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Study on relationship between different type of erosion and soil properties of Chambal ravines

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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 behavior (erosional forms) in the regions of Chambal ravines. Soil samples were collected randomly from different form of erosion as a complete randomized designed after field survey. 48 (0-30 C.M.) soil samples were collected from the surface layer of sheet, rill, gully and badland (12 each) erosion area and 24 soil samples from underlying layer of gullies and badland (12 each) of village Aisah Morena district.

The present study revealed that surface soil of sheet, rill, gully, and badland erosion was slightly alkaline to moderately alkaline in nature; whereas subsurface sites of gully and badland erosion site shows moderately alkaline nature. Since sands have low conductivity and clays have high conductivity, soil electrical conductivity correlates very strongly with particle size and soil texture. The presence of excessive amounts of exchangeable sodium reverses the process of aggregation and causes soil aggregates to disperse into their constituent individual soil particles. The particle density is higher if large amount of heavy minerals such as magnetite; limonite and hematite are present in the soil. The bulk density varies indirectly with the total pore space present in the soil and gives a good estimate of the porosity of the soil. Bulk density is of greater importance than particle density in understanding the physical behavior of the soil.

Keywords: Erosion, sheet, rill, gully, badland, alkaline, electrical conductivity

Introduction
None of the natural resource is as valuable as land. (Blum 1995) [3] defined soil degradation, ‘as a loss or a reduction of soil energy’. The word ravine denotes gullied land containing system of gullies running more or less parallel to each other and entering a nearby river flowing much lower than the surrounding table lands. It is associated with an isolated gully. Land degradation by ravines and gullies is wide spread in India. The national commission on Agriculture (1976) [10] estimated that 3.67 mha (1% India’s area) and 0.683 m ha area in Madhya Pradesh is damaged by erosion. According to Sharma (1980) [13] about 4.19 lakh ha area in Madhya Pradesh is affected by ravines, with annual rate of expansion of 1.93 ha for each 1000 ha of existing ravines land. Available from Chambal Badlands of central India are one of the most extensive badlands in the world, and are one of the four severely dissected landscapes within the Middle Alluvial Ganga Plains (MGAP).

Rills are shallow drainage lines less than 30 cm deep. They develop when surface water concentrates in depressions or low points through paddocks and erodes the soil. Rill erosion is often described as the intermediate stage between sheet erosion and gully erosion. Gullies are channels deeper than 30 cm that cannot be removed by normal cultivation. They can be spectacular to look at but over time actually lose soil than sheet and rill erosion. Gullies occur when smaller water flows concentrate and cut a channel through the soil Narayan and Babu (1983) [9] claim 4,000,000 ha as a more reasonable estimate of land covered by gully. In colonial days the problem was considered to be even worse. Ravine Soil are sandy in texture, low in organic carbon and low to very low in nitrogen and phosphorus. The physical properties like aggregate analysis, bulk density particle density are very poor and low in organic carbon (Anonymous 2013). The water dispersible aggregates show that the soil of ravine study area has very weak binding properties.

Bryan and yair (1982) [5] reported that ravines or badlands are usually defined as extremely dissected landscapes with short steep slopes and narrow interfluves that can support sparse vegetation but are anyhow unsuitable for agriculture.

The study shows that in all soil profiles and depth. Maximum aggregates (50 to 70%) are in finer size (>125 micron) fraction only very less (8-14%) are in coarser (>1 mm) Size rate of expansion is 1.93 ha for each 1000 ha of existing ravines land.

Moreover, erosional processes in relation to Chambal region are very intensive, so that different figures of erosion particularly: badlands are the obvious characteristics at Chambal erosion therefore with proper recognition of some characteristics of Chambal ravines such as their physical and chemical soil properties we may be able to fight against the harms received by erosion from these vulnerable lands. The present study was therefore, carried out with some aims i.e. to identify different forms of erosion in ravines of Chambal, to study the physical and chemical properties of soil in different form of erosion in ravines of Chambal, to determine the role of physical and chemical properties in the severeness of different forms of erosion.

