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ESTIMATION OF SLOPE LENGTH FACTOR (L) AND SLOPE STEEPNESS FACTOR (S) OF RUSLE EQUATION IN THE EUPHRATES RIVER WATERSHED BY GIS MODELING

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ABSTRACT

Specific effects of topography over any area watershed erosion are estimated through the LS factor as the product of slope length L and slope steepness factor S using RUSLE equation. The LS factor map of Euphrates watershed was derived from the raw Digital Elevation Model (DEM) by using of ArcMap 10.2 software, the DEM images were provided from United State Geological Survey (USGS) website. The DEM were consisting of sixteen images with cell resolution of 30m*30m, the DEM of Euphrates watershed is ranged from -100 m to 466 m, 98.83% of Euphrates basin area of DEM within the range 0 to 457 m. The slope in percentage rise map of Euphrates watershed is required to estimate the LS factor, the most of slope of this study was ranged from zero to five which represent about 93.12% from total area of basin. The LS factor of Euphrates basin is ranged from (0) to (8010.61), 94.25% of Euphrates watershed area have the LS factor of the range from (0) to (1). Furthermore, the LS factor values more than 500 of watershed have a small area, so the factor value can be considered up to 500 and neglect the other large values of LS factor. The LS values more than 3 were identified the lines of Euphrates river, distributary channel, rills, interrill and gully.

KEYWORDS: Erosion, RUSLE, Slope Length, Slope Steepness

1. INTRODUCTION

Wind and water are the main reason to remove the soil surface materials, this meaning is soil erosion losses (Kirkby and Morgan 1980). The most dominant parameter of the soil erosion is the water, this agent is processed including detachment, transportation and deposition of the particles by raindrop impact and flowing water (Foster and Meyer 1977; Wischmeier and Smith 1978; Julien 2002). The soil erosion is caused to reduce the soil productivity, pollutes the streams and fills the reservoirs, so this is major problem in agriculture and natural resources management (Fangmeier et al. 2006). There are many parameter to accelerate the process of erosion, transport, and sedimentation such as human activity like construction of road, highway and dams or control works on streams and rivers, mining and urbanization (Julien, 2010). The raindrops hit the topsoil of ground surface and detach soil particles (sediments) by splash, this phenomena is called the soil erosion (Julien, 2002). The sheet erosion or interrill erosion is detached particles and laterally transported to rills by a thin overland flow (Foster and Meyer 1977). The rills were gradually joined together to form large channels and this results in gully erosion which is similar to rill erosion but the large in scale. To estimate the soil erosion losses, there are many empirical models such as the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) (Fistikoglu and Harmancioglu, 2002). The RUSLE equation is the upgraded version of USLE model (Renard et al. 1997), this model is incorporates improvements in factors based on new data but keeps the basis of old model USLE equation. There are general equation to estimate the annul erosion losses for the specify watershed as shown in equation below:

$$A=R.K.LS.C.P \qquad 1$$

Where, A is the average annul of soil erosion loss per unit area ($tons.acre^{-1}.year^{-1}$ or $tons.ha^{-1}.year^{-1}$), R is the factor of the rainfall-runoff erosivity, K is the soil erodibilty factor, L is the slope length factor, S is slope steepness factor, C is the cover/crop management factor and P is the support practice factor.

The topography effective on soil erosion modeling in RUSLE equation can be shown in the slope length factor L and the steepness factor S. The increasing of the slope length L is caused to increase the erosion due to a progressive accumulation of runoff in the direction of downslope. The increasing the slope steepness factor S is increased the soil erosion to cause of increasing in the velocity.

In 1978, Wischmeier and Smith are defined the Slope length L as the horizontal distance from the original of surface land flow to point where either the slope gradient decreases, so the deposition was began or runoff was became concentration in a defined channel. The ratio of soil loss from field slope length to that from 72.6 ft (22.13 m) length under different specify condition is also defined the Slope length L as the schematic Fig. 1. The L factor is evaluated by the equations used in RUSLE equation (McCool et al., 1987; McCool et al., 1997; Renard et al., 1997):

$$L = (\frac{X_h}{72.6})^m \qquad 2$$

Where, Xh: is the horizontal slope length (ft or m) and m: is exponent of the variable slope as it's defined to the ratio ε of rill erosion to interrill erosion by equation below:

$$m = \frac{\varepsilon}{1+\varepsilon} \qquad 3$$

ε : is computed for the soil erosion is moderately supsceptible to rill and interrill erosion as equation below:

$$\varepsilon = \frac{\sin\theta}{0.0896\times(3\times(\sin\theta)^{0.8}+0.56)} \qquad 4$$

θ : is the slope angle.

