International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:2, No:7, 2008

Using Field Indices of Rill and Gully in order to Erosion Estimating and Sediment Analysis (Case Study: Menderjan Watershed in Isfahan Province, Iran)

Masoud Nasri, Sadat Feiznia, Mohammad Jafari, Hasan Ahmadi

***Abstract*—Today, incorrect use of lands and land use changes, excessive grazing, no suitable using of agricultural farms, plowing on steep slopes, road construct, building construct, mine excavation etc have been caused increasing of soil erosion and sediment yield. For erosion and sediment estimation one can use statistical and empirical methods. This needs to identify land unit map and the map of effective factors. However, these empirical methods are usually time consuming and do not give accurate estimation of erosion. In this study, we applied GIS techniques to estimate erosion and sediment of Menderjan watershed at upstream Zayandehrud river in center of Iran. Erosion faces at each land unit were defined on the basis of land use, geology and land unit map using GIS. The UTM coordinates of each erosion type that showed more erosion amounts such as rills and gullies were inserted in GIS using GPS data. The frequency of erosion indicators at each land unit, land use and their sediment yield of these indices were calculated. Also using tendency analysis of sediment yield changes in watershed outlet (Menderjan hydrometric gauge station), was calculated related parameters and estimation errors. The results of this study according to implemented watershed management projects can be used for more rapid and more accurate estimation of erosion than traditional methods. These results can also be used for regional erosion assessment and can be used for remote sensing image processing.

***Keywords*—**Erosion and sedimentation, Gully, Rill, GIS, GPS, Menderjan Watershed

I. INTRODUCTION

THE problem of land degradation and soil loss is a major problem in the all countries. Erosion by water is a primary agent of soil degradation at the global scale, affecting 1094 million hectares, or roughly 56% of the land experiencing human induced degradation [21,12]. Soil erosion is the most important limitation for the sustainable development, optimal land and water management and development. The understanding of the most important factors on soil erosion and sediment yield are the main keys for decision making and planning.

Masoud Nasri: Ph.D student of Islamic Azad university, science and research Branch, Faculty of Agriculture and Natural Resources, Department of watershed management, Tehran, Iran,
Email: ps_sepahan@yahoo.com
Sadat Feiznia: Professor, University of Tehran, Karaj, 3158777878, Iran, Email: sfeiz@ut.ac.ir
Mohammad Jafari: Professor, University of Tehran, Karaj, 3158777878, Iran ,
Email: jafary@ut.ac.ir
Hasan Ahmadi: - Full Professor, University of Tehran, Karaj, 3158777878, Iran

In recent years, most of the regions in the world are exposed to degradation and erosion caused by increasing population and over use of land resources.

Soil erosion has been recognized as the major cause of land degradation world wide. In the past decades, priority of research has been given to address agricultural issues at the plot scale and thus to rill and inter-rill erosion [24]. This is explained by an increasing concern for off-site impacts of soil erosion that can be tackled only at the catchment scale. It is now well recognized that increased exploitation of land resources in the upper parts of catchments results in increased sediment yield and elevated nutrient loads in runoff that reduce water quality and availability to downstream users. Furthermore, control of sedimentation in reservoirs requires that all the potentially significant sediment sources and sinks are known. Recent studies [27,14,5,11] indicate that gully erosion is often the main source of sediments. Gully erosion has been long neglected because it is difficult to study and to predict.

In recent years, most of the regions in the world are exposed to degradation and erosion caused by increasing population and over use of land resources. Logan et al., (1982) expressed the need for quantifying soil erosion processes and factors as an essential task for investigation. Land cover, soil conservation practices, and the presence of soil erosion control measures all influence actual soil loss. Land users can modify all of these. Measuring erosion is costly and time consuming whereas results may be conditioned by single events such as rain storms [13]; Lal (1994a) called it an art rather than a science. Calibration requires soil loss data from the full range of field situations for which the model will be applied. In practice, calibration is often based on data from few runoff plots with or without use of an artificial rainfall simulator [6], and/or on data from sites in other environments and/or measured according to nonstandard techniques [15,16]. All of these limit the predictive capacity of soil erosion models [4]. Monitoring schemes based on field measurement and the estimation of the volume of rills and gullies in a time span such as several years, are necessary in order to assess erosion at the landscape scale [22].

