BIABAN

BIABAN (Desert Journal)
Online at http://jbiaban.ut.ac.ir

BIABAN 12 (2007) 61-68

Testing the four models for prediction of gully head advancement (case study: Hableh Rood basin- Iran)

H. Ahmadi[a], A.A Mohammadi[b*], J. Ghodousi[c], A. Salajegheh[d]

[a] *Professor, Faculty of Natural Resources, University of Tehran, Iran*
[b] *Ph.D. Student of Watershed Management, Islamic Azad University, Scientific and Research Campus, Tehran, Iran*
[c] *Assistant Professor, Watershed Management and Soil Conservation Institute,Iran*
[d] *Assistant Professor, Faculty of Natural Resources, University of Tehran, Iran*

Received 21 August 2006; received in revised form 30 May 2007; accepted 15 August 2007

Abstract

Gully erosion is one of the most complicated and destructive forms of water erosion. In order to prevent this erosion, the important factors advancing gully head must be recognized. Nowadays, several models have been proposed in measuring gully head advancement and identifying the severity of erosion. These models must be calibrated for each country to see whether they are applicable or not. So it has been tried to study the necessities of the calibration in this research. This has been done in one of the sub-basins of Hableh Rood basin called Dehnamak in arid and semi-arid climate of Iran. Three aerial photos of 1956, 1967 and 2000 years have been used to measure the gully head advancement in different periods of time including 1956-1967, 1967-2000 and 2000-2005. Then in order to calibrate four models: 1- Thompson, 2- SCS (I), 3- SCS (II) and 4- FAO, all factors have been measured and studied. Statistics studies such as relative error percent, absolute error percent and change variable percent have been used. The results of the mathematical study show that SCS (II) and FAO model have a relative error percent and absolute error percent with amounts of 37.3 and 7.51 and, 40.06 and 18.21, respectively. Regarding to change variable percent, only 0.51% can be seen as a different between SCS (II) and FAO models, because of the usage of same factors and coefficients, each of two models are close to each other. Finally, the best models in the studied area are SCS (II), FAO and SCS (I) respectively, and Thompson model cannot be proposed.

Keywords: Hableh Rood basin; Gully erosion; Aerial photos; Iran

1. Introduction

Soil is affected by the result of interaction among factors, which strengthen, or decline the effect on erosion. The soil erosion is important in Iran because about 90 percent of the country is covered by arid and semi-arid climate and precipitation has not a normal distribution. In this condition, lack of vegetation cover and run off increase have caused soil loss up to 2.5 billion ton per year (Ahmadi 1999). It has also caused many damages through sediment accumulation in reservoir dams, water canals, bed of river and agricultural lands in the country. For instance, soil erosion has been increased four times between 1951 to 1999 in the country, which show the critical condition of erosion, and necessity of control (Ahmadi, 1999). But prevention or combating water erosion needs the recognition of critical areas and the role of each kinds of water erosion in land degradation and sediment production. Since this issue has not been recognized completely, thus researching on this issue is important and needs extensive scientific activities. The results of conducted research in the world show that occurrence of gully and bank erosions causes, a bulk volume of soil to be lost compared to other kinds of water erosion.

* Corresponding author. Tel.: +98 21 66713955;
fax: +98 21 33861281
E-mail address: aliasgharmohammady@yahoo.com

However first studies on gully erosion were done in 1960 in the united states then, other countries such as Spain, Japan, China, England etc carried out some studies.

