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INVESTIGATION OF TOPOGRAPHIC THRESHOLD RELATIONS OF GULLY CREATION IN VARIOUS LAND USE IN FARS PROVINCE, I.R.IRAN)

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ABSTRACT

Due to sediment production and tremendous damages resulted by land destruction, roads and construction factors in Fars province, gully erosion is considered of high priority. One of the studied thresholds in gully erosion is topographic threshold. This threshold is given as exponential relation between area and slope above the point of gully. The current research is to compare topographic threshold in gully creation in various land use in Fars province, south west of I.R.Iran. Six most important gully regions were chosen and in each region, 30 active gullies were selected for detailed study and sampling. At the first stage, watershed and gully erosion boundary, and their land uses were determined on the topographic map with a scale of 1:25000. Area and slope above the point of gully outlet were measured in the field, land physical properties and soil chemico-physical properties in each gully were determined by lab measurement. Area and slope relationships of gullies were determined in different lands and the chart was drawn in Excel software. The findings indicated that the power relationship exists between watershed areas and slope gradient above gully outlets for three land uses including bare land, cropland and rangelands. The relationship for bare land, cropland, and rangelands were calculated for and respectively. The obtained power of value was lower than the results obtained from other investigations in different regions of the world susceptible soil, poor vegetation cover, and miss-management of land uses are the reasons for low threshold in Fars province.

KEYWORDS: Gully Erosion, Topographic Threshold, Land Use, Fars Province

Threshold is the point where system's behavior changes right after it (Phillips, 2006). Threshold can be correlated with internal factors like geologic formation, soil or external factors such as climate. The most common thresholds in ecosystem are the propellant proportion to resistance of surface, and water flow or wind velocity for particles and sediment transportation. Gully erosion has some thresholds including topographic thresholds, hydraulic, pedology, land use, and land coverage (Poesen et al., 2003).

This concept was used in geomorphic systems for the first time by Patton and Schumm (1975). Based on this theory; the drainage area was used as a surrogate for surface runoff for areas where there is no runoff measurement. With increasing slope gradient, watershed area will be decreasing if surface runoff is dominant hydrologic process and vice versa. Therefore, there are different topographic thresholds to create and develop a gully system in different conditions of ecosystems.

In order to initiate and develop a gully, there is a threshold for drainage area (A) and slope gradient (S) above the point of gully creation or existing head cuts (gully development) (Montgomery and Dietrich, 1993). Topographic threshold in gully erosion is declared by power relationship between watershed areas and slope gradient. Points which placed on top of the threshold line are faced with gully erosion.

Topographic threshold relationship can be written as or, in which t is equal to and defined as topographic threshold. Positive sign of B refers to subsurface runoff and negative sign implies on surface runoff on gully creation or development. Therefore, places face the gully erosion risk where is maintained (Poesen et al., 2003).

Montgomery and Dietrich (1993) determined the fact that if there is a direct relationship between the upstream area and slope of gully, the dominant performance is related to the subsurface process, and if there is a reverse relationship between the two parameters, the dominant performance is related to surface flow.

Nachtergaele et al. (2002) in their study in Loess Belt, Belgium compared topographic thresholds for gullies with different depth. They found that equation exponent and coefficient are greater for winter gullies (average depth more than 0.8 m), than shallow summer gullies (average depth less than 0.8 m). It implies that surface runoff has effective performance in deepening the gullies (Equations 1 and 2).