Gully erosion is a serious problem in many parts of the world, and particularly in the Mediterranean basin, because of climate, lithology, soils, relief and land use/cover characteristics. The causes, processes, prediction and control of gully erosion have aroused the interest of many researchers in different countries.. Most research has been addressed to analyze gully morphology and the stages of gully development as a first step in evaluating gully processes and assessing the potential for gully erosion. Gully erosion modeling has focused more on development of qualitative and empirical–statistical models than in the formulation of physically based models [2]. Most recently, with the aid of digital elevation modeling, research has been addressed to predict the threshold contributing area and/or other topographic effects and limits on the initiation, distribution and location of ephemeral gullies in different conditions [19].

First studies on gully erosion goes back to 1960 in the United States of America, and then other studies in some countries such as Spain, Japan, etc have been performed [1]. Ghoddusi (1994) has described that main effective factors in creation and development of gullies (in case study of Sarcham region in Zanjan province, Iran) are :Dissolved materials of soil, concentration of surface runoffs, soil properties, precipitation intensity, vegetation cover, geological formations, soil type and land use. Harley and Ronalds (1999) used digital data and three series of aerial photos in two regions in New Zealand and determined average gully growth about 0.73 to 0.01 meter per year.

Application of GIS techniques in the study of erosion in watershed has high potential for decreasing computer time used and increasing accuracy of the sediment and erosion estimation [20].

The aim of this study is estimating volume of transported soil from gullies and rills using positioning by GPS and GIS techniques in order to distinguish and management of critical erodible areas in the catchment. Also in this study will distinguished potential of error related to evaluation of soil loss volume of gullies and rills that can be affects these measurements in general, so it is necessary that researcher note them for increasing of measurements precision.

II. MATERIALS AND METHODS

A. Study area

The study area is Menderjan watershed located in Esfahan province with coordinates, 50°, 27´ to 50°, 40´ eastern longitude and 32°, 45´ and 32°, 56´ northern latitude and has 230.2 km^2 areas and altitude ranging from 2100 m to 3560 m above sea level. Position of study area in Esfahan province and Iran country has been shown in figure 1.

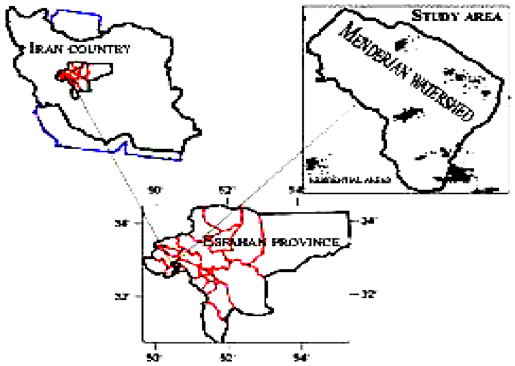


Fig. 1 Position of study area in Isfahan province and Iran country

Most important of study area characteristics have been described as following:

Average slope is 13.25 % , most important of land use in study area are rangelands, dry lands and irrigated lands and cultivated crops are barley, wheat, potato and forage plants, cereal. Average annual precipitation is 364 mm, volume of annual water discharge 83.8 MCM, average temperature 9.2 Celsius degree. Geology formations of area are mainly alluvial terraces and in the mountainous parts are cretaceous lime stones.

B. Methods

There are many indicators that are use in estimating of soil loss related to erosion types in the field assessments, such as rills, gullies, Pedestal, armor layer, tree mound, plant/tree root exposure, rock exposure, sediment in drains etc [25,26,23]. The most important indicators that are more distribution in erosion occurrence and sediment yield were seen in study area are rill and gully erosion. So in the next sections will describe only these indicators.