Ghodousi, in a study titled "gully advancement and development in Sarcham area of Zanjan province-Iran" found out that gully advancement has a direct equation with the amount of soluble materials in the soil, concentration of surface runoff, properties of soil horizons, rainfall intensity and vegetation cover. However, geological formations, type of soil and land use are the main factors affecting gully advancement and extension (Ghodousi, 1994). Karimi, studied the prevention of gully advancement in Zahan area of Khorasan province-Iran pointed out that among models presented for gully advancement such as SCS, FAO, Beer and Segnier; FAO model is the best model for gully advancement estimation in arid areas (Karimi, 1997). Ghaffari, using remote sensing (RS) and geographic information systems (GIS) evaluated the ability of EGEE model for predicted of gully longitudinal advancement in Charmahal and Bakhtiari and found out that EGEE model was one the best one model for these studies (Ghaffari,1998). Harley and Ronald, using digital information and applying them on the three series of aerial photos for two areas in New Zealand, showed the mean gully advancement of studied area as 0.01 to 0.73 meter per year and stressed that aerial photos have a good capability for studying gully longitudinal advancement (Harley & Ronalds, 1999). Felfoar *et al.*, using aerial photos in period of 1952-1963, 1963-1974 and 1974-1989 in a watershed with 1400(ha) area in Old mires of Tunisia have conducted a research study on equation between drainage basin of gully with its advancement applying and found out that there were differences in the longitudinal and velocity of gully advancement in the studied time periods (Felfoar et al, 1999). Vandekerckhove et al, using aerial photos and field control of satellite images calculated gullies volume and figured out that gully only could be studied by using aerial photos and satellite images in long-term and shown that there are good correlations between field measures of length of gullies with detected lengths (Vandekerckhove et al., 2002).

2. Material & Methods

2.1. Study area

Dehnamak basin is one of the sub basins of the Hableh- Rood basin, Semnan Province (Fig.1) located on the north of Dehnamak village in 52° 42' 36" to 52° 48' E and 35° 15' 13" to 35° 32' 33" N with 243.25 km^2 area. Main amount of precipitation in the studied area is related to Mediterranean circulation that influences area from west in autumn to spring. Since upper land of watershed is located on South Mountain of central Albors, arid and semi-arid climate is predominant. The southern of watershed, is adjacent to desert and so is influenced by desert climate condition. Eocene rocks have been extended and have formed the oldest alluvial's in this area. To the east, west and north, in 35 30' N, old rocks are seen as out crops. Finally, in the studied area, due to development of Tertiary rocks no older sediments can be seen. So, no lithological variety can be seen and totally igneous and evaporated and low amount of Pyroclastic rocks related to Oligocene-Miocene (lower red and Qom and upper red formation) have been developed in this area. Geomorphologic, vegetation-covered pediment with flat areas and mountain-surrounded plains with gully erosion have a maximum area percent as 59.77%.

2.2. Research Methods

1- Preparing statistics and information including meteorological data, maps and existing reports on studied area with relevant topic from organizations, as follows:

- Topographic maps with scale of 1:50000 Geographical Organization of Armed Forces of Islamic Republic Iran.
- Geologic maps with scale of 1:100000 NIOC.
- Aerial photos with scale of 1:55000 (1956) and 1:40000 (2000) Geographical Organization of Armed Force of Islamic Republic Iran and 1:20000 (1967) Surveying Organization of Country.

2- Selection of gullies: At first stage, 16 gullies in the area with drainage density over 5 Km/Km^2 were selected based on interpretation of aerial photos and field surveys to facilitate the measurement of their length in the photos during different periods and to use measured precipitation data.

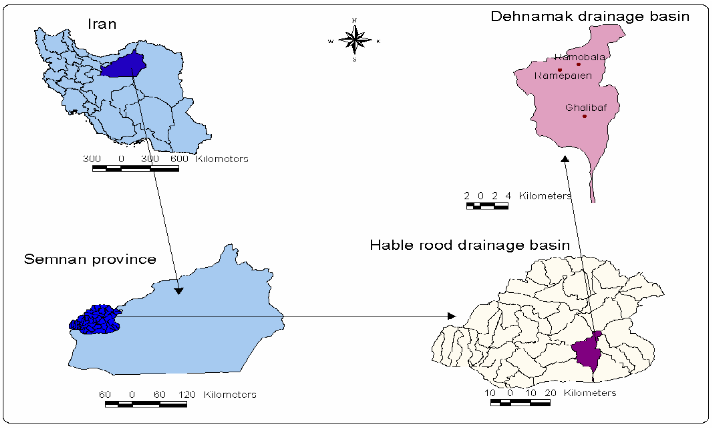

Fig. 1. Geographic position of Dehnamak basin

3- Determining spatial location of gullies: To determine spatial location of gullies and their location on the aerial photos, a GPS was used. So that, the 16 selected gullies were located (Fig2).

