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Estimating the Sediment Load Transported by the Valleys to Makhoul Dam Reservoir (Under Construction)

Idan Ibrahim Ghdhban [a*], Raad Hoobi Irzooki [b]

a Department of Water Resources Technologies, Hawija Technical Institute, Northern Technical University, Kirkuk, Iraq.
b Environmental Engineering Department, Engineering College, Tikrit University, Tikrit, Iraq.

Keywords:
Makhoul Dam; Soil Erosion; USLE Model; Sediment Load.

Highlights:

- The effect of the sedimentary load of the valleys surrounding the Makhoul Dam on the capacity of the dam's reservoir.
- Using remote sensing programs to estimate the sedimentary load of the valleys surrounding the Makhoul Dam.
- Using GIS software to estimate the shape and size of the Makhoul Dam Lake.

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*Corresponding author:

Idan Ibrahim Ghdhban

Department of Water Resources Technologies, Hawija Technical Institute, Northern Technical University, Kirkuk, Iraq.

Abstract: The problem of sediments in dam reservoirs has negative effects on the life of dams and the associated financial costs for removing them from these reservoirs. This research is concerned with studying soil erosion in six valleys that flow into the Makhoul Dam reservoir and estimating the amount of sediment that will move into this reservoir annually. Three of these valleys (Al-Jirnaf, Umm Al-Shababit, and Al-Qasr) are located on the western (right) side of the reservoir, and the other three valleys (Al-Shook, Al-Rakhma, and Al-Fudha) are located on the left (eastern) bank of the reservoir. The sediments load expected to flow into the reservoir from these valleys were estimated by calculating the amount of soil erosion using the Universal Soil Loss Equation (USLE) and geographic information systems programs (GIS and Global Mapper) in addition to surfer program. Next, by figuring out the sediment delivery ratio (SDR), it was determined how much sediment load will be reached the reservoir from every valley. The results indicated that the total annual erosion of soil from these six valleys amounted to 1,010,677 tons, of which 249,175 tons are expected to reach the Makhul reservoir annually as a sediment load, divided as follows: Annual erosion from Al-Jarnaf valley is 518,700 tons, of which 121,467 tons reach the reservoir, at a rate of 48.7%. As for Al-Fudha valley, the annual erosion amounted to 232,198 tons, of which 54,692 tons reached to the reservoir, at a rate of 21.95%. The Umm al-Shababit valley occupied third place in terms of annual erosion 128,725 tons, of which 34,529 tons reached the reservoir at a rate of 13.85% of the total sediment load from the six valleys. Al-Shouk, Al-Rahma and Al-Qasr catchments came in fourth, fifth and sixth place, respectively. These catchments have annual erosion quantities of 52,299, 42,415, and 36,338 tons, and will contribute 14,901, 12,484, and 11,100 tons per year to the reservoir as a sediment load, which comes to 5.96%, 5.01%, and 4.45% for each of them, respectively.

تقدير حمولة الرواسب التي تنقلها الوديان إلى خزان سد مكحول (قيد الانشاء)

عيدان إبراهيم غضبان[١]، رعد هوبي إرزوقي [٢]
[١] قسم تقنيات الموارد المائية/ معهد الحويجة التقني/ الجامعة التقنية الشمالية/ كركوك - العراق.
[٢] قسم هندسة البيئة/ كلية الهندسة/ جامعة تكريت/ تكريت - العراق.

الخلاصة

إن مشكلة الرواسب في خزانات السدود لها آثار سلبية على عمر السدود وما يرتبط بها من تكاليف مالية لإزالتها من هذه الخزانات. يهتم هذا البحث بدراسة انجراف التربة في ستة أودية تصب في خزان سد مكحول وتقدير كمية الرواسب التي ستنتقل إلى هذا الخزان سنوياً. ثلاثة من هذه الأودية (الجرناف، وأم الشبابيط، والقصر) تقع في الجانب الغربي (الأيمن) من الخزان، أما الأودية الثلاثة الأخرى (الشوك، والرخمة، والفضا) تقع على الضفة اليسرى (الشرقية) للخزان. تم تقدير حمولة الرواسب المتوقع تدفقها إلى الخزان من هذه الأودية من خلال حساب كمية تعرية التربة باستخدام معادلة فقدان التربة العالمية (USLE) وبرامج نظم المعلومات الجغرافية (GIS وGlobal Mapper) بالإضافة إلى برنامج Surfer. بعد ذلك، من خلال معرفة نسبة توصيل الرواسب (SDR) تم تحديد مقدار حمولة الرواسب التي ستصل إلى الخزان من كل وادي. أشارت النتائج إلى أن إجمالي التعرية السنوية للتربة من هذه الأودية الستة بلغ 1,010,677 طناً، منها 249,175 طناً من المتوقع أن يصل إلى خزان مكحول سنوياً كحمل رواسب، مقسمة على النحو التالي: التعرية السنوية من وادي الجرناف 518,700 طن منها 121.467 طن تصل إلى الخزان بنسبة 48.7%. أما وادي الفضا فقد بلغ الانجراف السنوي 232198 طناً، يصل منها 54692 طناً إلى الخزان بنسبة 21.95%. واحتل وادي أم الشبابيط المركز الثالث من حيث التعرية السنوية 128,725 طناً، يصل منها 34,529 طناً إلى الخزان بنسبة 13.85% من إجمالي حمولة الشوك والرخمة والقصر في المراكز الرابع والخامس والسادس على التوالي، حيث بلغت كميات تعرية أودية الرواسب من الأودية الستة. وجاءت التربة السنوية لهذه الوديان 52,299، 42,415، و36,338 طنًا، حيث ستساهم بكميات 14,901، 12,484، و11,100 طن سنويًا في الخزان كحمولة رواسب وبنسبة 5.96%، 5.01%، و4.45% لكل منها على التوالي.

الكلمات الدالة: سد مكحول، تعرية التربة، نموذج USLE، حمل الرواسب.

