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Study of effective factors on gully erosion and its zonation in Neyzar region of Qom province

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ABSTRACT

Different soil erosion types including water and wind erosion which result in soil degradation and reducing fertility potential of soil, cause desertification in the region. "Gully Erosion" is one of water erosion types that with progressive trend results in soil degradation, and on the other hand, produces a lot of sediments. Determination of effective factors on gully erosion and its hazard zonation is one of substantial approaches in order to manage and control this phenomenon, and select the most appropriate and applied effective option. Hence this study is performed to classify effective factors on gully erosion, and identify regions with high potential in gully erosion using analytical hierarchy process method in Neyzar region, Qom. The most effective factors in gully erosion including slope degree, slope aspect, lithology, land use, and land suitability, were collected and digitized in geographical information systems. Then, gullies inventory map prepared using 1:20000 aerial photos (1372), and field studies was carried out by GPS. In the next step, effective factors were compared in pairs, and the weight of each factor was calculated that illustrates their contribution. Next, scaled map of each factor in respect to their quantities was prepared, and finally, gully erosion was zoned using scaled layers and scale index related to each factor. Results indicate that lithology (0.4978), and land use (0.2227) are the most important factors in gully initiation, respectively. For the assessment of zonation map, gullies inventory map shows that about 91% of gullies are located in zones of high and very high risk in this region. Therefore, due to the fact that AHP is based on dual comparision of factors, results in easy and accurate necessery calculations and it includes many effective factors, it is a suitable and efficient method for gully erosion hazard zonation.

Introduction

Nowadays, the phenomenon of erosion is amongst the most problematic issues of humans, So that of 1500 million hectares of the world's croplands, 430 million hectares has been lost due to erosion between 1960 to 2000(sufi; 2002).

Among the types of erosion, water erosion is one of the major forms of land degradation and environmental destruction which results in physical removal of soil and eliminate materials and nutrients and elements that are needed to plants and weaken the soil qualitatively and quantitatively. Again, one of the main types of water erosion is Gully erosion which cause a lot of damages and problems. Generally gully erosion has two important aspects. First, in this type, removal of soil is several times more than that of rill or surface erosion (Morgan, 1995) which negatively fills reservoirs, reduces transport capacity of steams and rivers, and destruct lower hand croplands. Furthermore, it takes expensive measures to compensate negative consequences. Second, compared to other types of erosions little researches has been done on it. For example Valcarcel et al (2005) investigated the temporary gully erosions of Southern Spain and found that agricultural activities as the main factor of occurring such gullies. The reason is behind the fact that in such areas especially in the seasons with low precipitation, rills of plow develop to gullies. Leyland and Derbay (2008) studied the gullies of beach cliffs in southern England. In their research, they developed conceptual model of spreading the gullies and the ditches. Also Wua et al (2008) conducted a study at northern China on the extend of gullies using GPS data. Results show that sediment delivery rates in the summer rainy days were the highest values (average of 56 percent). Nazari Samani (2008) while assessing the effective processes of gully occurrence and development, used slope-area relations, run off depth and critical shear stress to simulate the stream movement in field, along with using of topographic threshold and land use pattern defined the lands prone to this type of erosion. Ghafari and Charkhabi (1999) with studying the 36 gullies and their sub-basin, gathered 16 parameters for each of them such as basin length, basin shape, percentage of bright brown soil, percentage of vegetation cover, ratio of height difference to basin length, basin slope ratio of silt to clay etc. They concluded that linear regression are suitable for estimation gully growth or expansion. Karimi et al (2007) with calibrating the models of FAO, Tamson and SCS, for Zahan basin, city of Qayen, stated that it is just the FAO model that can predict the longitudinal expansion of gully erosion for the next years.

Regarding to the aforementioned issues nd particularly considering harsh consequences of gully erosion, therefore, doing researches on identifying factors of occurrence and zoning is a major part of, and crucial tools to manage and monitor this

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type of erosion. For that reason, in this study the aim is to identify and to characterize the factors of gully erosion, zoning, determining the level of each factor (weightening) and locating the areas prone to gully erosion.

