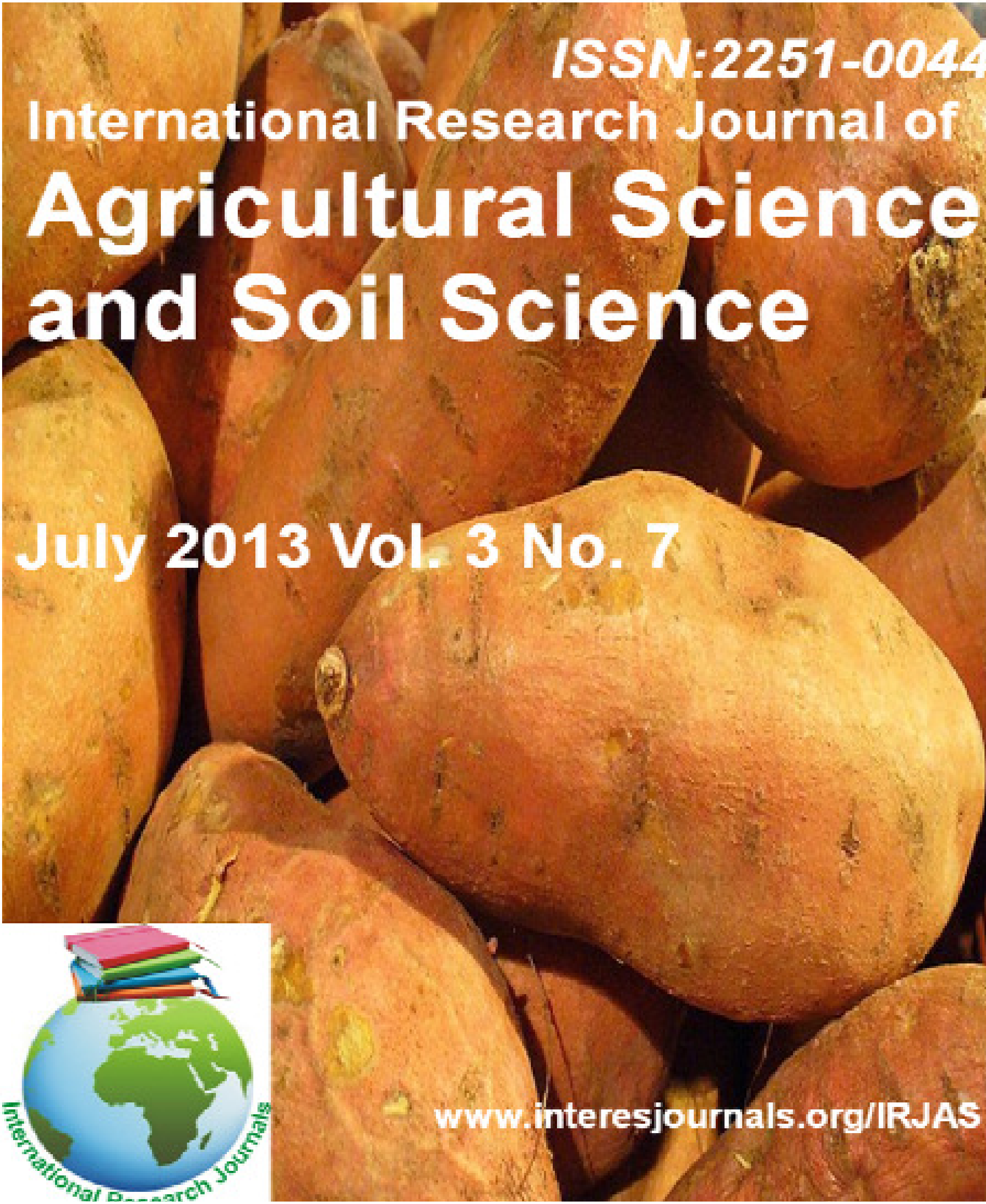
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Full Length Research Paper

Study of soil erosion in Chaqan watershed using Universal Soil Lose and Modified Musgrave Equations