1.INTRODUCTION

Since dam reservoirs effectively achieve many goals, including generating electrical power, preventing flood risks, irrigating agricultural lands, and other uses, studying the most important factors affecting storage effectiveness is necessary. Water coming from valleys due to rainfall and forming surface runoff causes the erosion of the surface soil and transport of sediment loads into the mainstream. When the flow reaches the reservoir, its velocity decreases, and thus, the sedimentation process begins, depending on the sediment's size and shape. The sedimentation continues over time as the sediments occupy the storage space. Changing the flow pattern, as fine particles of silt and clay settle near the dam body and its outlets, may cause several operational problems [1]. Sediment load production in the reservoir represents only part of the total erosion within the basin, as a large portion of the sediment load is deposited before reaching this reservoir [2]. Understanding the relationships between the different components of a river is one of the most important factors in understanding the behavior of these components [3]. Shifting cultivation on hillsides, non-adoption of soil conservation techniques, and over-exploitation of land or crop production due to population stress lead to massive soil erosion [4]. The sediment delivered to the reservoir comes from two main sources. The first source is the main river that enters the reservoir, and the second source is the valleys on both sides of the reservoir [5]. Alshraifat [6] estimated soil losses in the catchment of one of the valleys in northern Jordan called Al-Rajeb. The researcher used the global equation model RUSLE and the ArcGIS program in this study. The researcher produced a map of the ability of the parts of the basin to erosion. Ghamid and Abu Sammour [7] studied the Azraq catchment to assess soil erosion losses. This study showed that 24.5% of the Azraq catchment area is classified as suffering from a very high rate of soil erosion. The study also showed that al-Mudaisat valley catchment is the most sub-basin of the Azraq catchment in terms of the expected rate of sedimentary return, which constitutes 58.4% of the material washed in it. Al-Mohamed and Al-Belbeisi [8] applied the universal soil losses equation model, identifying areas of soil degradation by erosion, calculating their area in the Al-Arab Valley catchment, and producing soil degradation maps. They discovered the areas of degraded soil, calculated their area, identified areas of erosion and degradation at the level of small soil units, and estimated the extent of soil degradation, whether it was light, medium, or serious. Sami [1], Muhammad et al. [9], and Khalil and Mahmoud [10] studied the sediments entering the Mosul Dam reservoir from the valleys on the West Bank (right) of the reservoir. Sami [1] estimated 1994–2012 sediment using daily precipitation data at the dam station. Khalil and Mahmoud [10] estimated the amount of sediment load the reservoir received from the main valleys between 1988 and 2016. These studies relied on the Water Action Runoff and Erosion Estimation Model (WEPP), supported by a Geographic Information System (GIS) called

Geowepp, and the SWAT tool to estimate surface volume.

The present study estimates the annual soil erosion due to rain on the catchments of valleys that flow into the Makhoul Dam reservoir, which is expected to cause an annual decrease in the reservoir's size. Since this area has yet to be investigated, this study aims to estimate the annual sediment loads entering the reservoir. To achieve this goal, the universal equation of the soil losses model was utilized to estimate the valley sediment loads.

2.DESCRIPTION OF THE STUDY AREA

The area of the valleys under study is on the eastern (left) and western (right) banks of the Makhoul dam reservoir. Three main valleys on the western bank of the reservoir, i.e., Al-Jirnaf Valley (whose water flows into the Tigris River at the village of Al-Jirnaf, north of Al-Sharqat City), Umm Al-Shababit valley, which transports water into the Tigris River at the village of Al-Khasam, south of Al-Shirqat City, and Al-Qasr valley, which is also called Al-Jafr valley locality, flowing into the Tigris River near the ruins of Qasr al-Bint. On the reservoir's eastern side, three other valleys flow into the reservoir from Al-Shook Valley, i.e., its water flows into the Tigris River at the village of Sedira, Al-Rakhma Valley, i.e., transporting water into the Tigris River north of Zab City), and Al-Fudha valley, which its water flow into the Tigris River south of Shumayt Village. The valleys of the West Bank flow through the Makhoul highlands towards the reservoir. Figure 1 shows each valley location on the west bank. Most of the area is rural and demolished, and its lands are cultivated with wheat and barley crops, mostly irrigated from rainwater, except for a small percentage of lands irrigated with well water. The region's residents are villagers living on agriculture and livestock. The study area includes the cities of Shirqat, in the basins of Al-Jirnaf and Umm Al-Shababit, and the Zab sub-district, between the basins of Al-Rakhma and Al-Fudha valleys, in addition to many villages.