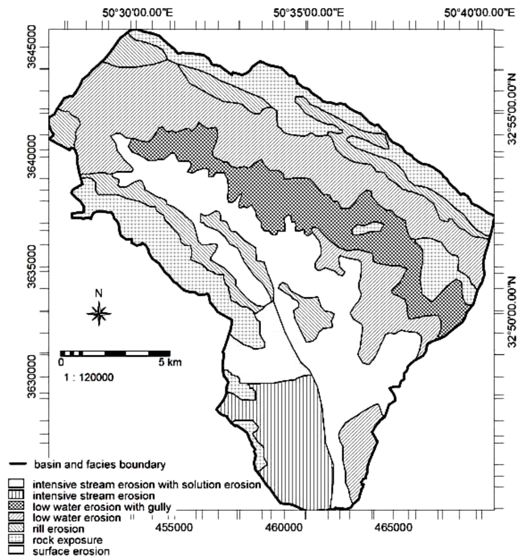


Fig. 2 Erosion forms map of study area

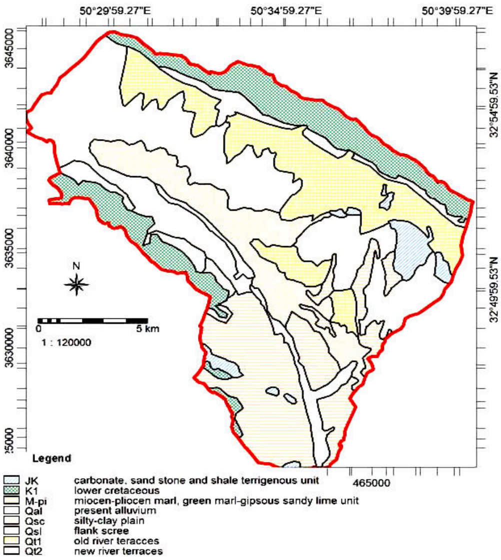


Fig. 3 Geology map of study area

In this study using field surveying and many observations and measurements about gully and rill and pedestal erosion was recorded important data.

We used GPS tool for determining of rill and gully position for distinguish of their location on topographic map and drainage network map in GIS technique. GIS technique was used for calculation of basin area boundary of each rill or gully and extract needed data and maps. In the field surveying was measured dimensions (with, length, depth etc in various sections) of rills and gullies using meter, ruler, tiltmeter and etc.

Rill: A rill is a shallow linear depression or channel in soil that carries water after recent rainfall. Rills are usually aligned perpendicular to the slope and occur in a series of parallel rill lines A rill is a shallow linear depression or channel in soil that carries water after recent rainfall. Rills are usually aligned perpendicular to the slope and occur in a series of parallel rill lines A rill is caused by the action of water. Runoff is channeled into depressions which deepen over time to form rills. A rill is, then, a product of the scouring action of water in a channel. It is also a means of rapidly draining a small part of a field and efficiently transporting sheet eroded sediment

from the rill's catchment. A broadly accepted distinction between rills and gullies, often applied in soil conservation, is that the former can be eliminated using normal agronomic practices (such as ploughing), whereas gullies require specific large interventions such as bulldozers, concrete lining or gabions (rock filled bolsters placed in gully to accumulate sediment). Rills tend to occur on slopes, while gullies occur along drainage lines.

The commonest assessment of rills is the volume of soil that has been directly eroded to create the rill: i.e. the Space volume and the associated mass of soil now missing because of the rill. This calculation does not include any estimate of the amount of erosion that occurs between rills, i.e. inter-rill erosion, which can be measured using other techniques such as pedestals. The measurement of soil loss from rills assumes that the depression forms a regular geometric shape. Triangular, semicircular and rectangular cross-sections are most common [23].

Calculations:

(1) Covert the average width and depth of the rill to meters (by multiplying by 0.01). Thus, an average horizontal width of 12cm is equal to 0.12m and an average depth of 4.2cm is equivalent to 0.042m.

(2) Calculate the average cross-sectional area of the rill, using the formula for the appropriate cross-section: the formula for the area of a triangle (i.e. ½ horizontal width x depth); semi-circle (1.57 x width x depth); and rectangle (width x depth). Thus, assuming a triangular cross-section it is:

$\boxed{}$ x WIDTH(m) $\boxed{}$ x DEPTH(m) $\boxed{}$ = CROSS-SEC AREA $\boxed{}$

(3) Calculate the volume of soil lost from the rill assuming that the measurements above were taken from a rill measuring 2.5 meters in length.

CROSS-SEC AREA (m2) $\boxed{}$ x LENGTH (m) $\boxed{}$ = VOLUME LOST $\boxed{}$

(4) Convert the total volume lost to a volume per square meter of catchment.

VOLUME LOST (m2) $\boxed{}$ ÷ CATCHMENT AREA (m2) $\boxed{}$ =SOIL LOSS(m3/m2) $\boxed{}$

(5) Convert the volume per square meter of catchment.