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ABSTRACT

In Iraqi Kurdistan region, little amount of research has been conducted to evaluate the extent of soil erosion and examine the relation between soil erodibility and other soil indices. Universal soil loss equation (USLE) and Modified Musgrave equation were conducted to predict the amounts of soil that have eroded annually in different zones of Chaqan watershed, which is one of the catchment areas of Darbandikhan Lake in Sulaimani Governorate. Field measurements and laboratory analyses were executed to obtain the parameters of Universal soil loss and Modified Musgrave equations. The results indicated that the amount of annually soil erosion computed by Universal soil loss equation was greater than that obtained by using Modified Musgrave equation. It is evident from the results that the watershed has medium erodibility class (0.1-0.3), and has steep slope, which lead to occurring the great amount of soil erosion. On the basis of gross erosion, the watershed is placed in the severe erosion hazard class (50-200 ton/ha/yr), the possible explanation is its high gradient value. According to this study the watershed can be divided into different zones of the degree of erosion which are geological, very severe, severe, moderate, and light erosion based on the degree of resistant of erosion.

Keywords: Erosion, Chaqan watershed, Universal, Modified Musgrave

INTRODUCTION

Erosion is the detachment and transportation of material from a surface. It takes place whenever the eroding or driving forces exceed the resisting forces. Erosion is the detachment and transportation of soil material by erosion agents (Ellison, 1946).

Soil erosion is caused by the action of water, wind, grazing animals and human activity (DEFRA, 2005). Water erosion is more common in wet regions with a slopping mountainous terrain results in a loss of the topsoil reach in humus, and lead to incline in long term productivity. Soil erosion causes loss of soil productivity and deposition of sediments which may pollute surface and underground water resources, clog streams, reservoirs, and estuaries (Hillel 1998).The increased erosion is damaging lands, polluting streams and reducing the storage capacity of reservoirs.

In Kurdistan region of Iraq, little amount of research has been conducted to evaluate the extent of soil erosion and examine the relation between soil erodibility and other soil indices, progress in understanding the mechanism of erosion and developing techniques to control it are attentively of vital importance. Universal soil loss equation (USLE) has become the major conservation-planning tool used in the United States and other countries of the world. USLE only predicts the amount of soil loss that results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion (Stone and Hilborn, 2000).

When deciding, what conservation measures to apply, pretences always given to agronomic treatments (Morgan, 1986). From conservation point of view, mulching (covering the soil surface with crop residue) is the most useful as an alternative to cover crops in regions where insufficient rain prevents the establishment to a green cover before the onset of heavy rain.

Universal soil loss equation (USLE) and Modified Musgrave equation were conducted to predict the amounts of soil that have eroded annually in different zones of Chaqan watershed, which is one of the catchment areas of Darbandikhan Lake in Sulaimani Governorate.

Accordingly, this study was initiated and the objectives were:
1- to determine the erosion in this watershed by using USLE and Modified Musgrave Equations and making a map for Chaqan watershed to show degrees of erosion.
2- to recommend the lands that needs soil conservation inside this watershed.

MATERIALS AND METHODS

1. Data collection:

During field trips Hand Abney level for measuring slope, tape, and stop watch were used. Also topographic maps of 1: 20 000 and 1:100 000 and vegetation map of Iraq by Guest and Al-Rawi (1966), were used.
Mean monthly rainfall data was obtained from the prepared maps of the Bureau of Iraqi Meteorology by interpolation and extrapolation and then compared with daily rainfall recoded by Penjween and Said-Sadiq Meteorological Stations.

2. Analysis of soil:

Particle size distribution was performed using the procedure described by [Kilmer and Alexander (1949).
Organic matter was determined by using modified Walkley-Black method Allison, (1965).

Field measurements

Soil permeability:

Soil permeability in the field was measured at each location of samples by using inverse auger hole method that was described by (Al-Lamy and Al-Janaby, 1992). And in the form of the following equation:

$$K = (r/2) * [\ln(h1 + r/2) - \ln(h2 + r/2)] \Big/ \Delta t \quad \ldots\ldots\ldots\ldots (1)$$

Where:
K= Soil permeability in cm/hr.
r = radius of hole.
h1= height of water at time t1.
h2= height of water at at time t2.