Material and methods

Soil samples were collected randomly from different form of erosion as a complete randomized designed after field survey. 48 (0-30 c.m.) soil samples were collected from the surface layer of sheet, rill, gully and badland (12 each) erosion area and 24 soil samples from underlying layer of gullies and badland (12 each) of village Aisah Morena district which is located at 26°40' N latitude and 76°06'E longitude and 80 km away from Vishwa Vidyalaya Head Quarter. The soil samples were prepared for physical and chemical analysis of soil and statistical analysis were done. Analysis of physical and chemical properties of soil was carried out in laboratory of Department of Soil Science and Agriculture Chemistry, College of Agriculture, Gwalior. Field visit for reconnaissance survey was carried out to identify different form of soil erosion (sheet, rill, gully, and badland) at ravines of Chambal. Particle size distribution of sand, silt and clay was determined by a Bouyoucos hydrometer method as described by Bouyoucos (1936) [4]. Pycnometer was used to determine volume and weight of soil particle as per method described by Black (1965) [2]. Bulk density is a measure of the weight of the soil per unit volume (g/cc), usually given on an oven-dry (105° C) basis. Soil aggregate stability was determined by wet sieving method, using the klute (1986) [8] method. The pH of soil was determined by using glass electrode pH meter using 1:2 soil water suspensions. The supernated liquid of the soil suspension formerly used for pH determination was used for the determination of electrical conductivity by conductivity meter. Organic carbon was estimated by the Walkley-Black (1935) method. Calcium carbonate was determined by using rapid titration method as described by Piper (1950) [11]. Cation exchange capacity (Richards 1954) [12]. ESP was computed on the basis of exchangeable cation *viz*. Na^+ and cation exchange capacity (CEC) of soil which were determined as per the method of Richards (1954) [12]. Exchangeable cations by using flame photometer (Jackson, 1973) [7], Standard deviation coefficient of variance (CV) correlation multiple regressions were workout by adoption of standard statistical procedure Fishar (1958) [6].

Results and Discussion

A. Chemical properties

Soil pH

Soil pH recorded from 12 samples as shown in Table 1 collected from surface layer of sheet erosion shows maximum pH value of 8.4 whereas minimum was 7.0. In case of gully erosion, range of pH varied from 7.9 to 8.6. While Badland surface erosion recorded maximum value of pH 8.9 and minimum 8.0. The maximum and minimum value of soil pH was 8.9 and 7.9 from rill erosion. The relationship of pH with different variable i.e. ESP (r = -0.883**), was negative and highly significant shown in Table 13. Surface erosion shows slightly alkaline to moderately alkaline nature of soil where as subsurface erosion soil shows moderately alkaline nature. In slightly to moderately alkaline soils, whereas no specific trend of pH in subsurface to underlying layer.

Table 1: Soil pH

pH					
Sheet Erosion	**Gully Erosion**	**Badland Erosion**	**Rill Erosion**	**Badland Erosion**	**Gully Erosion**
0-30 cm				**30-45 cm**	
7.1	8.1	8.9	7.9	8.0	8.2
7.5	8.2	8.7	7.8	8.3	8.4
7.0	8.4	8.6	7.5	8.5	8.3
7.8	8.6	8.7	8.9	8.4	8.4
7.9	8.5	8.4	8.0	8.2	8.4
8.0	7.9	8.3	8.8	8.4	8.4
8.1	7.8	8.5	8.2	8.3	8.3
8.4	8.1	8.4	8.3	8.3	8.4
7.9	8.3	8.3	8.4	8.4	8.5
8.1	8.5	8.1	8.2	8.3	8.5
8.0	8.1	8.2	8.1	8.3	8.4
7.2	7.8	8.0	8.0	8.4	8.4

Electrical Conductivity

Maximum Electrical conductivity shown in Table 2 recorded for surface erosion in sheet, gully, badland and rill was 0.46 d Sm^{-1}, 0.45 d Sm^{-1}, 0.46 d Sm^{-1} and 0.46 d Sm^{-1} respectively, whereas minimum value was noted 0.32 d Sm^{-1}, 0.35 d Sm^{-1}, 0.37 d Sm^{-1} and 0.37 d Sm^{-1} for same. Maximum electrical conductivity of 0.46dSm^{-1} and 0.45dSm^{-1} observed from subsurface badland and gully erosion respectively, while 0.37 d Sm^{-1} was observed the minimum in subsurface badland and gully erosion. Samples collected from soil of surface and subsurface layer indicated liacks in proper organic matter content in soil. Since sands have low conductivity and clays have high conductivity, soil electrical conductivity correlates very strongly with particle size and soil texture. Soils prone to drought or excessive water will show variations in soil texture that can be delineated using soil electrical conductivity. Soil electrical conductivity also can delineate differences in organic matter content and cation exchange capacity.