SOIL LOSS (m3/m2) $\boxed{}$ x BULK DENSITY (t/m3) $\boxed{}$ x $\boxed{10000}$ =SOIL LOSS(t/ha) $\boxed{}$

Gully: A gully is a deep depression, channel or ravine in a landscape, looking like a recent and very active extension to natural drainage channels. Gullies may be continuous or discontinuous; the latter occurs where the bed of the gully is at a lower angle slope than the overall land slope. Discontinuous gullies erode at the upslope head, but sediment themselves at the end of the discontinuity. Hence, several discontinuous gullies may occupy the same landscape depression, their shapes progressively moving upslope. Gullies are obvious features in a landscape, and may be very large (meters wide and deep) causing the undermining of buildings, roads and trees. A gully is caused by the action of water. Runoff is channeled into grooves which deepen over time to form a distinct head with steep sides. Gullies extend and deepen in an up-valley direction by waterfall erosion and progressive collapse of their upslope parts; gully sides may collapse by water seepage or undermining by water flow within the gully. Several conditions are conducive to gully development. They tend to form where land slopes are long and land use has resulted in loss of vegetation and exposure of the soil surface over a large area so that the land now produces more runoff. They are particularly prevalent in deep loamy to clayey materials, in unstable clays (e.g. sodic soils), on pediments immediately down slope of bare rock surfaces and on very steep slopes subject to seepage of water and to landslides. The measurement of soil loss from gullies is essentially the same as that for rills, except on a larger scale and with a different cross-sectional shape. Gullies usually have a flat floor and sloping sides, and account must be taken of these. In measuring gullies, the estimate being made is of the amount of soil displaced from the area now occupied by the gully furrows. This calculation does not include any estimate of the amount of sheet erosion occurring on the land adjacent to the gully [23].

Calculations:

(1) Calculate the average cross-sectional area of the gully, using the formula (w1+w2)÷2 x d.

(AV WIDTH W1 + AV WIDTH W2) x DEPTH(m) =CROSS-SEC AREA

(2) Calculate the volume of soil lost from the gully assuming that the measurements above were taken from a gully measuring 200 meters in length.

CROSS-SEC AREA x LENGTH (m) = VOLUME LOST

(3) Convert the volume lost to a per meter equivalent, assuming a catchment area of 1 km2, or 1,000,000 m2.

VOLUME LOST ÷ CATCHMENT AREA (m2) =SOIL LOSS (m3/m2)

(4) Convert the volume lost to tones per hectare over the whole catchment area.

SOIL LOSS (m3/m2) x BULK DENSITY (t/m3) x 10000 = SOIL LOSS t/ha

III. RESULTS

- Soil loss estimation in gullies and rills

Using field surveying in and utility of GPS this study located position of each gully and rill in the Menderjan catchment. In the next step was measured dimension (with, length and depth in several cross-sections) of rill and gully and was recorded related data. Then using recorded coordinate of gullies and rills and topographic maps and GIS techniques was distinguished basin area of each gully and rill, so was provided position map of mentioned erosion forms.

According to the field surveying was recorded data of 28 gullies and 90 rills. After that was calculated volume and weight of transported soil by gullies and rills separately.

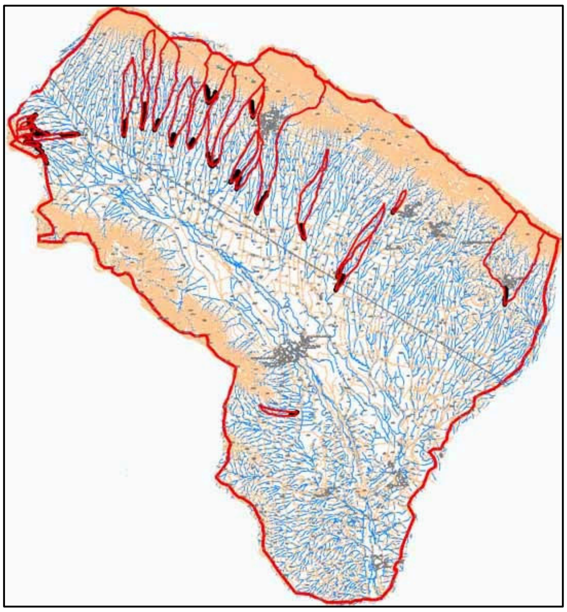


Fig. 4 position map of gullies and their basin areas

According to calculation steps that mentioned above, was calculated volume of soil loss that results has been shown in the following table for some gullies and rills in the catchment. With accordance to table 1:

Sum length of all observed gullies=12100.98 m

Sum volume of transported soil by the gullies=18954 m^3

Sum weight of transported soil by the gullies=24640 ton

It is important to note that above values special volume and weight of soil loss is related to time length of gullies generation not per one year that it can be use for calculation of average annual soil loss.

