DESERT

Desert
Online at http://desert.ut.ac.ir

Desert 22-2 (2017) 157-166

Analysis physical and chemical properties of soil and morphometric impacts on gully erosion

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Received: 26 June 2016; Received in revised form: 12 September 2017; Accepted: 28 September 2017

Abstract

It is widely known that the development of gullies causes the loss of a great amount of soil and can be considered as one of the principal causes of geo-environmental degradation. The study area of the present research is located in the eastern shores of Urmia Lake. This study sought to evaluate the rate of growth and effective factors on the area's gully dynamic over a year. To achieve this goal, levels of Electrical Conductivity (EC), Sodium Adsorption Ratio (SAR), pH, types of soil, and morphometric analysis were used for categorizing and analyzing effective factors on the creation of gully erosion. In addition, as the climate index, the coefficient of moisture in the area's formation for analyzing the area's gully erosion potential was also employed as relevant indicators. The results based on climate indices show that the area's gully erosion potential is high. Analyzing the taken samples' structures indicated that the constructing components of geological formations provided highly appropriate conditions for vertical and horizontal leveling of gullies because of the weak building of aggregates in a way that the results of the morphometric monitoring of the gullies represent the area's high growth speed and dynamicity. High accumulation of soluble salts especially high values of SAR and EC have led to dissolution erosion that provides the conditions for creating tunnel erosion. The results of the research showed gully erosion formation in the study area and its expansion due to two factors, climate factors together with the chemical and physical characteristics of an area's soils. The results of the present research are of great importance for gully erosion modeling tasks in the study area and can be used as the base of future researches for identifying the relevant criteria and indicators in gully erosions.

Keywords: Gully erosion; Morphometric; Soil chemical properties

1. Introduction

There are three types of water-induced soil erosion: sheet, rill, and gully erosion (O'Geen & Schwankl, 2006). Gully erosion begins when runoff concentrates into channels, and results in the development of rills that enlarge into deep trenches on the land surface over time (Nandi & Luffman, 2012). Gully erosion is one of the different types of soil erosion charged by water that initiation and advancement. Technically speaking, it can tend to the great changes on landscape, degrades the lands, and deteriorates the environment. This type of erosion is one of the most damaging erosions, which studies about it have started in the world since 1930 and in Iran since the 1990s (Shahrivar, 2012). Considering the variety and rate of different factors affecting the initiation and progress of gully erosion that varies from place to place, recognition of the most important factors contributing to gulling that can lead to identify alternative solution for its prevention and control (Sarvati *et al.*, 2008). Formation and behavior of gully erosion processes and consequently formation of gullies are influenced by a group of five factors (topography, precipitation, land cover, physical characteristics of material, and linear predispositions). Topography is a limiting factor, so in case of inappropriate configuration of land surface, gully erosion does not occur. Topography is described by morphometric variables. The system of morphometric