Table 2: Electrical Conductivity

EC (dSm^{-1})					
Sheet Erosion	**Gully Erosion**	**Badland Erosion**	**Rill Erosion**	**Badland Erosion**	**Gully Erosion**
0-30 cm				**30-45 cm**	
0.42	0.42	0.43	0.43	0.43	0.41
0.35	0.39	0.44	0.44	0.44	0.43

0.36	0.35	0.42	0.42	0.42	0.44
0.41	0.45	0.39	0.39	0.39	0.38
0.39	0.36	0.40	0.40	0.40	0.40
0.35	0.37	0.38	0.38	0.38	0.42
0.36	0.38	0.37	0.37	0.37	0.37
0.46	0.40	0.44	0.44	0.44	0.43
0.39	0.41	0.42	0.42	0.42	0.43
0.36	0.42	0.45	0.45	0.45	0.44
0.35	0.43	0.46	0.46	0.46	0.41
0.32	0.44	0.38	0.38	0.38	0.45

Exchangeable Sodium Percentage (ESP) %

Maximum value of exchangeable sodium percentage was noticed with surface layer of sheet erosion, gully erosion, badland erosion, rill erosion are 9.5 %, 10.5%, 10.0%, 11.6% respectively and minimum value are 10.3%, 9.1%, 9.1%, 10.4% respectively. Maximum value of exchangeable sodium percentage was noticed with sub surface layer of badland erosion and gully erosion are 10.0 and minimum value are 9.1 as described in Table 3. The data revealed that EC was and $Mg2^{+}$ Ca_2 (r = 0.734**), MWD (r=-0.679*) was positive and significant as described in Table 13. A soil is considered "sodic" when the Exchangeable Sodium Percentage (ESP) is 6% or greater. Soil samples collected from soil erosion area shows sodic to moderately sodic nature of soil. The presence of excessive amounts of exchangeable sodium reverses the process of aggregation and causes soil aggregates to disperse into their constituent individual soil particles. This is known as deflocculation and occurs in sodic soil. The major issues arising from high sodium levels relative to the other exchangeable cations are on the physical properties of soil. In surface soil horizons this imbalance in the ratio of cations results in poor soil structure. This is evidenced by surface soil crusts or the setting of soil into large blocks on drying. A sodic soil with few stabilizing agents in the topsoil will ultimately be susceptible to erosive soil loss during intense rainfall or irrigation cycles via rill and gully erosion. This is because water intake is usually so slow, owing to the poor soil structure. This is especially the case in soil high in silt and clay particle size fractions. In the subsoil, soil sodicity leads to decreased permeability to water and air and poor soil drainage over time.

Table 3: Exchangeable Sodium Percentage (ESP)

ESP (%)					
Sheet Erosion	**Gully Erosion**	**Badland Erosion**	**Rill Erosion**	**Badland Erosion**	**Gully Erosion**
0-30 cm				**30-45 cm**	
10.2	9.1	10.0	11.0	10.0	9.9
10.1	9.2	9.8	11.1	9.8	9.1
10.0	9.4	9.7	10.9	9.7	9.5
9.9	9.6	9.6	10.8	9.6	9.8
9.5	9.8	9.9	10.4	9.9	10.0
9.9	9.0	9.5	10.8	9.5	9.6
9.7	10.1	9.1	10.5	9.1	9.2
10.3	10.2	9.6	10.7	9.6	9.8
9.5	10.5	9.5	10.8	9.5	9.9
9.7	10.1	9.4	11.2	9.4	9.7
9.9	10.2	9.3	11.6	9.3	9.6

Sodium Adsorption Ratio (SAR)

Maximum significant SAR for sheet erosion (13.6), gully erosion (10.9), badland erosion (11.3) and rill erosion (11.0) was obtained from surface erosion whereas, from sub surface erosion in badland it was 11.3 and in gully erosion 11.1 respectively shown in Table 4. SAR showed positive and highly significant correlation with MWD(r= 0.853**), positive and significant correlation with OC(r= 0.606*), LL(r= 0.645*) PL(r= 612*) shown in Table 13. Surface and subsurface soil shows sodic to saline nature. It is also a standard diagnostic parameter for the sodicity hazard of a soil, as determined from analysis of pore water extracted from the soil.

