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The effects of soil physical characteristics on gully erosion development in Kohgiloyeh & Boyer Ahmad Province, Iran.

[1]Shahrivar, A., [2]Christopher, T.B.S.

[1,2]Faculty of Agriculture, Department of soil science, University Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia.
[1]Jahad Sq. Agricultural and Nutural Resources Research Center, Department of Watershed Management, Yasuj, Kohgiloyeh & Boyerahmad.

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ABSTRACT

Gully erosion is an important form of soil erosion in arid and semi arid lands of Iran. This form of erosion is an key procecces of land degradation. This paper focuses on the some basic aspects of role of soil physical properties upon gully erosion in semi aride region of 210 km^2. For this case, Abgendi watershed which has the largest amount of gully erosion was selected. In this area 35 gullies were studied. From main water way of each gully, soil sampling from head-cut & two walls in two depths (0-30 cm & 30 cm to bottom of gully) were carried out. To compare the soil physical properties in different sizes of gullies, the gullies were classified based on gully volume in four sizes big, medium, small and very small gully. To identify the role of gully soil texture as the important physical characteristic on the gully erosion development the gullies were also classified and compared based on soil texture. Moreover, to compare the soil physical characteristics of gully to the control (the area without gully), using the gullies scattering map and field survey the study area, three control areas with at least 5 hectares were chosen randomly as the control in the study area. In each control area five samples of the depth 0 – 30 cm were taken and mixed then one of them was taken. For depth 30 – 60 cm, was done the same process. For both gully and control samples, soil physical characteristics such as clay, sand, silt, soil texture, AS (aggregate stability) and MWD (main weighted diameter) were determined. In addition these factors, gully volume and gully length as independent variables and two important indexes of gully erosion development were measured. The result of the comparison between the gully volume groups showed that MWD in deeper layer and AS in both deeper and surface layer were increased from big gully to very small gully. The results of soil texture comparison in soil texture groups showed that the gully length and volume were increased from loam to clay loam. The gullies frequency were also showed that gullies have silt loam and silt clay loam texture in their surface and deeper layer respectively had the most frequency, while, the gullies with silt loam in their surface layer and loam in deeper layer have the least number of gullies. Moreover, comparison of the gully and control indicated that there is a significant difference between both two areas in terms of sand and silt, as the amount of sand and silt the control areas are higher than the gully erosion areas.

Key words: gully erosion, kogiloyeh and Boyerahmad, soil physical charateristics, gully volume, gully length.

Introduction

Gully erosion is one of the types of water erosion that development of it can cause severe soil degradation. Gully is considered to be one of the most important soil erosion processes [8]. At one time it was thought that gullies developed as enlarged rills but studies of the gullies revealed that their initiation is more complex process [6]. Gully is a channel with a minimum width and depth equal to 0.3 m and 0.6 m respectively by Brice [1]. Imeson & Kwaad [5] were used minimum depth of gully equal to 0.5 m. Gully erosion is one the form of accelerated soil erosion and the occurrence of gullies often indicates an extreme form of land depredation warranting special attention [15]. gully erosion usually represents a permanent loss of soil where agricultural production proceeds without appropriate protective measure and re-cultivation [16]. Although this type of erosion is one of the most damaging erosion, but the studies on it has started in the world since 1930 and in Iran since 1990s [9]. During the past twenty years, many researchers paid attention to the process of rill and sheet erosion while some

Corresponding Author:
Shahrivar, A., Faculty of Agriculture, Department of soil science, University Putra Malaysia, 43400 UPM, Serdang, Selangor, Malaysia.

