Classification of Gully Erosion Based on Morphoclimatic and Soil Characteristics in the Northeast of Iran, Golestan province

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1. Abstract

Designing control measures to mitigate gully erosion requires understanding and recognition of dominant processes acting on gullies and also classification of gullied regions based on their morphoclimatic and soil characteristics. In this research, gully erosion with an area larger than 5 sq.km was recognized using historical evidence and field suryeying. The climate of the regions affected by gully erosion was determined by modified De-martons method. In each climatic zone, two regions were selected and in each region at least three representative gullies were selected to measure fifteen variables. The variables include gully length, top and bottom width, depth of headcut, area of gully erosion, elevation above sea level, average annual rainfall, clay, silt, sand, SAR, Ca, EC and slope. Cluster analysis using average method was used to classify the regions affected by gully erosion. In order to compare similar groups of gullied regions, variance analysis and mean comparison were used in the SPSS software.

The results of this research indicated that six regions were affected by intensive gully erosion in Golestan province. The gullies were formed dominantly in cold and mild arid and semi-arid climates. The soil texture was dominantly silt loam. The depth of the gullies varied between 1 and 8 meters. The view plan of the gullies was linear and their headcuts view plans were rounded and digitated.

Using cluster analysis we classified the gullies into three groups. The first group included the regions number 1 (Alagoul) and (Hajighosan) with the similarity level larger than 97 percent. The second group included the regions number 2 (Damagh) and 6 (Tamarghozi) with the similarity level larger than 95 percent. The third group involved regions number 3 (Maraveh-tappeh) and 4 (Arabgrahaji) with the similarity level larger than 57 percent. The important factors for separating homogenous regions include elevation above sea level, particle size (sand) and chemical soil properties such as Ca and Ec. The third group had longer, wider and deeper gullies in relation to other groups although there was no significant difference between them. The geology of the third group was loess and its land use was poor rangeland. The results indicate that overgrazing on Loess hilly areas in Golestan province produce more surface runoff and intensive deeper and wider gullies.

Keywords: gully erosion, morphoclimatic, soil, characteristics, Iran, Golestan, control measures, overgrazing

2. Introduction

Gully erosion is a widespread feature in the arid and semiarid regions around the world. This form of erosion has received much less attention and has been recognized as a major source of sediments in USA, Australia, Europe and China (Foster, 1982; Prosser, 1991 and Poesen et al., 2003; Zhang et al., 2007). Gully is an erosion channel which can not be obliterated by normal operation tillage (Soil science society of America, 2001) and as a steep side channel with a cross sectional area larger than 1 square foot that is formed due to intermittent flow or runoff after snow melt (Poesen et al., 2003). Gully erosion had a great impact on the faster drainage of soil moisture and ground water in the arid and semiarid regions (Avni, 2005 and Neyssen et al., 2004). This phenomenon accelerated desertification in the prone areas such as Iran. Gully erosion was triggered by human exploitation of natural ecosystems in different forms such as forest clear cutting, rangeland change to rain fed farm, urban development, road construction in recent century in different parts of the world (Starr,1989;Melville and Erskine, 1986;Eyles, 1977; Prosser and Slade, 1994; Prosser, 1991; Nachtergaele, 2001; Fulkner , 1995; Moyerson, 2000; Croke and Mockler, 2001). This phenomenon is critical in I.R.Iran. This research was done in the northeast of Iran, Golestan provice. The aim of this research was to determine the distribution of major regions with gully erosion. This research was a part of national plan starting in 2002 and planed to provide a data bank about gully erosion in this province.

3. Methods

This research was carried out in Golestan province, the northeast of IR. Iran. The regions with gully erosion area larger than 5 km^2 were determined using historical and anecdotal evidence and field surveying. The climate of gully regions was determined using Demarton's classification. In each climatic zone, two regions with gully erosion were selected and in each region at least three representative gullies were selected to determine fifteen variables. The variables include gully length, top and bottom width, depth of headcut, depth of gully in the middle, area of gully erosion, elevation above sea level, average annual rainfall, clay, silt, sand, SAR, Ca, EC and slope above headcuts. Cluster analysis using average method was used to classify the regions affected by

gully erosion. In order to compare similar groups of gullies, variance analysis and mean comparison were used in the SPSS software. Other characteristics of regions including physical conditions of regions such as annual and 24-hour rainfall, temperature, soil depth and structure, vegetation, physiographic features such as slope gradient, drainage area, morphometric characteristics of gullies such as width, depth, length, shape of cross-sections, present and old land use around gullies, alternative controls applied to control gully development and damages due to gully erosion were recorded by completing a questionnaire for each gully.

