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Lithology effects on gully erosion in Ghoori chay Watershed using RS & GIS

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Abstract

Gully erosion, which is the most damaging effect on soil, is occurred in agricultural lands in Iran and caused diminishing soil fertility and filling dams and reservoirs, also it is a threatening for roads, buildings and agricultural lands.Gullies are the extensive kind of soil erosion and for controlling it, you should know the factors effects on gully extension. One of the factors which control erosion in watersheds is lithological characteristics of the watershed.In this study, after digitizing the lithological map by using ILWIS3.4 software, resistance to corrosion coefficient factor and the map of erosion susceptibility was obtained.The map of gully erosion in watershed was prepared based on the Field trials by GPS, IRS, satellite images and aerial photographs. Finally, by using statistical analysis, the map of susceptible to erosion in ILWIS software was segmented with the gully erosion map. Results showed high Correlation coefficient with 0.97 and indicated gully erosion in Ghoorichay watershed is more influenced by the kind of lithological structure.

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Introduction

One of the main types of water erosion is gully erosion which causes problems and damage natural resources and agricultural lands. So it is one of the most destructive and the most complex types of water erosion.

The morphology of Ghoorichay watershed with two faces, mountains in south, plain and hills in the north. Each faces consists of units of sedimentary rocks, sandstone, and conglomerate. In the plains as well as coarse sediments, silt and clay deposits have been expanded considerably. This area is part of the sedimentary plains of the Moghan plain. In these areas, Different forms of soil erosion like gully erosion can be visible.

Literature Review

Among the three types of rocks: igneous, sedimentary and metamorphic rocks, the sedimentary rocks are generally unstable to corrosion. Variety of lithological formations in the area will increase the work load. Faiznia (1995) based on her studies, divided resistance of lithological formation in different location of Iran in two climate group, humid to semi-humid and semi-arid to arid, by using field observations and aerial photographs. Soil erosion with more depth, such as ditches and canals, are influenced by the type of lithological formation which this phenomenon is clearly visible in the Ghoorichay watershed. Casali (1999) and stotle (2003). Studies demonstrated the important role of lithology in head cut activities.

Ahmadi (2007) indicated gully erosion occurs mainly in Iran on the Neogene formations in semi-arid and arid area with some gypsum and soluble mineral, so basically gullies are formed in marny area with gentle slopes and flat plains with clay soils.

So far, extensive scientific review has not been done in this area to identify factors affecting gully erosion and special features using GIS and RS.

Therefore, according to the gully situation in watershed, aggravation of land degradation and non-systematic exploitation, detailed study of the environmental effects is necessary in the gully erosion such as lithological factor.

Materials and methods

Study area

The study area is Ghoorichay watershed which is located in the north of Ardabil province, with geographic coordinates from 39 '12 to 39° 12' north latitude and 47° 35' to 47° 45' east longitude. This watershed is located in the 20 kilometers of the border between Iran and Azerbaijan with area of 15,267 hectares. The maximum altitude of watershed is 1058 meter and the lowest is 240 meter above sea level.

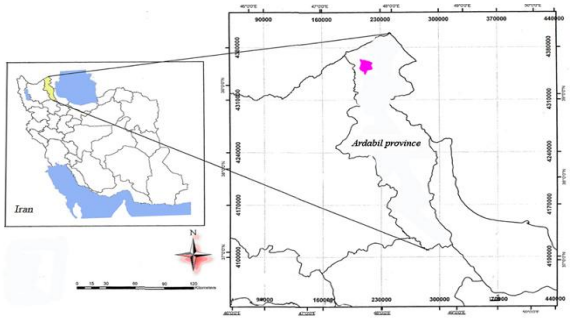

Fig. 1. Location of study area with 1:2500000 scale.

For preparing lithological structure map, the lithological map with 1:100,000 scales has been used. After entering a lithological map in ILWIS3.4 software and determining the border of watershed, lithological formations were digitized. So units with an area less than 25 hectare (size 1 × 1 cm on the map) were combined in a single unit. Therefore, this lithological map of the area was contained 17 kind of lithological structure (Figure 2).

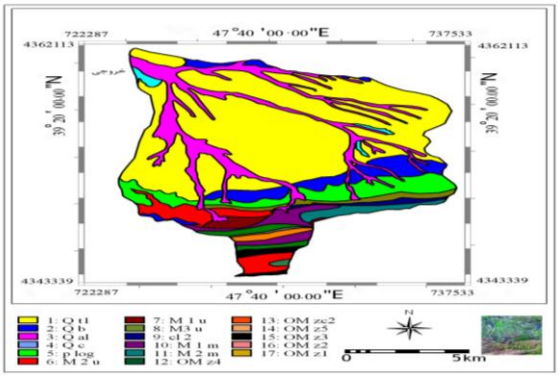

Fig. 2. The map of lithological structure to erosion.