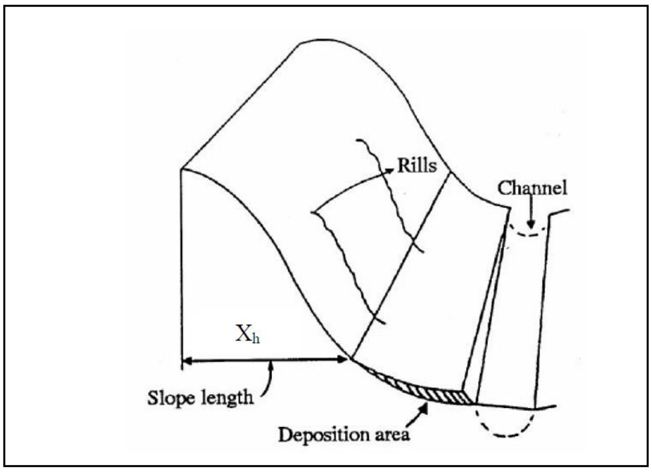


Fig. 1. Schematic slope profiles of RUSLE equation (Renard et al., 1997)

The definition of the ratio of soil loss erosion from field slope to that drom 9% slope under the specify conditions, the S factor of RUSLE equation is shown in equations below (McCool et al., 1987; McCool et al., 1997; Renard et al., 1997):

$$S = 10.8 \times \sin\theta + 0.03 \qquad \sigma \leq 9\%$$

$$S = 16.8 \times \sin\theta - 0.50 \qquad \sigma > 9\%$$

Where, θ: is the slope angle and σ is the slope gradient in percentage.

The slope steepness factor S is easy computed than the slope length factor L (Ouyang and Bartholic 2001). Furthermore, the 10% error in the slope length is resulted of the value 5% error in calculated soil erosion, while the same error in the slope steepness will be given the 20% error in computed soil losses erosion (Morgan 2011).

In 1985, Moore and Burch can be developed the equation to compute the length-slope factor in ArcGIS from the Digital Elevation Model (DEM) as below:

$$LS = (\frac{A_s}{22.13})^m \times (\frac{\sin\theta}{0.0896})^n \qquad 5$$

Where:

A_s: is the identify catchment area, in ArcGIS, the A_s is computed the function of the hydrology – spatial Analyst Tool "flow accumulation" multiply by the cell size.

θ: is the slope angle in degree, in ArcGIS, θ is calculated the function of the Surface – Spatial Analyst Tool "slope"

m = 0.4 – 0.6 and n = 1.2 – 1.3

The equation (5) is applied by many researcher like Moore & Wilson; 1992, Moore et al; 1993, Jain & Kothyari; 2000, Van der Knijff et al; 2000 and other. The exponent value m can be taken that 0.4 while the value of n can be taken equal to 1.3 (Moore et al; 1993, Jain & Kothyari; 2000 and Van der Knijff et al; 2000).

2. STUDY AREA

Iraq is a country of western Asia that content from eighteen provinces, there are two major rivers Tigris and Euphrates in the country. The Euphrates river is the longest and one of the most historically main rivers of Western Asia. The originating in eastern Turkey, the flows through Syria and Iraq to juncture the Tigris in the Shatt al-Arab. The present study is the Euphrates river basin, the Euphrates basin contains from eight provinces. This study of Euphrates watershed was included of seven provinces, the total area of watershed is 131722 km2 about 30% of entire area of Iraq. The watershed provinces is contained from Najaf, Karbala, Al-Qadisiyyah, Babylon, Al Muthanna, Dhi Qar and Basrah as shown in Fig. 1.

