Journal homepage www.jzs.univsul.edu.iq
Journal of Zankoy Sulaimani
Part-A- (Pure and Applied Sciences)
ISSN:1812-4100

Assessment of soil erosion risk in Chamchamal catchment using RUSLE integrated into GIS Techniques

Tariq Hama Karim[1]; Kamal Sharif Qadir[2,*] & Danya Omer Mohammed[2]

[1] *College of Agricultural Engineering Sciences, Salahaddin University. Erbil-Iraq*
[2] *College of Agricultural Engineering Sciences, Sulaimani University. Bakrajo Street. Sulaimani-Iraq*
**Corresponding author E-mail: kamal.qadir@univsul.edu.iq*

Article info

Original: 3 March 2021
Revised: 30 May 2021
Accepted: 22 June 2021
Published online:
20 December 2021

Key Words: *Annual soil loss, RUSLE-variables, soil loss tolerance, WSER index, soil erosion RS, GIS*

Abstract

In Iraqi Kurdistan Region, as in most Mediterranean countries, assessment of soil erosion risks is a challenging task mainly due to the non-availability or insufficiency of relevant data. In the current study, the soil erosion risks have been estimated by integrating the spatial data on potential erosion rates and soil loss tolerance limits for conservation planning at the sub-catchment level in Chamchamal district, Sulaimani, Iraqi Kurdistan Region. To achieve the above objectives, the study catchment was delineated with the support of GIS after obtaining the Dem of Chamchamal district. The remote sensing (RS) and a geographic information system (GIS) were used to estimate the spatial distribution of soil erosion across the Chamchamal district, to identify the risk of soil erosion, and to develop a conservation priority map. People can reach a common goal: to gain actionable intelligence from all types of data. Additionally, the study catchment was subdivided into 12 subcatchments using the same tool. The estimated annual soil loss for different subcatchments is characterized by a wide range of variations. It ranges from a minimum of 7.08 t ha^{-1} yr^{-1} at subcatchment 1 to as high as 252.31 t ha^{-1} yr^{-1} at sub-catchment 3. With a few exceptions, the soil tolerance limit at the investigated grid points was estimated at10 t ha^{-1} yr^{-1}. The results also revealed that around 12% of the whole catchment has a negligible risk of soil erosion above the tolerance limits, and does not call for immediate soil conservation measures. The remaining area (454.96 km2) requires conservation planning with different prioritizations. Subcatchments 2, 3, 7, and 10 were identified as the worst affected districts in terms of soil erosion and therefore require immediate attention of natural resources. The weighted soil erosion risk index (WSERI) categorized sub-catchments 2, 3, 7, and 10 as being of topmost priority as it is the most severely affected areas. The recommended measures to conserve soil and water encompassed three broad categories, namely, vegetative, soil, and mechanical measures. Within the same sub-catchment, one or a combination of several measures can be implemented based on the nature and intensity of the problem.

Introduction

As the world population increases, arable, fertile land becomes scarcer, and land use tends to be intensified, which often results in soil degradation. One of the most important phenomena leading to soil degradation is water erosion on croplands ***[1]***. Soil erosion is one of the biggest global environmental problems resulting in both on-site and off-site effects. It has accelerated in most parts of the world, especially in developing countries due to increasing population, deforestation, intensive land cultivation, uncontrolled grazing, and higher demand for firewood ***[2, 3]***. Clearing of vegetation, overgrazing, cultivation on steep slopes and thunderstorms in the spring season are the main factors that accelerate erosion in the Iraqi Kurdistan region in general, and in the study area in particular. Controlling water erosion to preserve soil quality and to maintain agricultural productivity is, therefore, a great challenge and one of the most pressing environmental issues ***[1]***. In a country like Iraq, where there is a lack of data, it is imperative to apply soil erosion models that require fewerdata. Soil erosion models integrated intoa GIS are a means to assess the spatial distribution of water erosion. Shiferaw ***[3]*** revealed that the Revised Universal Soil Loss Equation, (RUSLE) is the most frequently used methods as it can be applied in many situations, on topographically complex landscape units such as steep slopes and rugged terrain and can be supported by GIS because it is helpful to map the RUSLE factor layers. Despite the severity of soil erosion in the study area, there have been few studies at the regional level to quantify erosion rates and describe its spatial variability. Since different portions of the study area vary in sensitivity to erosion due to differences in land cover, topography, soil properties, and other attributes, it is, therefore, necessary to identify high water erosion areas to select the most suitable way and methods to control the eroded areas. Soil erosion risk assessment becomes an essential foundation for the planning and implementation of soil and water conservation projects ***[4]***. The acceptable rate of soil erosion (T-value) is defined as the maximum amount of erosion at which the quality of a soil as a medium for plant growth can be maintained ***[5]***. On shallow soils, a T-value of 5 Mg $ha^{-1}yr^{-1}$and a prevailing erosion rate of 12.5 Mg $ha^{-1}yr^{-1}$would result in rapid loss of productivity. In contrast, a T-value of 12.5 Mg ha^{-1} yr^{-1} in a deeper soil with similar erosion may not have much impact on crop productivity [6]. Accordingly, the current study was conducted to target the following objectives: 1) Assignment of site-specific soil tolerance limit, 2) To assess the potential soil loss from Chamchamal basin under different land uses and landforms, 3) To compare the expected soil loss to the soil tolerance limits, 4) To prepare a soil erosion map for the area under study and 5) To prioritize the erosion risks into different classes and identify the best management practices for each class.

