The Impact of land use and Soil Characteristics on Gully Formation in an Arid Ecosystem, Southwest of I.R.Iran

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1. Abstract

Human impact on land degradation has been reported by many researchers in recent years. This paper presents the results of several researches conducted on gully erosion in the south west of Iran. Historical evidence such as topographic maps and aerial photos with different serial times and scales, extensive field surveying and soil sampling were used in a five year period. The area of different land uses was measured on the topographic maps. The vegetation density was measured in the field using 1 m^2 quadrates. Statistical analysis was performed using regression method in SPSS software.

The results of this research indicated that gully erosion existed in a limited area on the sodic soil in the past four decades. Gullies formed on the croplands and alluvial plains around the roads. They are 5 meters wide and 3 meters deep. After the urban development and rangeland degradation from four decades ago, gully erosion extended very rapidly. Historical evidence indicated that the area of gully erosion increased up to 3 folds. Most of the important gully sites were located near the populated areas and degraded croplands.

Statistical analysis indicated that two variables, area of bare land and length of roads, were the most important factors controlling gully area in this part of Iran. In some regions, the area of bare land and in the others the length of the roads played the most important role in controlling gully erosion.

Comparison of the effect of vegetation density on gully erosion in a homogenous soil indicated that gully erosion appeared where vegetation cover decreased below 20 percent. It implies that by increasing vegetation cover higher than 20 percent on the degraded lands, it is possible to mitigate gully initiation and development.

The results of another research with flume experiment on different land uses including pasture, native rangeland and cropland indicated that land use changes from rangeland to cropland increased the chance of gully formation. Exclosure of rangeland had a significant impact on preventing gully erosion in an arid ecosystem with sandy loam soil.

Keywords: land use, soil, gully formation, arid ecosystem, Iran, human impact, land degradation

2. Introduction

Changing native rangelands to low yield rain fed farms and leaving them after some years and regional development in watersheds specially road construction had detrimental impact on the initiation and development of gullies in different countries (Moeyersons, 2000; Wemple and et al., 1996). Available researches in the Middle East and Africa showed that gully erosion would have great impact on the quantitative and qualitative degradation of forests and rangelands in arid regions due to extensive destruction of lands and its effects on the faster drainage of soil moisture and groundwater (Avni, 2005 and Neyssen et al., 2004). In the case of gully erosion and drainage of soil moisture content in natural resources, less moisture would be available for native forests and rangelands even in the wet years. Therefore, the occurrence of this phenomenon causes reduction of vegetation density cover and also accelerates desertification. Human impact on land degradation has been reported by many researchers in recent years (Gilles; Williams pie, 1981 et al., 1991; Eyles, 1977; Melville and Erskine, 1986; Starr, 1989; Prosser and Slade, 1994; Prosser, 1991; Bork et al., 2001; Avni, 2005; Neyssen et al., 2004; Fulkner, 1995; Wemple et al., 1996). Eyles (1977) by referring to anecdotal and historical evidence indicated that gully erosion was triggered in Australia and New Zealand after migration of European to these countries. The main causes of gully initiation and development worldwide are mentioned to be as follows: land use change from rangeland to cropland and occurrence of severe floods, over grazing specially in drought periods, ecosystem destruction by road construction and vegetation clearance in Australia (Starr,1989; Melville and Erskine, 1986; Eyles, 1977; Prosser and Slade, 1994; Prosser, 1991), vegetation clearance in the 9th and 10th centuries in England (Harvey, 1996), overexploitation of land and coincidence with severe rainfalls in Germany in the 14th century (Bork et al., 2001), increasing maize cropping in central Belgium (Nachtergaele, 2001), increasing of almond planting without terracing after native vegetation clearance in south of Spain (Fulkner, 1995) and road construction (Moyerson, 2000; Montgomery, 1994; Wemple et al., 1996). This research was carried out in the Lamerd and Ala-marvdasht watersheds with an area around 8500 km^2 in the southwest of Iran between 1999 and 2002. The aim of this research was to determine causes of gully erosion in order to prepare alternative controls for gully erosion mitigation.