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variables consists of a relatively limited group of commonly used morphometric variables (e.g. slope, aspect, horizontal curvature, etc.) and of a larger group of not so commonly used morphometric variables (Burian *et al*., 2015). Gullies occur when a geomorphologic threshold is exceeded due to an increase in water flow erosivity and/or sediment erodibility (Conoscenti *et al*., 2014). According to the Hungarian classification, gully erosion is one of the processes of linear erosion (Kertész, 2009). A gully is usually defined as a deep channel eroded by concentrated flow of water, removing upland soil and parent material, which is enlarge to be obliterated by normal tillage operations (Conoscenti *et al*., 2014). The greatest threat to the environmental settings of east Urmia Lake plain is the gradual but constant dissection of the landscape through soil erosion by water. Although the incipient stages of soil erosion through rill and inter-rill are common and easily managed by the people through recommended soil conservation practices, the gully forms have assumed a different dimension such that settlements and scarce arable land are threatened. Therefore, gully erosion problems have become a subject of discussion among soil scientists, geographers, geologists, engineers, and social scientists (Igwe *et al*., 1995). Assessment of gully erosion is often based on soil erodibility, an estimate of the soil's ability to resist erosion based on the integrated effect of rainfall, runoff, and infiltration (Lal, 2001). Gully processes have a three-dimensional nature affected by a wide array of factors and processes (Valentin & Poesen, 2005). Gullies are controlled by a variety of closely related factors such as lithology, soil type, climate, topography, land use, and vegetation cover (Ogbonna *et al*., 2011). Some factors such as the physical and the chemical properties of the soil influence erodibility. The erodibility of soils is one of the most important properties that depend on some soil physical and chemical properties. The inherent susceptibility of soils to detachment and transport by various erosive agents is a function of the physical and chemical properties of soil (Dondofema *et al*., 2008). Erosion reduces soil stability and nutrient efficiency by altering the soil's physical, chemical, and biological properties (Lal, 2001; Lobo *et al*., 2005; Santis *et al*., 2010). Further, the state of soil dispersion and erodibility in erosion-prone areas has been related to the exchangeable sodium percentage (ESP), the sodium adsorption ratio (SAR), the sodium percentage (SP), and the total amount of dissolved salts (TDS) of the surface soils (Piccarreta *et al*., 2006; Torri *et al*., 1994). Shahriver *et al*. (2012) concluded that the interaction of Electrical Conductivity (EC) and SAR rises the soil sensitivity to gully erosion. Moreover, these properties not only can increase the susceptibility of soil to erosion, but can limit the vegetation growth on the soil as well. Different soil physic-chemical effects on gully erosion have been discussed by many researchers (Nandi & Luffman, 2012; Battaglia *et al*., 2002). The aim of this study is investigating the rate of growth and the dynamicity of the studied gullies over one year, the chemical and physical properties of the area's soils, and the climatic features for gully erosion in the studied area.

2. Materials and Methods

2.1. The study area

The study area was Osku county which is located in north-west of Iran as a part of the East Azerbaijan province and the city of Osku, an small area at the coordinates of 37° 51´ 30 "latitude and 47 ° 50´ 30" longitude on the size of 2 to 4 km. The average height of the area is 1282 m a.s.l., an area without topography and very low slope toward Urmia Lake (Fig. 1). The vegetation cover of the study area consists of poor rangelands that make it highly vulnerable to the gully erosion hazard (Fig. 2). Considering the geology map of the study area, all area gullies are formed and developed in loose formation of loess fine, alluvial terraces, and alluvial formations containing sand, gravel, and silt with a very high degree of salinity and sodium. According to calculated temperature gradient equations, average annual temperature of the selected stations is 12.6° C. August with the average temperature of 25.8° C is the hottest and January with the average temperature of -1.2° C is considered as the coldest month of the year. The rate of average rainfall of the area's stations is 246.6 mm.

The main data used in this study are topographic and geology maps with the scale of 1:25000 and 1:100000 respectively, as well as meteorological data of temperature and rainfall. Ajabshir, Sharafkhaneh, Sahand, and Tabriz stations have been used as part of dataset as well. Field works and lab operations were also performed to model and investigate the gully erosion potential. The research steps are summarized as follows:

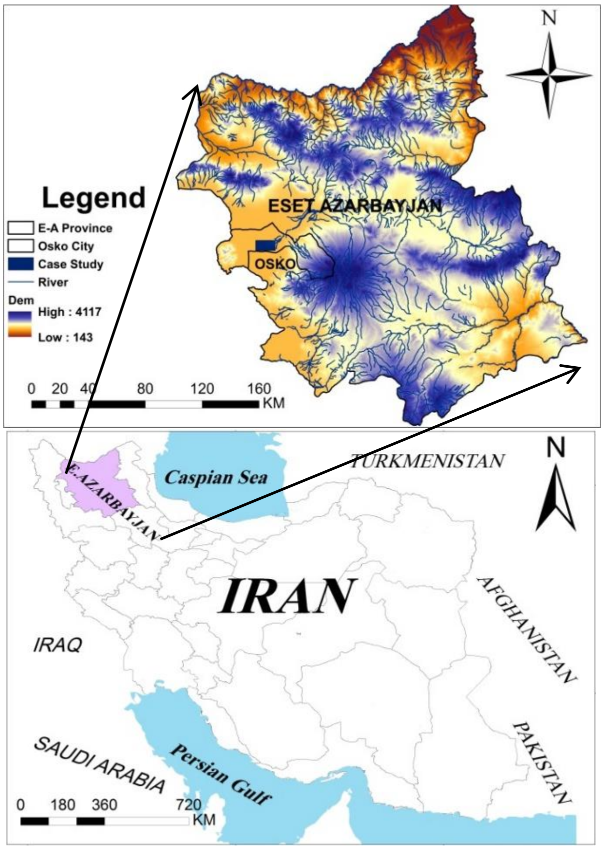

Fig. 1. The location of the study area in Iran and East Azerbaijan

2.2. Field studies

Considering the frequency and uncertainty about the number of gullies in the area, 25 gullies were selected for morphometric analyzing and evaluating the rate of growth. Then the study area of this research was investigated field over the one year. The determined gullies were measured based on the parameters of length for measuring longitudinal leveling, width for measuring the lateral advancing, and the gully depth in July 2014 once. They were measured again in June 10th 2015 in order to determine the rate of growth and the development of study gullies. The created rills in 2014 under the influence of winter rainfall and especially spring showers 2015 have converted to gullies whose morphometric was recorded as well. Categorizing the area's gullies was done based on length parameter, wherein gullies less than 120 meters are considered small, 120-240 meters' medium, and more than 240 meters are considered large (Ahmadi, 2006).

2.3. Lab analysis

To measure soil chemical and physical parameters, 20 samples of combined soil separately were taken from 10 introducing gullies in two depths of soil (0-30 and 30-60 cm) inside gullies. For parameterizing the soil components (clay, silt, and sand), the parameters were measured through hydrometer method. Soil samples were analyzed for Ca, Mg, and Na, and SAR was calculated. The EC of the samples was measured by Electro Conductometer method (Shahrivar *et al*., 2012) and the soil reaction with pH meter. SAR was calculated using Equation 1.

$$SAR= [Na+]/ (([Ca2+] + [Mg2+]) .2) 1.2 \qquad (1)$$

For statistical analysis of chemical and physical properties data of the selected samples, paired-sample T-test in the confidence level of 95% was used.

2.4. Classification of gullies based on EC and SAR

Both EC and SAR are commonly used to classify salt-affected soils. All soils classified in three groups as in table 1 (Shahrivar *et al*., 2012).

Since all soils behave differently, there is no exact definition of sodicity. Christos *et al*. (2010) classified soil desertification risk for the degradation process salinization risk based on EC values in four groups such as EC > 8 dS/m (very high risk), EC = 4 – 8 dS/m (high), EC = 2 – 4 dS/m (moderate), and EC < 2 dS/m (low) (Shahrivar *et al*., 2012). Soil pH has not been shown to directly affect gully erosion. However, a correlation between a change in soil pH and erosion processes has been observed, but as vulnerable for gully erosion, the value of pH= 5.9 and EC= 0.1 is the threshold of piping rill and gully erosion (Abedini, 2013).

Table 1. Classification of soils based on EC and SAR values

SAR	pH	EC (dS/m)	Soil type
<13	<8.5	>4	Saline
≥13	>8.5	<4	Sodic
≥13	<8.5	>4	Saline-Sodic

2.5. Humidity coefficient in the area formation

This coefficient was obtained using climate factors for identifying gully potential of the area. Alternate warm and dry seasons cause in warm seasons with earth drought and withering vegetation, some cracks are created in the level of fine formations and these cracks become the place for watercourses concentration as well as the creation of gully and Rill Erosion at the time of first sudden rainfalls. Therefore, the reduction or negativism of Ws gets importance when after one period of drought among rainfalls as well as misbalancing of earth, the first raining starts.

