



**THE EFFECT OF DIFFERENT SLOPE STEEPNESS ON SOIL LOSS AND SURFACE RUNOFF  
BAKRAJOW UNDER NATURAL RAINFALL.**

Kamal Sh. Qadir\*

\*Soil and Water Science Dept, Agricultural Sciences Faculty, Sulaimani University. Iraq  
Corresponding author, e-mail: [Kamal.soil@yahoo.com](mailto:Kamal.soil@yahoo.com)

**ABSTRACT:** This study was carried out during 2013-2014, at Bakrajow Research Farm to investigate the effect of two slopes (7 and 11.3%), four runoff plots (8 × 2 m) were constructed on each slope. The results showed that average runoff and soil loss of 11.3% slope were about 3 and 2 times more than the second slope of 7.0% respectively. Then the difference was significant at the level of 0.05.

**Keywords:** water erosion, slope steepness, surface runoff.

## INTRODUCTION

Water erosion is a main agent that degrades soils besides each of wind, tillage, soil compaction, poor drainage, acidification, alkalization and Salinization [1]. It affects nearly 1.1 million hectares worldwide, representing about 56% of the total degraded land [2]. Water erosion is one of the major causes of soil loss and soil degradation [3]. As it is being known, slope is one of the universal soil loss equations, (USLE) [4]. In general, erosion becomes greater with increasing slopes from 0 to 10 % [5]. [6, 4] have developed an empirical relationship between potential soil loss per unit area and soil, slope, vegetation and rainfall factors known as universal soil loss equation, (USLE). The USLE predicts soil by sheet and rill erosion, does not include gully erosion [4]. However, there have been investigations in the Tropics on the effect of slope steepness on soil loss [7], generally indicating a somewhat exponential increase in soil loss with slope steepness [8]. Much of this research has been in the context of determining the slope length/slope steepness factor in the Universal Soil Loss Equation [4]. Erosion is directly affected by the steepness and length of the slope. Greater slopes cause to increase the runoff velocity and the movement of sediment carried in runoff [9]. The determination of slope steepness factors is an integral part of most soil erosion prediction models. Several scientists have investigated slope steepness effects on soil loss. Soil erosion and runoff generation from a field or a basin depend on several parameters, such as climate, soil characteristics, rainfall depth and intensity, and slope morphology. The effect of slope gradient on soil loss and runoff were studied extensively, with the general conclusions that eroded materials and runoff increase with higher slope steepness [10, 4, 11, 12, and 13]. There is a great relation between erosion and uniform slope [14]. More of the slope steepness effect comes from erosion by surface runoff than by raindrop impact [15]. [16] suggested that soil losses from the interrill areas at 20% slope were only about double those measured at 2% slope, whereas widely used erosion equations show that total field erosion would increase about 20-fold over this range of steepness's. The influence of slope gradient on erosion rate differs for rill and interrill conditions. Rill erosion increases substantially more with increasing slope gradient than interrill erosion [17]. Severe or prolonged erosion can cause changes in yield potential and soil productivity, depending on topsoil thickness and subsoil properties. In addition, nearly all organic matter is located in the topsoil, along with approximately 50 percent of plant-available phosphorus (P). A similar relationship exists for potassium (K). Erosion causes to decrease in available nutrients for plants then decrease in yield potential of the soil, plant [9].

The aim of this study is to investigate the effect of slope steepness on runoff and soil erosion.