Materials and Methods

The study area is located beside the Salafchegan Road south of Qom, falls between 34° 05' to 34° 23' geographical north and 50° 17' to 50° 42' east within Qomrud basin. Its area is about 48000 ha. Its weather according to modified deMarton classification is temperate desert.

Informative layers of slope, aspect, land use, land capability and resources and lithology (which are the main factors inducing gully erosion) were prepared in ILWIS software. Then prepared layers were compared and were assessed as paired AHP model.

In this study an arithmetic average was used to weighten each factor through paired comparison matrix.

In fact the values or numbers of each column were added and then each value is divided in to the sum of columns of the same value and finally get the average values of each row.

- Classification of the factors

Different quantitative factors were classified based on cumulative curves between values of these factors against their pixels frequency and recognizing sudden changes of such factors in their natural inheritage, (Nagarajan et al 1998). Qualitative factors were classified based on current methods as well.

- Wheights of different classes of factors in hierarchical model:

To this aim, using the percent of gully area in each class of factors, scores of 0 to 100 were given. As such the biggest score (100) was given to the class that included the highest percentage of gullies and accordingly the next classes were given different (lower) scores based on area covered with gully. (Esmaly et al 2002).

Model representation and zoning by hierarchical method:

After weightening the classes of different factors in the hierarchical model, weightened map of each factor was produced and multiplied in its own coefficient and finally sum of the values gave the final map.

Results

Combining layers of affected areas (by gully erosion) with the layer of slope, clears that about 92.02 percent of gullies were occurred on the slope of 0 to 3 percent and generally gully area had the slope of lower than 5% above which no any gully was occurred or detected.

In addition, by over crossing the layers of aspect and gully effected area, it was observed that 53.86 percent of gullies falls in the flat class (with no aspect).

Moreover, relating the lithology and gullies clarifies that gullies occures in lithologycal units of PQ^{m} , Qt^{2}, Q^{al} and Qt^{1}. These are layers of hardened Conglomerates with inter-layers of sand-clays. Table 4 presents the distribution of those geological layers and the area of which has been converted to gullies.

In the study area there are five types of land use: bare lands, dry farming, agri-garden, agri-fallow and rangeland.

By combining land use map and gully erosion map, it was found that most of gullies (49.43%) occurred in barelands.

When investigating the relationship between resources and capabilities with areas that were affected by gully erosion, It is noticed that approximately 36.6 percent of gullies were felt in unit 1 and 7and 30 percent in unit 402 which encompass flood plain with low trains and mild slope along with many shallow streams of 1 to 2 percent of slope and also flat plain hills without trains, with low to moderate salinity, having deep heavy texture soils.

Table 5 shows the results of pair comparison of effecting factors in gully erosion of Neyzar, Qom.

Tables 6 and 7 represents the weightened arithmetic coefficients and weights of each class in AHP model, respectively.

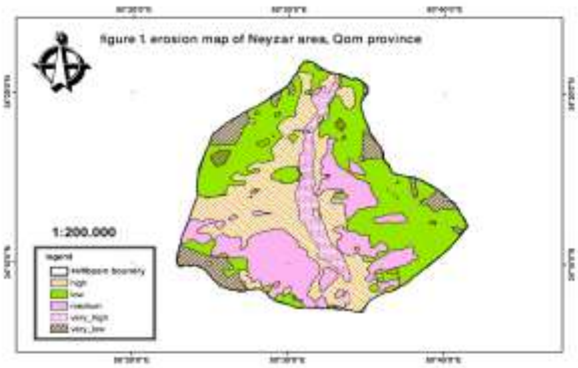
Priority of each factor in producing gully erosion was calculated as bellow:

1. Lithology a1= 0.4978
2. Land use a2= 0.2272
3. Slope a3= 0.146
4. Resources and Land capabilities a4= 0.0808
5. Aspect a5= 0.048

Using weightened coefficient of each factor and produced weightened map, and by entering them into the following equation, final maps was prepared:

$$\text{Zonation}= 0.4978\,(M_1) +0.2272\,(M_2) +0.146\,(M_3) +0.0808\,(M_4) +0.408\,(M_5)$$

Figure 1 shows the zoning of gully erosion using hierarchical model in Neyzar, Qom.