researchers have showed that rill and sheet erosion on the plot is not an ideal indicator of the total amount of soil erosion [4]. In the past decades, priority of research has been given to address agricultural issues at the plot scale and thus to rill and inter-rill erosion [13]. Nowadays, gully erosion is a major process of land degradation in arid and semi arid of the world. Researchers have showed that causes of gully erosion initiation in different climates can be different. Poesen, Nachtergaele *et al*. have indicated that in many landscapes under different land use has been observed the presence and dynamics of various gully types such as ephemeral gullies, permanent or classical gullies and bank gullies. Gullies not only occur in marl (clay + lime) and mountainous or hilly regions but also more globally in soils subjected to loess (European belt, Chinese Loess Plateau, North America) and sandy soils (Sahelian zone, north-east Thailand) or in soils prone to piping and tunneling such as dispersive soils [13]. Soil properties, rainfall and runoff intensity, wind action, geological, hydro-geochemical and geotechnical characteristics, and anthropogenic activities are factors generating soil and gully erosion processes [3]. The studies have been shown that soil physical properties can be effective on sully erosion development. In this case, the studies of dry regions of Iran indicate that sediment production due to gully development is related to three variables including drainage area, silt and sand percent of the watershed above the gully heads [10]. Sand, sandy loam and loam textured soils tend to be less erodible than silt, very fine sand, and certain clay textured soils [14]. According to study by Raisi *et al*, demonstrated that gully depth has a direct relationship with clay content. The study area is a dry area where is located southwestern Iran. The geographical location, climatic conditions and dry winds blowing in Iran have caused over 80 percent of the country's total area (164 million hectares) of land to have dry and semi dry conditions to an extent that the rate of rainfall in these regions is between 50 to 350 mm per year. This condition is suitable to soil erosion. The average of soil erosion in Iran was reported in 1999 more than 20 tons per hectare annually [12]. Last report of average of soil erosion in Iran in 2010 was reported over 30 tons per hectare (i.e about 6 time more than the limit soil erosion). This warning becomes more serious when annually, 600,000 hectares of farmland in Iran are destroyed annually that 500,000 hectares of these areas are under effect the gully erosion. Moreover, the studies by Soufi [11] have shown that important damages due to gully erosion in different area of Iran can be including disconnection rural roads and bridge breakage, recession of water table, immigration of rural people and movement of the location of villages. Therefore, to prevent, control or reduce all the damages due to soil erosion, the best way to combat in each area, identification the factors which affecting soil erosion as the first measure. Researchers have also shown that knowing the effective factors in forming and expanding the gully erosion is necessary to carry out the effective control and prevention programs. So, some soil important characteristics of the gullies to identify the most effective factors were determined and statistical analyzed. The important objectives the research are determining the factors that have important role in gully erosion development to identify the most susceptible area to use in control programs. Moreover, lake of comprehensive reasearch on this topic in south of Iran, formed the main incentive to carry out the present paper.

Materials and methods

Abgendi sub-catchment with the largest number of gully erosion was selected. This area is one of the sub catchment of Khirabad river with 21000 hectares in the south of Kohgiloye Boyerahmad province (fig. 1). This region is from 45°, 23́ to 47°, 56́ longitude and 30°, 13́ to 33°, 52́ latitude. In this area average annual rainfall is 380 mm and average altitude is more than 450 meters above sea level. Land use the region are consist of poor range (vegetation cover < 25%), good range (vegetation cover > 50%) and dry farming with areas 11970, 5460 and 3570 hectares respectively. About 90% of the gullies occur in poor range land use. In this study the maps gullies scattering were prepared using GIS software. By revisiting the field and gullies scattering map all the gullies were coded and 35 gullies were chosen randomly from them. In order to determine the soil physical characteristics, soil sampling of the gullies was taken with two replications such as head-cut and two walls in two depths of soil (0-30 cm and 30 cm to gully bottom) (fig 2). After sampling from two walls and head-cut were taken soil samples of the depth 0 – 30 cm and mix them then was taken one mixed sample. For depth more than 30 cm, were followed the same process (in this paper 0-30cm and 30 to bottom of gully are called surface layer and deeper layer respectively). To compare the soil physical characteristics of gully to the area without gully using the gullies scattering map and revisiting the study area, three areas without gullies with at least 5 hectares were chosen randomly as the control. In each control area soil sampling from the depth of 0-30 cm and 30 – 60 cm were randomly done. Five samples of the depth 0 – 30 cm were taken and mixed and one of them was taken. For depth 30 – 60 cm, was done the same process. Each sample of gully and control was analysed in soil lab to determine soil characteristics such as: silt, clay and sand percentage, mean weight dimension (MWD) and aggregate stability (AS) (wet sieving apparatus was used). In order to gully volume regarding the gully width uniformity, each gully was divided into segments different lengths. In each segment, depth, top and bottom width of gully cross section were measured

by tape meter and between adjacent cross sections was 2 meters [2]. Regarding the cross section and length of each segment, volume of each segment was measured separately. Total segments volume is made up volume of a gully. In this study, after determining all considered factors, the gullies were classified based on gully volume in four groups including big gully (volume > 200 cubic meter), medium gully (volume = 100 – 200 cubic meter), small gully (50 – 100 cubic meter) and very small gully (volume < 50 cubic meter). In addition to this classification, the gullies were classified based on soil texture. In order to compare the categorized gullies in terms of gully soil physical characteristics One Way Anova were used. Moreover, comparison between deeper layer and surface layer of gully independent sample t-test was used.