Table 4: Sodium Adsorption Ratio

SAR					
Sheet Erosion	**Gully Erosion**	**Badland Erosion**	**Rill Erosion**	**Badland Erosion**	**Gully Erosion**
0-30 cm				**30-45 cm**	
13.2	10.5	10.1	10.2	10.1	10.5
13.1	10.1	10.6	10.5	10.6	10.7
13.0	10.6	10.9	10.6	10.9	10.9
13.5	10.2	11.1	10.1	11.1	10.2
13.6	10.7	10.4	10.0	10.4	10.6
13.5	10.8	10.3	10.2	10.3	10.3
12.0	10.9	10.5	10.8	10.5	11.1
12.5	10.0	10.6	10.1	10.6	10.8
12.3	10.1	10.7	11.0	10.7	10.3
12.0	10.6	10.8	10.9	10.8	10.7
13.5	10.7	11.2	10.6	11.2	10.6
13.0	10.1	11.3	10.5	11.3	10.5
10.0	9.9	9.5	11.9	9.5	9.3
13.0	10.1	11.3	10.5	11.3	10.5
13.0	10.1	11.3	10.5	11.3	10.5

Cation Exchange Capacity (CEC) (Meq /100g)

Maximum values of CEC noted in surface erosion were sheet erosion 15.1 meq/100g, gully erosion 15.1 meq/100g, badland erosion 15.2 meq/100g and rill erosion 14.9 meq/100g whereas in underlying surface, it was badland erosion and gully erosion 15.2 meq/100g in both as shown in Table 5. Data indicated loam to silt loam texture of soil. The relationship of CEC with PI (r= 0.971**), LL (r = 0.873**) CaCo3 (r= 0.723 **), was positive and highly significant as described in Table 13. CEC was found to increase in gully erosion. Considering the soil of all layers. The CEC of soils decreases from surface to sub surface horizon in all the three sites and is due to decrease in clay content with depth.

Table 5: Cation Exchange Capacity (CEC) (meq/100g)

CEC (meq/100g)					
Sheet Erosion	Gully Erosion	Badland Erosion	Rill Erosion	Badland Erosion	Gully Erosion
0-30 cm				30-45 cm	
14.0	14.1	15.1	14.5	15.1	15.0
14.9	14.2	14.9	14.6	14.9	15.2
15.0	15.0	15.2	14.2	15.2	14.9
15.1	14.9	14.8	14.1	14.8	15.1
14.8	14.8	14.9	14.2	14.9	14.5
14.7	15.1	15.0	14.0	15.0	14.7
14.6	14.8	15.1	14.1	15.1	14.8
14.9	14.7	14.6	13.9	14.6	14.9
14.7	14.8	14.8	14.7	14.8	15.1
14.6	14.6	14.7	14.9	14.7	14.7
14.7	14.3	14.6	14.5	14.6	14.9
13.1	14.4	14.5	14.6	14.5	14.8

Carbonate & bicarbonate

Carbonate and bicarbonate always occur together in solution in equilibrium with one another, with the pH and with atmospheric carbon dioxide. Highest level of $CaCO_3$ in sheet erosion 1.9, gully erosion 1.8, badland erosion 1.9 and rill erosion 1.9 were recorded from surface area whereas from sub surface area in badland and gully erosion it was 1.9 shown in Table 6. Carbonate & bicarbonate showed negative and highly significant correlation with sand (r = -0.745**), silt (r = -0.826**) shown in Table 13. Below the soil surface where the respiration of organisms is at work, concentrations of carbon dioxide in the soil atmosphere may be 100 times higher than in the above ground atmosphere. This lowers the concentration of carbonate in favor of bicarbonate. However, near the soil surface carbonate concentration is higher and may become even more elevated as transpiration and evaporation of water occurs. In extreme cases where pH and the concentration of carbonate in irrigation water are high, the soil will progressively become alkaline as well as sodic so that nutrient availability is also impaired. Similar findings were reported by Belmonte *et al*. (2002) [1].

Table 6: Carbonate and Bicarbonate ($CaCO_3$)%

$CaCO_3$					
Sheet Erosion	Gully Erosion	Badland Erosion	Rill Erosion	Badland Erosion	Gully Erosion
0-30 cm				30-45 cm	
1.5	1.1	1.0	1.5	1.0	1.2
1.2	1.2	1.4	1.0	1.4	1.9
1.3	1.4	1.3	1.2	1.3	1.7
1.6	1.5	1.2	1.2	1.2	1.6
1.4	1.6	1.5	1.3	1.5	1.4
1.5	1.7	1.6	1.4	1.6	1.0
1.4	1.8	1.8	1.2	1.8	1.6
1.9	1.3	1.9	1.0	1.9	1.4
1.4	1.4	1.7	1.1	1.7	1.5
1.4	1.5	1.4	1.2	1.4	1.8
1.5	1.7	1.2	1.6	1.2	1.9
1.9	1.8	1.5	1.9	1.5	1.3