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(Equations 2. Shallow Gullies)

Poeson et al. (2003) summarized the results of different researches about topographic threshold in different land uses (Fig. 1). In this figure, dotted lines show agricultural land use and full lines show forest, bush land, and woodlot. The findings indicate that agricultural land use (dotted lines) has less watershed area and slope gradient for gully erosion while forests and rangeland require much higher area (lines 6 and 10) and slope (lines 7, 8 and 9) to create gully in natural land uses like range and forest, it needs much of the space (lines 6 and 10) or slope (lines 7, 8, and 9) to create surface runoff for gully formation. The findings indicated different methods of measurement with different outcomes for topographic threshold. It indicated that measurement of slope on aerial photos or topographic maps produced lower figures than field measurements (lines 1 and 2 in Fig. 1). They stated that any land use types changing from natural ones to crops reduce biomass as well as resistance of soil surface, therefore, it decreases topographic threshold of gully erosion. As in non-agricultural lands (mainly rangelands), areas between 0.2 and 2000 hectares, and slope between 0.01 and 1m/m face gully erosion while in agricultural lands, less areas between 0.02 and 80hectares, and slope between 0.003 and 0.8m/m are necessary to form gullies (Table 1).

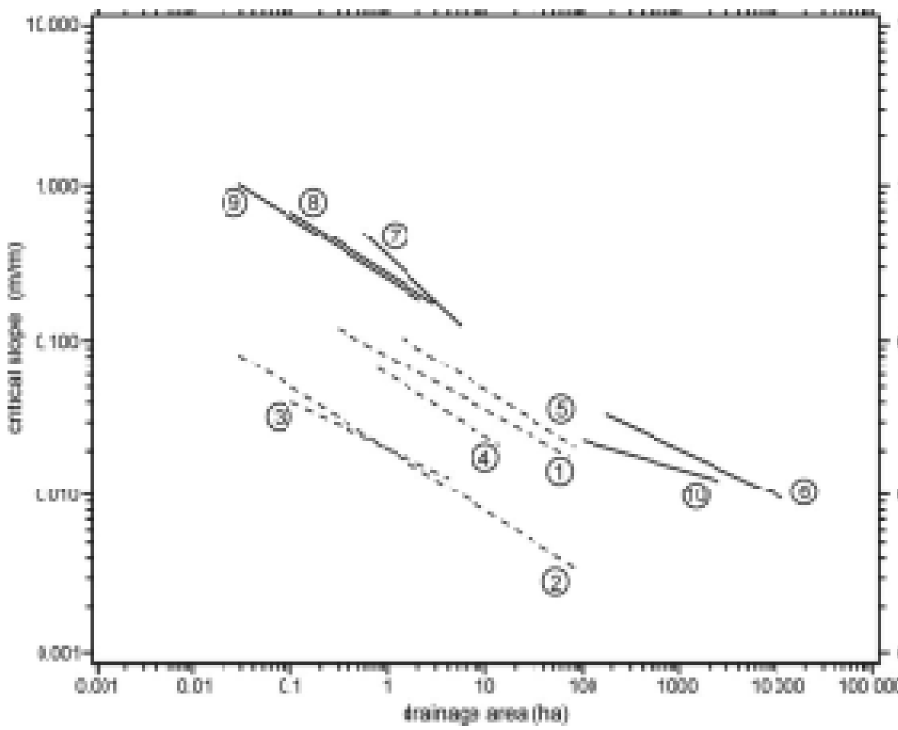

Figure 1: (Poesen et al., 2003): Relationship between critical slope of soil surface and drainage area for incipient gully development in a variety of environments (after Poesen et al., 1998). Dotted lines indicate threshold conditions for ephemeral gully development in cultivated cropland (1–5). Solid lines indicate threshold conditions for gully head development in noncultivated land (6 = sagebrush and scattered trees; 7 = open oak woodland and grasslands; 8 = coastal prairie; 9 = logged forest and 10 = swampy, reed-covered valley floors). (1) Central Belgium: field survey (Poesen,unpublished data); (2) Central Belgium: analysis of aerial photos and topographic maps (Vandaele et al., 1996); (3) Portugal: analysis of aerial photos and topographic maps (Vandaele et al., 1996); (4) France: analysis of aerial photos and topographic maps (Vandaele et al., 1996); (5) UK (South Downs): field survey (Boardman, 1992). (6) USA (Colorado): analysis of aerial photos and topographic maps (Patton and Schumm, 1975); (7) USA (Sierra Nevada): field survey (Montgomery and Dietrich, 1988); (8) USA (California): field survey (Montgomery and Dietrich, 1988); (9) USA (Oregon): field survey (Montgomery and Dietrich, 1988); (10) Australia (New South Wales): field survey (Nanson and Erskine, 1988).