Material and Methods

A. Description of the Study Area

Location and Area

The study catchment is within the administrative area of Kurdistan Region\ Chamchamal district. The latter is bounded by parallels N 34°58′ 03″ and N 35°54′ 33″ and meridians E 44°16′ 58″ and E 45°23′ 50″ (Fig.1). It is bordered from the east by Kalar and Karadag districts to the west by Kirkuk government and Aghjalar district and the north by Dokan district. The average altitude of the region is 780.94 m above mean sea level with a variation of 28 m to 3601 m. The whole area of the district is estimated at 5025.21 km^2, while the area of the study catchment is about 514.81 km^2.

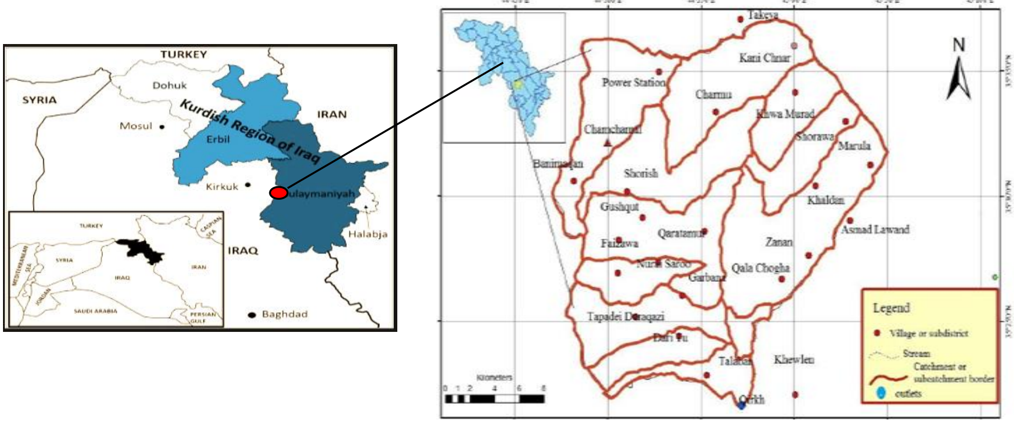

Fig. 1: Location map of the area under study.

Climate

In general, the climate of the region is of Mediterranean type, giving rise to cold and rainy winters and hot and dry summers. The area as a part of the Iraqi Kurdistan region is characterized by large diurnal and annual ranges of temperature. The coldest and the warmest months of the year are January and July respectively. Mean annual temperature amounts to 19 ºC with a mean maximum in July (44ºC) and a mean minimum in January (-3ºC).The mean annual rainfall (n=17 years) is 468.68 mm distributed over rainy months. The rainfall has a unimodal distribution. The annual potential evapotranspiration is estimated at1712.18 mm. The annual distribution shows a dry season lasting from June to September and a wet season from October to April.

Vegetation and Land Use

Vegetation is diverse, but there are no forest trees over most of the area. Poor to medium oak forest trees can be observed on the south-facing slopes of the mountains bordering the study area from the northern and eastern parts. Over the remaining parts, even the smaller woody shrublets have been eradicated by the plough, woodcutter, and fuel gatherer. The land use includes mostly grazing lands, agricultural, residential areas, and marginal spots. The grazing lands range from very poor grazing sites over steep slopes, undulating lands, gullied lands, and shallow soils over bedrocks to dense grazing lands at sites at remote places (places far from the villages). Overgrazing, repeated firing, mismanagements, and drought are responsible for the degradation of grazing lands and forestlands over most of the areas under study. Most of the cropped lands are under dry farming, wheat and barley are the principal winter crops.

Soil Physical and Chemical Analyses

Particle size distribution was carried out according to Klute ***[7]***. The soil bulk density was measured bythe core method as described byBlake and Hartage ***[8]***. The soil hydraulic conductivity was measured by the inverse auger hole method according toKessler and Oosterbaan ***[9]***. The soil organic carbon was measured by the wet oxidation method according to the Walkley-Black method ***[10]***. The pH of the saturation extract was measured with pH-meter Model Hanna pH211 according toConklin and Vitha ***[11]***, results present in (table 1).

B. Methods of Analysis

The database for rainfall erosivity was the monthly rainfall data of 17 years (2000-2016) obtained from the Chamchamal meteorological station. The average value of rainfall erosivity was based on rainfall erosivity calculated by six commonly simplified formulas. The values of the erodibility factor were computed for different grid points across the existing sub-catchments as per the Wischmeier and Smith ***[12]***. The grid system was composed of 28 points with coordinates of 35º 23' N, 44º50'E for first point at the left corner on the bottom to 35º36' N, 45º10'E at the right corner on the top of the study area. For the slope steepness factor, the map was generated using the spatial analyst toolkit of the Arc-Map Ver.10. The average weighted C- values for different sub-catchments within the main catchment were calculated. The calculation was based on typical C-values for different land uses within each sub-catchment. It is noteworthy to indicate that each typical value is obtained after the multiplication of different subfactors. These subfactors encompassed surface cover, tree canopy, organic matter content, consolidation effects, fine roots, prior land use, and surface roughness ***[13]***. Furthermore, a single sense (path/row 190/50) which taken in 15 May, 2016 by ETM sensor was used as a data image to detect land use/land cover of the study area. Prior to weighted P-value calculation, values of conservation practice factors for different land uses within each sub-catchment of the whole catchment were calculated. The value of 1 was assigned to land uses with no conservation practice factors like forestlands, grazing lands, vineyards, and cultivated lands that were tilled up and down the slope. In contrast, the value of 0 was assigned to urban areas and barren rock lands. Based on the classification scheme proposed by Singh *et al*. ***[14]***, the study catchment was subdivided into several erosion classes. Furthermore, the whole catchment was classified into three classes representing priority class I, II, and III, based on the weighted soil erosion risk (WSER) values using percentile analysis.

Table 1: Some physical and chemical properties of soil in the study sites.