The coefficient Ws is calculated through the below equation:

$$Ws = R - \frac{Rp}{t} \qquad (2)$$

where t shows monthly temperature, Ws existing humidity, R the average monthly rainfall to *mm*, and Rp the related coefficient to temperature are obtained through the following equation (Abedini, 2013):

$$p = 30\ (t+7) \qquad (3)$$

3. Results and Discussion

3.1. Soil physical and chemical properties

Considering tables (2 and 3) based on values (EC, SAR), the type of the area's soil is sodium salty[1] that has more destructive effects than salty soils and sodium soil. The risk of desertification in the area considering the desertification index of Christos *et al*. (2010) is very high. Considering table 2, the EC value of the area soils is so high that requires serious attention and doing necessary actions. The area's soils have the necessary threshold for linear erosion (piping, rill, and gully) based on (EC=0.1 and pH=5.9) (Abedini, 2013). Therefore, considering the criteria and various scientists' categorizations, the area's soils have high potential in expanding gully erosion provided that other conditions are met. Considering table 2, the texture of study gullies' soils is mainly silt loam. Silt is dominant in all gullies. Based on this, one of the factors for longitudinal and transverse advancing of study gullies is the presence of silt (because of high sensitivity to erosion) in the layers and different horizons of the area's soils. With increasing the rate of silt, soil erosion increases intensively because of the susceptibility of the clay particles (2 to 5 microns) (Rangavar, 2009). The resistance of silt particles against erosion is relatively low in terms of either measure or stickiness. Silt soils are usually seeded well, but because of being humid, aggregates are easily broken and silt particles are separated and transmitted. As water content increases in soil, clay and silt become softer, shifting from a solid to a plastic and eventually to a liquid state once the soil fails to retain its shape. Considering table 2, the value of soil texture fine elements is high. The value of clay is also high in the soil and is higher than 20 percent in all the samples. The smaller texture a soil has, the higher its capacity is for water maintenance. This phenomenon causes the clay's expansion and closing soil's pores so that water infiltration into soil will reduce and surface runoffs will be created. These runoffs gradually dig their ground and make it deep and some waterways will be created that through their aspects' increase, wide gully erosion happens (Fig. 2). Vandekerckhove *et al*. (2000) showed that most studied bank gullies were characterized by a fine earth texture belonging to the silt, silt loam, silty clay loam, loam, and sandy loam class. Moreover, the percentage of sand particles is very low in all samples and the value of existing

[1] Sodium ion has a big hydrate ion diameter and absorbs many water molecules. After absorbing water, it gets swollen, reduces soil influentially, and under the influence of rainfall and watercourses derived from that, soil erosion increases largely (Jha & Kapat, 2009).

sands in samples was very small. It should be considered that the textures of the existing soil fines in the area are the main factors of the formation and development of gully erosion because with increasing the rate of sand (being big), gullies' density and as a result, the possibility of gully erosion occurrence will reduce.

In terms of pH, the area's soils are identified to be poor acidic to neutral. Considering Table 2, the values of EC and SAR are very high in all samples, increasing the rate of soil saltiness and the SAR creates small seed building in soil that as soon as humidity in them, soil's building will decompose. Increasing salt in soil profile besides affecting the concentration of soil solution, may change the complex combination of exchange. Such a change particularly is exchangeable for increasing the percentage of sodium ion because sodium salts are the most dissolution types of salt in nature that their dissolution and releasing sodium causes soil's spreading. On the other hand, high values of sodium cause the reduction of soil water conduction through the phenomena of inflation and expansion of clay minerals. Resistance of aggregates will reduce through the increase of the SAR and as a result, soil erosion will intensify (Esmaeelnezhad *et al*., 2012). Considering table 2, high EC ratio of soil represents increasing dissolved material in it which is a very important factor of the formation tunnel erosion of gully peak (Fig. 2D). Considering the results of this research, the density of sodium and magnesium ions increases the intensity of contraction, further developing cracks and increasing the solubilizing capacity by water penetration. Therefore, deposits that have more calcium and especially sodium ions are more at the risk of dissolution and create deeper tunnels. In addition, creating tunnel erosion in the area is due to the chemical properties of the area's soils. The reason is that the creation of tunnels in underneath floors of the ground happens due to spreading of soil particles, which occurs due to the existence of sodium ion and the impenetrability of the substrates.