Soluble and exchangeable basic cation (Mg2+ Ca2+)

In soil samples collected from surface erosion shows maximum sheet (7.9), gully (9.9), badland (6.9) and rill erosion (11.8) site respectively. Exchangeable calcium magnesium was studied in different soil erosions and notice that was increasing the depth, where as no consistency at sheet, Rill, gully and badland erosion. Maximum values in underlying soil surface in badland are 11.8 and in gully erosion is 11.9 shown in Table 7. Mg2+ Ca2+ showed negative and highly significant correlation with(r = -0.613*) shown in Table 13. The amount and relative proportion usually reflect the soil's parent materials. Calcium (Ca) and Mg are plant-essential nutrients, and the ionic form of each held on the soil exchange sites is the form taken up by plants. Similar report was presented by Belmonte *et al*. (2002) [1] and Varavipour *et al*. (2010) [14].

Table 7: Soluble and exchangeable basic cation (Mg_2^+ Ca_2^+)

Mg_2^+ Ca_2^+					
Sheet Erosion	Gully Erosion	Badland Erosion	Rill Erosion	Badland Erosion	Gully Erosion
0-30 cm				30-45 cm	
7.1	9.1	6.3	11.1	11.1	11.0
7.2	9.5	6.9	11.8	11.8	11.3
7.3	9.4	6.0	11.3	11.3	11.1
7.4	9.2	6.8	11.7	11.7	11.4
7.1	9.0	6.6	11.8	11.8	11.5
7.9	9.6	6.7	11.6	11.6	11.7
6.9	9.3	6.0	11.5	11.5	11.9
7.0	9.5	6.5	11.4	11.4	11.2
7.1	9.7	6.4	11.5	11.5	11.4
6.9	9.8	6.2	11.8	11.8	11.6
7.9	9.9	6.1	11.7	11.7	11.5
7.0	9.2	6.8	11.0	11.0	11.3

Organic Carbon (OC) g/kg

Soil organic carbon recorded from 12 samples (Table 8) collected from surface layer of sheet erosion shows maximum OC value of 0.9g/kg whereas minimum noted was 0.6 g/kg. In case of gully erosion, range of OC varied from 1.20g/kg to 0.2g/kg. Badland surface erosion recorded maximum value of OC 1.4g/kg and minimum 0.8. The maximum value of soil OC 1.6g/kg and minimum 0.8g/kg was noted from rill erosion. Soil samples collected from underlying layer of badland and gully erosion shows significantly maximum organic carbon value is 1.4 g/kg, where as minimum value of OC recorded were 8.0g/kg and 1.1g/kg respectively. Soil organic carbon is present as soil organic matter. It includes relatively available C as fresh plant remains and relatively inert C in materials derived from plant remains: humus and charcoal. Soil organic carbon tends to be concentrated in the topsoil. Topsoil ranges from 0.5 g/kg to 3.0 g/kg organic C for most upland soils. Soils with less than 0.5 g/kg organic C is mostly limited to desert areas. Soils containing greater than 1.2 – 1.8 g/kg organic C is generally classified as organic soils. Levels are commonly highest in surface soils but wide variations from almost zero to above 1.5 g/kg C are possible.

Table 8: Organic Carbon (OC) g/kg

OC g/kg					
Sheet Erosion	Gully Erosion	Badland Erosion	Rill Erosion	Badland Erosion	Gully Erosion
0-30 cm				30-45 cm	
0.7	1.1	1.1	1.5	1.4	1.1
0.8	0.8	1.0	1.0	1.0	1.2
0.9	0.5	1.2	0.9	1.2	1.4
0.6	1.1	0.9	1.2	0.9	1.4
0.9	1.2	1.3	1.6	1.3	1.2
0.8	1.0	1.1	1.4	1.1	1.1
0.7	0.2	1.2	1.1	1.2	1.3
0.6	0.4	0.8	1.0	0.8	1.4
0.8	0.7	0.9	0.8	0.9	1.1
0.9	0.2	1.3	1.0	1.3	1.2
0.9	0.8	1.2	0.8	1.2	1.2
0.7	0.6	1.1	1.2	1.1	1.3

B. Physical properties

Particle Density

Average particle density in sheet erosion, rill erosion, gully erosion, badland erosion at surface layers are 2.6, 2.63, 2.66, 2.66 respectively and in gully and badland erosions are 2.65 in both at subsurface layer shown in table 9. PD showed positive and highly significant correlation with BD (r = 0.759**), clay (r = 0.752**) as shown in Table 13. The particle density is higher if large amount of heavy minerals such as magnetite; limonite and hematite are present in the soil. With increase in organic matter of the soil the particle density decreases. Collected data shows presence of fine sand soil.

