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Soil Erosion Assessment Using Revised Universal Soil Loss Equation for Selective Dry Valleys In the Eastern Desert of Egypt

W.A.M. Abdel Kawy and M. A.El-Nady

Soil Science Department, Faculty of Agriculture, Cairo University, Giza, Egypt.

Abstract: Soil erosion is one of a major environmental concern. It may cause serious problems on the cultivated land areas. Obtaining spatial information of soil loss by water erosion is very important for evaluating soil potentiality in agricultural expansion. Soil loss is commonly predicted using the Universal Water Loss Equation. In the current study, both Universal Water Loss Equation (USLE) and Revised Universal Water Loss Equation (RUSLE) were used to predict soil loss of four selective dry valleys in three selected regions located in the eastern desert of Egypt. The regions were (El-Minia – Giza, Suhag - El-Minia, and Luxor–Suhag). These regions were exampled by four valleys (Sannur, Tarfa, Asyuit and Qena) which exposed to soil loss by surface runoff. Geographic Information System GIS capabilities have been utilized to produce a geometrically corrected physiographic map for these dry valleys. Twelve soil profiles were chosen in this research to represent the four dry valleys. Soil parameters, slope and climate values were serve as inputs into the Universal and the Revised soil loss equations to evaluate the present state and the risk of soil water erosion. The results demonstrated that the highest soil erosion rate was recorded in (Luxor-Suhag) region while the lowest erosion rate was recorded in (El-Minia – Giza) region. Soil erosion rates obtained by the (RUSLE) were approximately close to those obtained by the (USLE). Both equations are reliable tools for determination of the relative change in soil loss of the studied valleys.

Key words: Egyptian eastern desert, remote sensing and GIS, Revised Universal soil loss equation, Universal soil loss equation, soil erosion.

INTRODUCTION

Egypt is divided into four major physical regions having different geological characteristics. These are the Nile Valley and its Delta, the Western Desert, the Eastern Desert and the Sinai Peninsula. The Eastern Desert lies between latitude 22^{O} and 29^{O} N covering about 22% of the Egyptian territory (222,000 km^2) and bounded by the Red Sea and Gulf of Suez on the east and the Nile Valley on the west. The Eastern Desert has attracted numerous investments in the last few decades, especially for the tourism and mining ventures. The area is undeveloped due to the limited availability of water and soil erosion.

Soil erosion has been recognized as a global threat against the sustainability of natural ecosystem and it may be a slow process that continues relatively unnoticed, or it may occur at an alarming rate causing serious loss of topsoil. The erosive actions of water are joint effects of energy of falling rain and subsequent runoff on the land surface. Universal soil loss equation (USLE) developed by (Wischmeier and Smith,1978), was derived by correlating the amount of soil loss gained from experimental plots with various topographic, climate, soil, and land use parameter (Schmidt, J. 2000). The Revised Universal Soil Equation (RUSLE) is an erosion model predicting longtime average annual soil loss due to water from specified slopes in specified cropping and management systems. This equation updates the information on data required after the (1978) release (Renard *et al.*, 1997). A principal modification is in R factor which includes rainfall and runoff erosivity factor, also there are changes in C factor which is based on computation of sub-factor called soil loss ratios (SLR). The SLR depends on sub-factors: prior land use, canopy cover, surface cover, surface roughness and soil moisture (Renard *et al.*, 1997). The (USLE) was used in GIS environment to predict the long-term average annual soil loss and its spatial distribution (Saro, 2004 and Breiby, 2006).

Regardless of the soil-loss model employed, surface erosion can vary spatially and temporally within and among rangeland communities due to climatic variability, topographic changes, soil and geologic inconsistencies, and natural and human-induced perturbations (Wood *et al.,* 1994).

Corresponding Author: W.A.M. Abdel Kawy, Soil Science Department, Faculty of Agriculture, Cairo University, Giza, Egypt

Effective control of soil erosion requires the ability to predict the amount of soil loss which would occur. Therefore, the present study aims to (a) establish information on soil erosion of four valleys in three regions in Eastern Desert of Egypt and (B) evaluate soil loss using two equations, the Universal soil loss equation (USLE) and the Revised Universal soil loss equation (RUSLE).