Table 1: Slope and Drainage Areas for Topographic Threshold in Different Studies

Name of researcher	Kind of study	Kind of land use	Area (ha(	$^m/_m$ Slope
Poesen (unpublished data(	Field	Agricultural	0.2-70	0.02-0.12
Patton &Schumm (1975(	Photo & map	Range (brush land(	200-10000	0.01-0.04
Montgomery & Dietrich (1988(	Field	Forest	0.2-4	0.2-0.5
Montgomery & Dietrich (1988(	Field	Range (grassland(	0.2-2	0.3-0.7
Montgomery & Dietrich (1988(	Field	Forest (lopped(	0.2-1	0.02-1
Erskine (1988) &Nanson	Field	Barren (swamp(	100-2000	0.015-0.025
Bordman (1992(	Field	Agricultural	1-80	0.015-0 .1
Vandaele et al. (1996(	Photo &map	Agricultural	0.02-100	0.003-0.8
Vandaele et al. (1996(	Photo & map	Agricultural	0.1-2	0.015-0.04
Vandaele et al. (1996(	Photo & map	Agricultural	0.5-10	0.025-0.07

Morgan and Mnomezulu (2003) stated that effective factors on topographic thresholds are land use, soil type, geologic formation, and rainfall regime.

Cheng et al. (2008) presented the equation of topographic threshold for gullies located on Loess hills, China (Table 2). They said that most of the gullies in the area are discrete and broken, forming quickly, and they have drainage areas between 100 and 300. The gullies have annual growth rate between 0.16 and 2.02.

Svoray and Markovitch (2009) in Yehezkel, Israel found that factors like heavy and long rainfall in winter, and the uncovered lands reduce topographic threshold for gully erosion.

Nazarisamani et al. (2009) studied threshold conditions of permanent gullies in arid land in slopes between 28% and 40% in south west of Iran, Samal catchment areas, Boushehr Province. They found the amount of exponent between -0.182 and -0.226 (Table 2). They also declared that soil attributes such as EC, SAR, and soil texture as well as operations related to land use, are important factors for gully formation.

Table 2: Comparison of Exponent (β) in Topographic Threshold for Gully Formation in Different Regions of the World

Name of researcher	Case study	(β Power)
Vandaele et al. 1996	Loess hills, Belgium	0.4
Desmet et al. 1999	Zone 1- Loess hills, Belgiumx	0.4
Desmet et al. 1999	Zone 2- Loess hills, Belgiumx	0.7
Desmet et al. 1999	Zone 3- Loess hills, Belgiumx	1
Vandekerckhov et al. 2000	Portugal & Spain	-0.133to -0.266
Nachtergaele et al. 2002	Loess hills, Belgium in deep gully	-0.152
Nachtergaele et al. 2002	Loess hills, Belgium in shallow gully	-0.141
Asch (2003) &Hessel	Loess hills, China	-0.2385to 0.1839
Mnomezulu (2003) & Morgan	Swaziland, South Africa	0.1102to 0.2610
Vanwalleghem et al. (2005(	Belgium	-0.141to -0.152
Cheng et al. (2008(	Loess hills, China	-0.2385
Nazarisamani et al. (2009(	South western of I.R.Iran	-0.182to -0.266