4. Results

Gully erosion covered over 600 square kilometers in the Golestan province. Although gully erosion was observed in 12 climates based on the modified Demartons' classification, most of the gullies occurred in arid and semiarid climates with loess soil. From six regions with extensive gully erosion, four have semiarid climate. Soil texture is dominantly silty loam in regions with dominant gully erosion. Gullies were formed dominantly in poor rangeland and rain fed farms that have appeared due to rangeland change. Most of the gullies are lateral,i.e. that means they are formed around natural drainages. They are deep and wide because their normal depths were more than 1 meter and their width was at least 5 meters. The length of the gullies varies between 50 and 1100 meters. Most of the gullies formed on the loess.

Statistical analysis revealed that the standard error between variables was not high between regions with dominant gully erosion, so there was no need to standard data. Cluster analysis of data classified the gullies of the Golestan province into three groups**.** The first group included the regions number 1, Alagoul, and number 5, Hadjighoshan, with the similarity level larger than 97%. The second group included regions number 2, Damagh, and number 6, Tamarghozi, with the similarity level larger than 95%. The third group involved regions number 3, Maraveh-tapeh, and number 4, Arabgharahaji, with the similarity level larger than 57% (Figure 1).

Comparison of the mean of the measured variables between three groups of gullies in the Golestan province indicated that there was no significant difference between three groups in view point of gully length, median depth, top and bottom width, headcut depth, average annual rainfall, clay, silt, SAR and gradient slope above headcuts but there was significant difference between elevation above sea level($P<0.05$), sand($P<0.05$) , Ec($P<0.05$) and Ca($P<0.01$) between gully groups(Table 1).

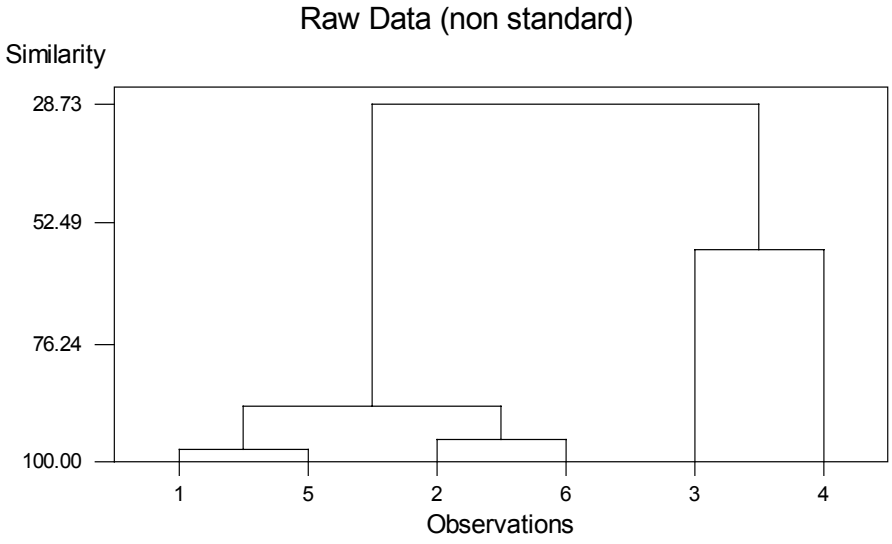

Figure 1 Classification of the Golestan gullies using Cluster analysis

Group 1: region number 1, Alagoul and number 5, Hadjighoshahn

Climate is mild arid in region no.1 and mild semi arid in region no.5. Geologic formation is loess and alluvial in region 1 and 5, respectively. The length of the gullies is between 60 and 160 meters. The general view plan of the gullies is linear and for the headcuts it is rounded. The shape of the cross-sections was U-shaped. Mean depth of the gully was 1 meter in no 1 and 4m in no 5. Mean W50/D50 was 5 in region no 1 and 2.2 in region no 5. Gradient slope above headcuts was 4% in region no 1 and 12% in region no 5. Soil texture is

loam in region no. 1 and silty loam in region no. 5. Present landuse was poor rangeland in region no. 1 and medium rangeland and rainfed farms in region no. 5.

