MORPHO-CLIMATIC CLASSIFICATION OF GULLIES IN FARS PROVINCE, SOUTHWEST OF I.R. IRAN

Majid Soufi
Fars Research Center for Agriculture and Natural Resources, Iran, Shiraz, P.O.Box: 71345-1756

Abstract
This research is a part of a national research plan, which was conducted in 20 provinces of Iran. The data were collected from watershed departments, historical evidence and field surveying to define the area and distribution of gully erosion. A digital map of 1:250000 scale was created in ILWIS environment to show distribution of gullies. The climate of each region was determined using modified De-Marton classification. In each climate zone, two regions and in each region three representative gullies were selected to measure morphometric and edaphic characteristics. A seven page questionnaire was also filled out for each represent gully. Gullies were divided into similar classes using cluster analysis. The results show that gullies are distributed in sixteen regions with seven climate zone in Fars province, dominantly in the temperate semi-arid climate. The soil texture is sandy-loam and loam in surface and sub-surface layers. The gullies plan view is dendretic and formed in rangeland and dryland farms near villages. The gullies have depths between 1 and 10 meters. Their cross sections are dominantly u-shaped in plains and v-shaped in hilly and mountainous areas. The width/depth ratio varies between 2 and 18 and is higher in cultivated areas. The gullies are divided into three classes based on cluster analysis.

Introduction
A gully is an eroding channel with steep banks and a sloping and active headcut which is formed by erosion due to intermittent surface runoff. Gullies are deep channels that cannot be obliterated by normal tillage (Bradford and Piest, 1980; Soil Society of America, 1984). As normal tillage varies temporarily and spatially, the definition proposed by Hauge (1977) could be used. So a channel with a cross section larger than 1 ft^2 is called a gully. Different criteria such as minimum width and depth equal to 0.3 m and 0.6 m, respectively (Brice 1966), minimum depth equal to 0.5 m (Imson and Kwaad, 1980) are used. Nachtergaele *et al*. (2002) used peak flow discharge to separate gullies from rills and streams. The relationship is reliable in homogenuous soils.

The shape of the gully is a product of processes of gully initiation. So the first step in the evaluation of processes of gully initiation is understanding gully morphology (Heed, 1970). Many scientists believe that differences in gully shapes are due to differences among processes of gully initiation(Ireland *et al*. 1930; Imson and Kwaad, 1980; Heed, 1970 and Crouch and Blong, 1989). Ireland *et al*. (1930) classified the plan view of gully heads into four groups as pointed, rounded, notched and digitated. They believed that rounded and digitated and notched v plans are created by seepage. They also classified the long profile of gullies into four groups as inclined, vertical, cave and cave with overhanging root mat or sod. They believed that the cave type was created by the combination action of surface runoff and seepage. Heed (1970) classified gullies based on their evolutionary stages into continous and discontinous. He believed that continuous ones area formed in uplands and discontinuous ones could be initiated at each point of the slope.

Some scientists such as Crouch and Blong (1989) and Imson and Kwaad (1980) classified gullies based on their cross sectional shape, bank shape and their location in the landscape. Imson and Kwaad (1980) believe that v-shape gullies were formed by surface runoff and the u-shape ones by sub-surface or surface runoff. Crouch and Blond (1989) classified bully banks into four classes: vertical, piped, fluted and sloping each of which is a product of a specific process. For example, fluted banks could be formed by rills due to rainsplash and surface runoff. Dietrich and Dunne (1993) classified the gully head into three classes as gradual, step and headcut base on the depth of the erosion. The headcut has a depth larger than one metre.

In Europe, two dominant classes of gullies, ephemeral and bank, were recognized based on their spatial location, morphology and dominant processes for gully initiation. Ephemeral gullies could be grouped into valley head, valley side and valley floor. Gullies based on practical consideration are prioritized using width- depth ratio(w/d) in agricultural lands (Poesen and Govers, 1990; Poesen *et al*., 1993 and 2003). Although many research have been done pertaining gully erosion, much contrarieties and vague problems exist. Some problems are related to the interaction between different processes and complexity in determination of the dominat shape and etc. Poesen *et al.*(2003) states that morphological characteristics such as length, width, depth of different gullies and their controlling factors such as topography, soil type, landuse and hydrology in a wide range of climates are not

collected systematically. Therefore this research started in Iran as a national plan and the findings in Fars province in the southwest of Iran are presented.