About of rills in the catchment, was recognized that sum of soil loss related to rills is 2691 m^3 equal to 3499 ton in the time of rill generation.

sum length of rills in the catchment = 23991 m

this length was calculated using GPS coordinate in the first and end and several cross-section in the across of rill in the field measurements.

According to various measurement in the field and calculations average depth of rills was 17 cm (centimeter) and average width of them was 66 cm. Average basin area of rill is about 2000 m^2 that has been calculated in the field by tools such as meter and assessment estimations using width and length and their figures in the nature by mathematical methods, however using GIS techniques can more precise and correct these assessments.

It is important to attend error potential because of nature of field studies and recording data with various effective factors that some of them may not be know yet. With this point view here are described some error potential about gullies and rills measurements, separately as following:

TABLE 1 MEASURED CHARACTERISTICS OF SOME GULLIES IN THE CATCHMENT (BULK DENSITY=1.3)

Gully No.	coordinate(UTM) by GPS		Length (m)	Slope %	sections	Up width (cm)	Middle width (cm)	Down width (cm)	Depth (m)	basin area (ha)	volume of transported soil(m^3)	weight of transported soil(ton)
	latitude	longitude				in two sections						
1	453485.15	3641101.9	572.09	6	sec. 1	150	100	70	110	80	571	742
					sec. 2	130	70	50	100			
2	454155.3	3641375.35	942.44	6	sec. 1	420	220	100	300	86	4,354	5,660
					sec. 2	280	200	100	120			
3	454622.01	3641323.5	418.89	6	sec. 1	100	75	60	120	166	449	584
					sec. 2	150	80	50	130			
4	455269.88	3640750.87	434.12	5	sec. 1	120	80	60	110	99	349	454
					sec. 2	100	60	40	100			
5	455919.29	3640643.86	368.24	5.5	sec. 1	150	100	80	170	102	566	736
					sec. 2	120	90	75	130			
6	455919.29	3640643.86	418.76	6.8	sec. 1	120	100	60	70	113	484	629
					sec. 2	220	170	100	110			
7	455919.29	3640643.86	599.7	6.8	sec. 1	85	60	50	100	113	478	622
					sec. 2	100	80	60	120			
8	456699.58	3640014.7	465.83	6	sec. 1	160	88	62	130	151	522	678
					sec. 2	130	70	50	110			
9	456778.93	3639988.48	275.69	6	sec. 1	260	200	160	180	205	860	1,118
					sec. 2	200	120	100	180			
10	458266.57	3641795.98	564.74	7.2	sec. 1	150	110	100	160	32	797	1,036
					sec. 2	100	80	65	120			
11	457444.84	3639410.16	496.81	3.5	sec. 1	85	65	40	100	63	363	472
					sec. 2	100	78	50	110			
12	457680.19	3639162.85	431.83	6	sec. 1	130	100	80	150	43	495	643
					sec. 2	95	80	65	100			
13	458414.16	3638223.24	875.53	3.5	sec. 1	90	80	60	110	644	958	1,245
					sec. 2	110	90	75	150			
14	460168.63	3637307.57	531.76	7.1	sec. 1	130	100	80	150	93	622	809
					sec. 2	100	80	50	110			
15	461398.88	3635891.07	471.22	3.6	sec. 1	120	90	65	130	62	654	850
					sec. 2	140	100	80	150			
16	461355.01	3635418.17	604.87	2.5	sec. 1	150	100	75	110	59	609	791
					sec. 2	120	80	50	100			
17	463445.46	3638274.54	174.9	8.2	sec. 1	250	150	90	170	11	541	703
					sec. 2	300	220	150	150			
18	467617.1	3634894.76	612.59	7.1	sec. 1	290	200	100	76	388	1,030	1,339
					sec. 2	260	175	60	110			
19	450072.14	3641774.13	112.99	8.5	sec. 1	220	160	90	140	11	199	259
					sec. 2	180	160	70	100			
20	450064.64	3641674.51	160.32	8.5	sec. 1	200	150	70	70	7	122	158
					sec. 2	180	100	60	50			
21	450230.98	3641860.88	133.38	8.1	sec. 1	250	180	80	120	4	198	257
					sec. 2	180	130	70	80			
22	450144.67	3641480.81	135.49	9	sec. 1	210	170	110	170	5	238	309
					sec. 2	110	100	80	100			
23	450221.65	3641356.75	173.04	8.6	sec. 1	260	200	160	180	15	540	702
					sec. 2	200	120	100	180			
24	450658.97	3641180.15	365.77	8	sec. 1	100	70	50	100	12	315	410
					sec. 2	110	80	60	120			
25	450034.87	3640999.73	238.81	6.1	sec. 1	260	200	160	180	4	745	969
					sec. 2	200	120	100	180			
26	451778.05	3641143.33	633.39	3.8	sec. 1	150	120	80	100	35	963	1,252
					sec. 2	170	140	100	140			
27	450002.96	3640872.08	159.21	6.3	sec. 1	250	180	150	160	2	396	514
					sec. 2	200	175	110	120			
28	450617.26	3640098.22	728.57	7.5	sec. 1	80	60	50	100	35	535	696
					sec. 2	95	70	65	110			
sum	-	-	12100.98	-	-	-	-	-	-	2,637	18,954	24,640