In turn, by combining Zonation map with gully erosion map, we saw that up to 91% of gully areas fell in the class of very high risk. Table 8 shows the distribution of classes in zoning gully erosion and the area of gully affected areas.

Discussion and Conclusion

Neyzar area of Qom has dry desert climate and involves gullies types which called “Side” with average length of 230 m, width of 11 m and depth of 2 m and belongs to the group of moderate gullies. Its plan is digitated and its cross section is V shaped. Frontal plan is pointed or dotted and vertical profile of head cut is biosed which implies on the effects of runoff in the gully forehead

Zare Mehrjerdy et al (2005) studied the gullies of Kandovan in Hormozgan. They found that in this area gullies occurred in plain and are old and of continued evolution. General plan was digitated with average depth of 2 – 4 m. But head space of gully has disdirtic plan, head profile was vertical with U shaped cross section. Gullies expand from head cut by tunneling with following sudden collapse of huge masses of soil. Gorli et al (2005) studied the morphological properties and climatic characteristics of Qom concluded that two main factors that induce gullies are natural factors and anthropogenic factors. Natural factors severe rains and floods in the past which produced runoff both on the surface and sub-surface. Those runoff, in their way to rivers, erode the walls and banks causing spreading of gullies. Ezech (2000) noted that the more the runoff the more developed the gullies.

Regarding to average volume of gullies in our study area (8456 m^3), having bulk density of the soil of1.55 ton/km^2, it is estimated that about 2198560 m^3 which equals to 3407768 ton sediment was eroded by gully erosion. Wau et al (2008) reported a higher sediment delivery rate (average 56%) for rainy summer season. They also express that the amount of eroded soil in temporary and permanent gullies is almost 1.5 times more than other types of surface erosion.

Resulty gained, with pair comparison and weighted coefficients based on thematic maps of the region and by integrating factors and expertise views. Finally the lithological factor with weighted coefficient of 0.4978 and land use factor with weighted coefficient of 0.2227 were found to be the main factors of creating gully erosions (among other factors such as slope, resources and land capability and aspect).

So they are the most important factors inducing gullies in Neyzar, Qom with lothology as the first and the most important factor and land use as the second one. All of the gullies were occurred on the slopes below 5%. So, our hypothesis that was the formation and land use in the main factors of gully occurrence, is verified. Rijsdic et al (2006) studied the runoff and sedimentation of gullies in two region of east Java, Indonesia and their role in volcanic lands. Results show that this type of erosion occurred there because of incorrect tillage and improper land use.

In land use type agri-garden, however we can see the greatest occurrence of gully erosion (67.75). While for mediate range lands is 3.25% and for total range lands is 2.84%

Considering the ratio of gully area to range land area (a class of land use) it can be concluded that in land use of type rangeland in Neyzar region, the lowest degree of gully erosion was occurred. So, It can be said that here the best land use is rangeland applications will arise the risk of gully occurrence. Descoix et al (2008)

With survey analysis and measuring run offs and soil erosion in Sierra Madre region in northern Mexico observed that overgrazing and deforestation were the main factors inducing erosion.

Also Menendez-Duarte et al (2007) considered that deforestation and regional changes as man factors that worsen the gully erosion.

Finally it was observed that in the hierarchical analysis model, almost 91 percent of gully erosions occur in areas with very high risk and high risk. Therefore, we suggest the hierarchical model as an appropriate method to zoning gully erosion because that is employs pair comparison, its ease and its precious and integrating many factors.

Fozooni (2007) assessed the role of different factors in desertification of Sistan plain. She suggested hierarchical model to determine the importance and the extend and degree to which each factor affects desertification, and state that this method gives a more precise estimation of what is happening.

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Table 1 – The scale of pair comparison in hierarchical model

Intensity of Value	Interpretation
1	equal cost.
3	slightly higher cost
5	strongly higher cost
7	very strongly higher cost
9	absolutely higher cost
2, 4, 6, 8	These are intermediate scales between two adjacent judgments.