By investigation on the structure susceptibility to erosion, according to the type of stone and by using the Feiznia table, their sensitivity to erosion for each of the structures was obtained, and totally all structures were categorized in three class in very susceptible to moderately resistant to erosion. However, due to the absence of resistant structures in watershed, the classification has been found in three classes (Table 2). Field studies have also confirmed the formation of classification accuracy.

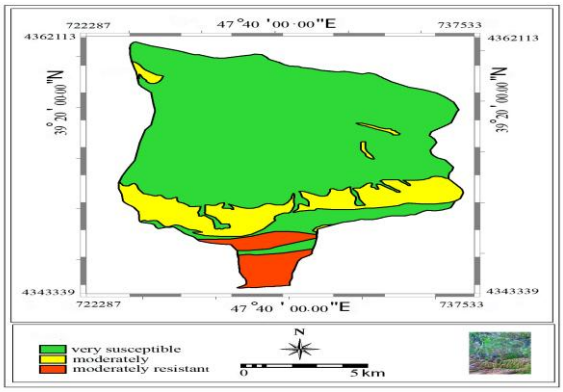

Fig. 3. The map of sensitivity structure to erosion.

In this study to identify areas affected by gully in the field, IRS satellite images and aerial photographs from 2010 were used.

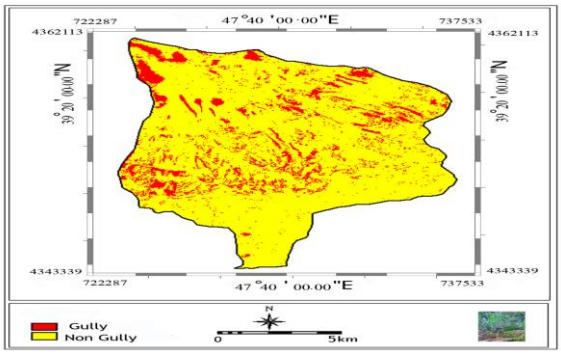

Fig. 4. The map of gully erosion in study area.

After identifying the areas affected by gully erosion, image processing was done by using multi-band images classification in GIS software. There is a problem which is affected the images such as light intensity, angle of radiation, atmospheric conditions, soil type and soil moisture, however this problem has been fixed to some extent by field observation in the GIS software. The method used in this study is supervised classification that is based on soil sampling. By using soil samples in the area, ILWIS 3.4 software will process all the information on the image (Figure 3). For statistical analysis, the susceptibility to erosion map was cut as a data layer with gully erosion map (Table 3) and the relationship between independent variables (Map susceptibility to erosion) and dependent one (percent of gully erosion)were obtained through correlation test method. The highest correlation coefficient (R^2) is obtained to gully occurrence which is shown in equation 1.

Results

Lithological map results

The lithological map of watershed was consisted of 17 structures and the final map was obtained which is illustrated in figure 2. Also table 1 is shown the lithological map of Ghoorichay watershed with the coefficient of resistance against the erosion according to Feiznia table (1995). Investigation of the susceptibility to erosion in Ghoorichay watershed according to the type of the rock and by using Feiznia table, sensitivity to erosion for each type of structures was obtained and finally all structures was divided to four class between sensitive to relatively resistant, also the structures of the pre-Quaternary and Quaternary formations have been separated. However, due to the absence proof of resistance structures in watershed, the actual classification formations in Ghoorichay watershed were divided in three classes which are shown in table 2.

Classes which are very susceptible to erosion are relates to the Quaternary units, Q_T ,Q_b and Q_{aL}, also pre-Quaternary unit M_m^1, C_{L2} and M^2_m. Moreover, The class consists of units susceptible to erosion in the area consist of pre-Quaternary units of M^1_u, M_u^2 ,M_u^3, Plag and Quaternary unit Q_c. Relatively resistant classes also is included of pre-Quaternary units $O^{ZC_2}_m$, O^{Z4}_m , O_m^{Z3}, O^{Z5}_m , O^{Z1}_m and is O^{Z2}_m. Soils of study area, according to the field studies and laboratory data, were coordinated based on American classification by Iranian approach which is consisted of Calcic Brown soils with the highest area and Regosols with the lowest area. In terms of soil texture class, most of the soils had silty loam texture.

Classification of rocks and structures

Areas with high infiltration are mainly coincided on Q_{al} and Qc units which is consisted of sandy coarse grains and detached gravel sediments. All area with high infiltration are composed of pebble and fluvial plain. Geomorphological properties in watershed can be explained in the northern part of the area that is expanded with river system and geomorphological structures. So that river system on the area is extensive dendritic drainage system with wide channel.