Sites	Particle Size Distribution, (%)			hydraulic conductivity ($cm\ hr^{-1}$)	Bulk density ($Mg\ m^{-3}$)	Organic matter (%)	Soil pH
	Sand	**Silt**	**Clay**				
1	6.59	43.23	50.18	7.91	1.38	1.56	7.15
2	24.02	35.64	40.34	6.16	1.22	0.81	7.21
3	25.24	46.62	28.14	5.52	1.18	1.09	7.30
4	27.48	42.97	29.55	8.36	1.39	**1.87**	7.20
5	36.46	31.59	31.95	50.52	1.18	1.09	7.30
6	8.99	60.05	30.96	7.70	1.43	1.02	7.10
7	31.75	23.72	44.53	9.24	1.43	1.73	7.29
8	9.91	54.56	35.53	7.74	1.42	1.29	7.38
9	27.61	39.45	32.94	8.67	1.46	0.88	7.30
10	17.89	46.13	35.98	5.18	1.39	1.22	7.15
11	24.05	36.67	39.28	8.34	1.36	**0.48**	7.90
12	11.27	56.78	31.95	7.98	1.41	1.73	7.18
13	9.51	50.52	39.97	8.01	1.39	1.70	7.24
14	27.95	38.58	33.47	8.02	1.45	1.84	7.42
15	21.72	33.27	45.01	7.70	1.37	1.26	7.22
16	40.33	24.03	35.64	5.37	1.39	1.09	7.24
17	17.35	55.11	27.54	7.65	1.44	1.56	7.91
18	16.93	42.88	40.19	4.42	1.18	1.84	7.33
19	26.87	44.23	28.90	5.50	1.34	1.73	7.20
20	29.75	34.13	36.12	7.67	1.37	1.39	7.81
21	10.09	41.37	48.54	8.97	**1.48**	0.68	7.16
22	27.16	36.32	36.52	**10.84**	**1.13**	0.68	7.12
23	32.75	28.33	38.92	5.19	1.40	1.73	7.70
24	18.25	41.41	40.34	7.81	1.28	1.67	7.25
25	31.50	33.71	34.79	7.79	1.15	1.26	7.25
26	19.12	36.01	44.87	5.25	1.46	1.43	7.27
27	33.12	35.94	30.94	**4.29**	1.45	1.36	7.43
28	22.55	44.25	33.20	7.72	1.46	0.95	7.57

C. Measurement of catchment characteristics in GIS Environment

The DEM of district was down loaded from http://earthexplorer usgs.gov/ after registering and logging in. The Dem data has a resolution of 1 arc sec (approx. 30 m). The study area was covered by 6 tiles. These tiles were stitched together through data management tools in Arc-Map. Thereafter, the merged Dem was clipped in Arc-map. The surface from the Spatial Analyst Tools was selected for preparing the topographic map of the whole catchment its sub-catchments. The morphometric characteristics of the sub-catchments were determining after running the Arc-Map software Ver 10.2. The same software was using for preparing soil erosion severity classes and priority classes. The Normalized Difference Vegetation Index (NDVI), an indicator of the vegetation vigor and health was also used to generate the C-factor value for the study area with the aid of ERDAS program

Results and Discussion

A. RUSLE Variables

The Rainfall Erosivity Factor (R-factor)

It is obvious from Table 2 that the rainfall erosivity varies from a minimum of 230.42 MJ $mmha^{-1}\ hr^{-1}\ year^{-1}$ according to the exponential model proposed by Eltaif *et al.* ***[15]*** to a maximum of 1172.70 MJ mm $ha^{-1}\ hr^{-1}\ year^{-1}$ based on the power model proposed byArnoldus [16] and those for the remaining models fell between these two extremes. Further, the average R-value for the years (2000-2016) was observed to be 716.91 MJ mm ha^{-1} hr^{-1} $year^{-1}$ (Appendix A, Table A1). As shown in Table 2, the average value of rainfall erosivity was based on rainfall erosivity calculated by six commonly simplified formulas.The estimate of rainfall erosivity due to unavailability of recording rain gage data or storm rainfall intensity over the study catchment, was the reason for using simple empirical formulas for predicting rainfall erosivity. The average rainfall erosivity predicted by these models was comparable with that obtained by interpolation for the study catchment from the isoirodent map of Iraq developed by Nikolov ***[17]***. The interpolated R-value for Chamchamal is 87.18 units. However, some models such asSingh *et al*. ***[14]***, which was derived originally for the central Mediterranean region under predicted the rainfall erosivity compared well that obtained from the Nikolov ***[17]*** erosivity map (49.95 versus 87.18metric unit).

Table 2: Some commonly simplified models to estimate rainfall erosivity at the study catchment

No.	Formula	Input parameters	Rainfall erosivity (SI unit)	Author (s)
1	$1.5 \log [p_{i2}/p]-0.8188$ $R=\sum_{i=1}^{12} 1.75 \times 10$	$P=\sum_{i=1}^{12} pi$ Pi = monthly rainfall P = annual rainfall (mm)	712.08	Wischmeier and Smith, (1978) … [12]
2	$R = 0.302\ F^{1.93}$	$\mathbf{F=\sum_{i=1}^{12} P_{i2}/P}$	1172.70	Arnoldus, (1977) …[16]
3	R = 4.17 F -1.52	F = Fournier’s index	300.36	Arnoldus, (1980) ... [18]
4	R = 4.04412 P – 965.53	P = annual rainfall	952.56	Ferrari et al. (2005)- linear [19]
5	$R = 0.092 \times P^{1.4969}$	F = Fournier’s index	933.31	Ferrari et al. (2005)- exponential
6	$R= 23.61\ e^{0.048P}$	P = annual rainfall	230.421	Eltaif et al. (2010 [15]
	The average value of rainfall erosivity			716.91

AppendixA, Table A1.Monthly rainfall distribution at Chamchamal meteorological station during the period 2000 to 2016.