MATERIALS AND METHODS

Specification of Studied Areas

Fars province has the area of 133299 sq/km; it includes 8.1 percent the area of the country (I.R.IRAN), and it is the fifth vast province in the country (Fig. 2). It has boundaries with Isfahan in north, Yazd and Kerman in east, Kohkilooye and Boyer Ahmad in west, Boushehr in south and south west, and Kerman in south and south east of I.R.Iran. It has 8.6 million hectares of rangeland, 1.212 million hectares of forest, and 1.6 million hectare of agricultural land. Average temperature varies between maximum 26.2 and minimum 10.8 in Fars province. Average annual precipitation varies from 100 mm to over 400 mm. Most of Fars province land in crashed zone of Zagros has alluvial of Quaternary, Asmari, Aghajari, Bakhtiari, Pabade, Jahrom, Khanekat, Gachsaran, and Mishan ages. The regions are in pediment geomorphologic unit. Some of the characteristics of the six studied sites in this research are shown in Table 3, 4 and 5.

Table 3: Some the Characteristics of Studied Sites

Name of region	Longitude		Latitude		Average elevation (m(	Average temperature)C° (	Average annual precipitation (mm(
	From	To	1. From	To			
Babaarab	00□ □ 41 53□	00□ □ 58 53□	45□ □ 31 28□	20□ □ 37 28□	1093	23	245
Dezhkord	45□ □ 57 51□	20□ □ 54 51□	15□ □ 40 30□	33□ □ 42 30□	2182	13.5	676.4
Konartakhte	00□ □ 29 51□	26□ □ 23 51□	52□ □ 28 29□	25□ □ 35 29□	540	23	306
Gouresepid	30□ □ 24 51□	42□ □ 19 51□	50□ □ 59 29□	45□ □ 04 30□	1148	21	445
Mishan	01□ □ 57 50□	51□ □ 52 50□	22□ □ 59 29□	29□ □ 03 30□	620	24	445
Neyriz	03□ □ 23 54□	30□ □ 20 54□	05□ □ 13 29□	40□ □ 14 29□	1630	18	209.2

Method of Research

To select gullies in six regions, first, the areas with gully erosion were identified by using topographic maps with scale of 1:25000 and satellite images of IRS (2008), and the boundary of watershed and areas affected by gully erosion was drawn (Fig. 2). (The reason for selecting such regions was their indexical gullies and more problems in agricultural, residential and industrial locations).

