Also, as MWD increases, resistance against wind erosion increases,too. For distinguishing of effective agents on MWD, using multi variant linear regression (step by step), correlation coefficient between soil parameters (physical and chemical) and MWD was calculated. Results showed (table1)that correlation coefficients were as follows: MWD with Silt+fine sand(r= -0.485**), % clay(r= -0.310*) ,%O.C(r= 0.505**)

Statistical analysis with Duncan test showed that only exchangeable and soluble Na, SAR, ESP and EC have significant difference ($P<0.05$) between different erosional forms. These parameters were increased from rill to gully and badland erosion, while, other parameters had no significant difference between all erosional forms.

The mean values of exchangeable(Naex) and soluble sodium(Nas), SAR, ESP , EC ,fc/tc, MWD,si,fc, c,Liq.li,f.sand and pH for different forms of erosion are given in Table 1.The least EC (8.1 ds/m) and the most (24.9 ds/m) rate is related to sheet and badland erosion respectively. The increasing trend from sheet to badland erosion is observed .In studied soils, soil salinity is high that causes to produce small granular structure in dry state but, as soon as they become wet, their structure destroys As is seen, sodium have the most correlation coeficient with soil salinity. In the other hand, soil salinity in marly lands is mainly affected by sodium.The mean value of pH in sheet to badland erosion are 7.6, 7.8, 8 and 8.1 respectively. In addition,there was a significant difference between all forms of erosion except sheet with rill and gully with badlands. In this soils because of high concentration of electrolites, pH was usually less than 8.5 but, if soluble salts wash away, soil pH because of sodium ions, increase up to 8.5 and soils will disperse. Mean percentage of organic carbon of marls is between 0.22-1.25. the minimum rate is related to badlands and the maximum rate is related to marls with sheet erosion It must be said that decreasing trend of organic carbon from sheet erosion to badlands is considerable. Organic matter protect aggregates against high amount of pH and SAR. In marly soils that is not any suitable condition for plants growing, lack of organic matter is very important.

This subject leads to decreasing of aggregate formation and these soil is prone to erosion. Therefore, the excess amount of organic carbon can be viewed as the other index for separating erosional forms in marls. Exchangeable and soluble sodium have a increasing trend from sheet to badland erosion and between all erosional forms observed statistically significant difference.

SAR in studied soils with sheet, rill, gully and badland erosion are 14.1, 53.6, 85.3 and 119.14 meq/lit1/2 that has a ascending trend from sheet to badland erosion. Minimum rate of sodium adsorption ratio (13.52) is pertaining to sheet erosion and maximum rate (220.9) is related to badlands and there was a significant difference between all forms of erosion. So, we can consider SAR parameter as a determinant factor for forms and types of erosion.When sodium is the main adsorbed cation to soil complexes, distances between soil particles slowly become further and with increasing moisture, this distance comes up to 7 nanomter and clay particles disperse.

The mean values of CEC have a progressive trend from sheet erosion to badlands and are 39.48, 42.1, 43.6, and 44.96 meq/100gr soil, respectively. Minimum value is 30.5 meq/100gr related to sheet erosion and maximum value is 48.5 meq/100gr related to badland erosion and only, sheet with badland erosion and sheet with gully erosion have significant difference,in the case of CEC.
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 be concluded that high CEC in these soils is related to clay portion (amount and type of clays). Results showed that, gullies and badlands forms in regions with high amount of EC, SAR, and ESP.

Comparison of surface and underlying (near the bedrock) layers in gullies and badlands indicated that EC, SAR, ESP and clay content increase from surface to bedrock but statistical analysis of t-test indicated that there was no significant difference between surface and deep layer of gullies. In badlands, only the SAR value from surface to greater depth were significant.

Moreover, investigation on the correlation coefficient between the depth of different rills with soil properties showed that MWD ($r = -0.614$), silt +fine sand ($r = 0.598$) and SAR ($r = 0.696$) was correlated ($p<0.05$) with depth of rills as equation: $Y=0.4\,SAR+0.3(si+f.s)-0.4MWD-0.68$ in which Y is the depth (in cm) of different rills in rill erosion, si is silt (%) and f.s (%) is fine sand. This equation indicate MWD decreased and depth of rill erosion increased.Correlation coefficient between depth of different gullies with soil properties, demonstrated that only SAR ($r = 0.669$), Na_s ($r = 0.619$) and the ratio of fine clay to total clay ($r = 0.611$) are important ($p<0.05$) as in equation

$Y= 0.6SAR+0.2Na_s+0.18(f.c/t.c)+0.35$ where Y is the depth (in cm) of different gullies and Na_s is soluble sodium ions .

It can be concluded that with increasing the ratio of f.clay/t.clay, retention of moisture increases and infiltration of water decreases which in turn, enhances the soil erodibility.Also , sodium ions which are able to increase the thickness of diffuse double layer of clay fraction, bring about the condition for more soil dispersing and causes to intensify soil erosion (Shinberg,et al., 2000, Ouhadi ,et al., 2003).

Table 1 Mean values of some soil properties in different forms of erosion

Soil property	Rill	Gully	Badland	Sheet
Na_s	101.1 [c]	148.4 [b]	299.7 [a]	33.1 [d]
Na_{ex}	20.9 [c]	25.1 [b]	29 [a]	15.5 [d]
SAR	53.6 [c]	85.3 [b]	119.1 [a]	14.1 [d]
EC	14.6 [c]	16.7 [b]	20.2 [a]	11.7 [d]
ESP	49.8 [c]	57.9 [b]	63.6 [a]	25.9 [dc]
fc/tc	0.29 [b]	0.35 [a]	0.37 [a]	0.26 [b]
MWD	0.34 [b]	0.25 [c]	0.23 [c]	0.52 [c]
si	33 a	36.5 a	33.2 a	30.5 [a]
f.c	9.9 c	13.2 b	15.3 a	8.3 [c]
c (clay)	34 bc	37.8 ab	41.4 a	32 [c]
Liq.li.	41.4 c	47.3 b	51.3 a	11.41
f.sand	38.7 a	44.5 a	52.9 a	37.2 [a]
pH	7.8 b	8.04 a	8.1 a	7.6 [b]

The same letters means no significant difference.

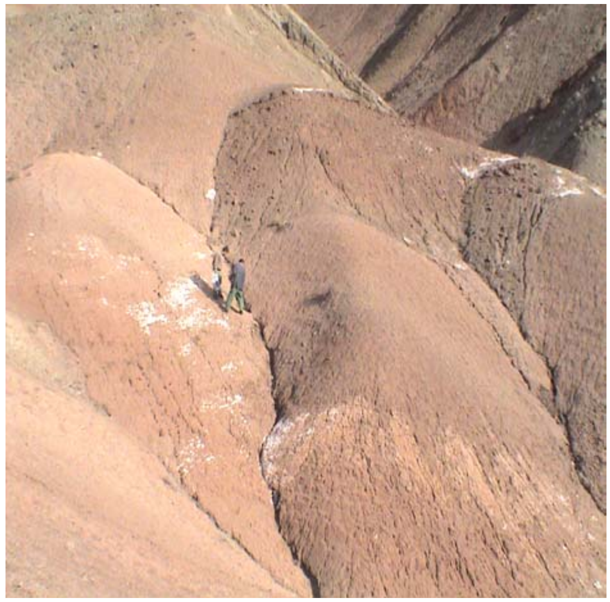

Figure 1 Study area showing different erosional forms

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