Group 2: region number 2, Damagh and number 6, Tamarghozi

Climate is cold arid in region no.2 and mild semi arid in region no.6. Geologic formation is alluvial and loess in region 2 and 6, respectively. The length of the gullies is between 50 and 180 meters. The general view plan of the gullies are digitated in region no. 2 and linear in region no. 6 and for the headcuts it is rounded and notched, respectively. The shape of cross sections was trapezoid. Median mean depth of the gully was 5.5 meter in no 2 and 3 .5m in no 6. Mean W50/D50 is 3.5 in region no 2 and 2.5 in region no 6. Gradient slope above headcuts is 6% in region no. 2 and 22% in region no 6. Soil texture is silty loam in both regions. Present landuse is poor rangeland in region no. 2 and rain fed farms in region no. 6.

Group 3: region number 3, Maraveh-tapeh and number 4, Arabgharahaji

Climate is cold semiarid in both regions. Geologic formation is loess and Loess-shale in region 3 and 4, respectively. The length of the gullies between 100 and 1100 meters. The general view plan of the gullies is linear and for the headcuts it is notched. The shape of cross sections is U-shaped. Median mean depth of the gully is 6m in no 3 and 7m in no 4. Mean W50/D50 is 5 in region no 3 and 2.3 in region no 4. Gradient slope above headcuts is 8.5% in region no 3 and 9% in region no 4. Soil texture is silty loam in both regions. Land use was rain fed farms in region no. 3 and rain fed and poor rangeland in region no. 4.

The results of this research revealed that chemico-physical characteristics of soil could be used to classify gullies in the Golestan province. This part of the country is very susceptible to concentrated soil erosion and produces a lot of sediment that would be detrimental to downstream water bodies.

Table 1 Comparison of mean measured variables among the classified groups of gullies in the Golestan province, northeast Iran

variable / Group	Regions	Length (m)	Depth,50% (m)	Top width,50(m)	Bottomwidth,50%(m)	Headcut depth (m)	Elevation above sea level(m)	Mean annual rainfall(mm)	Clay(%)	Silt(%)	Sand (%)	SAR	Ca	EC	Slope gradient above headcuts(%)
1	1-5	104.9± 16.86a	2.71± 0.765 a	7.58± 1.10 a	3.38± 1.46 a	2.208± 0.652 a	86.7± 37.4 b	343.83± 57.36 a	14± 1.8 a	61± 6 a	25± 4 a	33.6± 13 a	260± 69.8 a	50.95± 17 a	8± 1.8 a
2	2-6	105.58± 24.75a	4.58± 0.65 a	10.78± 2.15 a	3.61± 0.76 a	3.98± 0.86 a	123.33± 21.08 ab	360.8± 71.91 a	23± 7 a	64± 4 a	13± 2 b	44± 17 a	133± 4 ab	34.15± 8.52 ab	14± 3.6 a
3	3-4	338.3± 158.71a	5.13± 0.98 a	13.23± 4.11 a	3.30± 0.91 a	4.38± 0.96 a	257.5± 77.54 a	438.35± 37.23 a	13± 1 a	71.5± 1 a	15.5± 2 b	5± 2 a	64± 24.15 b	7.8± 3 b	8.75± 0.11 a

R^2		0.752	0.91	0.994	0.068	0.882	0.902	0.880	0.008	0.942	0.563	0.494	0.972	0.984	0.013
P		ns	ns	ns	ns	ns	<0.05	ns	ns	ns	<0.05	ns	<0.01	<0.05	ns

5. Conclusion

In the Gol

estan province, two out of six watersheds, Atrak and Gorgan river watersheds, experienced extensive gully erosion. The total area that covered by gully erosion was over 600 km^2. Gully erosion occurred in arid and semiarid climates. Most of the gullies in Golestan province formed and developed on the loess sediments. Cluster analysis classified Golestan gullies into three groups. Differentiation of three groups of gullies in Golestan province was related to the chemico-physical characteristics of soil and elevation above sea level. It seems that less Ca and Ec in the soil of the third group of Golestan gullies contributed creation of the longest and widest gully in Maraveh-tapeh region that produced a huge amount of sediment.

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