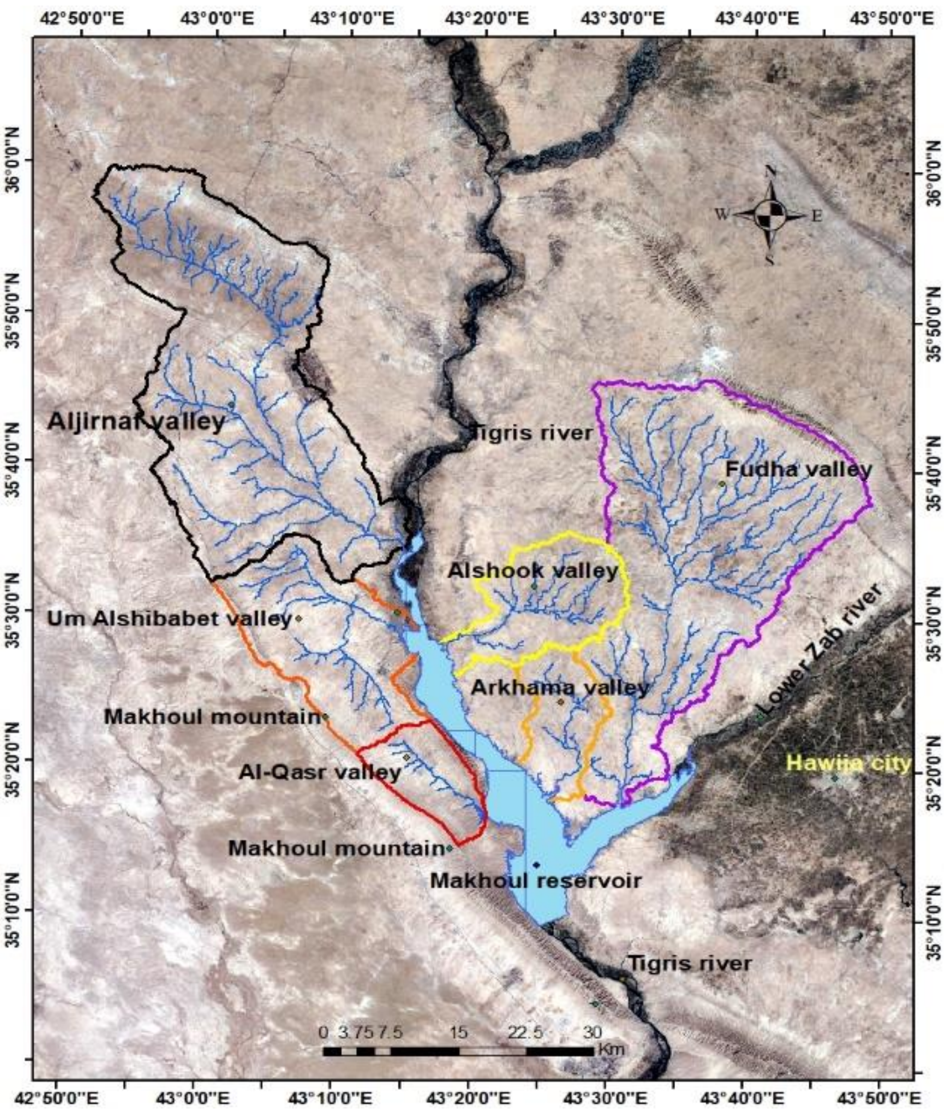

Fig. 1 Satellite Image Showing the Locations of the Valleys.

3.CATCHMENT AREA OF VALLEYS

The catchment limits for each of the studied valleys were measured using the GIS program by finding the watershed by digital elevation model (DEM) visualization, then finding the catchment limits for each valley for the last mouth of the valley in the river. Figure 2 represents the DEM for the study area with an accuracy of 30 meters. After finding the boundaries of the water catchment basins of the valleys, Fig. 3, soil erosion was studied for each valley separately, and the amount of sediment load that flows into the dam reservoir from each valley was estimated. Table 1 shows the information obtained for each valley.

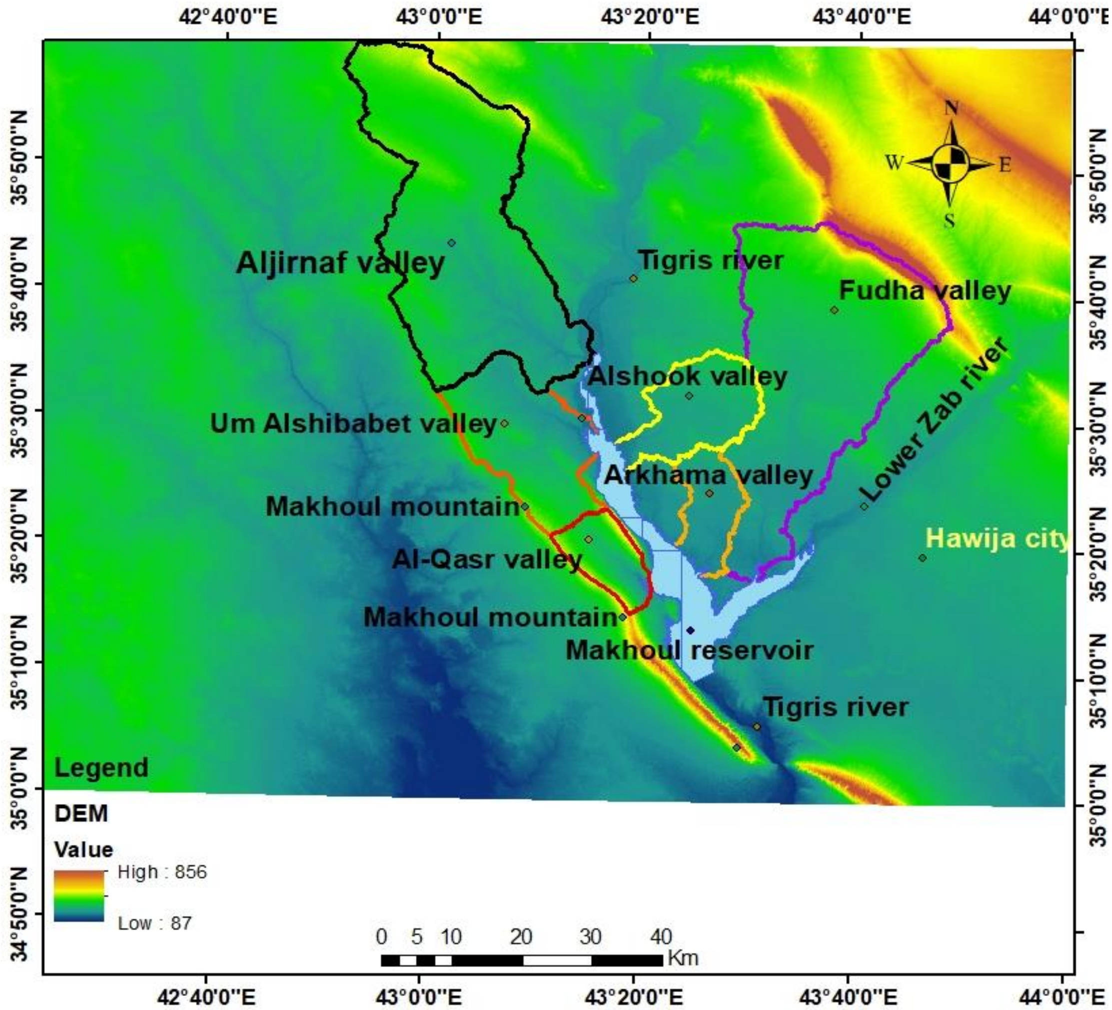

Fig. 2 DEM for the Study Area

Table 1 Information of Valleys According to the Results of the Analysis

No.	Official Name	Downstream Coordinates (UTM)		Catchment Area (km²)
		x	y	
1	AL-Jirnaf valley	340784	3937979	945
2	Umm-Shababit valley	342396	3925740	319
3	Al-Qasr (Al-Jafr) valley	349946	3905373	113
4	AL-Shook valley	342950	3920970	197
5	AL-Rakhma valley	355606	3905524	152
6	Al-Fudha valley	363984	3905219	902