Materials and Methods

Fars province has an area of about 133 299 km^2, and covers 8.1 percent of I.R.Iran. It is located between 27º3´ and 31° 42´ northern latitude and 50° 30´ to 55° 36´ eastern longitude. Fars province is surrounded by Isfahan province in the north, Yazd and Kerman provinces in the east, Khokiluyeh and Boyerahmad provinces in the west, Boushehr province in the south and southwest, Kerman province in the south and southeast of Iran. Its average annual rainfall varies between 100 mm in the southern parts and more than 400 mm in the northern parts of the province. This province has 8.6 million hectares of rangeland, 1.212 million hectares of forest and 1.6 million hectares of cropland. It has 11.18 million small animals (1999 data) classified as 6.28 million goats and 4.9 million lambs.

In this research, the data were collected from executive watershed department, historical documents such as maps and aerial photos and field surveying. A digital map with a scale of 1:250 000 was created in ILWIS environment to show the distribution of gullies with an area larger than 500 ha. The climate of each gullied region was determined using modified De-marton classification. In each climate class two regions and in each region three representative gullies were selected to measure morphometric and edaphic characteristics. Depth, top and bottom width in each representative gully were measured in the headcut, 25,50 and 75 percent of the gully length refering to the headcut. The soil samples were collected in each horizon in the headcut, 25, 50 and 75 percent of the gully length. General plan view and long profile of each representative gully were measured using theodolite. They were drawn using softwares such as Winsurf and Autocad 12. A seven page questionnaire was also filled out for each gully. Physical characteristics of region, morphometric characteristics of representative gullies, causes of gully initiation, on and off site damages of gullies were determined in the questionnaire. Natural characteristics such as rainfall, temperature, topography, geology, land type, landuse and vegetation cover and its trend were collected and measured using the existing documents and field surveying. Extensive field observations and measurements and interview with old people in the gullied regions have been carried out to complete the data.

Results and Discussion

The findings reveal that 27 gullied regions exist in Fars province. Gullies are distributed in seven climates. Dominant climates are temperate semi-arid and temperate desert arid that contains the most gullied regions(table 1).

Table 1. Representation of gullied regions in different climate classes (modified De-Marton's classification)

Climate	region
Temperate semi-arid	Michan, Goorspid, Tulsaman, Bushkan, Firoozabad, Mazayjan, Bidkarz, dominant part of Lamerd and Alla marvdasht
Temperate desert arid	Baba-arab(Jahrum), Khalili and Fadag(Larestan), small part of Lamerd and Alamarvdasht
Cold semi-arid	Dominat part of Goorspid, Sarvestan. Gazian(Korambid)
Temperate mediteranean	Bandgatar and Javid(Eghlid)
Cold desert arid	Neyriz
Warm desert arid	Dominant part of Konartagteh
Warm semi-arid	Small part of Konartagteh

The results indicate that gully erosion covers an area equal to 479.24 km^2 in Fars province. Physical and morphometric characteristics of representative gullies are presented in tables 2 and 3 repectively. The average annual rainfall varies between 194.7 mm (Larestan- Khalili) and 676.4 mm (Eghlid-Javid) in gullied regions. The alititude of gullies from sea level varies between 485m (Larestan- Kahlili) and 2182m (Eghlid-Javid). The maximum daily rainfall varies between 90 mm (Jahrrum-Baba-arab) and 207 mm (Kazerun-Konartaghteh). Soil textures in surface and sub-surface layers are dominantly sandy loam and loam, although some samples show clay loam and sandy clay loam textures. The data show that the clay content is higher in the surface layer in the gullied regions, so it contributes to producing more surface runoff. Most of the gullies are formed around natural drainage lines such as rivers and streams. The gullies were formed in the alluvial plains and marly hills. In the hilly areas,

gullies were formed in thalweg. Half of the gullies were formed in rangeland and the rest in croplands. The general view plan of gullies are dominantly dendretic. Most of the gullies in plains have u-shape cross sections while they are v-shaped in hilly areas. The length of the gullies vary between 14.5m and 435m. The depth of the gully heads varies between 0.3 and 2.4m.

Dominant causes of gully formation are rangeland destruction, landuse change from rangeland to dryland, mis-design and construction of road culverts, road cinstruction in sensitive areas, improper irrigation and destruction of channels for flood conveyance. The width-depth ratio of representative gullies vary between 1.5 (Kazerun-Bushkan) and 17.7 (Larestan-Khalili). Therefore, the first priority for gully control is Larestan (Khalili) which detriorates the cropland areas.