Table 2. The physical and chemical properties of soil samples of the study area

Gully Number	Sand (%)	Silt (%)	Clay (%)	EC (dS/m)	SAR	pH	Depth (cm)
1	12.49	64.16	23.34	278	17.3	6.69	0-30
	19.01	60.45	20.54	231	13.9	6.70	30-60
2	9.36	59.32	31.32	253	16.3	6.84	0-30
	11.19	67.12	21.69	246	15.2	6.65	30-60
3	9.05	61.52	29.43	234	14.4	6.74	0-30
	4.99	69.16	25.84	282	16.3	6.80	30-60
4	16.51	62.30	21.19	230	14.6	6.61	0-30
	6.97	65.72	27.31	217	16.2	6.49	30-60
5	11.23	59.21	29.56	248	17.1	6.66	0-30
	10.86	68.32	20.81	254	14.4	6.71	30-60
6	14.88	65.70	19.42	241	16.6	6.74	0-30
	9.99	66.66	23.34	208	18.6	6.62	30-60
7	18.07	60.63	21.30	226	13.8	6.59	0-30
	12.53	64.82	22.65	189	14.4	6.81	30-60
8	13.96	60.32	25.72	231	13.4	6.72	0-30
	10.46	63.13	26.41	212	12.2	6.74	30-60
9	7.49	61.66	30.84	302	15.7	6.78	0-30
	17.87	60.80	21.33	214	13.8	6.80	30-60
10	6.76	68.34	24.90	231	14.7	6.78	0-30
	13.88	63.52	22.60	247	17.2	6.75	30-60

The average of all study variables in table 3 and the selected samples in two groups of surface and underneath soils do not show significant difference in the level of 95%. Better saying, they do not have any differences and all soil's variables are equal in the depths of 0 to 60 cm. considering the properties of the area, all statistic results of Table 3 are absolutely rational. First, the study area in this research is very small, occupying less than 8 kilometers where the whole ground space is completely gullied and almost there is no non-gullied space. Secondly, this lowland area is Ajichay River that is the most important factor of Urmia lake saltiness and during the Quaternary Period, the accumulation of salt deposits has not created significant differences in the physical properties of the depths of 0-60 cm. Moreover, the most important factor is that morphometric control of the area over a year and deep growth of gullies more than usual is not the most important reason of the lack of significant difference in the physical and chemical properties. If it was so, the gully's development should have speeded low or stopped in depths more than 0-60 cm where such occurrence has not been created in the morphometric investigation of gullies.

Table 3. The obtained results of T-test for comparing the average of the values for physical properties of surface and subsurface soils

Variable	Depth (cm)	Mean	Sig	Df	T	Std deviation
pH	0-30	6.71	0.495	9	0.711	0.0786
	30 -60	6.66				0.1758
SAR	0-30	15.39	0.808	9	0.250	1.3955
	30-60	15.22				1.8766
EC	0-30	247.4	0.175	9	1.473	24.649
	30-60	230				27.365
Clay (%)	0-30	25.66	0.206	9	1.363	4.3839
	30-60	23.25				2.4355
Sand (%)	0-30	11.98	0.922	9	0.100	3.8532
	30-60	11.77				4.3424
Silt (%)	0-30	62.31	0.115	9	-1.747	2.9377
	30-60	64.97				2.9842