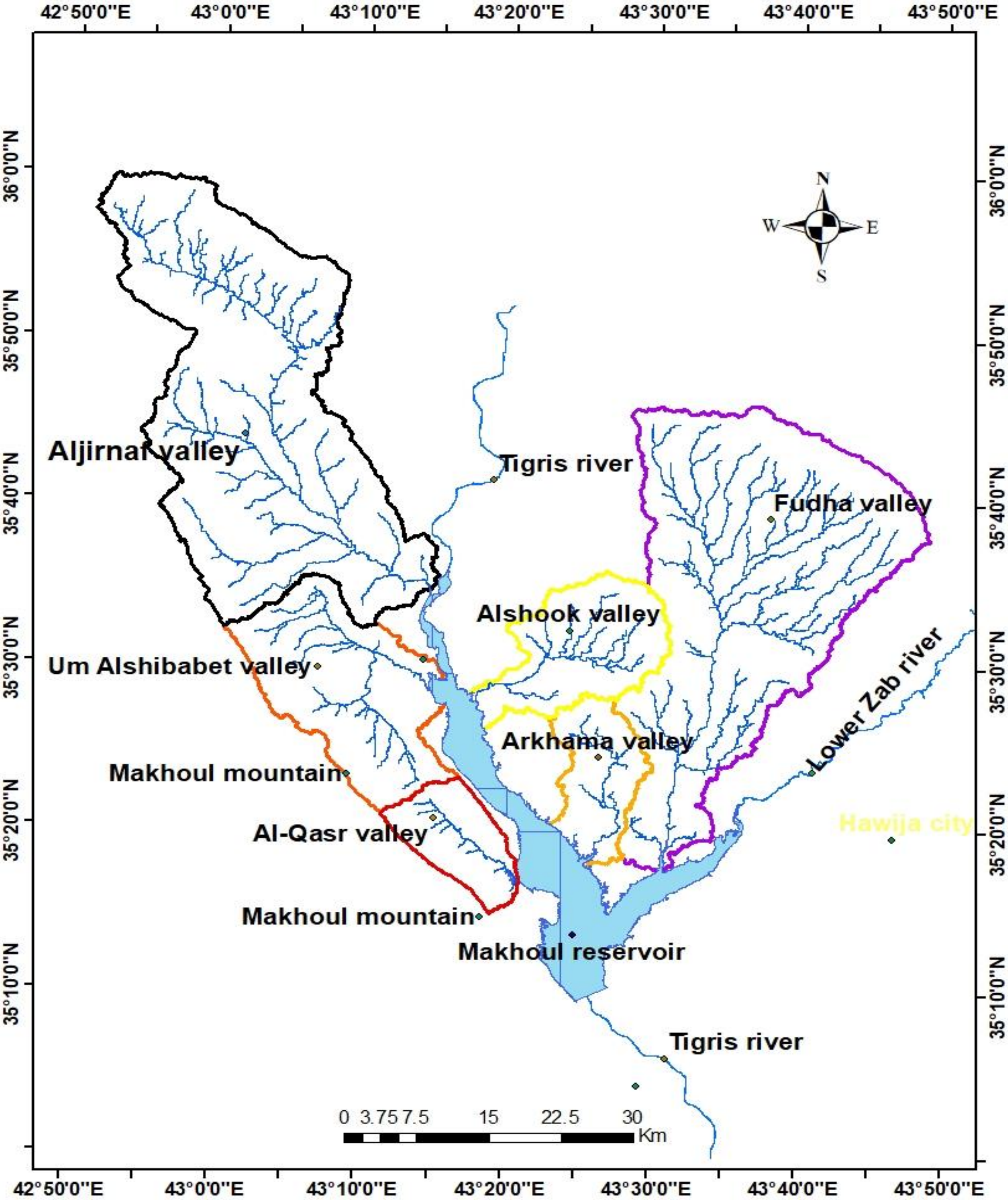

Fig. 3 The Borders of the Six Valleys.

4.UNIVERSAL SOIL LOSS EQUATION (USLE)

This study used the Universal Soil Loss Equation (USLE) model to estimate the sediment load expected to enter the dam's reservoir annually from the six valleys. This equation was applied to each valley separately. The (USLE) is the most widely used tool for estimating soil loss from agricultural watersheds for planning erosion control practices. The (USLE) is an erosion prediction model for estimating long-term averages of soil erosion from sheet and rill erosion modes from a specified land under specified conditions. This equation is written as:

$$A = RKLSCP \qquad (1)$$

Where:

A: The soil loss per unit area in unit time. Usually, the units of *A* are metric (tons/ha/year)

R: Rainfall erosivity factor (MJ.mm/ha. h. year)

K: Soil erodibility factor (t. ha. h/MJ.ha.mm)

L: Slope length factor

S: Slope-steepness factor

C: Cover management factor

P: Support practice factor, i.e., soil loss ratio with a support practice like contouring, strip-cropping, or terracing to that with straight row farming up and down the slope [11].

The flow chart in Fig. 4 shows the steps for applying this equation.