## MATERIALS AND METHODS

The instrumented runoff plots were conducted at Bakrajow location, located at the south west of Sulaimani city. The average rainfall, dominantly from convective storms, is about 616 mm. the data used in this paper are from two bare soil plots,. Two uniform slopes were selected. The first slope was 11.3% (Latitude: 34° 34' 40" N; Longitude: 45° 21' 33" E and altitude: 828 m), while the second experiment 7.0% slope (Latitude: 35° 34' 40" N; Longitude: 45° 26' 36" E and the site altitude: 831 m) was about 300 m away from of the 11.3% slope. Plots were hydrologically defined by metal barriers and kept bare from vegetative cover during the experiment using chemical weed control at the earlier stage of weeds growth. Six runoff plots (8m by 2m) were established in the studied area; mean three replication for each slope. The plots were separated by a buffer zone 1.0 m wide. Each plot was boarded at the sides and top of the slope by 20 cm high 22-gage galvanized metal dividers pressed into the soil to a depth approximately 10 cm to prevent piping and directing flow to the point of measurement. Runoff was routed from the plots through conveyance channels to collection tanks. The amount of rainfall was obtained from recording rain gage of the meteorological station of Agricultural Science Faculty at Bakrajow. Each plot was cultivated up and down its slope and maintained in bare condition during the experiment. The experimental plots shown as a diagram in (Fig.1). This experiment conducted according to Complete Randomized Design, (CRD) with three replication.



Fig. 1: Runoff plot design diagram for studied area

Bakrajow location as a county is an important agricultural area and situated with an intermountain valley in the mountain region of Sulaimani (Fig. 2).

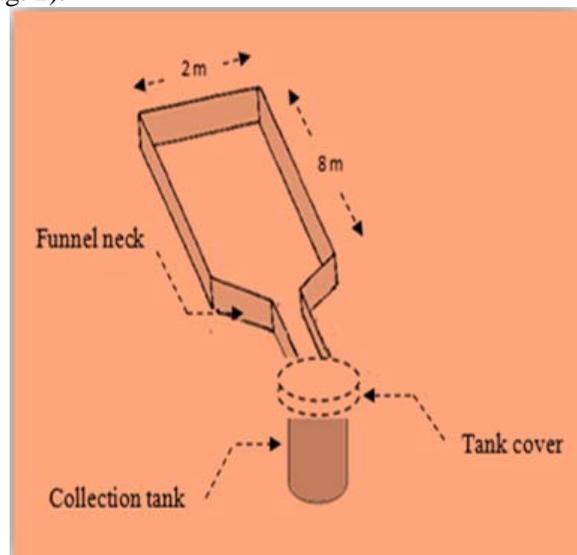


Fig. 2: Location of studied area in Sulaimani governorate [18]

In general, the climate of the region is of semiarid type. It can be classified as Interior Mediterranean, mild winter, dry and hot summer and is symbolized by Csa according to the scheme proposed by Koeppen [19]. There is no usually rain during the summer months. The average annual rainfall is more than 500mm. Based on records for a long period; there is surplus of water from about mid of October 2013 to the end of April 2014. On the other hand, there is water deficit over the remaining period. The area as a part of 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. The mean annual air temperature average is 19 °C with a maximum of (44 °C) in July and a minimum of about (-3 °C) in January. The average annual pan evaporation is estimated to be 2020 mm. Runoff was measured generally after each storm before determining soil erosion. The height of water in the tanks was converted to liters by means of calibration curve between height and runoff volume. Soil loss was determined by thoroughly stirring the content of the tanks after and quickly extracting one liter sample with a wide mouth one liter beaker after reducing the content by siphoning the relatively clear water. Samples were collected at depth of (0 to 0.3m), took to laboratory, air dried, passed on 2 mm sieve and stored until some selected chemical and physical properties had been determined (table 1). The particle size analysis was performed by sieving and pipette methods according to the methods described by [20]. Organic matter was determined by following the modified Wakley-Black method [21]. Soluble calcium and magnesium were measured by titration with EDTA, while soluble sodium and potassium were measured by flame photometer model corning 400 flame photometer. Calcium carbonate content was determined by acid neutralization method according to [22].

The statistical analysis of the data was done by using JMP7 software [2].

**Table 1: Some physical and chemical properties of the soil at the studied soil sample**

PSD (g kg <sup>-1</sup> )			Texture	OM (g kg <sup>-1</sup> )	CaCO <sub>3</sub> (g kg <sup>-1</sup> )	Soluble cations (cmol <sub>c</sub> kg <sup>-1</sup> )			
Clay	Silt	Sand				Ca <sup>2+</sup>	Mg <sup>2+</sup>	K <sup>1+</sup>	Na <sup>1+</sup>
436.0	511.3	52.7	SiC	23.3	449.2	5.4	1.9	0.16	0.92

Where: PSD = Particle size distribution  
SiC = Silty clay texture  
OM = Soil organic matter content.