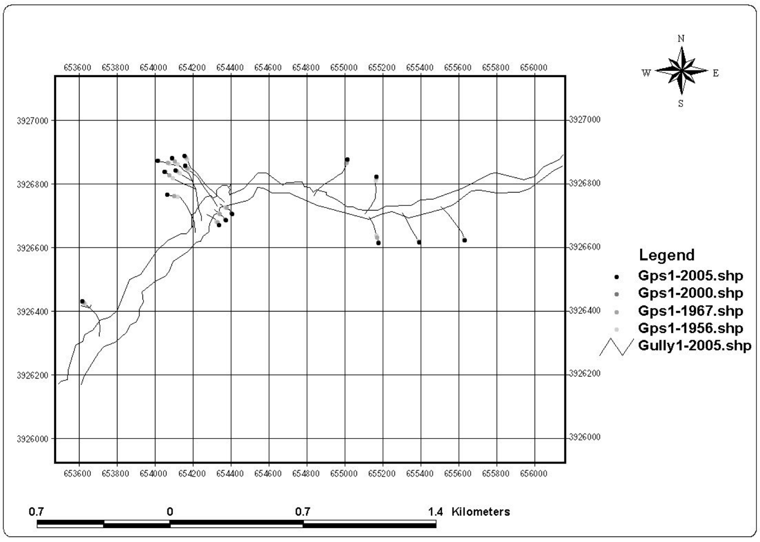

Fig. 2. Map of spatial position of gullies head cut

4- Determination of selected gullies location on the aerial photos: At this stage, with use of aerial photos with scale of 1:55000 (1956), 1:40000 (2000) and 1:20000 (1967) location of 16 studied gullies were determined after geo-referencing with use of topographic maps of studied area, locating of gullies using GPS[1] and field survey.

5- Measurement and locating of gullies length: To determine the length of each gully, positioned points were geo referenced using aerial photos and overlaid. Then through interpretation of aerial photos, head cuts were determined. In the three periods and their geographic position were recognized.

6- Calculation of longitudinal growth of gullies: The longitudinal growth of gullies was computed in three periods as 1956-1967, 1967-2000 and 2000-2005.

7- Estimation gully head advancement with use of studied models:

7.1- Thompson model:

$$R=0.15A^{0.49}.S^{0.14}.P^{0.74}.E \quad (1)$$

Where: R, is gully head advancement (foot/year), A is gully head watershed area (Acre), S is gullies bed slope (%), P is amount of precipitation equal or more than 0.5 inch in 24 hours and E is percentage of clay in the soil of watershed area.

[1]- Global positioning systems

7.2- First model of American soil conservation service (SCS (I)):

$$R=1.5W^{0.46}.P^{0.2} \quad (2)$$

Where: R, is gully head growth (foot), W is gully head watershed area (Acre) and P is Total precipitation in 24 hours equal or more than 0.5 inch during formation and advancement of gully (inch). With regard to this factor and limitation of precipitation information, this model was only used for periods of 1967-2000 in our area.

7.3- Second model of American soil conservation service (SCS (I I)).

$$R2= R1(A1/A2)^{0.46}(P2/P1)^{0.2} \quad (3)$$

Where: R2, is gully longitudinal growth in the future years (foot/year), R1 is gully longitudinal growth in the previous years (foot/year). It is important to mention that with regards to R1, this model is only used for periods of 1967 to 2000 and 2000 to 2005 in our area.