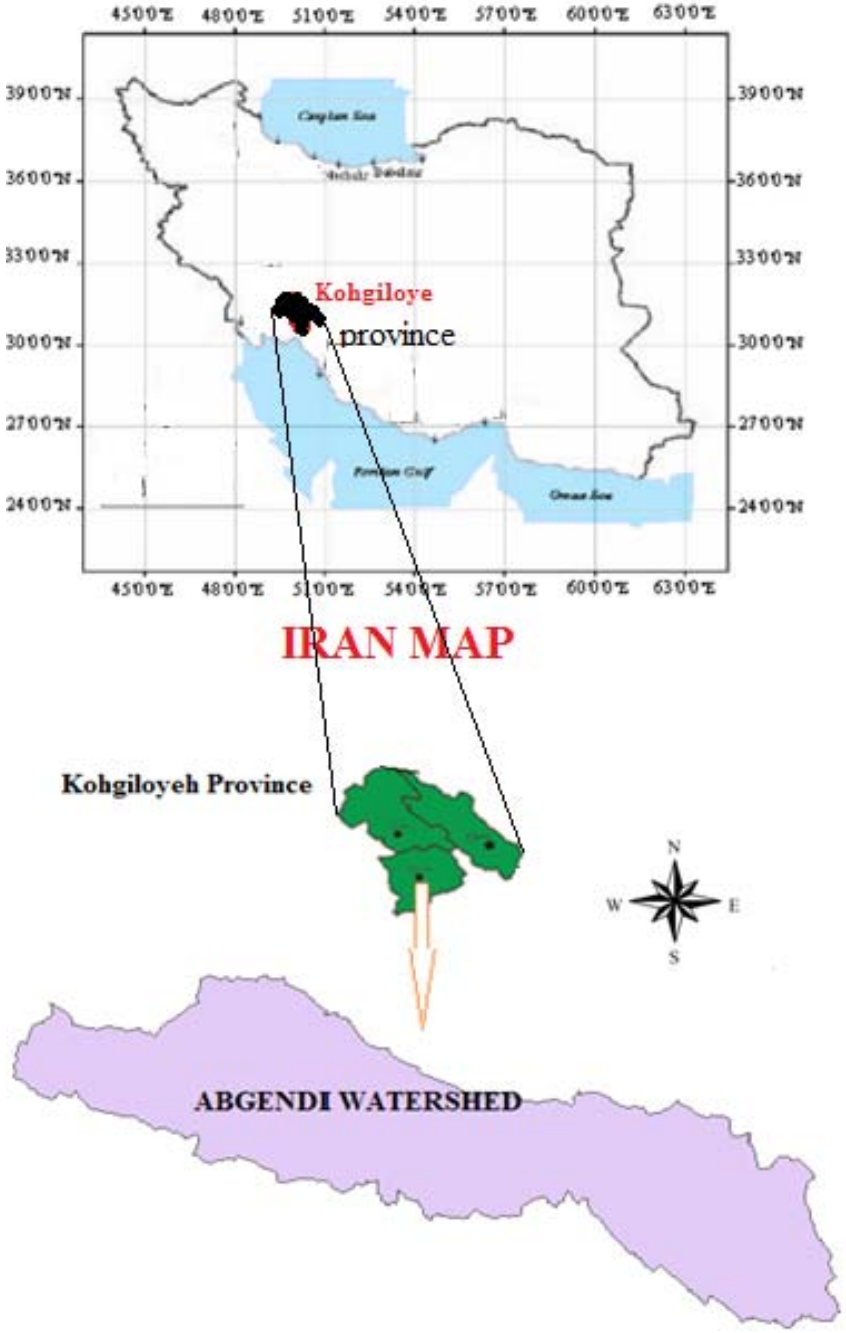

Fig. 1: Location of study area (Abgendi Watershed).