Sig< 0.05 is significant in level %95 sig<0.01 is significant in level %99

3.2. Analyzing the WS indices in different months of year

Gully erosion is more frequent under arid conditions and less frequent under humid climatic conditions (Poesen *et al*., 1996). Researchers have stated that being periodically dry or wet can reduce tensile strength during seasons. Climate conditions can on the one hand increase clay spreading and as a result, increase tensile resistance of dry aggregates. On the other hand, periodical dryness or wetness can decrease tensile resistance. A soil's clay content plays an important role in the formation of soil aggregates and reinforces soil stability. However, clays with a high swelling potential can have the opposite effect on soil stability. If expansive clays are present, these minerals will swell in the presence of water, and will shrink in dry conditions (Nandi & Luffman, 2012). Repeated shrink-swell cycles may destroy the clay aggregation and lead to further erosion. Further, in dry conditions, clay can shrink, producing internal cracks that may facilitate tunnel or piping erosion. When heavy rainfall occurs, runoffs enter the cracks and erode the soil from within. The tunnels or pipes eventually develop into gullies when the tunnel roof collapses (Crouch *et al*., 1986; Rienks *et al*., 2000). Field observations of the site indicated headward erosion of the existing gullies through the collapse of tunnels or pipes as subsurface runoff emerged spring-like at the head of a gully, similar to channel-head retreat observed in eroding tropical Ultisols (Chappell *et al*., 1999). The value of resistance increases in areas of rupture (due to the joining of the particles) and decreases because of the weakness of weakened areas of rupture (in consecutive dry period) depending on crop management and crop rotation. Analyzing the results of WS index shows (Table 4) that except in month January, in the rest of year's months, WS index is negative. Months of year, which have negative humidity fluctuation, are prepared for gully erosion. Therefore, based on the results of Table 3 of the study area, in the whole year, humidity fluctuation of the soil is prepared for gully erosion; that is, it happens in case of intense rainfall or showers in the area of soil erosion. Therefore, the area's climate conditions are quite prone to creating gully erosion. Global climate change is very likely to increase gully erosion risk. Extreme events are going to be more frequent. In summer, long periods of draught will alternate with storms (high intensity rainfalls). In winter, freezing, melting, and intensive rainfalls will alternate (Kertész, 2009).

3.3. Gully morphometric study

Study gullies' progress is made in two ways, the first one progressing based on head erosion where gully peaks will be done as regressing with falling material into gully (Fig. 2E). Of course, the other progressing type in this case is in the form of concentrating surface flows and investigating linear path in a shape of gully (Fig. 2F) that causes creation of micro-gullies. This process is the beginning of gully erosion as well (Fig. 2C).

Table 4. The results of WS index for year's months in the study area

Month	T	P	RP	WS
January	-1.20	12.85	174	157.85
February	0.33	18.10	220	-648.26
March	5.30	19.57	369	-50.05
April	11.40	36.54	552	-11.88
May	16.46	39.60	704	-3.15
June	21.80	10.14	864	-29.49
July	25.80	8.44	984	-29.69
August	25.60	2.26	978	-35.94
September	21.10	4.37	843	-35.58
October	14.40	8.84	642	-35.74
November	7.50	26.51	435	-31.49
December	1.60	14.70	258	-146.55

Fig. 2. A, a sample of gullies in the study area with a width of 220 cm and a depth of 140 cm, curvature flow and very tangible exploring the front range causes the gully curviness. B, the collapse derived from flow's walls' below cutting is the most important mechanism of the lateral development of gully. Wide amounts of disruption caused by collapse sometimes reaches even 1 meter because of heavy soil texture, collapse is with high volume. C, concentration of watercourses and ahead of the gully erosion because of high volumes of solutes, soil leaching is carried out with great intensity, very high saltiness also creates net gully system. D, tunnel erosion or corrosion of piping at the top of the gully with a length of 35 cm, a width of 25 cm, through collapsing roof, tunnel erosion causes longitude expansion of gully peak. E, development level of net gully systems that causes wide demolish of ground, the witness hill in image should be carefully crafted. F, the first level of rill erosion, which is converted to gully erosion, vegetation, demolishes, and especially protrusions of roots should be paid attention. G, highly activated gully wall with more than 2 meters' height, the direction of flow is cutting below and very large volumes of material will fall into the gully. H, high rate of saltiness in the area, it can be either seen in different horizons of salt dirt streaks or in the surface of earth crystalizing. Cross-section shapes of all the gullies are U-shaped