Table 1. The lithological map guide of Ghoorichay watershed and the coefficient of structure resistance to erosion.

age periods	period	Structure symbol	Lithological properties	Resistance to erosion coefficient	area
Cenozoic	Quaternary	Q_{t1}	Old alluvial	4	7945.5
		Q_b	sand - clay, marl, siltstone and tuff layers within	4	1010.4
		Q_{al}	Fluvial deposits of the present period	4	2320.1
		Q_c	Conglomerate lenses of marl	6	129.1
	Pliocene	Plag	Clays colorful conglomerate, sandstone and white tuff (Aghchageel structure)	5	1170.6
	Miocene	M_u^2	Alternation of sandstone, silt-clay and marn	6	465.5
		M_u^1	Gypsic Silts with sandstone and conglomerate	5	169.8
		M_u^3	Alternation of sandstone and marn and clay layers	6	308.8
		CL_2	within the sandstone	4	149.7
		M_m^1	Silty clay and marn, with red sandstone	4	450
		M_m^2	Alternation of silty clay, marn and sandstone with dolomitic limestone layers	4	288
			Rotation of the silt clay with thin layers of sandstone and limestone, dolomite		
	Oligo-Miocene	Q_m^{z4}	Alternation of sandstone with silt and clay	9	243.7
		Q_m^{zc2}	Conglomerate within sandstone layers	10	41.3
		Q_m^{z5}	Alternation of sandstone with plant residues and clay	10	140.6
		Q_m^{z3}	Alternation of sandstone with tuff, and clay shale	9	155.3
		Q_m^{z2}	Tull thick sandstone layers within layers Chile	10	249.8
		Q_m^{z1}	Colorfull silts with layers of sandstone	10	31.5
			Alternation of silt, sand or colorfull clays		

After preparing the lithological map of watershed and integration the structures that have similar sensitivity to erosion, the sensibility to erosion maps acccording to the Feiznia table were prepared and classified in three classes. Figure 3 shows the map of susceptibility to gully erosion.

Table 2. The classification of rocks and structures based on sensitivity to erosion.

Code no.	order	erosion sensitivity	erosion sensitivity coefficient	unit		area
				pre-Quaternary	Quaternary	
1	A	High sensitive	less than 4	cl_2 و M^2_m و M^1_m	Q_{t1} و Q_{al} و Q_b	12163.9
2	B	Sensitive	8-4	Plag وM^3_U وM^2_U وM^1_U	Q_c	2243.9
3	C	partly resistance	12-8	O^{Z5} وO^{Z3}_M و $O_M{}^{Z4}$ وO^{ZC2}_M		862.4
				$O_M{}^{Z\,2}$ و O^{Z1}_M	----	
4	D	resistance	More than 12	----	----	----

According to the gully erosion map, 2067.5 hectares (%15.6) of the total area is at risk with gully erosion. The table is based on an abstract analysis of parameter sensitivity gully formation, more than 86 percent of gully erosion have been occurred on high sensitive structures. The best fit equation in gully erosion occurrence was obtained as follows:

$Gu=345235(Geo)^{-6.2959}$ $R^2= 0.97$ [1]

Which: Geo is the lithological structure

Discussion

With increasing elevation, slope area is increasing and precipitations of snow will more happen which is seen in the southern part of the area. Also in this range of elevations, rocky protrusion and rock mass is increased, so the formations are more resistant to erosion. With reduced height, susceptibility to erosion is increased and the region is prone to gully erosion. Due to the high penetration of water in southern areas and the kind of lithological units that are composed of gypsum and lime, these areas are suitable for agriculture. Due to the kind of formation in the watershed, gullies can be easily detected as an active form and some of the dissolution gullies in the output of the watershed produced large amount of sediment.

Table 3. Results of cutting the map of lithological sensitivity to erosion with gully erosion map.

Gully erosion		Sensitivity structure parameter		
percent of area	Area(ha)	Area(ha)	Middle-class	code
86.73	1739	1157.06	4	1
7.81	161.5	1343.43	5	2
4.91	101.68	901	6	3
0.17	3.63	401.81	9	5
0.35	7.31	464.37	10	5

Erosion factors also mainly are located on of the folding and faulting of the region, which is exacerbated gully erosion in Ghoorichay watershed. Gullies are on the progress in head cut and walls of the gully that are threatened some of the facilities such as access roads and utility poles and some residential and agricultural lands. In this watershed, the collection of rocky and sedimentary units of Oligo-Miocene, Miocene, Pliocene and quaternary are existed and the age of this units from old to new respectively are the Oligo-Miocene, middle Miocene, upper Miocene, Pliocene and is quaternary. In the mountains unit of the area, in addition to erosion structures, tectonics and lithological factors are available. The way of lithological unit appearance is important factors of geomorphological components. With comparison of the frequency gully erosion map and Sensibility of structures, it is inferred that there was no resistance structure in the area. Therefore, gully erosion is affected by the type of lithological structure. In some parts, rock units have different behaviors exposed in the steep area and the type of appearance due to precipitation. Thus, the results of this investigation about gully erosion and the threat of gully risk is included in low step areas with limestone and marn structures on quaternary period which they are affected by gully erosion. This results is consistent with studies of researchers, Vafakhah(1388), Sufi (1382), zinck (2001) and Marzolff (2009).

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