Table 2. Physical characteristics of gullied regions in Fars province

Region	Altitude (m)	Surface texture	Sub-surface texture	Clay(%)	Silt(%)	Sand(%)
Bushkan	773	Loam	Loam-sandy loam	12(t) 12(d)	36(t) 38(d)	52(t) 50(d)
Tulsaman	850	Loam-sandy loam	Sandy loam	12(t) 14(d)	32(t) 38(d)	56(t) 56(d)
Konartagteh	651	Sandy loam-loam	Loam-sandy loam	32(t) 30(d)	28(t) 24(d)	39(t) 46(d)
Fadag	538	Sandy loam-loam	Sandy loam-loam	10(t) 14(d)	34(t) 28(d)	56(t) 58(d)
Khalili	485	Sandy loam	Sandy loam-loam	12(t) 10(d)	29(t) 23(d)	59(t) 67(d)
Goorspid	1148	Sandy loam	Sandy loam-loam sand	7(t) 6(d)	18(t) 8(d)	74(t) 86(d)
Bidkarz	655	Sandy loam	Loam-sandy loam	5(t) 17(d)	32(t) 30(d)	62(t) 53(d)
Michan	620	Sandy clay loam	Loam-sandy loam	14(t) 12(d)	41(t) 13(d)	46(t) 75(d)
Bangatar	1987	Sandy loam-loam	Sandy clay loam	32(t) 37(d)	19(t) 12(d)	49(t) 51(d)
Javid	2182	Loam- clay loam	Sandy loam	18(t) 26(d)	26(t) 15(d)	56(t) 58(d)
Ghazian	2148	Loam-sandy loam	Sandy loam	25(t) 19(d)	32(t) 17(d)	43(t) 64(d)
Firoozabad	1275	Loam-sandy loam	Clay loam	24(t) 28(d)	36(t) 30(d)	40(t) 42(d)
Neyriz	1630	Loam-sandy loam	Loam- sandy loam	15(t) 23(d)	22(t) 28(d)	63(t) 49(d)
Mazayjan	818	Sandy loam-loam	Sandy loam	12(t) 6(d)	32(t) 16(d)	56(t) 78(d)
Baba-arab	1093	Sandy loam	Sandy loam	11(t) 3(d)	34(t) 38(d)	55(t) 59(d)
Sarvestan	1595	Loam-sandy loam	Loam- sandy loam	14(t) 12(d)	35(t) 14(d)	51(t) 74(d)

(t) : soil surface layer (d) : soil sub-surface layer

Conclusions

Gullies are distributed in seven climate zones dominantly in the temperate semi arid climate in Fars province. Gullies were formed in rangeland and dryland farms with the view plan of dendritic. Using conventional tillage caused increasing surface runoff and gully initiation. Gullies have the medium depth class between 1 and 0 meters. Their cross sections are dominantly U-shaped in plains and V-shaped in hilly and mountainous areas. The width/depth ratio varies between 2 and 18 with a higher ratio in the agricultural plains. Cluster analysis shows five classes of similar gullies in Fars province.

Table 3. Some morphometric characteristics of representative gullies in Fars province

Region	Location	General view plan	Depth(m) (50% of gully length)	Topwidth(m) (50% of gully length)	Height of headcut(m)	Shape of cross section
Bushkan	Slope thalweg	digitdate	6.5	9	0.3	V
Tulsaman	Slope thalweg	digitdate	2.7	20.7	0.4	V
Konartagteh	Slope thalweg	digitdate	1	6	0.55	U
Fadag	plain	digitdate	1.45	4.3	0.4	V
Khalili	plain	digitdate	0.6	10.6	0.3	V
Goorspid	Slope thalweg	digitdate	1.54	2.7	0.5	U
Bidkarz	Slope thalweg	digitdate	3.4	3.1	1.8	V
Michan	Slope thalweg	digitdate	4.2	8.5	1.15	V
Bangatar	Slope thalweg	digitdate	12	30	0.7	V
Javid	Slope thalweg	Digitdate Linear	1.4	3.9	0.9	V
Ghazian	Slope thalweg	digitdate	1	3.9	0.5	V
Firoozabad	plain	digitdate	1.95	14	1.7	V
Neyriz	plain	digitdate	1.8	7.2	0.4	U
Mazayjan	plain	digitdate	1.5	9.5	0.78	U
Baba-arab	Slope thalweg	digitdate	6	12.9	2.4	V
Sarvestan	plain	digitdate	1.3	3.8	0.6	U

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