MATERIAL AND METHODS

Description of the Study Area(s):

The Eastern Desert is located in the extremely arid provinces in Egypt. According to the soil taxonomy system, bases Soil Survey Staff (2003), the soil temperature regime of the studied area is defined as thermic and the soil moisture regime as torric. Generally, the rainfall varies considerably from one season to another. Heavy showers are recorded occasionally during winter causing flash floods (Aggour and Sadek 2001). Three regions selected at the eastern desert of Egypt (El-Minia–Giza, Suhag-El-Minia and Luxor–Suhag) represented by Four valleys (Sannur, Tarfa, Asyuit and Qena), Fig. (1). Twelve soil profiles were chosen to represent the four valleys.

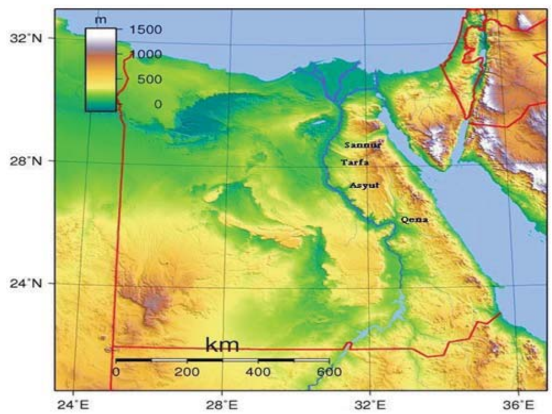


Fig. 1: Location map of the selective dry valleys in the Eastern Desert, Egypt.

Satellite Images Materials and Processing:

ArcGIS was used to manage and to process satellite images. The area of study is covered by four Enhanced Thematic Mapper ETM+ Satellite image of numbers 175/41, 175/42, 176/40 and 176/41. They were acquired in 2003. These images were subjected to the most image processing including (stretching, filtering, and histogram matching and rectification) using ENVI 4.4 software. To recognize land use pattern, Band combination 7, 4, 2 according to Lillesand and Kiefer, (1979) was used. The ETM+ Satellite images covering the study area was produced for compiling the physiographic maps.

Field Studies:

Soil profiles were examined in different locations of each valley. The exact locations of the soil profiles were precisely defined in the field by using the DGPS "System Cooperation MAGELLAN"-GPS NAV DLX-10 TM, and plotted on the maps. The number of observations was determined mainly by the inherent variability of the mapping units. Reconnaissance soil survey was done for identifying the major landforms. The total area of each valley is given in Table (1).

Table 1: Areas and lengths of the selective dry valleys at the eastern desert.

Morphometric parameters	Valleys			
	Sannur	Trarfa	Asyuit	Qena
Total valley area $(Km)^2$	3491.03	4405.41	9165.24	13383.24
Total valley length (Km)	148.65	169.24	226.33	248.92

Physical Properties:

-Particle size distribution using, dry sieving method, USDA (1991).

-Soil permeability, Klute (1986).

-Soil color was identified using Munssel Color Charts, Soil Survey Staff (1975).

-Soil Taxonomy was used to classify the different studied soils, Soil Survey Staff (2003).

Chemical Analyses:

-Soil pH, according to klute (1986).

-$CaCO_3$%, OM% & ECe dS/m, according to USDA (1991).

-Cation exchange capacity and exchangeable sodium, according to Robert (2008).

Soil Water Erosion Modeling:

An estimation of soil loss due to water erosion was generated using both Universal and Revised Soil Loss Equations (Wischmeier and Smith, 1978) and (Renard *et al.*, 1997). The soil loss equation is as product of six major factors:

A = R.K.L.S.C.P

Where,

A = average annual soil loss (ton/area/year).

R = rainfall erosivity index.

K= soil erodibility factor.

L = slope length factor.

S = the slope gradient factor.

C = vegetation cover factor.

P= conservation protection factor.