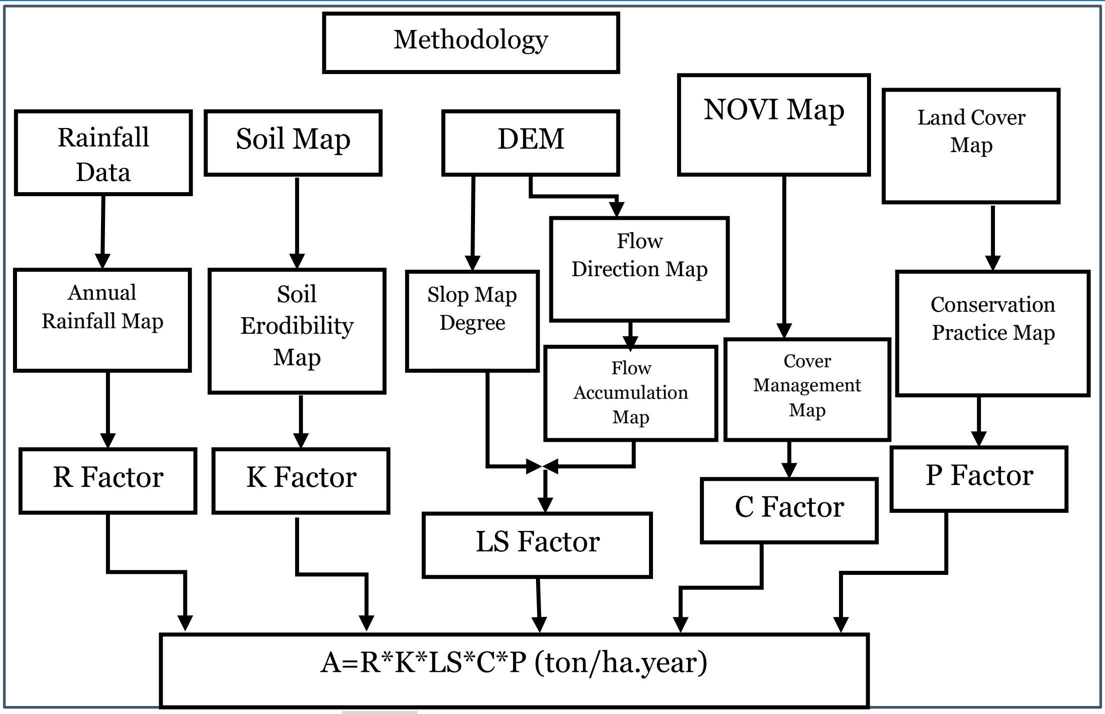

Fig. 4 Flowchart of Applying USLE.

4.1.Rainfall Erosivity Factor (R)

Rainfall erosivity is the erosive power caused by rainfall that causes soil loss, and it can be determined by multiplying (EI30) the total kinetic energy (E) of the storm by the maximum 30-min intensity (I30). R-factor is also an index of rainfall erosion, which is the average annual total of the storm EI values in a particular locality [12]. The researchers suggested many formulas through which the coefficient R-value can be calculated depending on the amount of rainfall in the area, i.e., daily, monthly, or annually.

4.2.Rainfall in the Study Area

There is no meteorological station in the study area, so rain data was adopted for the nearby stations. The annual rainfall rate map was made for each of the valleys' catchment basins, where the average rainfall was obtained for twenty-seven years for the stations of Kirkuk (from 1993-2020) and twenty-two years for stations of Tikrit (from 1991-2013) obtained from the Iraqi General Authority for Metrology and Seismic Monitoring, and the stations of Mosul and Tal-Afar (from 1971-2012) obtained by Al-Kenani [13]. The authors measured the amount of rain at Al-Zab station for a whole year, i.e., 2022-2023, due to the absence of a weather station there, see Table 2. Using the GIS program capabilities, the data of the meteorological stations shown in Table 2 were entered and processed in the program to obtain a rainfall map for the watersheds using the Interpolation command, then Eq. (2) [12] was applied to the rain map obtained in the GIS program. An R-factor map for the six valley catchments is obtained:

$$R = 0.55MAR - 24.7 \qquad (2)$$

where R: Rainfall factor (MJ.mm/ha.h.year)
MAR: Annual precipitation (mm)
After processing with the GIS program, R-factor maps were obtained for all the valleys' catchments, as shown in Figs. (5-10).

Table 2 Annual Rainfall Average for Stations.

No.	Station	Years	Coordinates (UTM) x	Coordinates (UTM) y	Average Annual Rain (mm)
1	Kirkuk	1993-2020	441697	3920822	327
2	Tikrit	1991-2013	379240	3826906	173
3	Zab	2022-2023	359572	3903585	195
4	Mosul	1971-2012	333646	4018931	444
5	Tal afar	1971-2012	270687	4028461	368

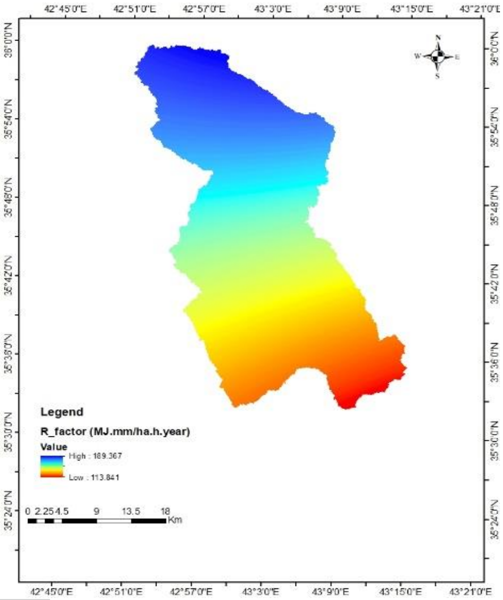

Fig. 5 R-Factor of Al-Jirnaf Valley Catchment.