(A1/A2) is ratio of watershed area to entire gully watershed area, (P2/P1) is ratio of amount of precipitation equal or more than 0.5 inches in 24 hours and mean annual precipitation.

7.4- FAO model:

$$Rf=Rp(A)^{0.46}(P)^{0.02} \quad (4)$$

Where: Rf, is mean rate of gully longitudinal growth in the future years (foot), Rp is mean rate of gully longitudinal growth in previous years (foot).

It is important to mention, this can be used for periods between 1967-2000 and 2000-2005 in our area. A is ratio of watershed area to entire gully watershed area, P is ratio of amount of precipitation equal or more than 0.5 inch in 24 hours and mean annual precipitation.

3. Results

1-The results of measure of gully longitudinal growth (Fig.2) are showed in table (1).

2- The result of execution of models can be summarized as follows:

2.1- The amounts of gully longitudinal growth estimation, with using Thomson model are showed in table (2).

2.2- The amounts of gully head development estimation, with using SCS (I)[1] model are showed in table (3).

2.3- The amounts of gully head development estimation, with using SCS (II)[2] model are showed in table (4).

2.4- The amounts of gully head development estimation, with using FAO model are showed in table (5).

With regards to the results of the models, it should be mentioned, that causes to definite the amounts of gully head development estimated in different period of times in studied area (table 2,3,4 and 5) in one aspect and the amounts of gully head development measured in accordance with time periods, head development of them as a base and index for calibration an evaluation amounts of testing the four models in other aspect (table1), have been done to comparison gully head development estimated with gully head development measured in the way of calculation of variable error percent, absolute error percent and change variable percent (Table 6 and 7).

4. Conclusion

With regards to calculation of relative error percent, absolute error percent and change variable percent related to estimate amount of gully longitudinal growth compared with amount of measured gully longitudinal growth (Table1), following results can be proposed:

A) As it shown in table (6), second model of American soil conservation service, (SCS (II)) is the most suitable model, with the least relative error percent (37.3) and absolute error percent (7.51). FAO model with the relative error percent as (40.06) and absolute error percent as (18.21) can be introduced as then suitable model for the other area with similar condition. In addition, with regard to the results of gully longitudinal growth, the mean gully longitudinal growth measured in studied area for period's 1956-1967, 1967-2000 and 2000-2005 was 0.206 meter per year (Table1). This amount is different from mean gully longitudinal growth estimated with SCS (II) (Table 4) and FAO (Table 5) models.

However with regard to gullies longitudinal growth in the studied area, it can be observed that gullies growth and advancement in this area is similar to the gullies development and growth in Zanjanrood basin, which have same environmental condition.

B) The comparison of change variable percent of estimated longitudinal growth using testing models (Table 7) showed that SCS (II) has the least change variable percent compared to other three models.

In addition, regarding to table (7), it can be observed that FAO model is different from SCS (II).

This is due to this reason that both models use the same parameters.

1- First model of American soil Conservation Service

2- Second model of American Soil Conservation Service

In other words, these two models are the most suitable ones for the studied area. This result is similar to the result of Karimi (1997), Ghodousi (2003) and Motezaie Fariz Hendi (2005), researches.

Table1. Measuring of gully head development in Dehnamak Drainage Basin in three Periods of time with using aerial photos