Soil structure:

The soil structure was examined using visual observation of soil aggregates in the field by throwing clods from a high of 1 meter, and observing the size and shape of the broken sub units.

Methods of computing soil erosion

The universal soil loss equation (USLE):

It is an empirical model and provides an estimate of the long term average soil loss from segments of arable lands under various cropping condition. The equation is presented in the form:

$$A = RKLSCP \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where:
A = the average annual soil loss in ton/ha/year.
R = a measure of the erosion forces of rainfall.
K = soil erodibility factor.
L = slope length factor.
S = slope steepness factor.
C = a crop management factor.
P = conservation practice factor.
This equation was introduced in 1958 by Wischmeier and Smith, and developments have continued since then to obtain a new version entitled the revised universal loss equation RUSLE.
Williams and Berndt, 1972 have shown that the USLE was developed primarily for field application and when the equation is used for sediment yields for watershed, all factors except the rainfall factor must be modified.

a- Rainfall Erosivity R:

The rainfall erosivity factor R assesses the ability of rain to erode unprotected soils, or it is the power of overland flow runoff to erode soil material. This is partly a property of the rainfall, and partly of the soil surface.

In this study, due to the lack of rainfall charts in both Penjween and Said-Sadiq Stations, Wischmeier ‘s 1959 EI30 index could not be used. Five years of monthly rainfall values were obtained from daily-read rainguage stations in Penjween and Said-Sadiq Stations which were located 20 km north and south west of the studied watershed respectively. Rainfall-runoff erosivity factor was obtained by examining 7 models which were, Arnoldus (1977), Renard and Freidmund (1994)-P), Lo et al.(1985), Yu and Rose welt (1996), [Ferrari et al.(2005 – linear and exponential), and Nicolov (1983, By interpolation using rainfall erosivity map), and then the average of the mentioned 7 models was taken to obtain the accepted value of rainfall erosivity in metric unit, Table (1).

b- Soil erodibility factor (K):

Soil erosion is a process of detachment and transportation of soil materials by erosive agents. Except for very sandy soils, these two phenomenons, detachment and transportation are essential component of soil erosion (Ellison, 1946). Soil of high detachability and high transportability are highly erodible (Kohnke and Bertrand, 1959). Soil detachment can also occur due to overland flow of water during a rainfall event (Hussein et al, 1988). On the other hand Wischmeier and Smith, 1961 defined it as soil loss in tons from unit area (acre) per unit of rainfall erosion index for a specific soil in cultivated fallow. Tilled up and down on a 9% slope and 22.1 meter long. It is reflected in the universal soil loss equation as K. when the above conditions are met, the variables, L=S=C=P=1.0 the soil erodibility can be obtained from the universal soil loss equation as follows:

$$K = A / R \qquad \text{............... (3)}$$

Where:
A= annual soil loss
R=rainfall erosivity
The K factor for a watershed under study is determined by weighting the K-value of each soil in the watershed according to the area covered by the soil:

$$K = K_i * D_{Ai} / D_A \qquad \text{............ (4)}$$

Where:
K = soil erodibility factor for the watershed.
K_i = soil erodibility factor for an individual soil.
D_{Ai} = the drainage area covered by an individual soil.
D_A = total drainage area of the watershed.

c- Slope length factor (L):

The length of slope factor is the ratio of soil loss from a specific length of slope to that from the length specified for the K factor of the equation. Slope length is defined as the distance from the point of origin of overland flow to either of the slope decreases to the extent that begins, or the point where runoff enters a well defined channel which may be part of a drainage network or a constructed channel The slope length for the watershed can be computed by (Barzinji, 2003):

$$l = 0.5 D_A / l_{ch} \qquad \text{............... (5)}$$

Where:
l= Slope length of the watershed
l_{ch}= The total length of the channels in the watershed.

d- Slope steepness factor (S):

The slope steepness factor represents the ratio of soil loss from a given slope to that from a 9 % slope when all the other factors are the same.
In this study the following equation was used to calculate the slope steepness factor :

$$S = 0.065 + 0.045s + 0.0065s^2 \qquad \text{............. (6)}$$

Where: s = land slope (%).