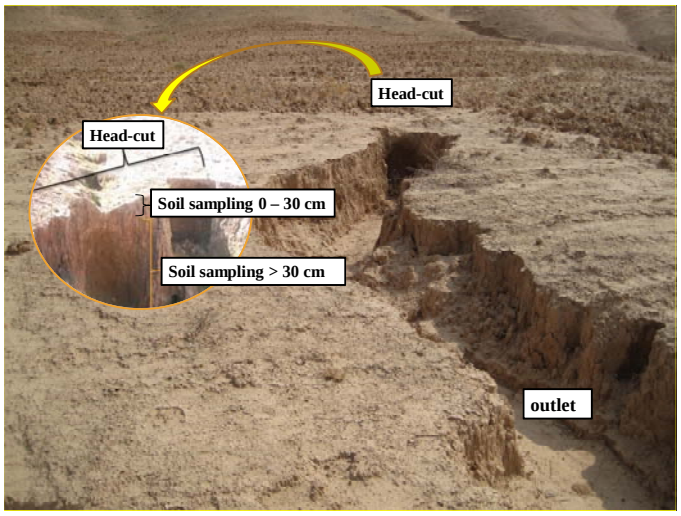

Fig. 2: Gully erosion & soil sampling location.

Results:

Soil texture:

In this study based on the USDA soil classification scheme (soil texture triangle method) five groups of soil texture such as loam, silt loam, silt clay loam, clay loam and clay in gully deeper and four groups including loam, silt loam, silt clay loam and clay loam in gully surface layer were determined.

The results of soil texture and frequency of gullies showed that the most of gullies were happened in the soil with silty clay loam and silt loam in their surface and deeper layer, while the least of gullies were happened in the soil with loam in their surface and deeper layers (table 1).

Comparison the soil texture groups in terms of gully volume & length:

Soil texture were categorized that including loam, silt loam, silt clay loam, clay loam and clay. These five groups were investigated in terms of gully volume and gully length in both two surface layer and deeper layer of gully (table 2 & 3), (figures 3 - 6). To compare the soil texture groups One Way Anova was used and the result showed that although there is no significant difference between the groups in terms of gully volume and length, mean values of gully volume and length is increased from loam to clay texture (table 2).

Comparison the gully volume groups in terms of soil physical properties:

The result of comparison between the gully volume groups showed that there is only significant difference between big gully and small gully group, as the amount of AS (78.5%) the gully surface layer of small gully group is higher than the AS (63.68%) of big gully in the same depth (table 4). In this case, correlation between the soil physical properties and gully volume and length were statistically carried out and the results indicated that there is a negative relationship between AS of surface layer and both gully volume and length (table 5).

Comparison between gully surface and deeper layer:

To compare the soil physical properties of two depths of gully, independent sample t-test method was used and equality of variances was tested by Levene's test. The results of the comparison showed that there is a significant difference between surface layer and deeper layer of gully in terms of clay, silt and AS at the 0.01 level (2-tailed) (table 7 & figures 7). The percentage of clay in deeper layer (mean value = 29.63%) is higher than percentage of clay in surface layer (25.1%). While the percentages of AS (72.3%) and silt (53%) in surface layer higher than these two factors 60.3% and 29.62% respectively in deeper layer (table 6). In this case there is not significant between two depths of gully in terms of sand and MWD.

Comparison between control area and gully soil texture:

To compare between gully and the areas without gully as control in terms of soil texture, soil texture of these areas were determined. In this case the result revealed that control areas have loam soil texture as dominant soil texture in surface and deeper layer that show highly amount of sand in control areas compared the both two depths of gully, while, gully soil have dominant soil texture such as silty loam and silty clay loam in surface and deeper layer respectively that indicates highly amount of clay (table 8).

Table 1: Frequency of gullies in different soil textures of surface and deeper layer.

Soil texture	surface layer		deeper layer	
	Gully frequency	%	Gully frequency	%
loam	5	14.3	7	20.0
Silt - loam	19	54.3	4	11.4
Silt-clay loam	10	28.6	17	48.6
Clay- loam	1	2.9	6	17.1
clay	0	0	1	2.5

Table 2: Mean value of gully volume & gully length in soil texture groups in the deeper layer.

Texture	Gully volume mean value	Gully length mean value
loam	65.9886	38.2214
silt loam	75.2075	39.7825
silt clay loam	85.9382	40.1606
clay loam	181.8167	94.4933
clay	242.0000	61.5500

Table 3: Mean value of gully volume & gully length in soil texture groups in the surface layer.