-error potential for gullies measurement

1) Gullies very often visually dominate the landscape. Many conservation schemes erroneously focus on the gully, rather than the reason for the gully, which lies in the catchment. It is

easy to forget that sheet erosion is likely to be ongoing and probably far greater in total sediment production.

2) Care needs to be exercised in measuring the catchment for gullies in order to make assessments of soil loss per hectare. In particular, the contributing area providing runoff decreases as the gully head extends up valley. Large gullies can be assessed from aerial photography or even maps.

-*error potential for rills measurement:*

1) Where rill erosion is evident, this is not the only form of erosion occurring. Rills are merely a visible symptom of sheet erosion. Therefore, it is important that any measurement of soil loss from a rill should not be treated as the total amount of soil lost from a particular area. The rill is indicative of the poor state of the immediate catchment of the rill, and wherever feasible, field assessments of sheet soil loss should be made. Experience indicates that the soil removed to form the rill is usually only a small fraction of the total soil loss from the catchment of the rill. This may not be the case if there is a dense network of rills.

2) Averaging cross-sections down the length of the rill, and then multiplying by the length of the rill, will give only an approximation of total volume, The more measured cross-sections and the closer the measurements are to the actual shape of the rill, the more accurate will be the rill erosion estimate.

3) As noted, rills occur where pre-existing depressions have become eroded by flowing water. The field assessor needs to estimate the volume of the original depression, and subtract this from the total volume, to calculate the soil removed by the rilling process.

4) Where redeposition of the materials removed from the rills occurs in the same field, to avoid overstating the level of soil lost an estimate of the amount of soil redeposited must be subtracted from the calculated soil loss from rills.

5) Rills are ephemeral features, easily obliterated by farming practice such as weeding. The evidence of erosion can, therefore, also disappear unless rapid and timely assessments are made. The early growing season in arable crops is especially conducive to rilling.

6) Estimation of the contributing catchment area to a rill must be made only after careful site inspection. Examine evidence of flow lines of water to determine the shape and size of the boundary of the contributing area. Look for the watershed between two rills as the boundary lines between contributing areas. In a leveled field between terraces or field edges, this is not usually difficult. The contributing area

may be of the order of 10 to 100m2.

7) Rills may be caused (at least in part) by run on from areas upslope. This should be taken into account when surveying for contributing area.

-*Sediment change trends*

With investigation of time series of suspended sediment yield [3] of Menderjan hydrometric gauge station and its sediment yield changes, it is possible that to distinguish and determine tendency sediment load in statistic years as figure 6.

Mean and standard deviation of observed data are 59.66 and 348.47 Mg/Lit respectively. In table 2 statistical tests has been shown.