The other type of progressing is as creating small and big holes in the area around gully's head (piping erosion) (Fig. 2D) in a way that considering the high saltiness of the area's soils (Fig. 2E) and the frequency of highly soluble salts (Table 2), gullies are dissolved from the middle area to lower horizons. Then, the upper levels of gullies also collapse that expands the gullies' length. Piping erosion is formed by concentrated flowing water in soils or unconsolidated deposits, which can cause the collapse of the soil surface and the formation of discontinuous gullies. The dimensions of the pipe can vary widely according to the conditions of formation, specifically the climatic conditions (Verachtert *et al.*, 2010). Tunnel erosion can be seen as horizontal holes in activated gullies' walls and gully grooves. The mentioned holes are passing the primary levels of their evolution and do not have many dimensional aspects. They are between 35 and 60 cm in diameter and up to 20 to 70 cm in longitudinal direction (fig. 2D). The expansion of these holes and then their roof collapse in more advanced levels change gully erosion expansion (Fig. 2D). Developing the width of study gullies in the left and right walls depends on water flow tendency at the time of rainfall. Water flow below cutting and wall emptiness and losing the relying point are the main factors in collapsing under the influence of the forces of gravity and lateral gully expansion (Fig. 2G and 2A). In study gullies, lateral erosion is dominant because firstly during flood flows, due to lateral below cutting of gully, mass ruptures happen that can be seen in concave curvatures (Fig. 2A). Secondly, created watercourse because of very low permeability power in the area causes the creation of tracks around the gully. Those tracks gradually develop and provide the beginning of the secondary gullies (Fig. 2C). The cross-section of the study gullies is U-shaped because of developing loose and intensively soluble lands. The U-shaped section represents the effect of underneath surface watercourses as well (Poesen *et al*., 2003). V-shaped section can only be seen in micro-gullies and gully erosion beginning because of the dominancy of linear erosion of spread flows that in developed levels and the creation of mature gully, the cross-section of all gullies is U-shaped without any exception (Fig. 2). The comparative comparison of the study gullies' morphometric in two periods of 2014 and 2015 represents the high potential of the area for longitudinal growth and lateral development of study gullies. Therefore, based on field studies, during showers, sometimes especially lateral development of gullies included from half to one meter, and the gullies' longitudinal development sometimes reached 10 meters. The data of Table 5 represent the high power and dynamicity of the area's gullying that can destroy high volumes of the area's lands. Basically, gullies are either continuous or discontinuous. Continuous ones are some parts of drainage network while discontinuous gullies are separated from drainage network (Posesen *et al*., 2002). The system of the study area's gullies is discontinuous. The reason is that existing water flows in the area are separated from the development system of the gullies in the area under study, but some part of the area may be affected in the past decades during the flood flow of Ajichay River. However, nowadays because of building dams on Ajichay River on the one hand and dredging the Ajichay River due to opening the path of river for transmission to Urmia Lake on the other, the development of the area's gullies is completely separated from Ajichay River.

The hydrologic flow of study gullies is only provided during wet seasons and by shower raining because of the high concentration of the flow derived from the very low permeability of the area's geological formation. Therefore, the system of study gullies is of the discontinuous type.

Table 5. Comparison of study gully morphometric in two periods of 2014 and 2015

Gully type based on length	2014	Width (m)	Deep (m)	Length (m)	2015	Width (m)	Depth (m)	Length (m)
Medium	1	2.2	1.40	210	1	2.25	1.45	215
Medium	2	2.6	1.10	170	2	3	1.30	182
Small	3	2.2	0.80	91	3	3.05	0.90	95
Small	4	0.8	0.60	42	4	1	0.70	46
Small	5	1.4	0.65	95	5	1.6	0.67	104
Small	6	0.3	0.15	8	6	0.57	0.51	11
Small	7	1.9	1.10	52	7	2.2	1.30	55
Small	8	0.8	0.50	7	8	1.1	0.87	8.5
Small	9	2.3	1.70	74	9	2.5	1.80	77
Small	10	2.7	1.60	67	10	2.9	1.70	71
Small	11	1.4	0.51	41	11	1.5	0.76	44
Small	12	1.2	0.44	58	12	1.4	0.68	62
Big	13	3.4	1.90	500	13	3.6	1.70	500
Big	14	3.1	2.10	500	14	3.5	2.15	500
Small	15	0.6	0.32	6	15	0.71	0.25	6.7
Small	16	0.5	0.25	4.5	16	0.6	0.32	6.2
Small	17	1.9	0.55	15	17	2.1	0.60	17.5
Small	18	1.5	0.40	12	18	1.7	0.50	13
Medium	19	2.4	0.65	120	19	2.6	0.70	130
Big	20	2.2	1.40	250	20	2.6	1.50	253
Medium	21	1.1	0.35	120	21	1.3	0.54	124
Small	22	1.9	0.55	92	22	2	0.62	96
Medium	23	3.1	0.75	140	23	3.3	0.90	148
Small	24	1.2	0.40	65	24	1.4	0.63	68
Small	25	0.7	0.55	32	25	0.82	0.73	36