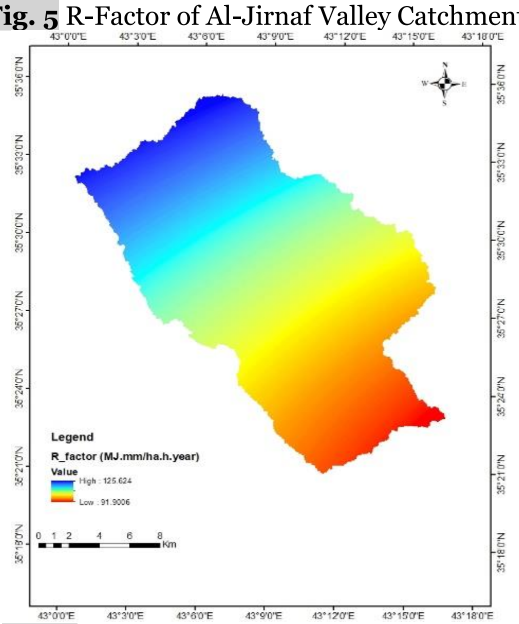

Fig. 6 R-Factor of Umm Al-Shababit Valley Catchment.

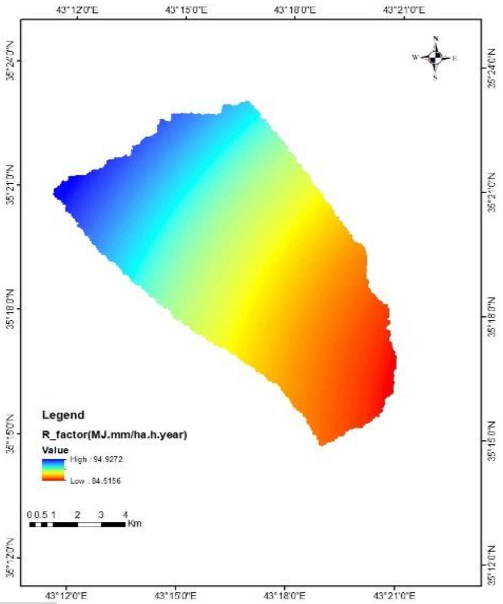

Fig. 7 R-Factor of Al-Qasr Valley Catchment.

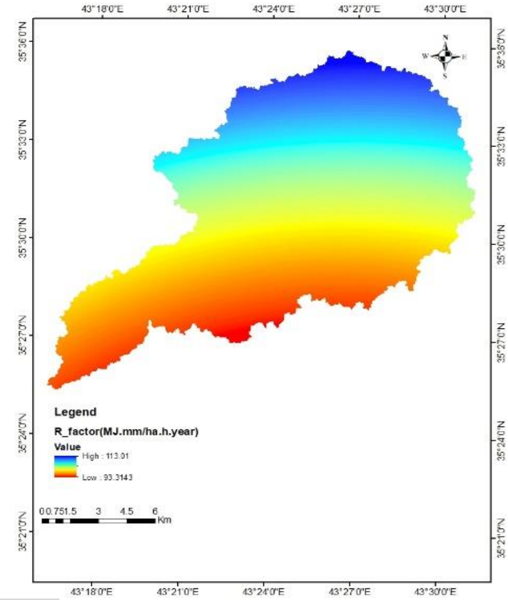

Fig. 8 R-Factor of Al-Shook Valley Catchment.

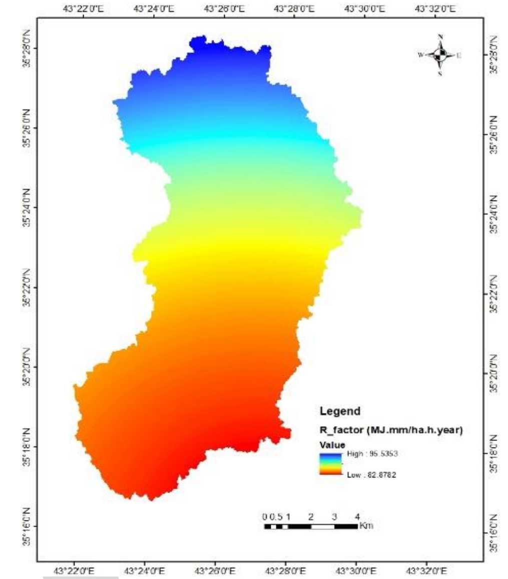

Fig. 9 R-Factor of Al-Rakhma Valley Catchment.

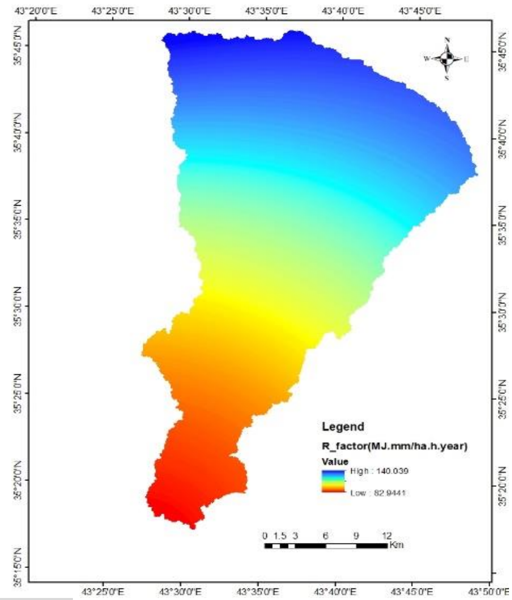

Fig. 10 R-Factor of Fudha Valley Catchment.

4.3.Soil Erodibility Factor (K)

The K-factor determines how easily soil erodes. The K-factor depends on the soil's biological and chemical aspects, including mineralogy, particle size, permeability, and organic matter [12]. Many formulas and equations were adopted to find the K-factor value depending on the soil type. In this study, the following equation was adopted to calculate the K factor value [14]:

$$K = 0.32\left(\frac{silt\%}{clay\%+sand\%}\right)^{0.27} \quad (3)$$

Figure 11 shows the soil classification map in Iraq obtained from the FAO website. Therefore, the soil was classified for each catchment, and through this classification, the K-factor was calculated for each type of soil through Eq. (3), as shown in Table 3. The value of the K-factor was calculated for the six catchments, and a K-factor map was drawn for each catchment, as shown in Figs. (12-17).