## RESULTS AND DISCUSSION

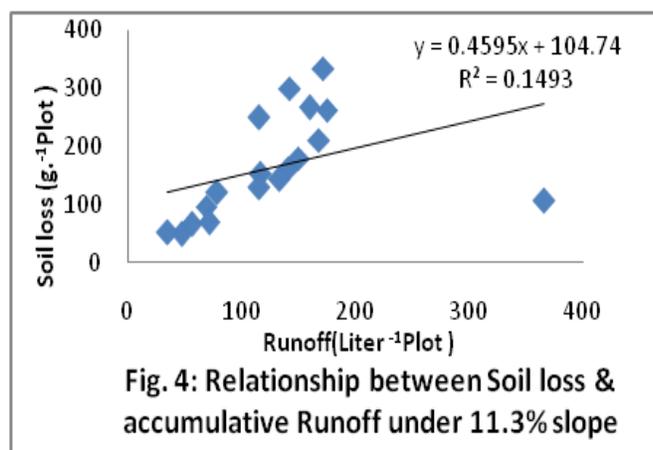
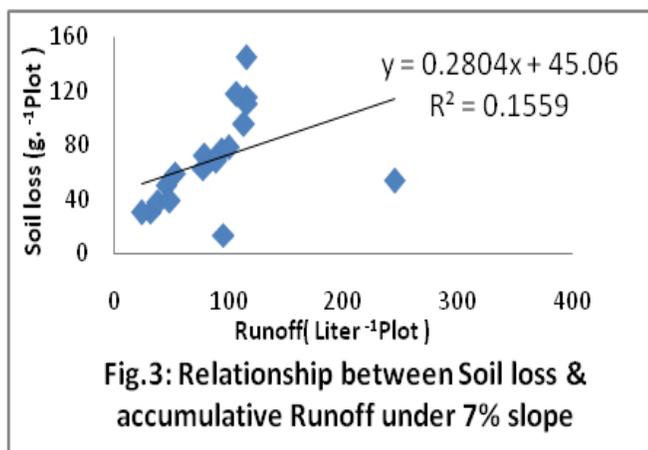
Runoff amount from each plots were calculated using the volume of water in each tank, which was measured manually with 24 hours of each major rainfall event or after a series of events that were separated by a short time interval. Coarse material and suspended sediment samples were collected as soon as possible after a rainfall event that product runoff, and the results are shown in (Table 2).

Figures (3) and (4) illustrated the annual soil loss from the silty clay soil at study site as affected by slopes (11.3% and 7%) during the rainy seasons of 2013- 2014. It is noticed from these two figures that the annual soil loss ranges from a minimum of 0.86 t ha<sup>-1</sup> under the slope of 7% to a maximum of 1.84 t ha<sup>-1</sup> of the 11.3% slope.

Soil loss due to water erosion tended to increase with increasing slope steepness. This result was agreed with the study conducted by [24]. He expected that soil losses will increase with slope steepness as a result of respective increase in volume of surface runoff. The amount of soil erosion per unit area on Munchong series with 807 mm rain depth increased approximately 9.8 times as the degree of slope is doubled, While the amount of runoff will be increased approximately 1.6 times as the degree of slope is doubled [24]. Similar result was obtained by [25] from two different sites (Qiliasan and Huana; in which slopes were 17.4 and 14.6 respectively. The results showed that Qiliasan is more erodible (9.9 t. ha<sup>-1</sup>) than the Huana site (8.2 t. ha<sup>-1</sup>). Slope alone does not significantly influence the amount of soil loss. Soil loss was also caused by the interaction of several other factors such as clay percent, organic matter content, Calcium carbonate and some soluble cations (Ca<sup>2+</sup>, Mg<sup>2+</sup>, K<sup>1+</sup>, and Na<sup>1+</sup>). A texture of Bakrajo showed a high percent of clay (43.6%), forming strong and stable aggregates which consumed large portion of rainfall's kinetic energy for destroying. Earlier study by [26] found that clay content accounted for most variation of soil erodibility in the Iraqi Kurdistan region. They found that the soil erodibility in Bakrajow was low (0.24) means that amount of soil loss as affected by slope was lower than expected.