Table (2)- distribution of lithological layers and area of gully erosion in Neyzar, Qom

Type of formation	The area of the class (hac)	Percentage of the class	Gully area (hac)	Percentage of gully area
E_5^c	433/39	0/90	-	-
EM_3, E_5^L, E_6^V	585/09	1/22	-	-
gy	62/73	0/13	-	-
K_1^l	328/50	0/68	-	-
M^{1m}	1997/56	4/15	-	-
M_s	2317/10	3/58	11/56	0/33
O_c	2079/93	4/32	-	-
OMq^{L1}	876/50	1/82	-	-
OMq^{m}	135/50	0/28	-	-
OMq^{s}	174/59	0/36	-	-
PL^{c1}	81/90	0/17	-	-
PL^{v}	610	1/27	-	-
PQ^{m}	3354/18	6/97	2521/60	71/25
Q^{a1}	733/19	1/52	348/68	9/85
Q_{t1}	2617/60	5/44	240/24	6/79
Q_{t2}	32347/05	67/19	416/56	11/77

Table (3)- pair comparison of factors inducing gullies

Factors inducing gullies	Lithology	Land Use	Slope	Resources and Land Capability	Aspect
Lithology	1	3	4	6	7
Land Use	$\frac{1}{3}$	1	2	3	5
Slope	$\frac{1}{4}$	$\frac{1}{2}$	1	2	4
Resources and Land Capability	$\frac{1}{6}$	$\frac{1}{3}$	$\frac{1}{2}$	1	2
Aspect	$\frac{1}{7}$	$\frac{1}{5}$	$\frac{1}{4}$	$\frac{1}{2}$	1
Sum	**1.8929**	**4.0333**	**7.75**	**12.5**	19

Table 4: Weightened coefficient of each factor

	Lithology	**Land Use**	**Slope**	**Resources and Land Capability**	**Aspect**	Sum	Average (weighted ratio)
Lithology	0/5283	0/5960	0/5161	0/48	0/3684	2/4889	0/4978
Land Use	0/1761	0/1987	0/2580	0/24	0/2632	1/1360	0/2272
Slope	0/1321	0/0993	0/1290	0/16	0/2105	3/6248	0/146
Resources and Land Capability	0/0881	0/0662	0/0645	0/08	0/1053	0/4041	0/0808
Aspect	0/0755	0/0397	0/0323	0/04	0/0526	0/2401	0/048

Table 7: Weights of different classes in AHP model for Neyzar region in Qom

Lithology		Land Use		Slope		Resources and Land Capability		Aspect	
weight	**Class**	**weight**	**Class**	**weight**	**Class**	**weight**	**Class**	**weight**	**Class**
0	E_5^c	100	Bare lands	100	0-3	0	1 .1	100	Flat
0	EM_3, E_5^L, E_6^V	1/362	Rainfed farms	8/589	3-5	1/42	1 .4	26/70	Northern
0	**gy**	71/916	Farming-horticulture	0	5-10	0	1 .6	1/84	Eastern
0	K_1^l	0	Farming-fallow	0	10-20	1/75	2 .1	35/61	Southern
0	M^{1m}	24/077	Medium rangeland	0	20>	0	3 .1	21/52	Western
0/463	M_s	0	Poor rangeland	-	-	0	3 .2	-	-
0	O_c	-	-	-	-	20/80	3 .26	-	-
0	OMq^{L1}	-	-	-	-	81/95	4 .2	-	-
0	OMq^m	-	-	-	-	100	7 .1	-	-
0	OMq^s	-	-	-	-	67/08	8 .1	-	-
0	PL^{c1}	-	-	-	-	0	9 .1	-	-
0	PL^v	-	-	-	-	-	-	-	-
100	PQ^m	-	-	-	-	-	-	-	-
13/825	Q^{a1}	-	-	-	-	-	-	-	-
9/530	Q_{t1}	-	-	-	-	-	-	-	-
16/519	Q_{t2}	-	-	-	-	-	-	-	-
0	Q_{tr}	-	-	-	-	-	-	-	-

Table 8: the distribution of classes in zoning gully erosion and the area of gully affected areas.in Neyzar region of Qom

categories	Area (ha)	Percentage	Gully area (ha)	Gully percentage
Very low	3743/53	7/78	-	-
Low	10176/71	21/14	28/18	0/82
Medium	21091/29	43/81	266/41	7/75
High	9817/96	20/39	758/36	22/05
Very high	3311/31		2483/29	69/38
Total	48140/8	100	3539/04	100