Gully number	Gully head advancement							
	1956-1967		1967-2000		2000-2005		Mean longitudinal growth	
	Foot/ Year	Meter/ Year	Foot/ Year	Meter/ Year	Foot/ Year	Meter/ Year	Foot/ Year	Meter/ Year
1	0.75	0.22875	0.32	0.0976	0.292	0.08906	0.454	0.13847
2	1.75	0.53375	1.06	0.3233	0.998	0.30439	1.27	0.38735
3	2.12	0.6466	0.84	0.2562	0.412	0.12566	1.124	0.34282
4	0.42	0.1281	0.57	0.17385	0.048	0.01464	0.349	0.10644
5	0.882	0.26901	1.572	0.47946	0.814	0.24827	1.09	0.33245
6	0.492	0.15006	1.1	0.3355	0.632	0.19276	0.741	0.22600
7	0.96	0.2928	0.44	0.1342	0.43	0.13115	0.61	0.18605
8	1.1	0.3355	0.28	0.0854	0.05	0.01525	0.47	0.14335
9	0.6	0.183	0.44	0.1342	0.44	0.1342	0.49	0.14945
10	1.27	0.38735	0.22	0.0671	0.079	0.02409	0.523	0.15951
11	0.273	0.08326	0.215	0.06555	0.106	0.03233	0.198	0.06039
12	0.19	0.05795	0.22	0.0671	0.117	0.03568	0.175	0.05337
13	1.2	0.366	0.79	0.24095	0.8	0.244	0.93	0.28365
14	0.46	0.1403	1.21	0.36905	1.2	0.366	0.965	0.29432
15	0.418	0.12749	1.218	0.37149	1.4	0.427	1.012	0.30866
16	0.63	0.19215	0.47	0.14335	0.159	0.04849	0.42	0.1281
Sum	13.51	4.12207	10.965	3.34435	7.977	2.43298	10.819	3.29979
Annual growth	0.844	0.25760	0.685	0.20892	0.4985	0.15204	0.675	0.20587

Table2. Estimation of gully head development in Dehnamak Drainage Basin with using Thompson model

Gully number	Gully head advancement							
	1956-1967		1967-2000		2000-2005		Mean longitudinal growth	
	Foot/ Year	Meter/ Year	Foot/ Year	Meter/ year	Foot/ Year	Meter/ Year	Foot/Year	Meter/ Year
1	34.65	10.5685	34.651	10.5685	34.645	10.5667	34.65	10.5682
2	113.7	34.6968	113.796	34.7077	113.74	34.6907	113.76	34.6968
3	53.00	16.1665	52.29	15.9484	51.133	15.5955	52.142	15.9033
4	15.56	4.7458	15.416	4.70188	15.402	4.69761	15.46	4.7153
5	53.48	16.3114	53.38	16.2809	52.442	15.9948	53.1	16.1955
6	44.19	13.4779	44.11	13.4535	43.669	13.3190	43.99	13.4169
7	53.5	16.3175	53.47	16.3083	53.43	16.2961	53.46	16.3053
8	15.82	4.8251	15.77	4.80985	15.757	4.80588	15.782	4.81351
9	53.13	16.2046	53.12	16.2016	53.093	16.1933	53.114	16.1997
10	31.73	9.67765	31.71	9.67155	31.71	9.67155	31.71	9.67155
11	31.07	9.47635	31.073	9.47726	31.06	9.4733	31.06	9.4733
12	31.02	9.46232	31.021	9.46140	31.021	9.46140	31.022	9.46171
13	89.99	27.4469	89.99	27.4469	89.984	27.4451	89.988	27.4463
14	115.6	35.2854	115.69	35.2854	115.624	35.2653	115.668	35.2787
15	98.55	30.0605	98.513	30.0464	97.95	29.8747	98.34	29.9937
16	54.9	16.7445	54.907	16.7466	54.901	16.7448	54.902	16.7451
Sum	89.05	27.163	88.907	27.1166	885.56	270.095	888.296	270.930
Annual growth	55.65	16.9756	55.5566	16.9447	55.347	16.8808	55.518	16.9329

Table3. Estimation of gully head development in Dehnamak Drainage Basin with using SCS (I) model