Table 2: Runoff volume and soil loss in study area

Date of storm	Depth of storm (mm)	Mean Runoff (liter plot <sup>-1</sup> )		Mean Soil loss (g. plot <sup>-1</sup> )	
		7% slope	11.3% slope	7% slope	11.3% slope
7.11.2013	12.2	31.34	94.51	30.76	48.80
8.11.2013	15.8	45.25	138.02	49.62	96.01
9.11.2013	68.8	115.33	349.95	115.61	262.65
10.11.2.13	24.4	94.02	282.00	75.99	161.96
29.11.2013	10.2	37.98	112.46	37.61	66.58
4.12.2013	14	48.26	143.29	38.82	69.48
5.12.2013	41	115.33	232.04	110.63	248.98
6.12.2013	24	99.91	299.73	78.31	179.12
7.12.2013	15.6	78.97	233.92	72.05	152.43
8.12.2013	32.2	112.82	336.97	95.22	210.69
12.12.2013	18	77.09	231.00	62.75	129.48
31.12.2013	15.6	244.45	732.31	53.43	105.77
28.1.2014	75.4	114.70	343.54	144.85	334.07
11.3.2014	52.4	95.40	285.11	13.85	299.53
13.3.2014	45.2	106.55	319.67	117.63	267.11
17.3.2014	20	89.00	267.04	68.40	144.08
30.3.2014	11.2	52.90	157.53	59.00	119.97
28.4.2014	14	23.44	70.33	30.42	52.23



## CONCLUSION

From the obtained results, following conclusions can be summarized as follow:

1. Slope steepness is the one of the important factor of universal soil loss equation, USLE, and however it increased the amount runoff and soil loss increased.
2. Amount of soil loss in plots with slope 11.3% was greater than the 7% slope.
3. Accumulation volume of surface runoff in 11% slope was also greater than 7% slope.
4. The low obtained results of average runoff and soil loss in Bakrajow wasn't being expected, due to high percent of clay particles and organic matter which tend to make stable aggregates. This means that a large portion of rainfall was used to destroy aggregates, then less amount of rainfall was remain to produce runoff.