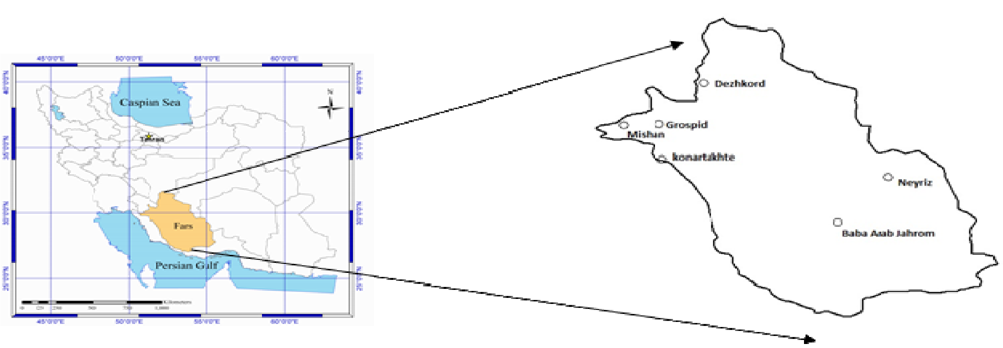

Figure 2: Preview of Geographic Location of the Six Selected Sites

Then Land use maps are provided by using satellite image interpretation, field check and Ilwis software. 30 gullies were selected for detailed study using Cochran formula. Calculation of some of the catchment characteristics such as drainage area and slope gradient above the gully point was measured in the field. In order to calculate drainage area above the point of each gully formation, it was measured with GPS (Majlan Model) in field in 2011, and it was determined by transferring field points to the GIS software. The slope above the point of each gully was measured by means of Sento clinometer. Characteristics of soil surface such as vegetation cover, gravel, litter, and bare soil was measured by placing at least 10 quadrates with an area of 1 along the transact randomly. Water infiltration into soil was measured by Double Ring in at least four places above each gully head. A combined soil sample was collected from the headcut and walls of each gully to determine soil characteristics such as Clay, Silt and Sand, EC, organic matter (OM), pH, and SAR. Then, all measured gullies are placed in three land use groups (agricultural, barren, and range). Relation between drainage area and slope gradient above the point of each gully was determined by means of Excel software in each land use group. Also the compared differences between variables were examined by one way ANOVA by means of SPSS (Version 16) and the significance was compared by Sheffe and Duncan tests.

FINDINGS

The findings indicated that 44% of gullies are formed in agricultural land use (mainly dry farm), 42% in barren land use, and 14% in range land use. Some characteristics of the studied regions are presented in Table 4. The findings showed that the studied regions are mainly in arid and semiarid areas (except for Dezhkord which has mild Mediterranean climate), and they are mostly located on the pediment and their geologic formations are Fars group and Quaterner. Dominant soil texture is loam which implies the sensitivity of the soil to soil erosion.

Table 4: Some Characteristics of the Studied Regions

Name of region	Climate (expand Dimarton(	Geomorphologic unit	Geologic formation	Soil tissue
Babaarab	Mild desertarid	Pediment	Alluvium	Loam
Dezhkord	Mild Mediterranean	Pediment	Khanekat	Clay- loam
Konartakhte	Warm desertarid	Pediment	Aghajari	Clay- loam
Gouresepid	Cold semiarid	Pediment	Gachsaran	Loam
Mishan	Mild semiarid	Pediment	Gachsaran	Loam
Neyriz	Cold desertarid	Pediment	Alluvium	Loam

Gullies were lateral, with U-shaped cross section. Gullies were located mainly at thalweg of hilly land and plain, and their general and headcutview plans were digitated and notched (Soufi, 2004) (Table 5).

Table 5: Some Characteristics of Gullies in the Studied Regions (Based on Soufi, 2004)

Name of region	Kind of gully	Width of gully profile	Gully location	General view plan	Headcut view plan
Babaarab	Lateral	U	Thalweg of hilly land & plain	Digitated	Notched
Dezhkord	Lateral	V	Thalweg of hilly land	Digitated-lining	Notched
Konartakhte	Lateral	U	Thalweg of hilly land & plain	Digitated	Punctuate
Gouresepid	Lateral	U	Thalweg of hilly land & plain	Digitated	Punctuate
Mishan	Lateral	U	Thalweg of hilly land & plain	Digitated	Circular
Neyriz	Lateral	U	Plain	Digitated	Notched

The findings on soil parameters of gullies measured in different land uses are given in Table 6. Clay varies accordingly, between 30.55%, 26.64% and 27.89% in barren land, agricultural and rangeland gullies (Soleimanpour, 2007). Also Silt average varies between 50.50% in range land and 58.28% percentage in agricultural land. Clay and silt are in the limits that were cited by Evans (1980) and Richter and Negendank (1977) for susceptible soil to water erosion. Mean value of organic matter (OM) is 0.51% in barren land use, 0.56% in agricultural land use, and 0.49% in range land use, which is less than what declared by Wischmeier and Smith (1978). According to Lebron et al. (2002) who cited that by increasing SAR, resistance of soil aggregates decreases. The risk is more in agricultural land use than two other land uses (Table 6).