Table 9: Particle Density (PD)

PD (g/cm^3)					
Sheet Erosion	Gully Erosion	Badland Erosion	Rill Erosion	Badland Erosion	Gully Erosion
0-30 cm				30-45 cm	
2.60	2.66	2.66	2.56	2.65	2.65
2.60	2.66	2.66	2.66	2.65	2.66
2.60	2.66	2.66	2.66	2.66	2.66
2.60	2.66	2.66	2.62	2.66	2.66
2.60	2.66	2.66	2.61	2.66	2.64
2.60	2.66	2.66	2.66	2.66	2.66
2.60	2.66	2.66	2.62	2.66	2.66
2.60	2.66	2.66	2.62	2.66	2.66
2.60	2.66	2.66	2.64	2.63	2.65
2.60	2.66	2.66	2.65	2.66	2.61
2.60	2.66	2.66	2.66	2.65	2.66
2.60	2.66	2.66	2.63	2.66	2.66

Bulk Density

Average Bulk density in sheet erosion, rill erosion, gully erosion, badland erosion at surface layers are 1.33, 1.32, 1.33, 1.33 respectively and in gully and badland erosions are 1.32 in both at subsurface layer as describe in Table 10. The relationship of BD was negative and highly significant correlation with Sand (r= -0.884**) as shown in Table 13. Data obtained shows silt loam type of soil. Bulk density normally decreases, as mineral soils become finer in texture. The bulk density varies indirectly with the total pore space present in the soil and gives a good estimate of the porosity of the soil. Bulk density is of greater importance than particle density in understanding the physical behavior of the soil. Fine textured surface soils such as silt loams, clays and clay loams generally have lower bulk densities than sandy soils.

Table 10: Bulk Density (BD) (g/cm^3)

(BD) (g/cm^3)					
Sheet Erosion	Gully Erosion	Badland Erosion	Rill Erosion	Badland Erosion	Gully Erosion
0-30 cm				30-45 cm	
1.33	1.33	1.33	1.33	1.32	1.33
1.33	1.33	1.33	1.33	1.33	1.32
1.33	1.33	1.33	1.33	1.33	1.33
1.33	1.33	1.33	1.31	1.33	1.33
1.33	1.33	1.33	1.3	1.33	1.32
1.33	1.33	1.33	1.31	1.32	1.33
1.33	1.33	1.33	1.33	1.33	1.33
1.33	1.33	1.33	1.32	1.33	1.32
1.33	1.33	1.33	1.33	1.32	1.33
1.33	1.33	1.33	1.33	1.32	1.32
1.33	1.33	1.33	1.3	1.33	1.33
1.33	1.33	1.33	1.33	1.33	1.33

Mean weight diameter of soil aggregates

The MWD value for sheet, rill, gull, and badland erosion at surface layer were 17.5, 15.24, 18.65, 18.4, respectively as shown in Table 11. Mean weight diameter of soil aggregates for subsurface badland erosion was varied from 17.8 g to 19.0 g and gully erosion it was 17.6 g to 18.9 g as described in Table 12. It showed negative and significant correlation with Silt (r= -0.653*) as shown in Table 13 data revels that presence of soil structure from fine to fine sand which leads to uniform weight even after sieve through different filters. The high levels of MWD in soil is a sign of the presence of high stable aggregates which are resistance to MWD increases, resistance against wind erosion will increase (Rafahi, 2000), Moreover, correlation coefficient between some soil properties and MWD showed that ESP and SAR had significant effect on MWD.