Texture	Gully volume mean value	Gully length mean value
loam	51.4860	26.8840
silt loam	114.2689	48.9263
silt clay loam	103.6580	64.5900
clay loam	91.4800	37.2000

Table 4: Mean value of soil particle percentage in gully volume groups.

	Gully surface layer					Gully deeper layer				
	silt	sand	clay	AS	MWD	silt	sand	clay	AS	MWD
VS	51.9375	23.8125	24.2500	75.0319	1.6637	49.13	22.28	28.91	64.9003	1.7347
S	55.1429	20.0000	24.1429	78.5107	1.7057	51.50	20.07	28.43	52.2343	1.6436
M	55.7143	16.9286	27.3571	66.1929	1.6607	49.43	18.07	32.50	59.8136	1.6729
B	53.0000	21.0000	26.0000	63.6800	1.6600	45.40	25.00	29.60	57.2860	1.6190

Table 5: Correlation between soil physical properties and gully volume and length.

	Surface layer					Deeper layer				
	sand	silt	clay	MWD	AS	sand	silt	clay	MWD	AS
Gully volumeA3	-.255	.165	.249	-.031	-.356*	-.008	-.155	.154	-.325	-.196
totallengthA3	-.213	.129	.234	-.104	-.392*	.026	-.178	.131	-.304	-.313

Table 6: Mean values of soil physical properties in two depths of gully.

depth	AS	MWD	CLAY	SAND	SILT
surface layer	72.3381	1.6710	25.1000	21.2714	53.4857
Deeper layer	60.2620	1.6876	29.6286	21.3857	29.6286

Table 7: Independent Samples Test.

	t	df	Sig. (2-tailed)	Mean Difference
AS	4.31208	68	.000	12.07614
MWD	-.48112	68	.632	-.01657
CLAY	-3.85337	68	.000	-4.52857
SAND	-.06371	68	.949	-.11429
SILT	18.3914	68	.000	23.85714

Table 8: Control areas soil texture.

Control No.	depth	Sand%	silt %	Clay%	Soil texture
1	control 0-30 cm	28	50	22	loam
2	Control 0-30 cm	44	44	12	loam
3	control 0-30 cm	40	26	34	clay loam
1	Control 30-60 cm	26	48	26	loam
2	control 30-60 cm	46	38	16	loam
3	control 30-60 cm	52	24	24	sandy clay loam

Table 9: Mean value of gully and control soil physical properties in two depths.

Soil physical properties	control surface layer	gully surface layer	control deeper layer	gully deeper layer
Sand	37.34	21.28	41.34	21.39
Silt	40	53.49	36.67	29.63
Clay	22.67	25.1	22	29.63
AS	67.76	72.34	59.9	60.27
MWD	1.76	1.68	1.69	1.69

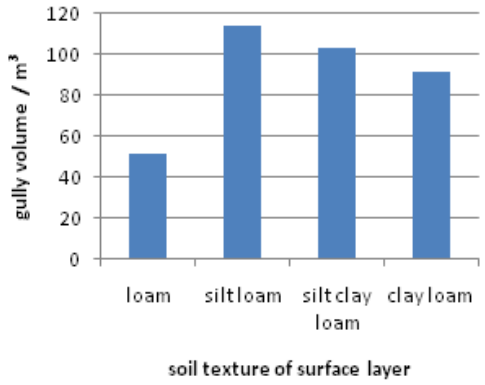

Fig. 3: Gully volume in different soil texture groups of soil surface layer.

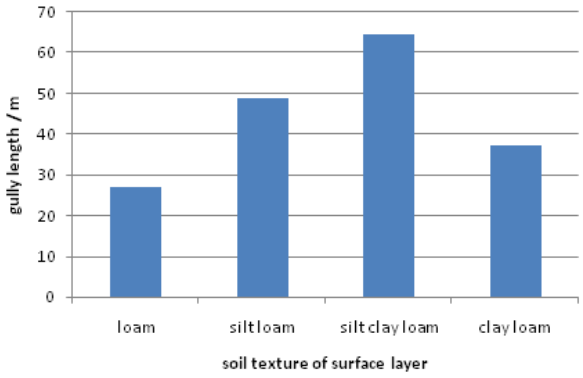

Fig. 4: gully length in different soil texture groups of soil surface layer.