Years	Months									
	Sept.	Oct.	Nov.	Des.	Jan.	Feb.	Mar.	Apr.	May.	Total
1999-2000	0	0	18.5	53	138.7	43.2	14.2	18.7	6	293.3
2000-2001	0.5	27.6	30.6	115.6	84.1	64.6	73.7	20.7	6	423.4
2001-2002	11	5.1	29.8	111.3	160.1	45.3	100	73.7	6.6	545.5
2002-2003	0	16.8	6	272.6	77.2	98.2	97.7	22.8	10.4	601.7
2003-2004	0	11.3	87.8	113.9	208.3	78.5	16.5	37	49.3	602.6
2004-2005	0	1.6	116.4	50.4	124.8	128	88.7	42.4	8.6	560.9
2005-2006	0	0	13	41.7	107.2	300.3	0	90	75.5	627.7
2006-2007	0	74.6	47	9.5	64.6	121.1	35.3	85.8	17.8	474.2
2007-2008	0	0	3.3	22	48.8	43.6	28.5	1.5	2	147.2
2008-2009	14.2	70.8	7.9	8.6	6.5	22.4	51.7	69	1	251.4
2009-2010	52	40.4	58.8	80.9	47.5	97.9	131.2	32.2	44.2	418.3
2010-2011	0	2	0	52.7	104.4	26.5	48.3	118.3	10.8	363
2011-2012	0.3	13.3	10.7	51.9	73.7	46.9	66.9	15.3	3.5	282.5
2012-2013	0	7.8	84	45	166.2	361.5	8.4	13.9	20.2	707
2013-2014	0	0	103	137.9	80.7	9.1	107.1	57.1	4.3	499.2
2014-2015	0	26.5	98.6	112.9	58	56.3	78.9	14.9	15.2	461.3
2015-2016	6.2	75.6	141.4	85.3	64.3	91.6	124.1	109.1	10.8	708.4

Table 3: Estimated soil from different sub-catchments within the study catchment using RUSLE model.

Sub-catchment No.	Rainfall erosivity factor, R(metric unit)	Soil erodibility factor, K (metric unit)	Slope steepness factor, S	Slope length factor, L	Cropping management factor, C	Conservation practice factor,P	Annual soil loss (ton ha-1 yr-1)
1	71.69	0.36	**0.79**	**5.38**	**0.084**	0.76	**7.08**
2	71.69	0.35	2.25	7.54	0.26	0.95	104.79
3	71.69	0.35	**3.48**	**12.02**	0.26	0.94	**252.31**
4	71.69	0.34	1.92	6.80	0.25	0.94	75.03
5	71.69	0.40	2.23	8.06	0.20	0.69	73.73
6	71.69	0.36	1.37	6.87	0.25	0.66	39.53
7	71.69	0.43	3.03	9.06	0.26	0.70	151.34
8	71.69	0.44	3.22	8.49	**0.28**	0.84	198.53
9	71.69	0.44	2.90	7.95	**0.28**	0.65	128.56
10	71.69	0.44	2.49	8.54	0.26	0.86	149.99
11	71.69	0.44	1.74	7.87	0.25	0.82	87.81
12	71.69	0.42	1.56	6.70	0.25	0.74	59.46

The Soil Erodibility Factor (K)

The values of the erodibility factor were computed for different grid points across the existing sub-catchments as per the Wischmeier and Smith ***[11]*** and the K-values were displayed in Figure 2 as rangesand Table 4. The clay varied from 27.54% to 50.18%, while the silt ranged from 23.72% to 60.05%, the organic matter was sandwiched between 0.48 and 1.87% as present in Table 4. The poor vegetation cover, particularly forestlands may be responsible for the relatively low organic matter of the study sites.The estimated K-factor among the study sites (grid points) varied from as low as 0.233metric unit at grid point 7 situated to the eastern part of the basin close to sub-catchment no.6 to as high as0.503 metric unit at grid point 17within , which is situated to the west of the basin. The K-factor for the other grid points was between these two extremes. The findings of Nikolov ***[17]*** indicated that the soil erodibility factor for a part of the study area between Kirkuk and Sulaimani ranged between 0.41 and 0.47 metric units. In fact, as reveals the silt content seems to be the main discriminator affecting the soil factor. The lower silt content (higher clay content) produced the lower soil erodibility factor and the reverse may be true. It was also observed that the soil at different grid points exhibited close values for soil structure code. This result is in concord with the findings of Hussein ***[20]*** and Assaf ***[21]*** that attributed the high soil erodibility at some selected sites to the predominance of silt-sized fraction. It can be noted that the K-factor values tend to increase as one proceeds progressively from the northern and eastern parts towards the southern and western parts of the main catchment. On the other hand, it was also noted that among the existing sub-catchments, the sub-catchments 4 offered the lowest soil erodibility values of 0.34 metric units, while the soil erodibility value of most of the studied catchment exceeded 0.40 metric units

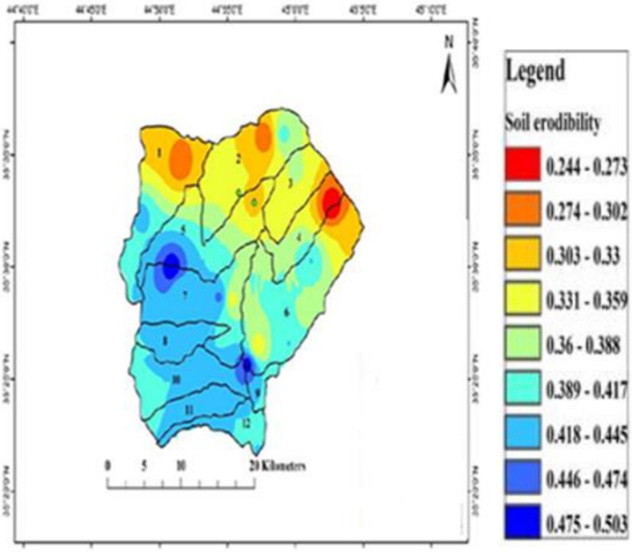

Figure 2: Soil erodibility map for the study catchment

Table 4: Soil erodibility factor for the soils at different sites calculated according to the equation propos by Wischmeier and smith (1978).