The LS factor can be obtained from one of the following equation:

$$LS = (l / 22.1) * (0.065 + 0.045\, s + 0.0065\, s^2) \qquad \text{............. (7)}$$

Where; s = land slope (%), l =Slope length, S=slope steepness factor.
L=slope length factor.

e- Crop management factor (C):

The crop management factor is defined as the ratio of soil loss under a given crop to that from bare soil. It has four sub-factors in crop and gazing land. These sub-factors are canopy, surface cover, surface roughness and prior land uses effect for crop lands, whereas under forest land the sub-factors are: canopy, surface cover, organic matter content and fine roots. The composite soil loss ratio is obtained by multiplying the component sub-factors (Hussein and Karim, 1998).
The cropping management factor for the studied watershed is computed by:

$$C = \sum Ci * D_{Ai} \Big/ D_A \qquad \text{............... (8)}$$

Where:
Ci = the cropping management factor for crop (i) grown in the
drainage area (D_{Ai}).

f- The conservation practice factor (P):

The conversation practice factor is defined as the ratio of soil loss with a specified practice (contouring, strip cropping, minimum tillage or terracing) to that from straight row farm up-and –down slope.

Musgrave equation:

Musgrave,(1947) presented a relationship to express soil loss due to sheet erosion as a function of soil characteristics: The land use or cover, degree of slope and maximum 30 minutes rainfall intensity expected once in two years. The equation is as follows:

$$ER = FR * (S/10)^{1.35} * (L/72.6)^{0.35} * (P_{30}/1.375)^{1.75} \qquad \text{................ (9)}$$

Where:
E = sheet erosion, ton/acre/year
F = soil factor, basic erosion rate, ton/acre/year
R = cover factor
L = length of land slope in feet.
P_{30} = Maximum 30-minute, 2-year frequency rainfall in inches.

Modified Musgrave equation:

Sheet erosion can be computed by a modification of Musgrave equation. This equation was developed by substitution the K-factor and rainfall index from USLE for

Table 1. Estimation of rainfall erosivity for the study catchment using different equations and methods

ID	Author	Equation or Method	Rainfall erosivity MJ.mm ha^{-1} h^{-1}
1	Arnoldus (1977)	$R = 0.302\ F^{1.93}$	3052.02
2	Renard and Freidmund (1994)-P	$R = 0.0.0483\ P^{1.61}$	2285.35
3	Lo et al.(1985)	R= 38.46 + 3.84 P	3114.99
4	Yu and Rose welt (1996)	$R = 3.82\ F^{1.41}$	3218.76
5	Ferrari et al.(2005 - linear	R = 4.0412 P - 965.53	2272.20
6	Ferrari et al.(2005 - exponential	$R = 0.092\ P^{1.4909}$	2043.53
7	Nicolov (1983)	By interpolation using rainfall erosivity map	1375.00
	Total values of accepted models		2480

Table 2. Mechanical Analysis of soil samples, (Soil particle Size Distribution)

No.	Name of Location	%coarse sand	% silt	% fine sand	% clay	Texture	*Organic matter %*
1	Chaqan- East of Jumaracy	1.97	54.32	0.34	43.71	Silty clay	2.5
2	Chaqan - Jumaracy	24.24	31.36	5.95	44.4	Clay	3.28
3	Chaqan – Bwari kamarasur	23.81	35.49	13.15	40.7	Clay	5.05
4	Chaqan – South of Jumaracy	52.61	24.71	4.81	22.68	Sandy clay loam	3.28
5	Chaqan – Borey sarw	19.33	40.61	8.36	40.06	Silty clay loam & siltyclay	3.78
6	Chaqan – North of Siamewa	33.47	40.78	11.07	25.75	Loam	2.02
7	Chaqan – Emamy Zamin	44.28	12.13	6.89	43.59	Clay	2.77
8	Chaqan - South of Siamewa	27.56	28.28	4	44.16	Clay	3.53
9	Chaqan – Siamewa & krnook	18.15	41.5	8.5	40.35	Silty clay	4.3
10	Chaqan - Zhazhie	34.01	36.48	5.29	29.51	Clay loam	4.04
11	Chaqan - Zangisar	21.19	24.52	6.12	54.29	Clay	4.29
12	Chaqan – front of Zangisar	24.49	28.44	21.47	47.07	Clay	5.00
13	Chaqan – out let	85.88	5.62	6.06	8.5	Loamy sand	3.28