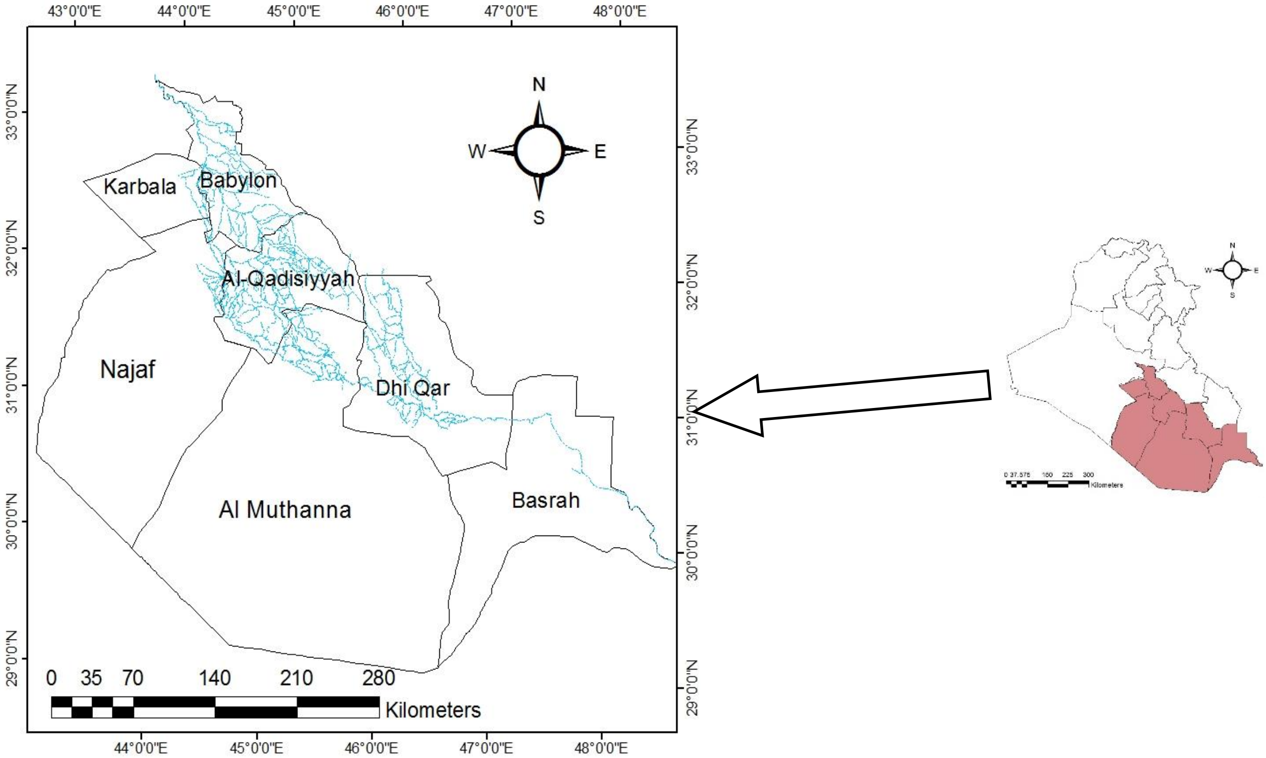


Fig. 1. Study area of watershed location map

The raw data of Digital Elevation Model (DEM) for Euphrates watershed is contented from sixteen images with a spatial resolution of 30m*30m. The DEM images can be derived from Shuttle Radar Topography Mission (SRTM) 1 Arc-Second Global of USGS (United State Geological Survey) in September 2014.The DEM images of Euphrates watershed can be derived by using the ArcMap 10.2 software that mosaic and extract by mask in the ArcGIS Spatial Analyst toolbox as shown in Fig. 2.

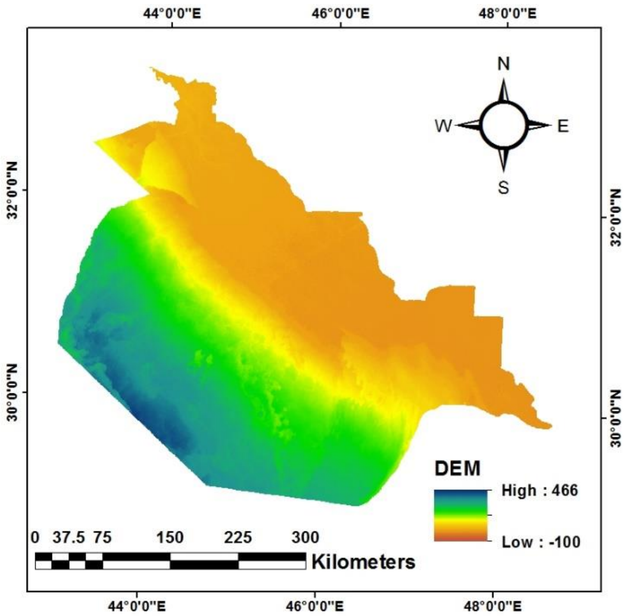


Fig. 2. DEM map of Euphrates watershed.