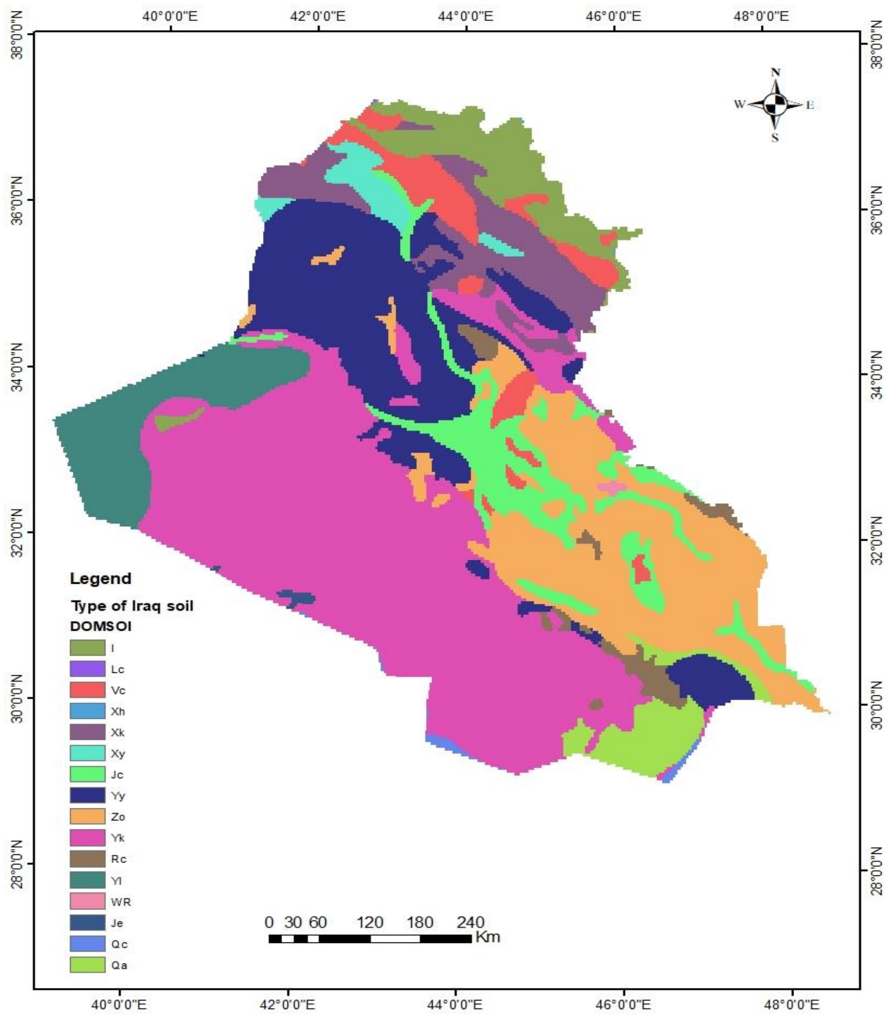

Fig. 11 The Soil Classification Map of Iraq.

Table 3 Soil Classification and K Factor for Catchments.

Valley catchment	Soil type	Soil unit symbol	Sand % Topsoil	Silt % Topsoil	Clay % Topsoil	K factor
Al-Jirnaf Valley	gypsic xerosol	XY	64.6	21.1	14.4	0.224
	chromic luvisoil	JC	39.6	39.9	20.6	0.2863
	gypsic yermosols	YY	49	10.7	40.3	0.18
	gypsic yermosols	YY	49	10.7	40.3	0.18
Umm Al-Shababit Valley	chromic luvisoil	JC	39.6	39.9	20.6	0.2863
	gypsic yermosols	YY	49	10.7	40.3	0.18
	gypsic yermosols	YY	49	10.7	40.3	0.18
Al-Qasr (Al-Jafr valley	gypsic yermosols	YY	49	10.7	40.3	0.18
	gypsic yermosols	YY	49	10.7	40.3	0.18
Al-Shook Valley	gypsic yermosols	YY	49	10.7	40.3	0.18
	gypsic yermosols	YY	49	10.7	40.3	0.18
	calcic xerosols	XK	48.7	29.9	21.6	0.254
Al-Rakhma Valley	gypsic yermosols	YY	49	10.7	40.3	0.18
	calcic xerosols	XK	48.7	29.9	21.6	0.254
Al-Fudha valley	gypsic yermosols	YY	49	10.7	40.3	0.18
	gypsic yermosols	YY	49	10.7	40.3	0.18
	calcic xerosols	XK	48.7	29.9	21.6	0.254

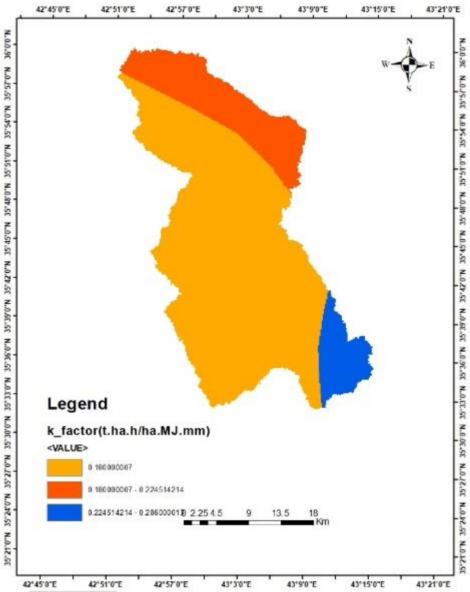

Fig. 12 K-factor of Al-Jirnaf Valley Catchment.