Each of the above mentioned factors has its own equations and assumptions as follows:-

Rainfall Erosivity Factor (R):

Rainfall erosivity factor (R), was calculated from the agro-climatologically data, Egyptian meteorological authority (2006), as (Rw) for the Universal soil loss equation and (Rr) for the Revised Universal soil loss equation. The (Rw) was calculated using Rw = KE x I_{30} where KE is rainfall kinetic energy and I_{30} is rainfall intensity for a 30- minute period, KE was calculated using the following equation: KE = 11.87+ 8.73 $\log_{10}$ I, where I is the rainfall intensity (mm/h). The (Rr) was calculated by the following equation Rr = $\sum_{i}^{12} P_i^2 / P_a$, where P_i is the amount of monthly rainfall (mm) and P_a is the amount of annual rainfall (mm).

Soil Erodability Factor (k):

Soil erodability factor (k), was calculated from the data obtained from grain size analysis, structure, permeability, and organic matter content by the following equation: $K=2.1\times10^{-6}(12\text{-OM})(M)^{1.14}$ +0.0325 (S-2)+0.025 (P-3), where OM is organic matter content %, M=(silt%+ very fine sand%)(100-clay%), S is soil structure code (factor) and P is permeability class.

Slope Length and Steepness Factor (LS):

The factor of slope length and slope gradient are combined in a single index (LS) and is obtained from the equation: LS factor= $(L/22.013)^{0.5}(0.065+0.045\ S+0.0065\ S^2)$, where L is the slope length (m) and S is the slope gradient in percent.

Cropping Management Factor (C):

Cropping management factor (C) is set to one; because it is a bare soil.

Erosion Control Practice Factor (P):

Erosion control practice factor (P) is also set to one because none of the erosion control practices is in use in the study area.

Integration of the Data in a Soil Map:

ArcGIS 9.2 software was used for maps production. The soil correlation between the physiographic and taxonomic units, were designed in order to identify the major soil sets of the area under investigation, after Elberson and Catalan (1987). Digital elevation model (DEM), interpolated from elevation contours, and was employed to generate the slope and LS-factor.

Statistical Analysis:

The data were statistically analyzed following the procedure outlined by (Snedecor and Cochran, 1980). Differences between the mean values were compared using student's t–test at 0.05 level of significance.

RESULTS AND DISCUSSION

physiographic Maps:

The present geo-pedological study is based on the interpretation of satellite images, integration among soil analyses and field observations and verification. Analytical data reveal that, the main identified physiographic units of the studied valleys soils could be summarized as follows:-

Vale – Valley bottom - Sand sheets – Alluvial/Colluvial fans – Colluvial/Alluvial fans – undulating surface - foot-slopes – Cliff's mid slope - Cliff's upper slope and Hills tops.

According to Soil Survey Staff, (2003), two soil orders were recognized 1-Entisols with sub great groups of -Typic Psammaquents.- Typic Torripsamments and Aridisols with sub great groups of Calcic Aquisalids.- Duric Haplosalids.-Gypsic Haplosalids.- Lithic Haplocalcids.-Typic Aquisalids.- Typic Haplocalcids.- Typic Haplosalids. Fig.(2) represents physiographic and soils of the dray valleys. The studied regions, according to the variation in the slope gradients are as follow:

(1) El-Menia-Giza region:

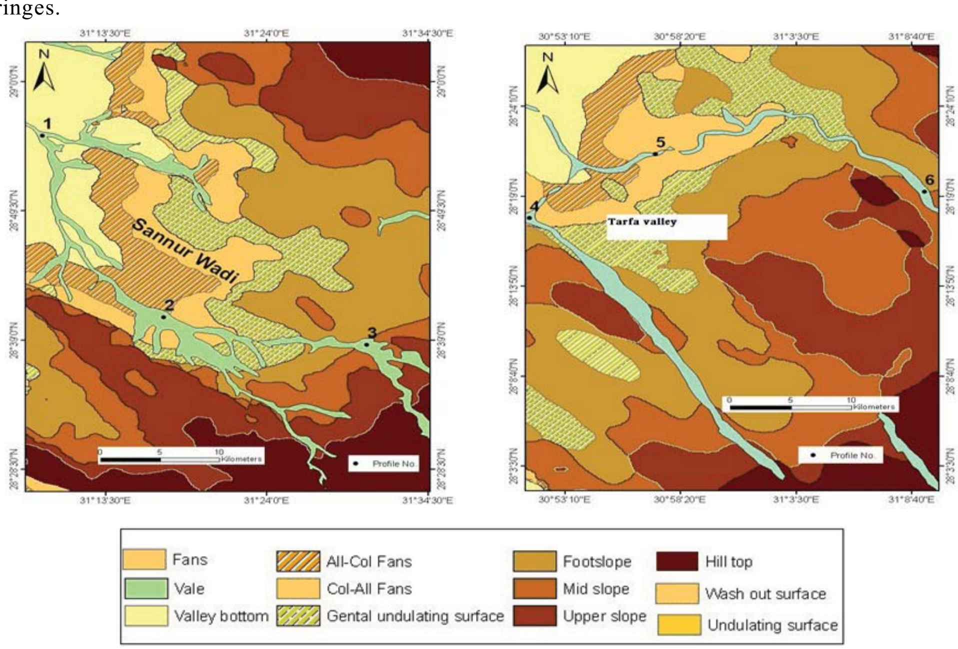
The range of slope gradient over eastern cliffs is (9.16 – 3.72%). In this region, the 150m contour line is far from the cultivated land, which goes into the valleys in the eastern desert. The majority of the drainage basins are of small to small sizes. The main streams are mostly meandering type, deep and narrow with high gradient slopes. The sediment load is bedrock with mixed types. The cultivated lands in this region are distributed in small areas. Those regions are moderately affected by water and sediment load discharge into the cultivated lands.

(2) Suhag – El-Menia region:

The range of slope gradient over eastern cliffs is (11.23 – 5.48%). In this region, the eastern cliffs are higher and closer to the Nile valley. Besides, the cultivated lands exist as very small land at the foot of the eastern scarps, separated by the rocky lands of limestone plateau. These small isolated cultivated lands in the eastern desert are more greatly affected by water flow.

(3) Luxor-Suhag region:

The range of slope gradient over the eastern cliffs is (12.72 – 6.33%). In this region, the 200 m contour line becomes closer to the cultivated land in most areas. The high gradient of the valley increases the velocity of water flow. The network drainage density is very high. In addition, Sediment load is bed and mixed load types of fine to coarse grain size. This region is highly affected by water and sediment load that discharge directly into the cultivated lands. The cultivated lands in this region cover the biggest areas in the eastern desert fringes.



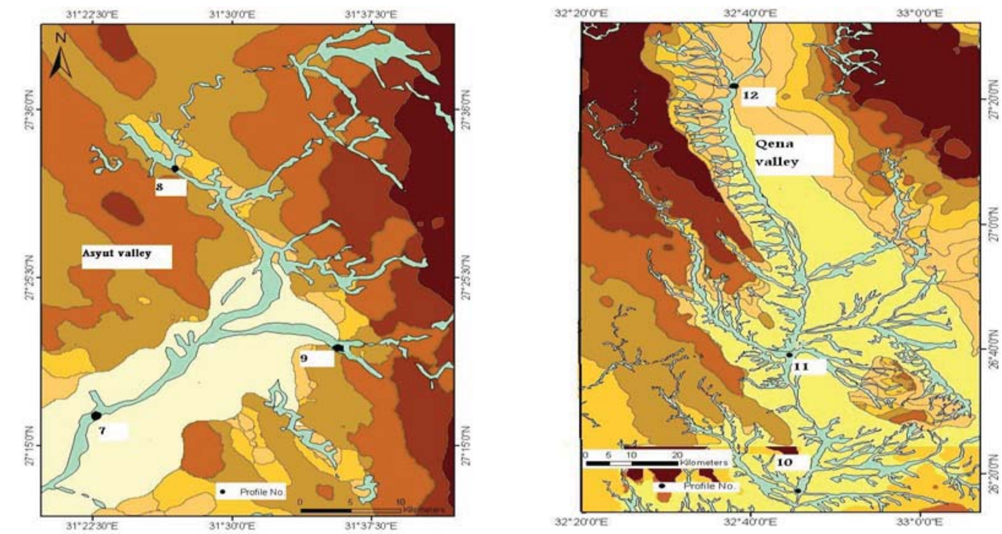


Fig. 2: Physiographic of Sannur, Tarfa, Asyut and Qena valleys in the eastern desert.