Table 6: Findings of the Measured Soil Characteristics in Different Land Uses of Fars Province

Pedology parameters	Barren land use			Agricultural land use			Range land use		
	Max	Av	Min	Max	Av	Min	Max	Av	Min
Clay	48.15	30.55	12.87	40.88	26.64	7.88	44.85	27.89	12.52
Silt	52.50	34.76	6.73	58.28	36.69	22.05	50.50	28.89	10.10
Sand	67.30	33.72	3.08	65.55	36.64	6.12	81.34	43.49	9.00
OM	1.48	0.51	0.06	1.55	0.56	0.15	1.09	0.49	0.10
SAR	56.04	0.90	0.10	14.02	1.70	0.09	1.77	0.72	0.18
EC	4.85	2.95	0.70	4.49	2.08	0.30	3.11	2.36	0.60
pH	7.69	7.31	7.03	7.92	7.48	7.21	7.81	7.25	7.03

Average values of some morpho-metric characteristic of gullies in studied regions are shown in Table 7. As it's understood from the findings, length values of the total road in the six regions indicate the fact that important gully regions focus around regions with urban development and population concentration and consequently road existence. Thus the most space of barren lands and the greatest length of the road are related to Babaarab, Konartakhte and Dezhkord regions, which include much more areas of such gullies. Although there's not a meaningful statistical relation between gully capacity, road length, land uses area (barren, agricultural, range, and garden), but field observations indicate the fact that gullies values increase by increasing road length and area of land use values like barren (Table 7). The statistics shows the increase in creation of gully erosion in regions with great area and without vegetation.

Table 7: Some Morpho-Metric Characteristics of Gullies in the Studied Regions

Regions	Kind of land use (km^2)				Total of catchment area (km^2)	Gully region area (km^2)	Volume of gully (m^3)	Road length (km)
	Barren	Garden	Farming	Range				
Babaarab	4268.06	-	2093.08	564.84	6925.98	34.45	1096.18	68.02
Dezhkord	9.03	-	-	5.25	14.28	3.01	392.26	2.18
Konartakhte	32.55	-	21.85	1.45	55.58	17.86	223.30	17.03
Gouresepid	7.24	2.88	0.28	0.11	10.51	1.99	500.49	0.91
Mishan	9.76	-	11.51	-	21.27	1.74	1062.86	0.90
Neyriz	5.34	-	1.44	-	6.78	0.66	187.84	0.85

Table 8 shows the features of gully erosion in different land uses. The findings reveal that the maximum gully length (295m) belongs to agricultural land use (dry lands).

Table 8: Morpho-Metric Values of Gullies in Different Land Uses of Fars Province

Gully characteristics	Barren land use			Agricultural land use			Range land use		
	Max	Av	Min	Max	Av	Min	Max	Av	Min
Length (m(	264.00	70.56	11.00	295.00	53.73	5.40	214.00	86.17	14.00
Upper width (m	11.50	3.50	0.51	21.20	3.81	0.26	6.01	3.11	0.92
Lower width (m	7.70	2.22	0.25	15.58	2.50	0.17	4.62	1.77	0.46
Depth (m(	6.36	1.88	0.33	5.81	1.87	0.35	3.56	1.38	0.52
(m^3 Volume(	8197.74	633.47	3.00	7255.08	554.19	1.35	2653.35	429.82	6.47
)m^3/ha (Soil losses	64493.27	16742.18	3146.44	54320.75	16892.38	1055.11	45103.09	12285.82	3592.04
)mm/hr (Infiltration	25.21	5.05	0.049	42.07	6.17	0.049	12.70	5.14	2.15

Topographic threshold power relation between area and slope are determined by Excel software to create gullies in each specific land use (agricultural, barren, and range) with 60% resemblance percentage (Fig. 15 to 17). Topographic threshold power relation of gully erosion creation in barren, agricultural, and range land uses is equal to , and respectively. Also, topographic threshold relation coefficients in gullies output are given in Table 9 by land uses division. The findings show higher amounts of regional coefficient in agricultural land use in comparison to range and especially barren land uses. Probably morpho-metric factors and soil physical and chemical properties are affective in transcending the coefficient.