Sites	Particle Size Distribution, (%)			Organic matter content (%)	Very fine sand (%)	Structure Class Code, (SC)	Permeability Class Code, (PC)	Soil Erodibility, K (metric unit)
	Sand	Silt	Clay					
1	6.59	43.23	**50.18**	1.56	1.83	4	2	0.244
2	24.02	35.64	40.34	0.81	7.50	4	2	0.292
3	25.24	46.62	28.14	1.09	11.33	4	3	0.490
4	27.48	42.97	29.55	1.87	12.25	4	2	0.400
5	36.46	31.59	31.95	1.33	19.88	4	2	0.3782
6	8.99	**60.05**	30.96	1.02	5.26	4	2	0.498
7	31.75	**23.72**	44.53	1.73	15.22	4	2	**0.233**
8	9.91	54.56	35.53	1.29	5.35	4	2	0.417
9	27.61	39.45	32.94	0.88	9.8	4	2	0.369
10	17.89	46.13	35.98	1.22	10.14	4	2	0.331
11	24.05	36.67	39.28	0.48	10.47	4	2	0.331
12	11.27	56.78	31.95	1.73	3.69	4	2	0.428
13	9.51	50.52	39.97	1.70	4.55	4	2	0.346
14	27.95	38.58	33.47	1.84	10.77	4	2	0.340
15	21.72	33.27	45.01	1.26	12.04	4	2	0.275
16	40.33	24.03	35.64	1.00	22.58	4	2	0.364
17	17.35	55.11	**27.54**	1.56	10.51	4	2	**0.503**
18	16.93	42.88	40.19	1.84	6.95	4	3	0.343
19	26.87	44.23	28.90	1.73	12.44	4	3	0.452
20	29.75	34.13	36.12	1.39	12.92	4	2	0.324
21	10.09	41.37	48.54	0.68	6.35	4	2	0.281
22	27.16	36.32	36.52	0.68	15.67	4	2	0.375
23	32.75	28.33	38.92	1.73	9.53	4	3	0.281
24	18.25	41.41	40.34	1.67	8.70	4	2	0.315
25	31.50	33.71	34.79	1.26	4.43	4	2	0.274
26	19.12	36.01	44.87	1.43	13.47	4	3	0.328
27	33.12	35.94	30.94	1.56	15.87	4	3	0.418
28	22.55	44.25	33.20	0.95	12.08	4	2	0.418

Slope steepness factor (S)

Fig.3 illustrates the distribution of slope steepness as a percent over the study catchment. This map was generated using the spatial analyst toolkit of the Arc-Map Ver.10. It was prepared after generating the raster layer of the slope gradient in percent. It can be elucidated from Fig. 3 that the slope steepness varies from a few percent (0-5.17%) to more than 87.3% at the northern border. The minimum value for slope steepness factor (0.79) was recorded for sub-catchment 1 and the maximum (3.48) for sub-catchment 3. The other values were situated between them as shown in table 3. As can be noticed in table 5, that the slope percent varies from as low as 7.04% at sub-catchment 1 to the northwest of the catchment to as high as24.35% at sub-catchment 3 situated at the northeast of the basin. Since the slope percent for the majority of sub-catchments is above 12%. This is an indication of the fact that most of the existing lands are suitable to be used as grazing lands and forestlands. The formula proposed by McCool et al. ***[22]*** was followed to calculate the slope steepness factor for each sub-catchment.

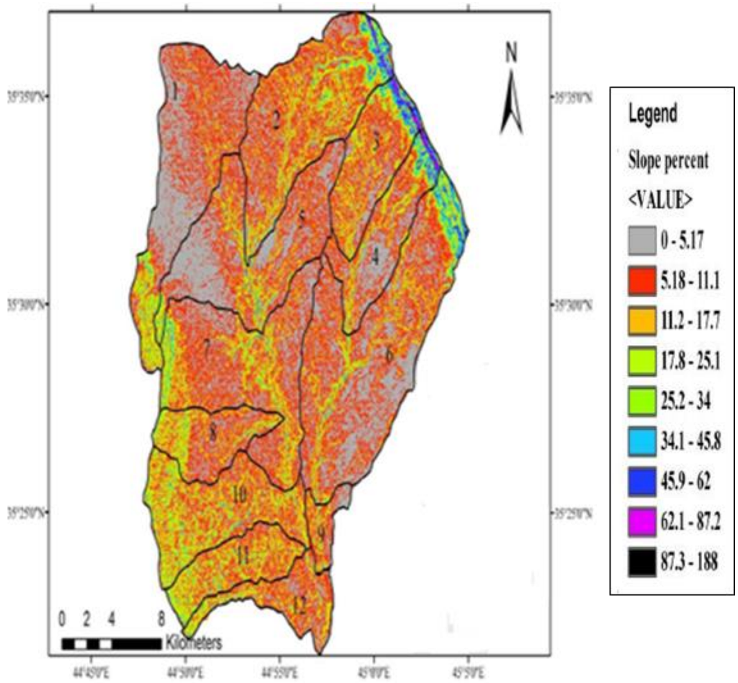

Fig 3: Slope percent for different sub-catchments within the study area

Table 5: Slope steepness factor computed for different sub-catchments within the main catchment.