Furthermore, the DEM of watershed can be classified into ten category to explain the number of cells with dimension 30 m * 30 m of Euphrates watershed as shown in Table 1 below:

Table 1. DEM classification of Euphrates watershed.

Range	Cells Number	Area km^2	Area %
-100 to -60	5	0.0045	3.41628E-06
-60 to -38	60	0.054	4.09954E-05
-38 to -20	665	0.5985	0.000454366
-20 to -12	2745	2.4705	0.001875539
-12 to -3	97853	88.0677	0.066858688
-3 to -1	402694	362.4246	0.275143249
-1 to 0	1211782	1090.6038	0.827957797
0 to 457	144642123	130177.9107	98.82765502
457 to 461	14	0.0126	9.56559E-06
461 to 466	2	0.0018	1.36651E-06

3. THE RESULTS AND DISCUSSION

The topographic factor LS of the Euphrates watershed can be derived from DEM by finding the function of the hydrology – spatial Analyst Tool “flow accumulation” divided by the cell size 30m in ArcMap 10.2 software. The hydrology – spatial Analyst Tool “flow accumulation” in ArcGIS is computes accumulated flow as the accumulated weight of all cells flowing into every downslope cell in the output raster. The flow direction of each cells, the number of cells that flow into each cell and the direction coding can be shown in the Figs. 3A, 3B and 3C respectively below; the direction coding is the possible direction of flow which can be in either one of the cardinal direction (i.e. N, S, E, W) or the diagonal directions (i.e. NE, SE, SW, NW) (ArcGIS Pro).

The slope in percent rise (degree) map of Euphrates basin can be computed by ArcMap with 30m * 30m cell size, and it's required to estimate the LS factor of watershed as shown in Fig. 4. Because, the Euphrates watershed of present study has large area, the watershed must be zooming to explain the percentage slope of water level. The Razaza Lake is located in Karbala province with percentage slope (0-5) and Fao city is laid in Basrah province, two location were selected to show the changing of slope percentage around the water and the ground surface as shown in figures below. The slope in percentage rise can be classification into eight categories to explain the cells number for each type as shown in Table 2.

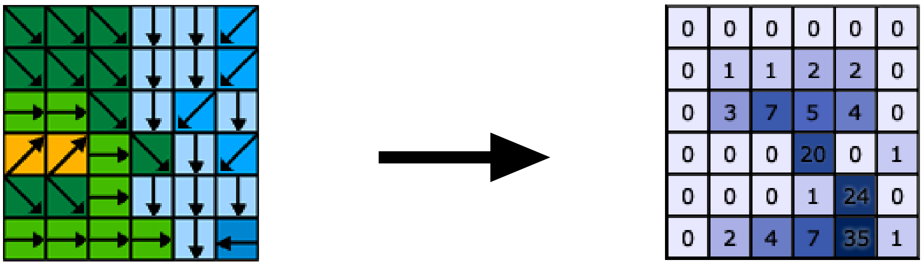


Fig. 3A. Flow direction **Fig. 3B. Flow accumulation**

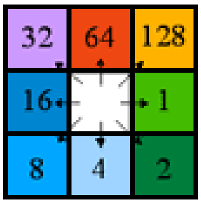


Fig. 3C. Direction coding

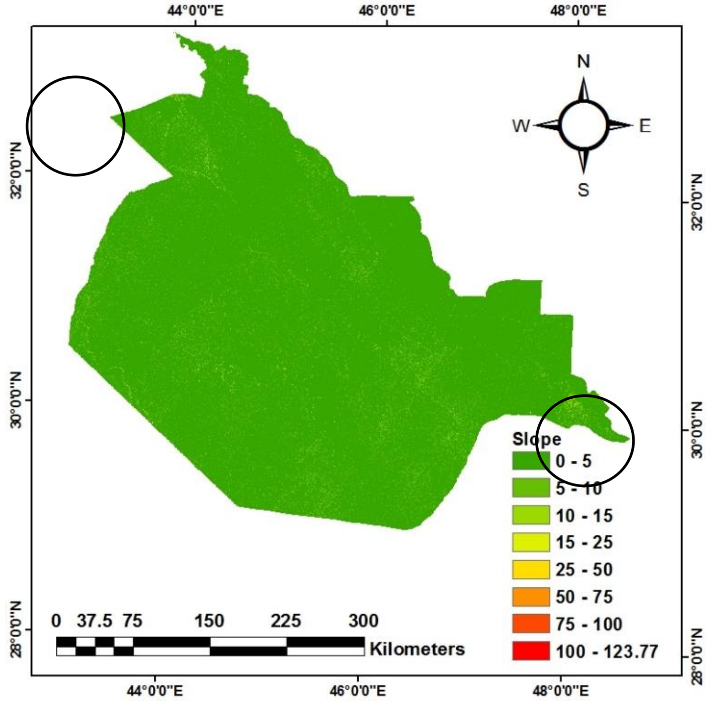


Fig. 4A. Slope percentage map of Euphrates watershed.