Gully number	Gully head advancement			
	1967-2000		1967-2000	
	Foot	Meter	Foot/ Year	Meter/Year
1	27.57	8.40885	0.835	0.254675
2	27.248	8.31064	0.825	0.251625
3	13.03	3.97415	0.394	0.12017
4	13.2	4.026	0.733	0.223565
5	13.18	4.0199	0.399	0.121695
6	13.15	4.01075	0.398	0.12139
7	27.07	8.25635	0.82	0.2501
8	13.197	4.025085	0.4	0.122
9	26.41	8.05505	0.8	0.244
10	26.35	8.03675	0.798	0.24339
11	25.49	7.77445	0.773	0.235765
12	26.21	7.99405	0.794	0.24217
13	26.35	8.03675	0.798	0.24339
14	27.23	8.30515	0.825	0.251625
15	28.43	8.67115	0.862	0.26291
16	27.24	8.3082	0.825	0.251625
Sum	361.354	110.213	11.279	3.440095
Annual growth	22.584	6.88812	0.7049	0.214995

Table4. Estimation of gully head development in Dehnamak Drainage Basin with using SCS (II) model

Gully number	Gully head advancement					
	1967-200		2000-2005		Mean of longitudial growth	
	Foot/ Year	Metter/ Year	Foot/ Year	Meter/ Year	Foot/ Year	Meter/Year
1	0.671	0.204655	0.2865	0.087383	0.47875	0.146019
2	1.565	0.477325	0.9483	0.289232	1.256	0.38308
3	0.9076	0.276818	0.35224	0.107433	0.63	0.19215
4	0.7854	0.239547	0.0477	0.014549	0.4165	0.127033
5	0.382	0.11651	0.67	0.20435	0.526	0.16043
6	1.686	0.51423	0.5569	0.169855	1.1214	0.342027
7	0.8546	0.260653	0.3914	0.119377	0.623	0.190015
8	0.1655	0.050478	0.042	0.01281	0.10375	0.031644
9	0.5346	0.163053	0.3918	0.119499	0.4632	0.141276
10	0.394	0.12017	0.0682	0.020801	0.2311	0.070486
11	0.5052	0.154086	0.0958	0.029219	0.3005	0.091653
12	0.43	0.13115	0.1074	0.032757	0.2687	0.081954
13	1.074	0.32757	0.7073	0.215727	0.8965	0.273433
14	0.412	0.12566	1.083	0.330315	0.7475	0.227988
15	0.39	0.11895	1.1325	0.345413	0.76125	0.232181
16	0.1947	0.059384	0.1458	0.044469	0.1703	0.051942
Sum	10.9516	3.340238	7.027	2.143235	8.994	2.74317
Annual growth	0.6844	0.208742	0.4391	0.133926	0.562	0.17141

Table 5. Estimation of gully head development in Dehnamak Drainage Basin with using FAO model

Gully number	Gully head advancement					
	1967-200		2000-2005		Mean longitudial growth	
	Foot/Year	Meter/ Year	Foot/ Year	Meter/ Year	Foot/Year	Meter/Year
1	0.7416	0.226188	0.316	0.09638	0.5288	0.161284
2	1.729	0.527345	1.047	0.319335	1.388	0.42334
3	1.002	0.30561	0.389	0.118645	0.7	0.2135
4	0.867	0.264435	0.0527	0.016074	0.46	0.1403
5	0.18	0.0549	0.734	0.22387	0.457	0.139385
6	1.862	0.56791	0.615	0.187575	1.238	0.37759
7	0.9437	0.287829	0.432	0.13176	0.688	0.20984
8	0.1827	0.055724	0.0464	0.014152	0.1145	0.034923
9	0.59	0.17995	0.4327	0.131974	0.51135	0.155962
10	0.435	0.132675	0.0753	0.022967	0.255	0.077775
11	0.558	0.17019	0.1057	0.032239	0.3318	0.101199
12	0.474	0.14457	0.1168	0.035624	0.3	0.0915
13	1.186	0.36173	0.781	0.238205	0.9835	0.299968
14	0.4549	0.138745	1.196	0.36478	0.835	0.254675
15	0.431	0.131455	1.25	0.38125	0.8405	0.256353
16	0.215	0.065575	0.1611	0.049136	0.188	0.05734
Sum	11.8519	3.61483	7.7525	2.364513	9.808	2.99144
Annual growth	0.74074	0.225926	0.4845	0.147773	0.613	0.186965