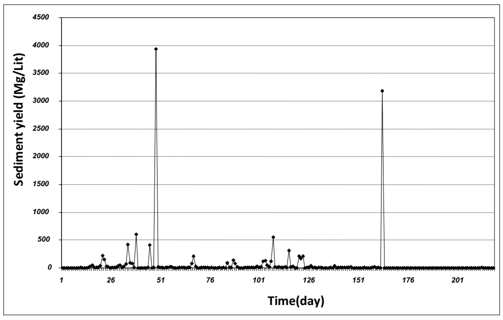
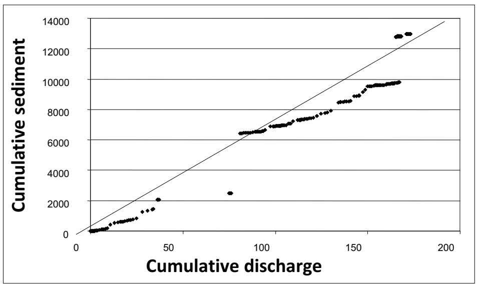


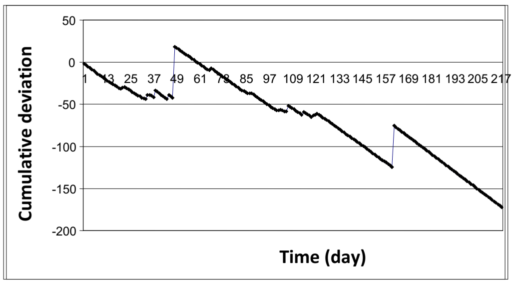
Fig. 5 suspended sediment time series in Menderjan hydrometric gauge station

TABLE II AMOUNTS OF DESCRIPTIVE STATISTICS OF SEDIMENT LOAD SERIES (MG/LIT)

Statistics	Observation numbers	minimum	maximum	mean	Standard deviation	skewness	kurtosis
amount	218	0	3936.69	59.66	348.47	9.8	100.25



a



b

Fig. 6 graph of cumulative sediment vs. discharge (a) and graph of deviation from cumulative mean (b)

IV. DISCUSSION

Because of important role of soil loss determination in natural and agricultural lands in order to sustainable management of those areas for land use system improvement in this study investigated some soil loss indicators such as gully and rill using GPS tools and GIS techniques with field measurement. So it can be result that existence of these indices shows erosion rate in catchment but distinguish sediment yield that is transported toward reservoir dams. Measurement in catchment helps to submit a suit model for estimating erosion and sediment yield. With using results can precise the empirical methods of erosion assessment and provide regional models. On the other hand according to created land forms in regional scale, it is necessary to note on error potential and reduction of it using more precision methods such as GIS techniques. In this point view it can express that in rills and gully traces and cross-section data recording to use GPS and GIS techniques for more reliable data making. However mentioned field measurements can evaluate with another indices of erosion and sediment yield assessment using satellite pictures and remote sensing techniques [8].

Performance of watershed management projects has importance role in reduction of sediment in watershed outlet(despite of more amounts of erosion in upstream of watershed in land unit) because of storage and deposition of sediment yield in the transportation process, so according to sediment analysis in Menderjan watershed , sediment reduction tendency shows the effective role of watershed management projects. In other words construction of lag structures (such as small dam and gabion dam etc) can affect transported sediment amount to downstream (toward watershed outlet-hydrometric gauge station). With regard to mentioned descriptions it is proposed that to manage land use and its changes comprehensively, and prevent from increasingly land use change especially such as recent years in order to mitigation of erosion and sediment problem in the watershed.

REFERENCES

[1] Ahmadi, H., Mohammadi, A., Ghoddusi, J. and Salajegheh, A., 2008, Management of gully lands by investigation of effective factors and developing model in order to gully length growth potential, case study; Hableh Rud watershed), proceedings of 4th national conference of sciences and watershed management engineering of Iran, 21 & 22 February, Tehran University, Iran.

[2] Bocco, G., 1991. Gully erosion: processes and models. Progress in Physical Geography 15 (4), 392–406.

[3] Brovitskaya, N., Kokorev, A. V., lemeshko, N. A., 2003. Rgional pattern in recent trends in sediment yields of Eurasian and Siberian rivers. Global and Planetary Change, 39: 127- 146.

[4] De Bie, C.A.J.M. , 2005, Assessment of soil erosion indicators for maize-based agro-ecosystems in Kenya. Catena 59 pp 231–251.

[5] De Vente, J., Poesen, J., Verstraeten, G., 2005. The application of semi-quantitative methods and reservoir sedimentation rates for the prediction of basin sediment yield in Spain. Journal of Hydrology 305, 63–86.

[6] FAO, 1993. Field measurement of soil erosion and runoff. FAO Soils Bulletin, vol. 68. FAO, Rome. 139 pp.

[7] Gyssels, G., Poesen, J., 2003. The importance of plant root characteristics in controlling concentrated flow erosion rates. Earth Surf. Processes Landf. 28, 371– 384.