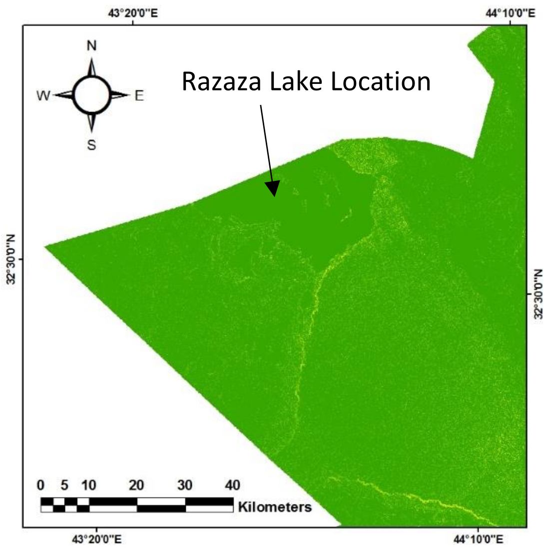


Fig. 4B. slope percentage map of Razaza lake.

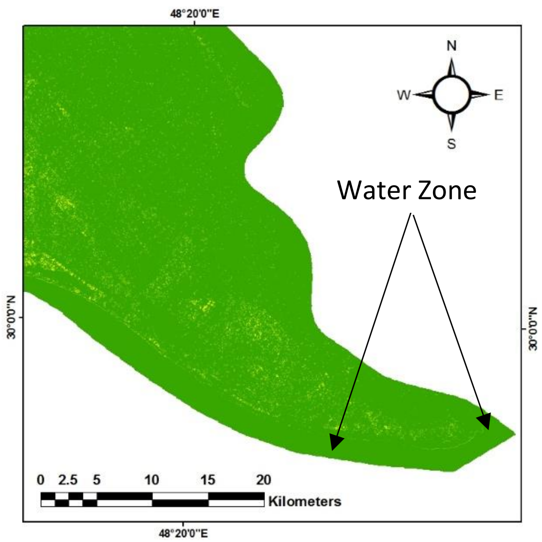
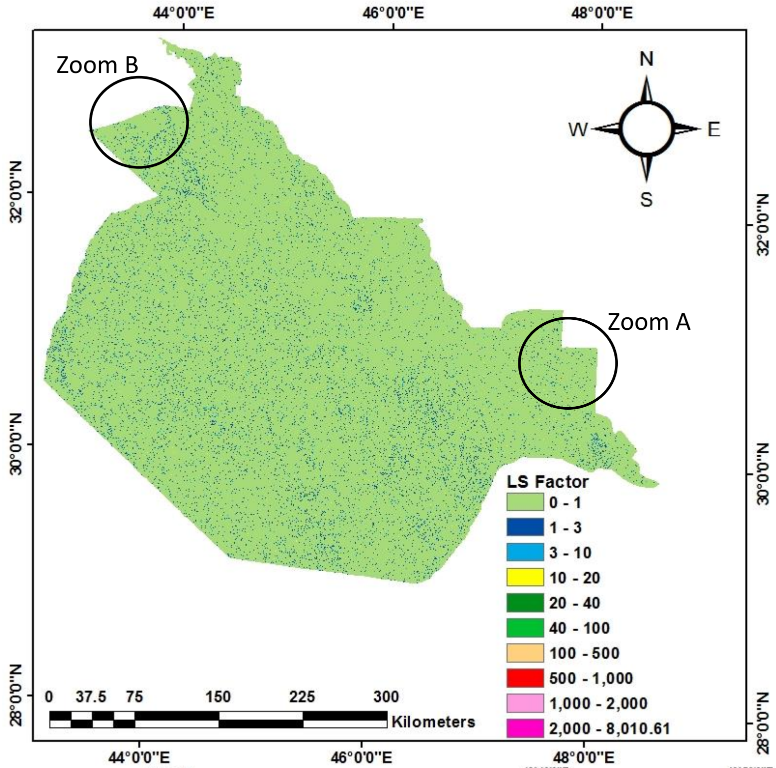