Soil properties:

Table (2) shows the main physical and chemical properties of the investigated soil profiles. The studied soil profiles are sandy texture and contain low gravels. All the studied profiles are characterized as non saline and non alkaline. The content of organic matter is very low; it ranges between 0.16 and 0.51 %. Soil content of calcium carbonate increased in some layers and ranges between 8.17 and 30.18 %.

Table 2: The main physical and chemical characteristics of soil of the studied dry valleys.

Valley name	Profile No.	Depth cm	Particle size distribution Clay <0.002 mm (%)	Silt+ V.F Sand 0.002-0.10 mm (%)	Sand0.1-2.0 mm (%)	Gravel >2.0 mm (%)	Texture class	pH (1:2.5)	O.M (%)	CaCo3 (%)	ECe (dS/m)	CEC (meq/ 100gm soil)	Permea bility (cm/hr)
Sannur	1	0-30	0.64	52.37	44.87	2.12	Sandy	7.5	0.43	18.18	0.81	4.10	13.16
		30-60	0.42	43.16	55.16	1.26	Sandy	7.6	0.30	9.10	0.60	2.18	
	2	0-30	0.46	53.94	41.42	4.18	Sandy	7.6	0.51	21.34	1.10	5.14	16.82
		30-70	0.28	46.70	49.63	3.39	Sandy	7.6	0.39	20.21	0.72	4.00	
	3	0-30	0.36	62.63	28.72	8.29	Sandy	7.5	0.41	24.11	1.24	6.19	18.23
		30-60	0.18	54.87	37.84	7.11	Sandy	7.6	0.29	19.19	0.62	5.42	
Tarfa	4	0-25	0.78	77.42	18.61	3.19	Sandy	7.6	0.36	9.16	0.95	2.71	12.46
		25-70	0.56	72.37	25.07	2.00	Sandy	7.5	0.21	8.25	0.61	2.00	
	5	0-30	0.46	73.95	21.32	4.27	Sandy	7.8	0.29	30.18	0.84	3.10	15.18
		30-80	0.39	66.93	29.49	3.19	Sandy	7.5	0.18	26.42	0.53	2.42	
	6	0-30	0.35	58.84	31.62	9.19	Sandy	7.6	0.30	21.28	1.17	3.10	17.14
		30-70	0.21	54.30	37.39	8.10	Sandy	7.6	0.19	20.19	1.00	3.00	
Asyut	7	0-20	0.42	66.20	29.86	3.52	Sandy	7.6	0.39	18.00	0.79	4.19	13.63
		20-80	0.31	59.98	38.07	1.64	Sandy	7.5	0.32	9.35	0.63	2.00	
	8	0-30	0.23	62.08	32.57	5.12	Sandy	7.5	0.48	21.23	1.07	5.01	16.72
		30-60	0.34	55.70	40.56	3.40	Sandy	7.5	0.35	20.34	0.76	4.09	
	9	0-30	0.14	56.23	36.48	7.15	Sandy	7.6	0.45	24.00	1.20	6.00	19.11
		30-70	0.10	46.24	47.66	6.00	Sandy	7.6	0.30	18.91	0.66	5.29	
Qena	10	0-20	0.56	55.56	41.72	2.16	Sandy	7.6	0.40	9.24	0.88	2.90	12.33
		20-60	0.34	41.21	56.45	2.00	Sandy	7.5	0.18	8.17	0.58	2.10	
	11	0-30	0.31	45.37	50.13	4.19	Sandy	7.8	0.31	29.90	0.77	3.22	14.64
		30-70	0.26	35.87	59.87	4.00	Sandy	7.5	0.16	26.51	0.61	2.35	
	12	0-25	0.11	43.46	48.23	8.20	Sandy	7.5	0.34	21.02	1.05	3.15	18.81
		25-70	0.09	39.87	53.52	6.52	Sandy	7.6	0.21	20.00	1.02	3.09	

Soil Water Erosion Modeling:

The factors used to calculate soil loss from the studied valleys by (USEL) and (RUSEL) are presented in Table (3).