F-factor and rainfall adjustment factor in the Musgrave equation.

$$E = KCR * (S^{1.35} / 10)^{1.35} * (L / 72.6)^{0.35} \quad \text{.............. (10)}$$

Where:
E= sheet erosion, ton/acre/year.
K= erosion rate, soil/factor, ton/acre/year/unit rainfall index.
C = cover factor.
R = rainfall factor, rainfall erosion indices.
S= land slope in percent.
L= length of slope in feet.

RESULTS AND DISCUSSION

The value of rainfall erosivity during the period of the study was determined by checking seven models. The annual rainfall erosivity was obtained from the average values of more accepted models, Table (1).

Table (2) shows the particle size distribution, organic matter content, for thirteen (13) soil samples collected from the surface layer of Chaqan watershed. It is appeared from this table that the percent of organic matter ranges from the minimum value of (2.02) to a maximum value of (5.05).The texture of soil is silty clay in mountainous areas and silty clay to clay in both hilly areas and bottom lands.

Table (3) exhibit soil structure, permeability, and soil depth, it is appeared from this table that the soil depth ranges from shallow to moderate at mountainous and hilly areas to deep in bottom lands. The estimated permeability was based on using inverse auger hole, while the structure class code was based on visual observation of soil aggregates in the field. It is indicated from this table that the permeability can be classified as slow to moderate according to permeability class code represented by Table (4), this might be attributed to high clay content of the soil texture. Moldenhauer and Long, 1964, have shown that the amount of soil loss decreased with increase in soil permeability through its effect on decreasing runoff, Wischmeier et al, 1971 observed that the soil erodibility decreased from 0.52 to 0.42 as the result of a shift in permeability class from slow to high. Table (3) also include percent of slope of the locations of

Table 3. Soil permeability, structure, and soil depth of the sample sites

No.	Permeability, cm/hr	Soil Structure	Soil depth, cm	Slope%
1	0.78	Blocky	0-16	60
2	0.786	Blocky	0-20	39
3	0.70	Granular	0-20	40
4	0.74	Granular	0-40	35
5	0.84	Massive	0-30	29
6	2.04	Massive	0-48	34
7	2.04	Columnar	0-60	45
8	0.36	Granular	0-52	48
9	0.513	Columnar	0-38	18
10	0.82	Columnar	0-20	28
11	0.48	Columnar	0-20	21
12	0.56	Massive	0-30	16
13	0.95	Granular	0-35	9

Table 4. Soil Permeability Class Codes

Permeability Value	Permeability Class	Permeability Class Code
0.1 cm / hr	Very slow	6
0.1 – 0.5	Slow	5
0.5 – 2.0	Slow to moderate	4
2.0 – 6.0	Moderate	3
6.0 – 12.0	Moderate to rapid	2
12.0	Rapid	1

soil samples, and it could be described as very steep at mountainous areas, very steep to steep at hilly areas and moderate to gentile at bottom lands.

All these information were used to compute the soil erodibility of each sub-zone using the soil erodibility equation suggested by Wischmeier and Smith, 1958 Table (5). The soil erodibilty factor, cropping-management factor and conservation practice factor were determined for the whole watershed by weighting these values according to the area covered by each zone, Table (6). It is apparent from Table (6) that the watershed has a low soil erodibility factor. This attributed to the high clay content, high degree of soil aggregation and moderate permeability of the existing soils in the watershed. The low cropping management factor is an indication that the majority of the lands are under forest and grasses.