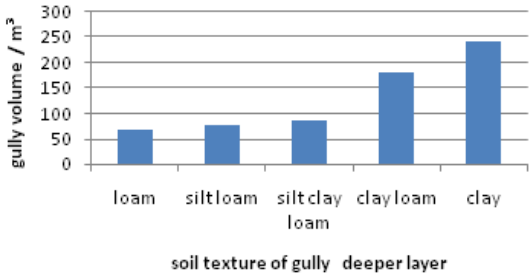

Fig. 5: gully volume in different soil texture groups of soil deeper layer.

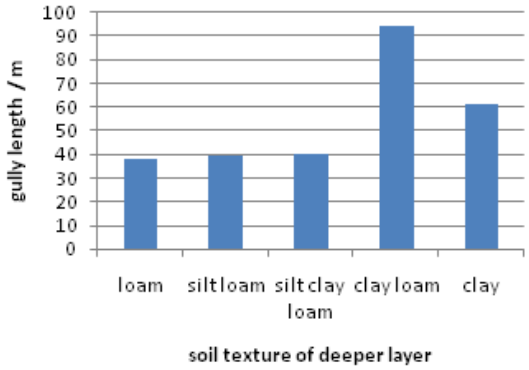

Fig. 6: gully length in different soil texture groups of soil deeper layer.

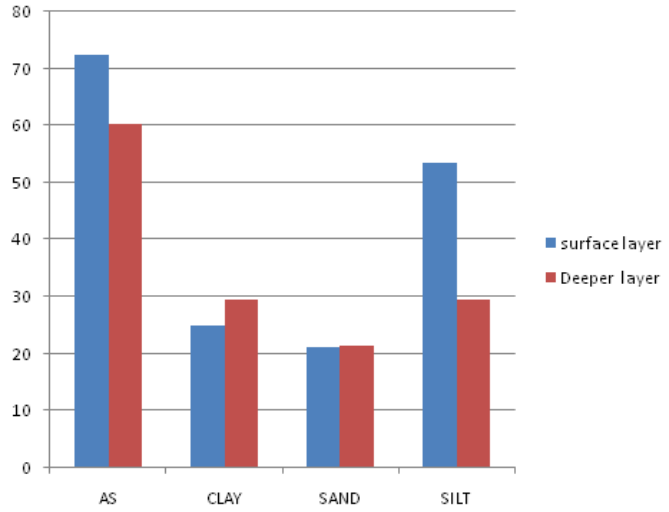

Fig. 7: The soil physical properties in two depths of gully.

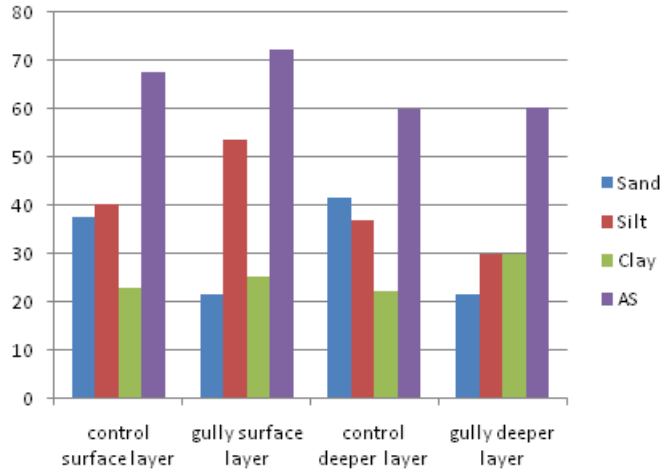

Fig. 8: The soil physical properties in two depths of gully & control.