[8] Feiznia, S., Mokhtari, A., Ahmadi, H., 2002, Using remote sensing for land use and land cover data layers in MPSIAC erosion model, Journal of Research and Reclamation(Iran), No. 54.

[9] Ghoddusi, J., 1994, Growth and development of gullies, research report, Institute of Researches of Forests and Rangelands, 28 ps.

[10] Harley,. J and Ronalds., D., 1999, elevation models as a tool for manitoring and measuring gully erosion. ITC, Volume1-Issue 2- 91-101pp.

[11] Huon, S., Bellanger, B., Bonte´, Ph., Podwojewski, P., Valentin, C., Velasquez, F., Bricquet, J-P., de Rouw, A., Girardin, C., 2005. Monitoring soil organic carbon erosion with isotopic tracers, two case studies on cultivated tropical catchments with steep slopes (Laos, Venezuela). Advances in Soil Science. CRC Press, Boca Raton, Florida, USA.

[12] Hoyos ,N., 2005. Spatial modeling of soil erosion potential in a tropical watershed of the Colombian Andes. Catena 63 pp85–108.

[13] Hudson, N., 1995. Runoff, erosion and sedimentation: prediction and measurement. In: FAO (Ed.), Land and Water Integration and River Basin Management, FAO Land and Water Bulletin, vol. 1. 85 pp.

[14] Krause, A.K., Franks, S.W., Kalma, J.D., Loughran, R.J., Rowan, J.S., 2003. Multi parameter fingerprinting of sediment deposition in a small gullied catchment in SE Australia. Catena 53 (4), 327– 348.

[15] Lal, R., 2001. Soil degradation by erosion. Land Degrad. Dev. 12, 519–539.

[16] Lal, R., 1994a. Methods and guidelines for assessing sustainable use of soil and water resources in the tropics. SMSS Technical Monograph, vol. 21. USDA and the Department of Agronomy, Ohio State University, Columbus. 78 pp.

[17] Lal, R., 1994b. Soil Erosion Research Methods, 2nd ed. Soil and Water Conservation Society, Ankeny, Iowa.

[18] Logan T.J., Urban D.R., Adams J.R., and Yaksichs, 1982. Erosion control potential with conservation tillage in the Lake Erie basin: estimates using the universal soil loss equation and the land resource information system (LRIS). Reprinted with permission of Journal of Soil and Water Conservation, 37: 50-55.

[19] Martı´nez-Casasnovas, J.A., 2003. A spatial information technology approach for the mapping and quantification of gully erosion Catena 50 pp 293– 308.

[20] Nasri M.,Gholami A., Najafi A. and Modarres R., 2006. The Estimation of soil erosion and sediment yield using GIS and statistical multivariate techniques, proceedings of 5th symposium Agro-inviron, Ghent university, Ghent, Belgium.

[21] Oldeman, L.R., Hakkeling, R.T.A., Sombroek, W.G., 1991. World Map of the Status of Human-Induced Soil Degradation. International Soil Reference and Information Center—United Nations Environmental Programme, Wageningen, Netherlands.

[22] Poesen, J., Boardman, J., Wilcox, B., Valentin, C., 1996. Water erosion monitoring and experimentation for global change studies. Journal of Soil and Water Conservation 51, 386– 390.

[23] Stocking, M.A., Murnaghan, N., 2001. Handbook for the Field Assessment of Land Degradation. arthscan Publications Ltd, London Sterling VA.

[24] Valentin, C., Poesen, J., and Li, Yong, 2005, Gully erosion: Impacts, factors and control, Catena 63, 132–153.

[25] Vigiak, O., Okoba Barrack, O., Sterk,G., Stroosnijder L. ,2005a. Water erosion assessment using farmers' indicators in the West Usambara Msountains, Tanzania . Catena 64 ,pp 307–320.

[26] Vigiak, O., Okoba Barrack, O., Sterk,G and Groenenberg,. S. ,2005b.Modelling catchment-scale erosion patterns in the East African Highlands. Earth Surface Processes and Landforms 30, pp 183–196.

[27] Wasson, R.J., Caitcheon, G., Murray, A.S., McCulloch, M., Quade, J., 2002. Sourcing sediment using multiple tracers in the catchment of Lake Argyle, northwestern Australia. Environmental Management 29 (5), 634– 646.