The data presented in Table (7) includes the average slope length and average slope percent (l and s) for the watershed. These two parameters were determined according to the method described by Williams and Berndt, 1972. Furthermore these two parameters were substituted into the universal procedure for computing slope length and slope steepness factors.

Table (7) also lists the required data to compute the soil loss for the watershed using modified Musgrave and universal soil loss equations. It is evident from Table (7) that the modified Musgrave equation tended to give a lower value of annual soil loss than that obtained by applying USLE (26.41 versus 54.129 metric ton/ha/yr).

Figure (1) illustrated the map of the zones of different degrees of soil erosion. It's evident from Fig (1) that the areas of watershed zones can be ranked from large to small and based on the degree of erosion as (severe >moderate> very severe> geological>light) erosion.

The soil loss equations estimate gross sheet and rill erosions and do not account for channel-type erosion (gully, valley trenches, stream bank, and road bank erosions. Since 20 –40% of the total sediment yield results from gully erosion (Bali et al., 1972, Piest, et al, 1975), the contribution of gully erosion should not be overlooked. The author proposed multiplying the annual soil loss by a factor of 1.3 to obtain the gross erosion. It is interesting to mention that it was difficult to estimate the gully erosion during the study because such kind of estimation needs a detailed field survey and a periodic cross section measurement, (Barzinji, 2003).

On the basis of gross erosion, the watershed is placed in the sever erosion hazard class (50-200 ton/ha/yr) in spite of its high clay content, moderate permeability and good grass cover. The possible explanation is its high gradient value.

Table 5. Calculation of soil erodibility for 13 soil samples collected from the surface layer of Chaqan watershed using soil erodibility equation

#	Clay (%)	Silt (%)	FS (%)	Sand (%)	Si + FS (%)	O.M%	S.C.	Permeability,(P)	P. Code	K
1	43.71	54.32	0.34	1.97	54.66	2.5	4	0.78	4	0.368
2	44.4	31.36	5.95	24.24	37.31	3.28	2	0.7	4	0.179
3	40.7	35.49	13.15	23.81	48.64	5.05	2	0.74	4	0.202
4	22.68	24.71	4.81	52.61	29.52	3.28	4	0.84	4	0.282
5	40.06	40.61	8.36	19.33	48.97	3.78	4	2.04	4	0.323
6	25.75	40.78	11.07	33.47	51.85	2.02	4	2.04	4	0.457
7	43.59	12.13	6.89	44.28	19.02	2.77	4	0.36	5	0.192
8	44.16	28.28	4	27.56	32.28	3.53	4	0.51	4	0.273
9	40.35	41.5	8.5	18.15	50	4.3	4	0.82	4	0.314
10	29.51	36.48	5.29	34.01	41.77	4.04	4	0.48	5	0.318
11	54.29	24.52	6.12	21.19	30.64	4.29	4	0.56	4	0.234
12	47.07	28.44	21.47	24.49	49.91	5.00	4	0.95	4	0.273
13	8.5	5.62	6.06	85.88	11.68	3.28	4	0.78	4	0.188

Table 6. Parameters of Universal Soil loss Equation for different zones of Chaqan watershed

Zones	Area of zone, Km	K Factor	C Factor	P Factor	Weighed zone area	Weighed K	Weighed C	Weighed P
1	6.12	0.368	0.07	0.9	0.143	0.053	0.010	0.129
2	13	0.259	0.0748	0.9	0.304	0.055	0.000	0.274
3	15.136	0.29	0.011	0.86	0.355	0.108	0.014	0.305
4	1.628	0.31	0.46	0.725	0.160	0.037	0.000	0.144
5	6.812	0.257	0.07	0.9	0.038	0.010	0.015	0.027
Total	42.696					0.263	0.040	0.879

Table 7. Estimation of annual soil loss from Chaqan watershed using Modified Musgrave and Universal soil loss equations