Subcatchment No.	Average slope			Sin (q)	Slope steepness factor
	(%)	**Radian**	**Degree**		
1	**7.04**	0.070	4.023	0.070	0.79
2	13.63	0.165	9.427	0.164	2.25
3	**24.35**	0.239	13.682	0.237	3.48
4	14.53	0.144	8.264	0.144	1.92
5	17.06	0.169	9.678	0.168	2.33
6	11.22	0.112	6.400	0.112	1.37
7	21.51	0.212	12.134	0.210	3.03
8	22.71	0.223	12.789	0.221	3.22
9	20.68	0.204	11.679	0.203	2.90
10	18.08	0.179	10.245	0.178	2.49
11	13.48	0.134	7.673	0.134	1.74
12	12.33	0.123	7.028	0.122	1.56

Slope Length Factor (L)

The required data for calculating the length of overland flow or slope length was obtained according to the scheme proposed by Williams and Berndt ***[23]***. The required data are the area of each sub-catchment and the total length of stream segments of all the existing orders. Additionally, it is apparent from Table 3 that the slope length factor ranges from the minimum value (5.38) for sub-catchment 1 to the maximum value of 12.02 for sub-catchment 3.It was also shown that the slope length factors computed by direct measurement were comparable with the values computed according to McCool et al. ***[22]***. In such studies, the slope length must reflect the distance from the point where surface flow originated to the outlet channel or a point in the downstream where deposition begins ***[12]***.

Cropping-Management Factor (C)

The C-values that are weighted according to the percentage of area occupied by each land use ranged from a minimum of 0.084 for sub-catchment 1 to a maximum of 0.28 for sub-catchments 8 and 9 (Table 3).It is worth mentioning to state that the database for cropping-management factors should be updated periodically because this factor is subjected to changes due to changes in land use, environment, agriculture, and management ***[14]***. Furthermore, this factor can be controlled through land-use change and consequently, the rate of erosion can be reduced significantly.

Appendix A, TableA2. The measured NDVI and the corresponding cropping-managementfactor for some selected site

NDVI	Factor
0.146	1
0.579	0.01
0.236	0.3
0.385	0.16
0.396	0.011
0.323	0.002
0.511	0.0004

Conservation Practice Factor (P)

It seems from the results presented in Table3that the minimum P- value was (0.65) for sub-catchment 9, while the maximum (0.95) for sub-catchment 2. The low value of P for sub-catchment 9 can be attributed to limited cultivated lands, extensive urban area. It is also apparent that most of the lands with subcatchment 2 are under grazing lands. This made this catchment attain the highest P-value. It is praiseworthy to mention that more reliable P-values can be obtained under contour farming when data on 10-year storm EI are available along with the dominant furrow grade in the catchment under study.

B. Estimated Annual Soil Loss

Table 3 presents the estimated annual soil loss for different subcatchments along with the input variables of RUSLE. As shown in Table 3, the estimated annual soil loss is characterized by a wide range of variations. It ranges from as low as 7.08 t $ha^{-1}yr^{-1}$at sub-catchment 1 to as highs 252.31 t $ha^{-1}yr^{-1}$at sub-catchment 3 and those for the remaining sub-catchments fell between these two extremes. Integration of relatively low topographic factors along with low cropping management factor is responsible forthe low rate of soil loss at sub-catchment 1. In contrast, excessive slope steepness along with great slope length may be responsible for the highest rate of soil loss at sub-catchment 3.It is also apparent from Table 3that the sub-catchments 2, 3, 7, 8, 9, 10, and 11 are the main contributor of annual soil loss within the main catchment. Indeed, a significant portion of the annual loss will become sediment yield and deliver a high amount of sediments to the Tigris tributary. This will cause a strong environmental impact and high economic costs via its effect on water quality ***[24]***. Based on the classification scheme proposed by Singh *et al*. ***[14]***, the study catchment was subdivided into several erosion classes (Table 6). About 49% of the total area felling very severe class of erosion (>80 t $ha^{-1}yr^{-1}$)(Table 6). This will cover an area of 250.99 km^2out of the total area of 514.81 km^2. Further, it can be noticed that 11.63, 18.84 and 20.78% of the total area exhibited annual soil in the range of 5-10 t ha^{-1} yr^{-1} (Slight); 20-40 t $ha^{-1}yr^{-1}$(High);

40-80 t ha^{-1}yr^{-1}(Severe).Quantitative assessment of soil erosion is a key to infer the extent and magnitude of the problem and identification of more vulnerable sites***[25].***

Table 6.The area and percent of total area covered by different erosion class in the study catchment.

Erosion Class	Erosion rate (t ha^{-1} yr^{-1})	Subcatchments included	Area covered (km^2)	Percent of total area	Erosion class
1	0 – 5		0.00	0.00	Very slight
2	5 – 10	1	59.86	11.63	Slight
3	10 – 20		0.00	0.00	Moderate
4	20 – 40	6	96.98	18.84	High
5	40 – 80	4, 5, 12	106.99	20.78	Severe
6	**> 80**	2, 3, 7, 8, 9, 10, 11	**250.99**	**48.75**	Very severe