Rainfall Erosivity (R-factor):

The rainfall erosivity R-factor assesses the capacity of rain to erode unprotected soil. The results show that the highest R-factor obtained by the Universal Soil loss equation (Rw) and by the Revised Universal Soil loss equation (Rr) is found in Qena valley followed by Asyut, Tarfa and Sannur valleys, respectively. The Rw values however, are lower than the Rr ones. The average of Rw is between 0.66 and 1.22 while, the Rr is ranges between 1.09 and 1.32. Renard *et al*., (1992) reported that the R-factor of the Revised Universal Soil

Loss Equation is generally recognized as one of the best parameters for the prediction of the erosive potential of rain drop impact, and therefore of the potential transport capabilities of run off generated by erosive storms.

Soil Erodability (K- factor):

Soil erodability factor (K) reflects the ease with which the soil is detached by splash during rain fall or by surface flow. Soil texture, organic matter content, structure and permeability determine the erodibility of a particular soil. The minimum and maximum (K) values are 0.42 and 0.66 ton/ha./year. Higher (K) values are mainly located in Tarfa valley while, lower values are in Qena valley.

Slop Length And Steepness (LS-factor):

Topography is one of the main factors that have great importance in determining the rate of soil loss. Soil loss increased more rapidly with slope steepness. Risse *et al.,* (1993) found that the topographic factor (LS) had a great influence on soil loss. The highest LS-factor is found at Qena valley which due to the higher slop gradient in this valley. The lowest LS-factor is found at Sannur valley which has the lowest soil gradient compared to the other valleys.

Soil Losses (A):

Soil losses (A) obtained in the four valleys by the Universal soil loss equation (Aw) and by the Revised soil loss equation (Ar), are presented in Table (3) and illustrated in Fig.(3). Soil loss in (ton/ha/year) was varied according to the used equation. The (Aw) is ranges between 1.98 and 0.24 (ton/ha/year) while, (Ar) ranges between 2.14 and 0.39 (ton/ha/year). Variation in the results of the soil loss between the two equations is due apparently to variations in the erosivity index values. Soil loss, estimated by the two equations, is varying among the four valleys. The higher soil loss is obtained in Qena valley while, the minimum soil loss is found in Sannur valley followed by Tarfa and Asyut valleys. The increase in soil loss of Qena valley is due to the higher slope gradient and higher rainfall intensity, compared to the other valleys. Lower slope gradient of Sannur valley decreased the rate of soil loss. Accordingly, a higher water erosion rate will be found in Luxor-Suhag region followed by Suhag - El-Minia and El-Minia – Giza regions, respectively. Soil losses (ton/ha/year) calculated for all the studied valleys are very slight**.** However, some damages may resulted by deposition.

Table 3: The calculated rainfall erosivity factor, erodibility factor, slope factor and the soil loss of the studied dry valleys at the Eastern desert.