Equation	Average slope, s(%)	Slope steepness factor, S	Average slope length, l,(ft)	Slope length factor, L	Average soil erodibility factor, K (metric unit)	Average conservation practice factor, P	Average cropping-management factor, C	Annual soil erosivity, R (metric unit)	Soil loss metric, A, ton/ha / yr	Gross erosion metric ton/ha/ yr
1.Modified Musgrave	32.46	8.37	176(577.43)	-	0.263	0.879	0.04	248	26.41	34.33
2. USLE	32.46	8.37	176(577.43)	2.82	0.263	0.879	0.04	248	54.129	70.367

$S = 0.065 + 0.045\ s + 0.0065\ s^2$
$L = (l / 22.1)^{0.5}$
Musgrave equation: $A = KCR\ (s/10)^{1.35}\ (l/72.6)^{0.35}$
USLE: $A = RKLSCP$

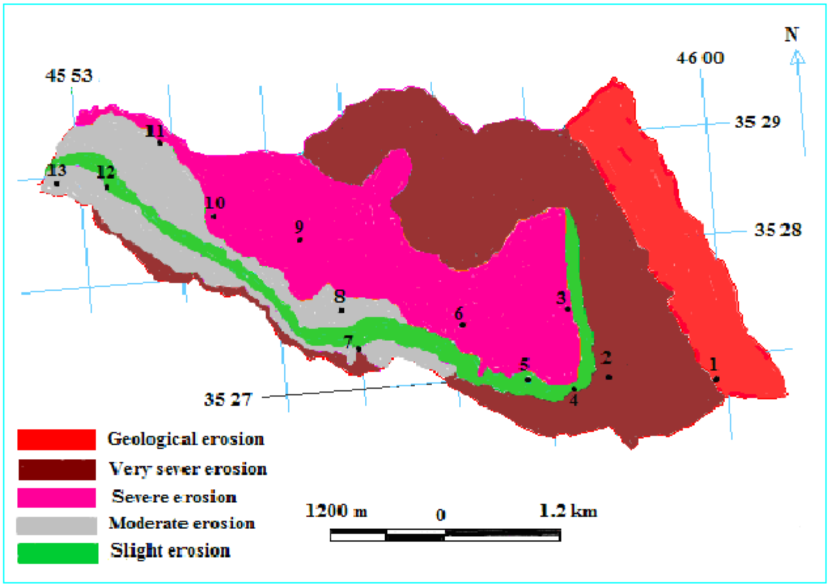

Figure 1. Erosion map of Chaqan watershed and the locations of soil samples

CONCLUSIONS

1. The depth of the soil is different from site to site, and usually the soil has less depth in most of the parts.
2. The modified Musgrave equation tended to give a lower value of annual soil loss than that obtained by applying the universal soil loss equation.
3. The watershed has medium erodibility class (0.1-0.3) according to Voznesenkii and Artsruni, (1940).
4. Based on the value of gross erosion, Chaqan watershed is placed in the moderate erosion hazard class (50 – 200 ton/ha/yr).
5. The watershed has steep slope which lead to occurring the great amount of soil erosion in this watershed which is affect both water quality and the capacity of Darbandikhan Lake.
6. To obtain the gross erosion the amount of measured soil erosion by both the two used models can be multiplied by the factors of 1.3.
7. Moderate to little forest of oak trees covers some parts, grasses cover others, while most of the area is denudation.
8. According to this study the watershed can be divided into different zones of the degrees of erosion, and the areas of watershed zones can be ranked fro large to small based on the degrees of erosion as (severe >moderate> very severe> geological>light) erosion.
9 Most of the areas inside the watershed have steep to very steep slopes and shallow soils. Bothe factors are causing heavy soil erosion, since watershed materials are transported easily on steep slopes by surface runoff and shallow soils absorb little water during the storm, and also support very poor cover. Therefore, the soil is exposed to the impact of rain drops.
10 Uneven distribution of rainfall, especially the long period of drought from May to October, causes great problems in developing a good vegetation cover. Even the rain fed crops are subject to insufficient amount of rainfall. Occasional heavy storms especially in spring causes heavy surface runoff which leads to severe sheet erosion.
11. Due to the steep slopes and rough topography the areas which are suitable for cultivation are very much limited.

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