Table 11: Mean weight diameter of soil aggregates

Mean weight Diameter of soil aggregates (g)					
Sheet Erosion	**Gully Erosion**	**Badland Erosion**	**Rill Erosion**	**Badland Erosion**	**Gully Erosion**
0-30 cm				**30-45 cm**	
17.1	18.2	18.9	17.8	18.9	17.6
18.0	19.1	18.6	12.9	18.6	18.2
17.0	18.5	17.9	13.8	17.9	18.4
17.3	18.8	17.8	13.8	17.8	17.9
17.9	18.7	18.5	16.9	18.5	18.6
17.7	18.9	18.4	15.6	18.4	18.5
17.5	19.0	18.5	14.0	18.5	17.9
17.8	18.6	19.0	12.8	19.0	18.1
17.9	18.4	18.2	17.2	18.2	18.8
17.5	18.2	18.1	17.5	18.1	18.9
17.7	18.3	18.8	15.2	18.8	18.5
17.0	19.2	18.9	15.4	18.9	18.7

Table 12: Physical properties of different form of erosion at ravine

	PD	**BD**	**MWD**	**LL**	**PL**	**PI**	**Sand**	**Silt**	**Clay**	**Silt + fine sand**
0-30cm.										
sheet erosion	2.6	1.33	17.53	69.66	38.66	31	36.5	31.33	32.16	63.5
rill erosion	2.63	1.32	15.24	53.33	27.8	25.5	34.16	32.16	34.25	64.66
Gully	2.66	1.33	18.65	63.66	34.5	29.16	34.83	31.91	33.1	64.25
Badland	2.66	1.33	18.46	57.41	30.5	26.91	35.75	33.25	31.66	62.5
30- 45										
Gully	2.65	1.32	18.34	58.25	31	27.25	34.58	32.83	33.66	63.91
Badland	2.65	1.32	18.46	54.33	27.66	26.66	34.91	33	33.41	63.75
SD	0.11	0.47	0.39	3.31	2.99	3.95	2.6	2.98	1.49	2.6
Cv	0.064	4.16	2.02	38.44	24.04	15.68	6.57	6.9	3.78	4.79

Atterbergs Limits (Liquid Limit, Plastic Limit and Plastic Index)

Average liquid and plastic limit in sheet erosion was 69.7 % and 38.7 % along with plastic index of 31.0. Gully erosion at surface area shows average 63.7 % liquid limit and 34.5 % plastic limit whereas plastic index of gully erosion was 29.2. Surface badland erosion noted average value 57.4 %, 30.5 % and 26.9 for liquid limit, plastic limit and plastic index respectively. Average liquid and plastic limit in rill erosion at surface level was noted 53.3 % and 27.8 % along with plastic index of 25.5%. Badland erosion at subsurface area shows average 54.3 % liquid limit, 27.7 % plastic limit and 26.7 plastic index. Underlying surface of gully erosion noted average value 58.3 %, 31.0 % and 27.3 for liquid limit, plastic limit and plastic index respectively. (Table 12). The relationship of LL with PL(r = 0.809**), was and positive and highly significantly, positive and significant with PL (r= 0.615) (Table 4.18). Plastic Index was negative and highly significantly clay (r = -0.909**) (Table 13). Soil sample collected from different layer in both surface and subsurface of soil shows average liquid limit of 59.4 %, plastic limit 31.7% and plastic index 27.8 %. Both the liquid and plastic limits depend upon the amount and type of clay present in the soil. A soil with a high clay content usually has high LL and PL, Colloidal clays have higher LL and PL than non-colloidal clays, Sand, gravel and peat have no plasticity, their PL= 0, Silts have plasticity only occasionally, their PL being equal to or slightly greater than 0. Soil samples collected from research area indicates that soil ranges between silt to clay type of soil.

Particle size distribution (%)

In the soil sample of sheet erosion have 36.5%, 31.3%, 32.2% and 63.5% of sand, silt, clay, and sand with silt, respectively. In case of surface gully erosion sand represents 34.8 %, silt shows 31.9%, clay 33.1 % and sand with silt noted 64.3 % share in soil. In badland erosion, sand occupied 35.8 %, silt 33.3 %, clay 31.7 % and sand with silt 62.5 % respectively. For surface rill erosion, sand noted 34.3 %, silt 32.2 %, clay 34.3 % and sand with silt occupy 64.7 %. In case of sub surface badland erosion, percentage of particle for sand noted 34.9 %, silt 33.0 %, clay 33.4 % and sand with silt 63.8 % correspondingly. Gully erosion shows particle size share of sand 34.6 %, silt 32.8 %, clay 33.7 % and sand with silt 63.9 % (Table 12). Clay showed positive and high significantly correlation with sand +silt (r = 0.893**) (Table 4.18). Type of soil present in experimental area shows silt to clay structure. Share of each texture was distributed according to soil type. Similar readings were presented by Ezochi (2000), and Belmonte *et al.* (2002) [1].