Soil Erosion Risk Analysis Erosion Risk Analysis

Table 7 displays the calculated risk values for each sub-catchment by deducting the T values from soil erosion rate according to the procedure outlined by Sharda *et al*. ***[26]***. The estimated soil erosion risk were ranged from as low as 29.53 t ha^{-1}yr^{-1}at sub-catchment 6 to as highs 242.31 t ha^{-1}yr^{-1}at sub-catchment 3, then the remaining sub-catchments fell between these two extremes except for the sub-catchment 1 (-5.42 t ha^{-1}yr^{-1}) which was outside the mentioned range, meaning didn't need any conservation panning. The procedure outlined by Biswas *et al*. ***[27]***. As stated earlier, this parameter simultaneously combines information on twoparameters: the percentage of the geographical area of a sub-catchment affected by soil erosion risk and the severity of the soil erosion risk to each sub-catchment.However, Table 8 illustrates that the sub-catchments 7 and 9offered the highest and the lowest weighted soil erosion risk values (1732.22 and 162.63 respectively), and those for the remaining sub-catchments fell between these two extremes. The weighted soil erosion risk (WSER) will assign a high priority to a sub-catchment with a greater proportion of its geographical area in the high erosion risk class. Based on the WSER index values, the whole catchment was classified into three classes representing priority class I, II, and III, using percentile analysis (Table 8). The data points of 0.28 and 0.55 were used to subdivide theWSER scores into three groups. These two values corresponded to 33 and 66 percentiles respectively. They were estimated by using Microsoft-Excel. The index categorized Subcatchments 2, 3, 7, and 10 as being of topmost priority as it is the most severely affected subzones of the study area (Table 8). This could be attributed to the longest slope length and steepest slope gradient in most cases. Subcatchments 5 and 8 appear second in the list. The remaining sub-catchments, with the lowest WSER values, are the least affected subareas of the study area. Examples of sub-catchments are sub-catchment 1 and 6. This is probably due to the relatively flatter general topography of these sub-catchments. It is noteworthy to indicate that the study catchment and the surrounding areas are belonging to the Mediterranean region. In general, these areas are prone to severe erosion due to improper cover management, long-lasting dry periods. Such areas are subjected to long dry periods followed by heavy bursts of erosive rainfall, falling on steep slopes with fragile soils, resulting in considerable amounts of erosion ***[28]***.

Table.7. Erosion risk from different sub-catchments within the main catchment.

Subcatchment No.	Annual soil loss (ton ha-1 yr^{-1})	Soil Loss tolerance limit , SLTL (ton ha^{-1} yr^{-1})	Erosion risk (ton ha^{-1} yr^{-1})
1	7.08	12.50	-5.42
2	104.79	10.00	94.79
3	252.31	10.00	**242.31**
4	75.03	10.00	65.03
5	73.73	123.50	61.23
6	39.53	10.00	**29.53**
7	151.34	12.50	138.84
8	198.53	10.00	188.53
9	128.56	10.00	118.56
10	149.99	10.00	139.99
11	87.81	10.00	77.81
12	59.46	10.00	49.46

Table 8: Priority classes based on the weighted soil erosion index values

Subcatchment No.	Area (%)	Soil erosion risk, SER (t ha^{-1} yr^{-1})	Weighted soil erosion risk (WSER)	Weighted soil erosion risk index (WSERI)	Priority class (PC)
1	11.63	-5.42	-62.98	-0.14	No treatment
2	12.42	94.79	1160.18	0.64	PC1
3	5.80	242.31	1404.79	0.79	PC1
4	5.57	65.03	362.34	0.13	PC3
5	11.47	61.23	702.50	0.34	PC2
6	18.84	29.53	556.33	0.25	PC3
7	12.48	138.84	**1732.22**	1.00	PC1
8	4.24	188.53	798.77	0.41	PC2
9	1.37	118.56	**162.63**	0.00	PC3
10	8.27	139.99	1158.04	0.63	PC1
11	4.36	77.81	339.14	0.11	PC3
12	3.74	49.46	184.88	0.01	PC3

Note: Subcatchment with a WSER index value of less than 0.28, 0.28-0.55, and more than 0.55, were grouped in classes PC3, PC2, and PC1, respectively.

Conclusions

The average rainfall erosivity predicted by commonly simplified formulas was comparable with that obtained by interpolation from the isoirodent map of Iraq that was developed by [18].Further, it was discerned that the silt content(Table 1: is the main discriminator responsible for the soil erodibility factor variation over the study area.The results also revealed that most of the sub-catchments have considerable risks of soil erosion and call for immediate soil conservationmeasures.The excessive steep slope along with lengthy slope length is the main factors fanning the flame of intolerable soil loss in most of the existing sub-catchments.Because of surface water shortage, increasing water supply via water harvesting is an essentialstep for a successful reforestation program, rehabilitation of wildlife and grazing animals, and providing water for supplementary irrigation.

References

[1] Pieri, L., Bttelli, M., WU, Q.J., Flangang, D.C. *Using the Water Erosion Prediction Project(WEPP) model to simulate field-observed runoff and erosion in Apennines mountain range, Italy*. J. Hydrol. Vol.(336).No. 1-2.PP. 84-97.(2007).

[2] Reusing, M., Schneider, T., Ammer, U. *Modeling Soil Loss rates In the Ethiopian highlands by integration of high resolution MOMS-02/D2-Streao-data in a GIS*. Int. Journal of Remote Sensing. Vol.(21).No. 9.(2000).

[3] Shiferaw, A. *Estimating soil loss rates for soil conservation planning in the Borenaworeda of south Wollo highlands, Ethiopia*. J Sustain Dev Afr. Vol. (13). No.3. pp. 87–106.(2011).

[4] Zhang, H., Zhang, J., Zhang, S., Yu, C., Sun R ., Wang, D; Zhu, C. and Zhang Ji.*Identification of Priority Areas for Soil and Water Conservation Planning Based on Multi-Criteria Decision Analysis Using Choquet Integral*. Int J Environ Res Public Health. (2020).