Table 9: Topographic threshold relation and coefficients in above the point of gullies output by land uses division

Kind of land use	Relation	Exponent	)t (α	β	R^2
barren	$S = 0.0259A^{0.1814}$	Positive	0.0259	0.1814	0.1389
agricultural	$S = 0.0268A^{0.1542}$	Positive	0.0268	0.1542	0.2856
range	$S = 0.0264A^{0.1827}$	Positive	0.0264	0.1827	0.1585

The study of the other land uses conditions show more amounts of Clay in barren land use (48.15%) towards the range (44.85%) and agricultural (40.88%) land uses. In addition, Silt amounts in lands with agricultural land use (58.28%) are further than the amounts in barren (52.50%) and range (50.50%) land uses. Also Infiltration amount of agricultural lands (6.17mm/hr) is more than this amount in range lands (5.14mm/hr) and barren (5.05mm/hr) land uses (Tables 6 and 8). The statistics express the fact that in regions which Silt, bare soil, and Infiltration amounts are high, the amount of decreases too, and gully erosion creation conditions are prepared quicker, faced with these conditions in lands with agricultural land use in Fars province.

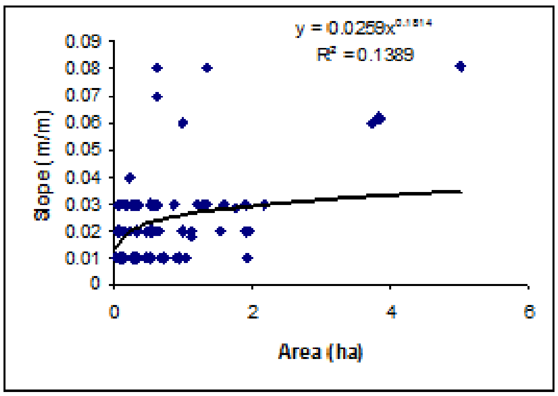

Figure 3: Relation between Area and Slope above the Point of Gully in Barren Lands in Fars Province

As it is obvious in Fig. 3, most of gullies with barren land use are gathered at the bottom of cycloid that shows their amounts near slope above the point of gully (0.01 to 0.04m/m) and area above the point of gully (0.01 to 2hectare). This set of gullies which mainly have same slope and different area, have difference in vegetation cover condition and soil physical and chemical properties, while 9 gullies located on higher parts of figure show further amounts of slope above the point of gully (between 0.06 and 0.08m/m) and area above the point of gully (between 0.61 and 4.99hectare). The 9 gullies are related to Mishan and Konartakhte regions which are different from other gullies due to some of morpho-metric properties. The gullies have further amounts of length (between 43 and 264m), volume, depth, and up and down widths.

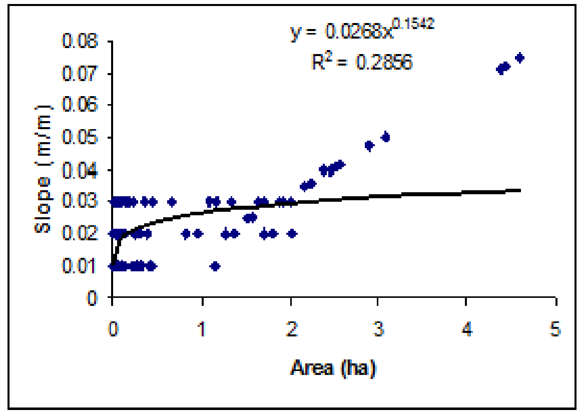

Figure 4: Relation between Area and Slope above the Point of Gully in Agricultural Lands in Fars Province

As it is shown in Fig. 4, most of the gullies with agricultural land use are gathered in the middle part of cycloid and it indicates the propriety between slope above the point of gully (between 0.01 and 0.03m/m) and area above the point of gully (between 0.01 and 2 hectares). While near 8 gullies which located on higher and right of the figure, show further slope above the point of gully (from 0.035 to 0.05m/m) and area above the point of gully (from 2 to 3.2hectare), which are related to some of the gullies in Konartakhte, Gourespid, and BabaarabJahrom regions. These gullies have further length, volume, depth, and up and down widths in comparison to other gullies. 4 gullies which located on top right of the figure have further slope amounts (from 0.07 to 0.08m/m) and area above the point of gully (between 4 and 5hectare), which are related to gullies in Konartakhte region that have further amounts of length, volume, depth, and up and down widths in comparison with other gullies.