## REFERENCES

- [1] Blanco, H. and Lal, R. 2008. Principles of Soil Conservation and Management. Springer Science Business Media B.V.
- [2] Oldman, L. R. 1994. The global extent of land degradation. In: Greenland, DJ, Szabotes I. (eds). Land resilience and Sustainable Land use. CAB International, Wallingford UK, pp 99-118.
- [3] Dorren, Luke & Rey, Freddy. 2011. "A review of the effect of terracing on erosion." Soil Conservation and Protection for Europe. Web. 28 Oct. pp: 119-128.
- [4] Whischmeier, W.H. and Smith, D. D. 1978. Predicting rainfall erosion losses USDA. Agric.. Handbook 573. U.S. Gov. Print, Washington D.C, pp 58
- [5] Defersha, M. B; Quraishi S and Melesse, A .2011. The effect of slope steepness and antecedent moisture content on interrill erosion, runoff and sediment size distribution in the highlands of Ethiopia. Hydrol. Earth Syst. Sci., 15, pp 2367–2375.
- [6] Whischmeier, W. H., and Smith, D. D. 1965. Predicting rainfall erosion losses from cropland east of the Rocky mountains. Guide for selection of practices for soil and water conservation. U. S. Dep. Agric. Agricultural/ Handbook No. 282
- [7] Dangler, E. W., and El-Swaify, S. A. 1976. Erosion of selected Hawaii soils by simulated rainfall. Soil Sci. Soc. Amer. J., 40, pp 769–773.
- [8] Roose, E. J., 1977. Application of the Universal Soil Loss Equation of Wischmeier and Smith in West Africa. Conservation and Soil Management in the Humid Tropics, D. J. Greenland and R. Lal, Eds., Wiley, pp177–187.
- [9] Gerald Miller and Michael J. Tidman, 2001. Integrated Crop Management News pages 3-4 of the IC-486 (1) issue. Iowa State University. University Extension,
- [10] Young, R.A. and Mutchler, C.K. 1969a. Effect of slope shape on erosion and runoff. Transactions of the American Society of Agricultural Engineers 12, pp 231-233,
- [11] Liu, B.Y., Nearing, M.A., and Risse, L.M. 1994. Slope gradient effects on soil loss for steep slopes. Transactions of the American Society of Agricultural Engineers 37, pp 1835-1840.
- [12] Gabriels, D. 1999. The effect of slope length on the amount and size distribution of eroded silt loam soils: short slope laboratory experiments on interrill erosion. Geomorphology 28, pp 169-172.
- [13] Chaplot, VAM., Le, Bissonnais Y. 2003. Runoff features for interrill erosion at different rainfall intensities, slope lengths, and gradients, in an agricultural loessial hillslope. Soil Science Society of America Journal 67, pp 844-851.
- [14] McCool, D. K., Brown, L. C., Foster, G. R., Mutchler, C. K., and Meyer, D. 1987. Revised slope steepness factor for the universal soil loss equation. Transactions of the ASAE, 30, pp 1387-1396.
- [15] Foster, G.R. 1982. Modeling the erosion process. In C.T. Hann (ed.) Hydrologic modeling of small watersheds. Am. Soc. Of Agric. Engineers, St. Joseph, Mich, pp 297-360.
- [16] Lattanzi, A.R; Meyer, L.D and M. F. Baumgardner, M.F. 1974. Influences of Mulch Rate and Slope Steepness on Interrill Erosion. SSSAJ. Vol. 38, No. 6, pp 946-950.
- [17] Foxa, M. Dennis and Bryanb, Rorke B. Bryanb. 2000. The relationship of soil loss by interrill erosion to slope gradient. Catena. Vol. 36, Issue 3, pp 211-222.
- [18] www. Telematique.co.uk
- [19] Khurshed, S.H. 2003. Study of swell shrinkage potential of soils in Sulaimani governorate and its surroundings. A thesis submitted to the College of Agriculture, University of Sulaimani in partial fulfillments of the requirements for the degree of Master of Science in Soil Science (Soil Physics),
- [20] Gee, G. W. and J. W. Bauder. Particle size analysis. In Klute, A., (ed), 1986. Methods of soil analysis, Part1 2nd ed., Physical and mineralogical methods. Am. Soc. Agron, Madison, WI, 383-411
- [21] Allison, L. E. Organic carbon. In CA. Black, 1965. Methods of soil analysis. Part 2. Agronomy. 9: 1367-1378. Am. Soc. of Agron. Madison. Wis
- [22] Richards, L. A. (ed.). 1954. Diagnosis and improvement of saline and alkaline soils. Agriculture Handbook No.60. USDA. US Government printing Office. Washington. D. C
- [23] JMP, Version 7. SAS Institute Inc. Cary, NC, 1989-2007.

- [24] Ali, Mohd Fozi. 2000. The Effect of Slope Steepness on Soil Loss under Natural Rainfall Distribution. MSc thesis, University Putra Malaysia.
- [25] Qadir, K. Sh. 2001. Study of erodibility of soils in Iraqi Kurdistan Region. M.Sc. Thesis. College of Agriculture. University of Sulaimani
- [26] Karim, T. H., Ibrahim, M. A., and Tahir, M. K. 1998. Soil erodibility as predicted by the soil erodibility Nomograph and its variability in northern Iraq, University of Salahaddin-Erbil, Iraq. Zanko J. 10: No.2