3. Methods

Aerial photos with a scale of 1:55000 (1954) and 1:40000 (1994), topographic maps with a scale of 1:50000 and 1:25000 were used to determine the area of different land uses involving rangeland, irrigated crop land, rain fed farm, gardens, bare land, residential area and road length. The location of gully erosion in eight watersheds was determined on topographic maps with scales of 1:50000 and 1:25000 which were prepared by photogrametry using aerial photos with scales 1:55000 and 1:40000, respectively. The area of gully erosion and different land uses were measured using digital planimeter. The length of gully erosion was measured using curvimeter. The area of gully erosion as dependent variable and area of different land uses and length of road as independent variables were considered to determine the effective factors on gully initiation and development. Statistical analysis was done using stepwise method in SPSS software. As field surveying and measurements on the topographic maps indicated, gullies focused around bare lands and residential areas. The most areas and locations of gully erosion belongs to the Lamerd and Ala-marvdasht watersheds. Therefore, three sites with different forms of erosion including sheet, rill and gully erosion and one site without any signs of soil erosion as control were selected in the Lamerd watershed to show the relationship between vegetation cover, soil characteristics and soil erosion. In each site, one transect with 1 km length was determined in the field and vegetation cover was measured in a 1 m^2 plot along the transect with 200 meters interval. One soil sample was taken from each transect. In the fourth site in the Lamerd watershed, an open hydraulic flume with 15m length, 0.3m width and 0.5m depth was used to compare and test the critical shear stress on the native rangeland and rainfed farms resulting from changing rangelands.

4. Results

The results of the researcher's studies during the last 10 years indicated that gully erosion was formed in 26 locations in seven climates, dominantly in semiarid climate in Fars province (Soufi, 2004a,b). Sixteen locations with different climates out of 26 locations were selected to show the impact of land use change on gully formation. Ten locations with 50 percent of total area of gully erosion in Fars province belong to the Lamerd and Ala-marvdasht watersheds in the south of the Fars province (Table 1). Comparison of the area of different landuses in the Lamerd and Ala-marvdasht watersheds revealed that during four decades since 1954 to 1994, the area of residential, changinging rangelend to rainfed and gully erosion increased 10, 3 and 4 folds, respectively. The field survey indicated that native rangeland was changed to rainfed farms and after some years they were abandoned as barelands. Gully erosion was initiated and developed on the bareland. Statistical analysis reveals that the area of gully erosion has direct and positive correlation with the area of barelands in the Lamerd and ala-marvdasht watershed (Table 1).

The results of the second research in the other six watersheds except Lamerd and Ala-marvdasht with different climates in different parts of Fars province revealed that gully erosion was affected by variables such as the length of roads (Z1), area of bare land (Z2), area of rain fed farms (Z4) and area of rangeland (Z6). Gully erosion had a direct and positive correlation with the area of bare land, area of rain fed farms and the length of roads but a negative correlation with the area of rangeland (Table 2). These four variables had significant influence on the area of gully erosion in the six watersheds with R^2 equal to 99.9 and P<0.01. Among the four variables, the highest influence belongs to the area of bare land with β =1.043 and the least influence to the area of rangeland with β = - 0.292 (Table 2).

Table 1 Correlation between gully area and bare land area and road length in the Lamerd and Ala-marvdasht watershed (Soufi, 2004)

Equation 1	Standard coefficient		R^2	P
	β_I	β_1		
$Y = 0.748X_1 - 0.351X_2$	0.970	-0.569	0.77	0.05

Table 2 Correlation between gully area and area of different land uses and length of roads (Soleimanpour et al., 2007)

Equation 2	Standard coefficient				R^2	P
	β_I	β_1	$\beta_{\ddot{O}}$	$\beta_{\ddot{o}}$		
1)Y=0.012+0.108Z2+ 0.719Z4-2.932Z6+0.066Z1	1.043	0.358	0.292−	0.40	99.9%	0.01

Table 3 Area of different land uses and the length of roads in the Lamerd and Ala-marvdasht watersheds in Fars Province (Soufi, 2004a; Soleimanpour, 2007)

Gully erosion (km^2)	Road LENGTH (km)	Land use area(km^2)					Name of site location
		Rangeland (km^2)	Garden (km^2)	Rain fed farms (km^2)	Irrigated cropland (km^2)	Bare land (km^2)	
0.66	3.64	–	0.37	–	1.66	4.75	Neyriz
17.87	7.80	–	0.41	18.61	–	36.82	Konartateh
38.13	26.94	3.7	48.02	10.60	–	367.92	Fadagh (larestan)
3.01	6.12	0.296	–	3.18	–	10.80	Deshkord (Eghlid)
1.99	9.77	–	4.17	1.04	–	5.31	Goorspid (Mamasani)
1.74	2.67	–	–	0.60	–	9.71	Mishan (Mamasani)
91.74	22.24	–	–	8.99	–	106.06	Kamali(Ala-marvdasht)
35.65	76.69	–	–	17.3	–	76.31	Keirgoo(Ala-marvdasht)
25.60	53.71	–	–	15.45	–	65.94	Chaheini(Ala-marvdasht)
15.48	11.88	–	–	20.12	–	35.37	Chahkoor(Ala-marvdasht)
9.29	52.10	–	–	44.25	–	16.95	Kahnooyeh(Ala-marvdasht)
37.24	45.47	–	–	8.50	–	40.79	Labshekan(Ala-marvdasht)
12	9.19	–	–	19.48	–	33.07	Chahvarz(Ala-marvdasht)
10.99	74	–	–	18.04	–	31.84	Mohr (Lamerd)
24.63	127.05	–	–	33.35	–	92.26	Sigar (Lamerd)
30.70	107.44	–	–	17.41	–	92.40	Kashkoo (Lamerd)