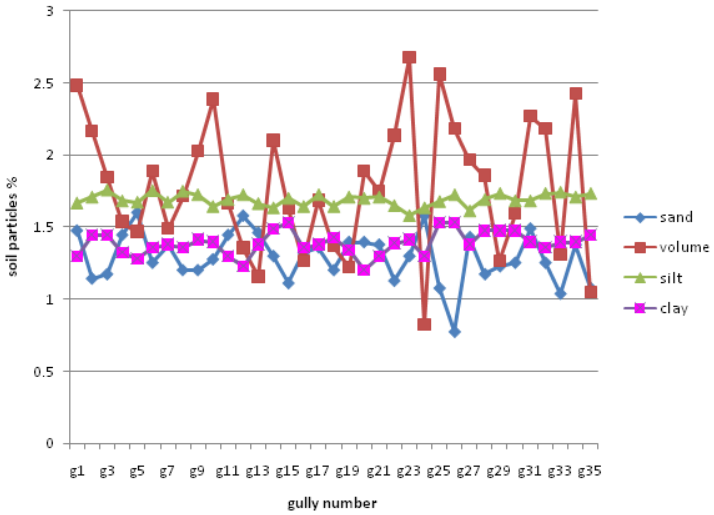

Fig. 9: Gully volume and percentages of soil particles the gullies surface layer.

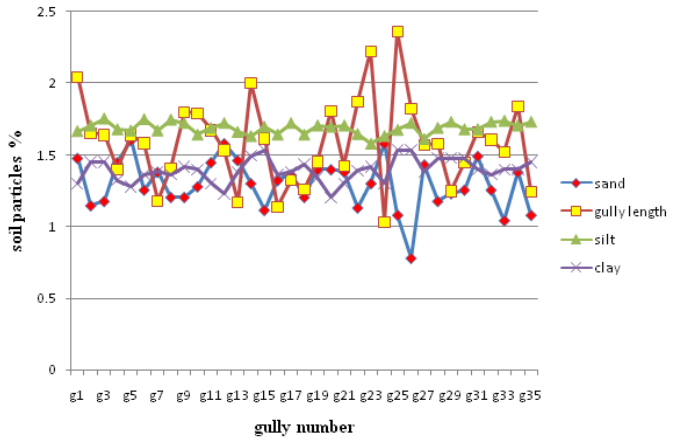

Fig. 10: Gully length and percentages of soil particles the gullies surface layer.

Comparison between control and gully in terms of soil physical properties:

To compare the control with gully areas, One Way Anova method and SNK (Student Newman Keuls) test was used. The results of comparison between control and gully areas showed that there is significant difference between gully and control in terme of sand at the 0.01 level (2-tailed) in both two depths of gully to the same depths of control area (figure 8). The percentage of sand in surface layer (37.3 %) and deeper layer (41.34) higher than percentage of sand in gully surface layer (21.3%) and deeper layer (21.4%) (table 9). There is also significant between gully and control in terme of silt in surface layer at the 0.01 level (2-tailed). The percentage of silt in surface layer of gully (53.49%) higher than percentage of silt (36.67%) in the same depth of control. SNK test indicated that control and gully in termes of MWD, AS and clay are not significantely different.

Discoussion and conclusion:

Comparison between the gully volume groups in term of soil physical properties showed that except for AS other physical properties of gully volume grops are not significantly different. This is showes that the smaller gullies can be develope to bigger gullies in the next time. Investigation and comparison the soil surface and deeper layers of gullies indicated that AS of surface layer is higher than deeper layer while, percentages of silt and clay in deeper layer is more than surface layer. In this case it can be concluded that erodibility of deeper layer is higher than surface layer. Because low AS and high amount of silt and clay in a soil can cause to decreas the resistanse of that soil to erosion. Therefore, if in this area the soil in depth of 0-30 cm is removed the gully will be larger imidiately. Frequency of gullies in different soil texteure showed that the most number of gullies were happen in the siol with silt loam and silt clay loam in their surface and deeper layer. While, the least number of gullies have been created in the soil with clay loam and clay in their surface and deeper layer respectively. Moreover, the comparison between the gully texture groups in terms of gully volume and length indicated that gully length and volume is increased from loam to clay texture in both two depths. However the number of gullies with clay texture in their two layers are the least, the volume of the gully with this texture is the most.

The result of comparison between the gully soil and control showed that dominant soil texture of control is loam in both two depths while, dominant soil textures of the gullies in surface and deeper layer are silt loam and silt clay loam. Morover, investigation and comparison the gully and control demonstrated that amount of silt in both two layers of control is lower than gullies while, percentage of sand in surface layer of gullies higher than control. Therefore, the gully area because of low sand in it`s surface layer and decreasing the infiltration, production of runoff is increased to gully erosion initiation. These procces are vise versa in the control. In this case Øygarden [7] demonstrated that gullies are extended strongly with increasing the propertion of silt to sand ephemeral.

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