[5] Mandal, D. and Sharda,V.N. *Assessment of permissible soil loss in India employing a quantitativebio-physical model*. Current Science, Vol.(100).No. 3.pp. 383-390.(2011).

[6] Mandal, D., Dadhwal, K. S., Khola, O. P. S., Dhayni, B. L. *Adjusted T-values for conservation planning in Northwest Himalayas of India*. J. Soil Water Conserv. Vol. (61)No.6. pp. 391-397. (2006).

[7] Klute, A. *Water retention: Laboratory methods*. In A, Klute (ed.) Methods of soil analysis. Soil analysis, Agron.9, part 2nd ed. ASA and SSSA, Maddison WI. pp.635-662. (1986).

[8] Blake, G.R.A. and Hartage K.H. *Bulk density*. *In method of soil Analysis, part 1: Physicaland mineralogical methods*.2nd. Edited by A. Klute. pp.363-375. (1986).

[9] Kessler, J. and Oosterbaan, R.J. *Determining hydraulic conductivity of soils. In:"Drainage Principles and Applications"*, Part III, Publication 16, Internat. Inst. For Land Reclamation & Improvement,(ILRI) Wageningen, The Netherlands.(1974).

[10] Allison , L.E. *Organic carbon. In C. A. Black et al. (ed.) Methods of Soil analysis*, part2.Agronomy. Vol. (9).pp.1367-1378. Am. Soc. of Agron. Madison, Wis. (1965).

[11] Conklin, Alfred R and Vitha, Mark F. *Introduction to Soil Chemistry: Analysis and Instrumentation*. 2nd Edition.John Wiley & Sons, Incorporated. pp: 105-106. (2013).

[12] Wischmeier, W.H. and Smith, D.D. Predicting rainfall erosionlosses :A guide to conservation planning. Agriculture handbook No. 537, USDA, Washington D.C. pp. 58. (1978)

[13] Hussein, M.H and Karim,T. H. *Deriving the cropping-management factor for majorl and uses in northern Iraq*. Journal of Agricultural Sciences (Zanco), Vol. (6). No.1. pp. 73-86. (1988).

[14] Singh, G., Babu, R., Narain, P., Bhushan, L.S., Abrol, I.P. *Soil erosion rates in India*. J. Soil & Water Conservation.Vol. (47).No. 1. pp.97-99. (1992).

[15] Eltaif, N., Gharaibeh, M., Al-Zaitawi, F., Alhamad, M. *Approximation of rainfallerosivity factors in North Jordan*.Pedosphere.Vol. (20). pp.711–717. (2010).

[16] Arnoldus H.M.J. *Methodology used to determine the maximum potential average annual soil loss due to sheet and rill erosion in Morocco.* FAO Soils Bull.Vol. (34).pp. 39-51. (1977).

[17] Nikolov, S. P. *Rainfall erosion in northern Iraq. An aid to soil conservation.* Ministry of Agriculture and Agrarian Reform. Baghdad, Iraq. (1983).

[18] Arnoldus H.M.J. *An approximation of the rainfall factor in the Universal Soil Loss Equation*. In: De Boodt M, Gabriel s D (eds) Assessment of erosion .Wiley, Chichester. pp. 127-132.(1980).

[19] Ferrari R., Pasqui M., Bottai L., Esposito S. & Di Giuseppe E. *Assessment of soil erosionestimate based on a high temporal resolution rainfall dataset*. In: Proc. 7thEuropean Conference on Applications of Meteorology (ECAM), Utrecht, Netherlands. pp. 12-16 September(2005).

[20] Hussein, K.S. *Conservation planning for Bastora catchment based on detection of erosion risk prone areas.* A thesis submitted to the college of Agriculture, University of Salahaddinas a partial fulfillment of the requirement of the degree of Master in Soil andWater Science (SoilConservation). (2016).

[21] Assaf, S.M. *Design of terrace spacing in Shaqlawa district.* A thesis submitted to thecollege of Agriculture, University of Salahaddin as a partial fulfillment of the requirements forth degree of Master in soil conservation. (2015).

[22] McCool, D.K.L., Brown, L.C., Foster, G.R., Mutchler, C.K., Meyer, L.D. *Revised slope steepness factor for the universal soil loss equation.* Transactions of the American Society of Agricultural Engineers., Vol. (30).pp.1387-1396. (1987).

[23] Williams, J.R. and Berndt, H.D. *Sediment yield computed with Universal Soil Loss Equation.* Journal of Hydraulic Division, ASCE, V.98, HY12, p.2087-2098.(1972).

[24]Lal, R. Long- term and maize monoculture effects on a tropical Alfisols in Western Nigeria: I. Crop yield and soil physical properties. Soil and Tillage Research, No.42.pp.145-160. (1997).

[25] Belayneh, M., Yirgu, T. & Tsegaye, D. *Potential soil erosion estimation and area prioritization for better conservation planning in Gumara watershed using RUSLE and GIS techniques*'. Environmental Systems Research (2019).

[26] Sharda, V.N., Mandal, D., Ojasvi, P.R.*Identification of soil erosion risk areas for conservation planning in different states of India.* Journal of Environmental Biology, Vol. (34). pp. 219–226. (2013).

[27] Biswas, H., Raizada, A., Mandal, D., Kumar, S., Srinivas, S., Mishra, P. K. *Identification of areas vulnerable to soil erosion risk in India using GIS methods.* Solid Earth.Vol. (6).pp.1247–1257. (2015).

[28] Van der knijff, J.M., Jones, R.J.A., Montanarella, L. *Soil erosion risk assessment in Europe.* EUR 19044 EN. Office for official publications of the European Communities, Luxembourg. pp.34. (2000).