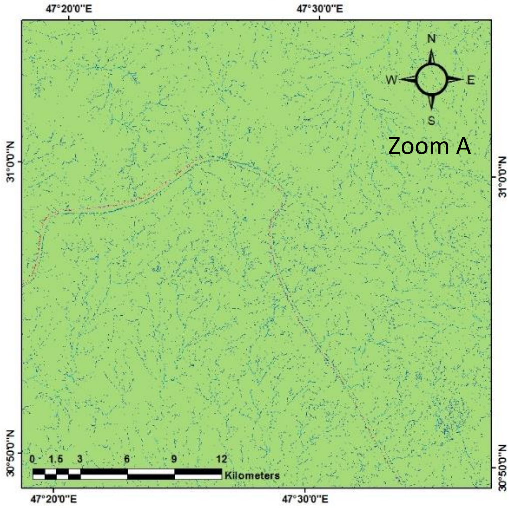
Fig. 4C. slope percentage map of Fao city.

Table 2. Slope classification of Euphrates watershed.

Range	Cells Number	Area km^2	Area %
0 - 5	136285333	122656.7997	93.1178255
5 - 10	9406479	8465.8311	6.42703694
10 - 15	551525	496.3725	0.37683298
15 - 25	103156	92.8404	0.070482
25 - 50	11292	10.1628	0.00771533
50 - 75	135	0.1215	9.224E-05
75 - 100	19	0.0171	1.2982E-05
100 - 123.77	3	0.0027	2.0498E-06

The equation (5) can be used and applied by raster calculator with ArcMap to estimate the LS factor of Euphrates watershed in Fig. 5, the exponents m and n can be taken depended on past research that equal 0.4 and 1.3 respectively, the Euphrates river channel of watershed map was drawn with different values of LS factor. The topographic factor LS of watershed can be classified into ten categories to estimate the number of cells 30m * 30m and measuring the area of each kinds as Table 3.





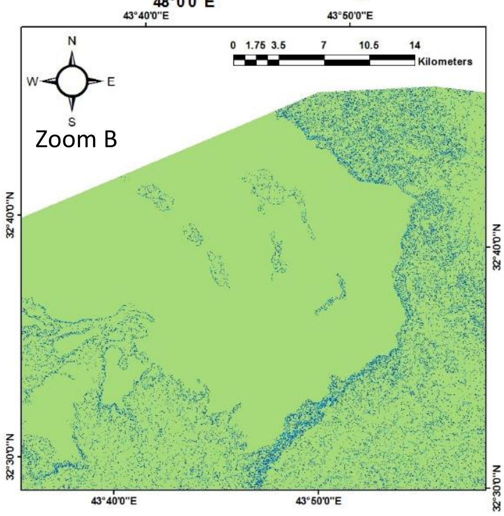


Fig. 5. Topographic factor LS map of Euphrates watershed.

Table 3. LS factor of Euphrates watershed.

Range	Cells Number	Area km^2	Area %
0 - 1	137947183	124152.465	94.25329447
1 - 3	6428618	5785.7562	4.392394337
3 - 10	1540054	1386.0486	1.052251739
10 - 20	256029	230.4261	0.174933451
20 - 40	109966	98.9694	0.075134972
40 - 100	54439	48.9951	0.037195795
100 - 500	18514	16.6626	0.012649809
500 - 1000	1487	1.3383	0.001016002
1000 - 2000	1250	1.125	0.00085407
2000 - 8010.61	403	0.3627	0.000275352

4. CONCLUSION

The LS values more than 3 were identified the lines of Euphrates river, distributary channel, rills, interrill and gully. The most of slope in percentage rise of Euphrates watershed was ranged from zero to five which represent about 93.12% from total area of basin. The LS factor of this study is ranged from (0) to (8010.61), 94.25% of Euphrates watershed area have the LS factor of the range from (0) to (1). Furthermore, the LS factor values more than 500 of watershed have a small area, so the factor value can be considered up to 500 and neglect the other large values of LS factor. The raw of Digital Elevation Model (DEM) of Euphrates watershed is ranged from -100 m to 466 m, 98.83% of Euphrates basin area of DEM within the range 0 to 457 m.

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