Valleys	Profile no.	I 30	KE	Rw	Rr	Clay <0.002 mm %	Silt+ V.F Sand 0.002-0.1 mm %	Sand 0.1-2.0 mm %	O.M %	Soil Structure grade	Permeability factor	K	Slope %	LS	Aw ton/ha/year	Ar ton/ha /year
Sannur	1	26.2	25.3	0.66	1.09	0.64	52.37	44.87	0.43	V. Fine granular	Mod.	0.42	7.18	1.54	0.42	0.69
	2	26.2	25.3	0.66	1.09	0.46	53.94	41.42	0.51	Fine granular	Mod.	0.43	5.24	1.02	0.29	0.48
	3	26.2	25.3	0.66	1.09	0.36	62.63	28.72	0.29	Course granular	Mod. To Rapid	0.52	3.72	0.69	0.24	0.39
Tarfa	4	28.6	29.8	0.85	1.14	0.78	77.42	18.61	0.36	V. Fine granular	Mod.	0.66	9.16	2.18	1.22	1.63
	5	28.6	29.8	0.85	1.14	0.46	73.95	21.32	0.29	Fine granular	Mod.	0.63	7.27	1.57	0.84	1.12
	6	28.6	29.8	0.85	1.14	0.35	58.84	31.62	0.30	Course granular	Mod. To Rapid	0.49	4.19	0.78	0.32	0.43
Asyut	7	32.8	31.4	1.03	1.30	0.42	66.2	29.86	0.43	V. Fine granular	Mod.	0.55	11.23	2.96	1.67	2.11
	8	32.8	31.4	1.03	1.30	0.23	62.08	32.57	0.51	Fine granular	Mod.	0.51	7.96	1.78	0.93	1.17
	9	32.8	31.4	1.03	1.30	0.14	56.23	36.48	0.41	Course granular	Mod. To Rapid	0.46	5.48	1.08	0.51	0.64
Qena	10	35.6	34.4	1.22	1.32	0.56	55.56	41.72	0.36	V. Fine granular	Mod.	0.45	12.72	3.59	1.98	2.14
	11	35.6	34.4	1.22	1.32	0.31	45.37	50.13	0.29	Fine granular	Mod.	0.36	8.18	2.05	0.90	0.97
	12	35.6	34.4	1.22	1.32	0.11	43.46	48.23	0.30	Course granular	Mod. To Rapid	0.34	6.33	1.29	0.54	0.59

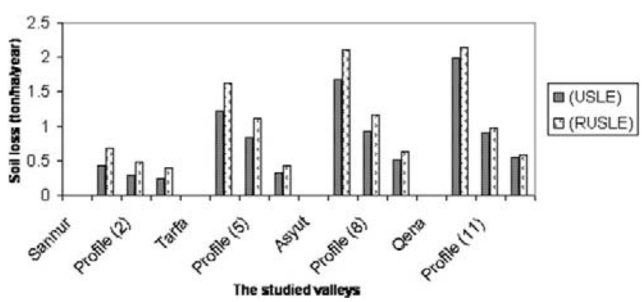


Fig. 3: Soil loss (ton/ha/year) of the studied valleys calculated by (USLE) and (RUSLE).

Total Soil Loss of the Valleys:

Table (4) shows the average values of rainfall erosivity factor, erodibility factor, slope factor and total soil loss of the studied dry valleys. The (Rr) values, obtained by (RUSLE) are higher than (Rw) values obtained by (USLE). T-test value, indicate no significant difference between (Rw) and (Rr). The results also show that, soil loss values ((Aw) and (Ar)) obtained by the two equations are approximately close, no significant difference was found between them. Renard *et al.,* (1994) however, reported that the Revised soil loss equation (RUSLE) was considered scientifically superior to Universal soil loss equation, consequently, it was expected that (RUSLE) would perform better than (USLE).

Table 4: Average values of rainfall erosivity factor, erodibility factor, slope factor and the soil loss of the studied dry valleys.

Valleys	Rw	Rr	K	LS	Aw (ton/ha/year)	Ar (ton/ha/year)
Sannur	0.66	1.09	0.46	1.08	0.32	0.52
Tarfa	0.85	1.14	0.59	1.51	0.79	1.06
Asyut	1.03	1.30	0.51	1.94	1.04	1.31
Qena	1.22	1.32	0.38	2.31	1.14	1.23
t-test value	2.05			0.86		

Conclusion:

The results of the study showed that a higher soil erosion rate was found in Qena followed by Asyut, Tarfa and Sannur valleys, respectively. The higher soil erosion rate in Qena and Asyut valleys are mainly due to the higher slope gradient and higher rainfall compared to Sannur and Tarfa valleys. The erosion rate however, is classified as very slight in all the studied valleys. Although, the soil loss is very slight; a serious problem may arise with the accumulation of sediment by the time. The results also found that both (USLE) and (RUSLE) could be used to estimate the potential annual soil loss at these regions. Proper conservation practices should be implemented in order to reduce soil degradation in these areas.

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