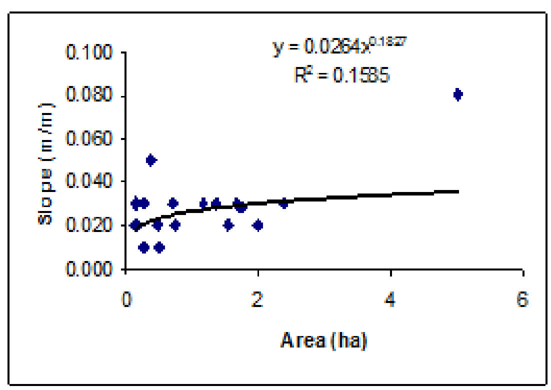

Figure 5: Relation between Area and Slope above the Point of Gully in Range Lands in Fars Province

As it's clear in Fig. 5, most of the gullies with range land use are gathered at the bottom of the cycloid which shows propriety between slope above the point of gully (from 0.01 to 0.03m/m) and area above the point of gully (between 0.01 and 2.5hectare) values. While a gully located on top of the figure has further amounts of slope (0.081m/m) and area above the point of gully (5.01 hectares) which are related to gully in Konartakhte region. This gully has lower amounts of length, organic matter percentage, vegetation cover percentage, further amount of bare soil and depth in comparison with other gullies.

DISCUSSION AND CONCLUSIONS

Topographic threshold exponential relation of gully erosion creation in barren, agricultural, and rangeland uses are equal to , and respectively. Therefore, according to Table 2, topographic threshold exponent value ( ) of gully erosion creation are lower in obtained land uses than in other accomplished investigation in different regions of the world. It could be because of the difference in vegetation cover of upstream catchment divide, as in some of the prior studies; good range coverage and difference in soil type, and consequently potential of Fars Province lands to create this kind of erosion are other factors of the low topographic threshold of gully erosion creation in studied regions. The accomplished investigations in Europe show that exponent was negative in many of the researches.

In other words, it shows surface runoff effect in loess and alluvial regions, Belgium. While this exponent is positive in three land uses, and has subsurface runoff effect in creating gullies. Its reason could be related to morpho-metric properties, soil, and vegetation cover above the point of gully in studied regions. Also based on Fig. 1 and given values in it for different conditions and land uses, it is specified that every kind of change in land uses cause decrease in producing biomass and surface soil resistance towards erosion, which decreases topographic threshold of gully erosion. As it is seen in Fig. 1, in lands with non-agricultural land use (mainly forest and meadow), slope and area above the point of gully values are higher, and consequently threshold of gully erosion creation is higher, while in regions with agricultural land uses, the numbers are lower, and threshold of gully erosion creation will occur faster. Studied regions in Fars province are in this group too, and morpho-metric and weather factors have lower values of threshold because of bad natural conditions (soil, vegetation cover), are faced with types of erosions and especially gully erosion much faster. According to these cases, it could be reported that wrong land use and improper use of lands potential are the reasons for this issue in the studied land uses in Fars province.

Solutions including correct use of lands symmetric to their potential, protecting vegetation cover (forest, shrubberies, and natural thicket) appropriate management of ranges and their preservation, and observing the right rules of road construction helps decrease gully erosion rate. Thus, the more dry lands face erosion, left like bare and obsolete lands, and the road length increase, the more gullies spaces will increase. So it suggests that inefficient dry lands convert to ranges, and control and manage produced runoff by building new roads (transfer streams).

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