Table 6. Mean amount of variable error percent and absolute error percent of studied models

Row number	Models	Mean of relative error percent	Mean of absolute error percent
1	Thompson	12197.56	12197.76
2	SCS (I)	96.09	61.58
3	SCS (II)	37.3	7.51
4	FAO	40.06	18.21

Table 7. Mean amount of change variable percent of studied models

Row number	Models	Estimated primary C.V[a]	Mean of measure	C.V (%)
1	Thompson	1038.41	0.675	153738.51
2	SCS (I)	0.033	0.675	95.11
3	SCS (II)	0.1306	0.675	80.65
4	FAO	0.134	0.675	80.14

a. CV: Change Variable

Recommendations

With regard to the results of the study, the following recommendations can be proposed:

1- Considering number, variation and comparison of minded factors in invention models presented to prediction or estimation gullies longitudinal growth as a index to gully erosion growth and expansion recommended in soil conservation project and combating with erosion and watershed management projects, only used models that’s correction and minute of which in country have been confirmed.

2- With regard to variety conditions of climate and meteorology, tectonic and rock units, soil particularities and other environment of earth condition, recommended, models calibration in different weather and environment of earth condition with different variation of earth factors in frame of research projects defined and to be executed adequately.

3- Although gullies longitudinal growth agent is one of the main agent and is index for gully erosion growth and expansion, and amount of sediment production and in this reason that sediment portion of this erosion in comparison with other kinds of water erosion is high, thus recommended, regular research about relation between gullies longitudinal growth and volume variation and sediment producing in one aspect and variations limits of which with different kinds of gullies from such as: bulb gullies, frontal,…

References

Ahmadi, Hassan, 1999. Applied geomorphology, Volume1 (water erosion). Third edition, University of Tehran publications, 688 pp.

Felfoar, Mlaouhi, Boussema, Snane, 1999. Assessment of the influence of the litho-logy and rainfall events on gully erosion in Owed maize watershed in central Tunisia, 2nd inters Regional conference in environmental- water 99.

Ghaffari, A.R., 1998. Aerospace Techniques Applied to Gully erosion studied in Shahre-kord, Iran. Master science thesis ITC, Enschedule, the Netherlands, 113 pp

Ghodousi, Jamal, 1994. Gully growth and extension, Rangelands and Forest of country researches organization institute, Research report, 28 pages.

Ghodousi, Jamal, 2002, gully erosion morphology modeling and hazard zonation(studied area: Zanjanrood drainage basin), Ph.D. thesis, Natural resources faculty, Tehran university, 368 pages.

Harley, D.Betts, CdeRose, 1999. Digital elevation models as a tool for monitoring and measuring gully erosion. ITC, Volume1-Issue 2- 91-101pp.

Karimi, Mohammad, 1998. Study effect factors or gully erosion and introducing the best ways to prevention it in Zahan e Ghaen area, MSc thesis, Agricultural faculty, Tarbiat Modares University, 192 pp.

Mortezaie Fariz Hendi, Ghasem, 2004. Evaluation of the quantitative effects of environmental parameters on occurrence of gully erosion in order to introduce the most relevant estimation model for longitudinal development of gully, Ph.D thesis, Scientific and research campus, Islamic Azad university, 154 pages.

Vandekerckhove. L, Nachtergaele. J, Poeson. J, Oostwoud Wijdense. D., 2002. Medium-term evolution of a gully developed in a loess derived soil. Geomorphology 46, 223-233.