Table 13: Correlation Co-efficient between soil properties

	Ph	**EC**	**ESP (%)**	**SAR**	**CEC (meq/100g)**	**CaCo3**	**Mg+Ca+**	**OC (%)**	**PD (g/cm3)**	**BD (g/cm3)**	**MWD**	**LL**	**PL**	**PI**	**Sand**	**Silt**	**Clay**	**Sand+ Silt**
Ph	1																	
EC	0.21569NS	1																
ESP (%)	-0.08832**	0.23942NS	1															
SAR	-0.37755NS	-0.40750NS	-0.20727NS	1														
CEC (meq/100)	0.40331NS	0.16768NS	-0.2723NS	-0.03046NS	1													
CaCo3	-0.24430NS	-0.20041NS	-0.10474NS	0.21016NS	0.07237**	1												
Mg+Ca+	-0.11834NS	0.12515NS	0.73467**	-0.3995NS	-0.3827NS	-0.2809NS	1											
OC (%)	-0.2257NS	-0.37280NS	-0.14306NS	0.60685*	-0.05775NS	0.10151NS	-0.28577NS	1										
PD (g/cm3)	0.32708NS	0.30391NS	-0.18967NS	-0.5869NS	0.28561NS	-0.0560NS	-0.046909NS	-0.5465NS	1									
BD (g/cm3)	-0.15262NS	-0.1040NS	-0.42068NS	0.25063NS	0.34400NS	0.1177NS	-0.4771NS	0.12658NS	0.07593**	1								
MWD	0.11458NS	-0.04601NS	-0.67990*	0.08536**	0.4868NS	0.3752NS	-0.6136*	0.03196NS	0.2321NS	0.43907NS	1							
LL	-0.22171NS	-0.32498NS	-0.45595NS	0.6455*	0.08736**	0.2209NS	-0.4096NS	0.53027NS	-0.33538NS	0.3376NS	0.44975NS	1						
PL	-0.25888NS	-0.31058NS	-0.365115NS	0.61233*	0.03842NS	0.23609NS	-0.33472NS	0.37848NS	-0.29871NS	0.35216NS	0.34079NS	0.809529**	1					
PI	-0.02984NS	-0.13624NS	-0.2859NS	0.27678NS	0.09712**	0.05912NS	-0.24799NS	0.39453NS	-0.16989NS	0.10201NS	0.30806NS	0.61544*	0.03549NS	1				
Sand	0.17720NS	0.03784NS	-0.1471NS	0.1217NS	0.2073NS	0.07455**	-0.28046NS	0.25016NS	-0.02271NS	0.008835**	0.01858NS	0.22911NS	0.30021NS	0.01304NS	1			
Silt	-0.11915NS	0.03101NS	0.033187NS	-0.05319NS	0.02965NS	0.08232**	-0.1168NS	0.10554NS	0.2354NS	0.16475NS	-0.0653*	-0.14966NS	-0.02106NS	-0.2264NS	0.19024NS	1		
Clay	0.10181NS	0.01373NS	0.39508NS	-0.18285NS	-0.16717NS	0.29987NS	0.53208NS	0.24326NS	0.075296**	-0.3733NS	-0.3076NS	-0.1659NS	-0.14224NS	0.09092**	0.12495NS	0.13975NS	1	
Sand+Silt	-0.29007NS	-0.1106NS	0.31055NS	-0.12331NS	-0.2671NS	0.16348NS	0.43771NS	0.14392NS	0.03376NS	-0.1112NS	-0.3245NS	-0.13546NS	0.013494NS	-0.2487NS	-0.1804NS	0.36096NS	0.08936**	1

* = significant at, p=0.05

** = highly significant at, p=0.01

Conclusion

The present study revealed that surface soil of sheet, rill, gully, and badland erosion was slightly alkaline to moderately alkaline in nature; whereas subsurface sites of gully and badland erosion site shows moderately alkaline nature. Since sands have low conductivity and clays have high conductivity, soil electrical conductivity correlates very strongly with particle size and soil texture. The presence of excessive amounts of exchangeable sodium reverses the process of aggregation and causes soil aggregates to disperse into their constituent individual soil particles. The particle density is higher if large amount of heavy minerals such as magnetite; limonite and hematite are present in the soil. The bulk density varies indirectly with the total pore space present in the soil and gives a good estimate of the porosity of the soil. Bulk density is of greater importance than particle density in understanding the physical behavior of the soil. The plasticity index is expressed in percent of the dry weight of the soil sample. It shows the size of the range of the moisture contents at which the soil remains plastic. In general, the plasticity index depends only on the amount of clay present. It indicates the fineness of the soil and its capacity to change shape without altering its volume.

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