4. Conclusion

The results of categorizing various soils based on various methods showed that the saltiness degree of the area's soils had been very high and also based on research indices, the risk of desertification was very high in the area. The results of analyzing the texture of the selected samples showed that the fineness of the constituent components of geological formations has provided very appropriate conditions for vertical and horizontal leveling of gullies because of the weak building of aggregates. Moreover, the morphometric monitoring of the gullies represents the area's growth speed and high dynamicity in a way that in small-grain and heavy soils, due to the high percentage of silt (more than 60% in the area's soils) and clay (more than 20%), the saturation percentage (higher than the limit for starting gully erosion) and the percentage of water remaining in the soil increase the risk of developing and creating gully erosion. The field observations and morphometric monitoring of the area's gullies confirm such a state in the area. These results correspond with the results of (Tajik *et al*., 2002; Ahmadi, 2006; Esmaeelnezhad *et al*., 2012; Key & Dexter, 1992). The results of climate indices including the existing wetness in the formations of the area represent the high potential of the area for creating gullies. The results of this part correspond with the results of Posesen *et al*. (2003); Abedini (2013), and Servati *et al*. (2008).

The high accumulation of soluble salts especially the high values of SAR and EC in plain level with very low slope[2] increases the possibility of creating dissolution erosion. We should also pay attention that increasing EC of soil usually is derived from increasing soluble salts in the soil. Increasing soluble salts in the soil severely increases the possibility of creating tunnel erosion especially when dissolution components particularly sodium in the soil have a high ratio which is high in the area's soils. Ghodousi and Davari (2012) concluded in investigating the effect of chemical components on creating gully erosion that the formation and creation of the different types of gully networks is a function of soil saturation percentage and EC in a way that with increasing the existing salts in the soil, the occurrence of tunnel erosion and the creation of compound front gully will severely increase. This is also stated by almost all researchers.

The results of the research showed that the formation of gully erosion in the study area and its development are under the influence of two factors: first, the climatic factors that cause the creation of watercourses and variation in the permeability, and second, the chemical and physical properties of the area's soils. In other words, most of the area's gullies are developed under the influence of shear stress power and the power of carrying concentrated watercourses with the dissolution of existing material in the deposits and soils because of the occurrence of dissolution erosion. In the low-slope area, because of the accumulation of soluble salts, the occurrence of tunnel erosion is high in a way that other factors play the role of the determiner or intensifier of two mentioned factors since one is the erosive factor and the other is considered the erodible factor. The mentioned subject has been stated by a great range of researchers. The results of morphometric monitoring of the area's gullies represent their high growth speed and dynamicity that have high abilities for destroying the existing lands in the area. Field investigation also showed that action and erosion in the forehead, walls, and the floor of gullies are mainly created after severe rainfalls. Based on the results of this research, it is recommended that preventing watercourses' concentration as well as optimizing the chemical and physical properties of the area's soils will be the main factors in preventing the creation and development of gully erosion in the area. Results of this research are also important for governmental departments (e.g. ministry of natural resources, regional water authority, etc.) for a variety of tasks in land use planning and the mitigation of gully erosion in Osuko county. In terms of the method, the results are also of great importance for future researchers in identifying the most effective gully erosion methods.

[2] The formation of gullies in low-slope lands is 6.1 times higher than relatively sloped lands. This rate will increase to 10 times in the spring because in low-slope lands there is a good soil increasing. Moreover, watercourses have adequate opportunities for hydrolyzing, dissolution and separation of components, and getting loose material out (Abedini, 2013).

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