The statistical analysis implies that by increasing one unit of bare land, rain fed and road length increases 1.043, 0.358 and 0.40 unit of gully area, respectively. Increasing one unit of rangeland decreases 0.292 unit of gully area (Equation 2). While in the Lamerd and Ala-marvdasht watersheds increasing of one unit of bare land increases 0.97 unite of the gully area (Equation 1).

The results of these two researches indicated that the area of bare land had a very important role on gully formation and development. This result implies the preventing of land use change from native rangeland to rain fed farms in the arid ecosystem in order to overcome the problem of concentrated erosion. In order to show the impact of vegetative cover on the gully erosion, four sites in the Lamerd watershed were selected. One site was selected as a control site and without of signs of soil erosion. This location has sodic soil (Karimi et al., 2008) with 0.4% gradient slope from west to east. Soil was developed by water erosion of the surrounding Miocene marlstones hilly area. The aerial photos of 1954 indicate that gully erosion was concentrated in this location 40 years ago. A highway was constructed in the this location in 1981 with the direction of south to north so that it is perpendicular to the flood direction. The site with no sign of soil erosion was located in the left side of the highway and the other three sites were located in the right hand side (east) of the highway. This highway was acting as a small detention dam in winter. Therefore, a huge amount of flood water remains behind the highway and spreads on the site without soil erosion. Backwater of flood water helped to establishment of bunch grasses (Soufi 2004a). The results of variance analysis reveal that there is a difference between the sites

due to vegetative cover and the difference is significant (P<0.01)(Table 4). There is no difference between sites in view point of physico-chemical characteristics. These results emphasize on the impact of land use change and the role of bare land on the gully development in the arid ecosystem.

Table 4 Comparison of sites with different erosion forms in the Lamerd Watershed (Soufi, 2004)

Form of erosion Factor	Site 1 (Without erosion)	Sites 2,3 and 4 (Sheet and rill erosion)	Site 5 (Gully erosion)
Vegetaive cover (%)	20	6.7	0
Organic Matter (%)	0.76	0.98	0.65
EC (mmos/cm)	23	47	46
SAR	41	60	65
Clay (%)	23	16.3	10
Silt (%)	25	23.8	22
Sand (%)	52	60	68

The results of another research (Adelpour et al., 2005) with flume test in the Lamerd watershed revealed that vegetation density and cover was decreased by changing land use from native rangeland to rain fed farms. Critical shear stress for good rangeland was 2.5 times that of rain fed farms. These results indicated that no channel heads formed in the good rangeland but 19 in the bare land.

5. Conclusions

The results of several researches since 1999 revealed that gully erosion was localized in the previous four decades around Lamerd city in the south of Fars province. With increasing land use change from native rangeland to rain fed farms and destruction of vegetation, the chance of flow concentration and gully formation was increased. The area of gully erosion was increased three times in relation to the previous four decades. After 40 years (1954-1999), sixteen main locations of gully erosion was recognized on the aerial photos. Gully erosion concentrated around cities and roads where bare land due to land use change exists. Different signs of human impact on gully formation and development are available. Statistical analysis indicated that variation in gully erosion area was interpreted by variation in bare land area in the Lamerd and Alamarvdasht watersheds. The results of the second research in another six watersheds in different climates of Fars province revealed that variation in the area of gully erosion was interpreted by variation in bare land, rain fed farms and gardens area and in the length of roads. It implies that by increasing land use change from native rangeland to rain fed farms, bare land and roads, the chance of gully erosion increases. Therefore, these results imply that gully erosion would be prevented if rangelands protected or vegetation cover increased. The results of the third research in the Lamerd watershed indicated by increasing of vegetation cover over 20%, overland flow was not able to create gully erosion. The fourth research indicated that by changing native rangelands to rain fed farms, the critical shear strength of soil surface decreases 2.5 times.

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