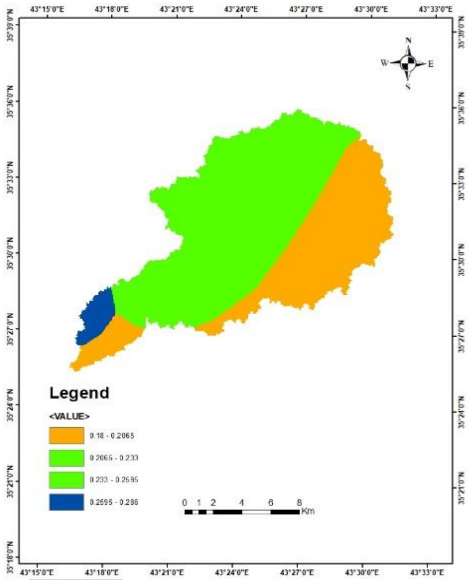

Fig. 15 K-factor of Al-Shook Valley Catchment.

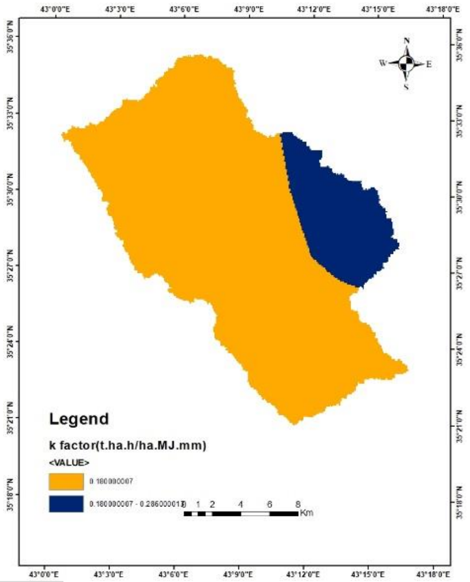

Fig. 13 K-factor of Umm Al-Shababit Valley Catchment.

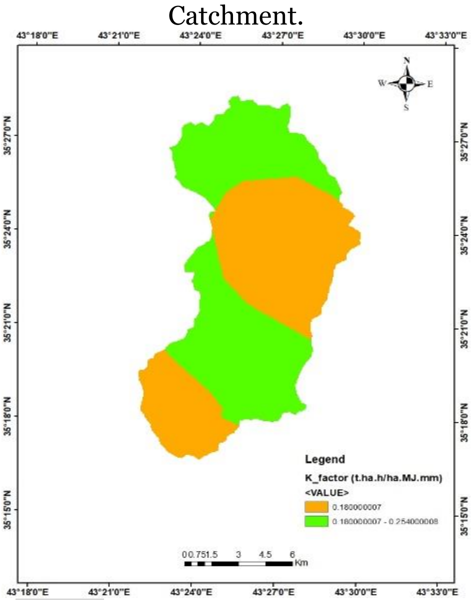

Fig. 16 K-factor of Al-Rakhma Valley Catchment.

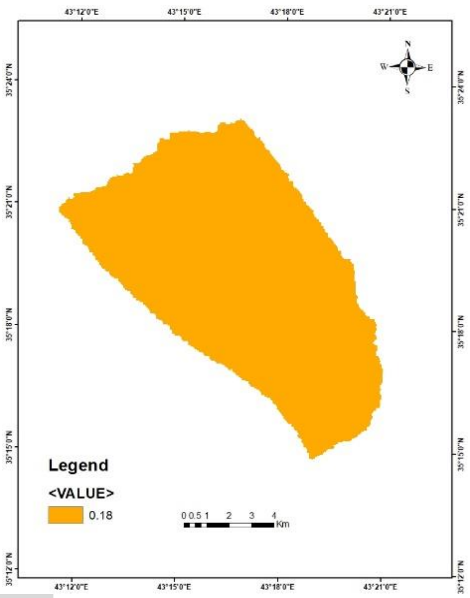

Fig. 14 K-factor of Al-Qasr Valley Catchment.

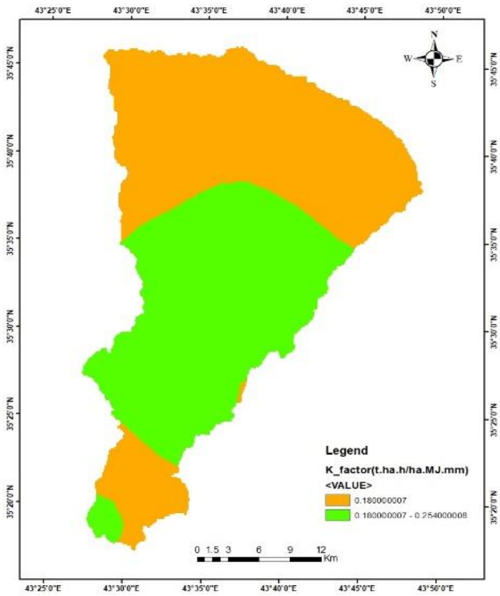

Fig. 17 K-factor of Al-Fudha Valley Catchment.

4.4.Topographic Factor (Length Slope) (LS)

The LS factor depends on two factors that represent the land's topography. The first factor is the slope (S), measured in degrees. Increasing the land slope degree increases the surface runoff velocity and thus increases soil erosion. The second factor is the slope length (L), which represents the land area affected by runoff. Several equations were developed to calculate the LS factor based on both previous factors. In the present study, the most recent equation among these equations was used [12].

$$LS = \left(\left(\boldsymbol{Flow\ accum.}\right) * \frac{\boldsymbol{grid\ size}}{22.13}\right)^{0.4} * \left(\sin(\boldsymbol{slop}) * \frac{0.01745}{.09}\right)^{1.4} \quad \textbf{(4)}$$

A DEM with a resolution of 30 meters was used in the GIS program, as shown in Fig. 2. Initially, DEM was used to calculate the flow direction and the slope and draw maps for them. Then, from the flow direction maps, the flow accumulation was found, and the LS was found using Eq. (4). The value of the LS factor was calculated for the six catchments, and maps were drawn accordingly. Figures (18-23) represent the factor map for all valleys catchments.

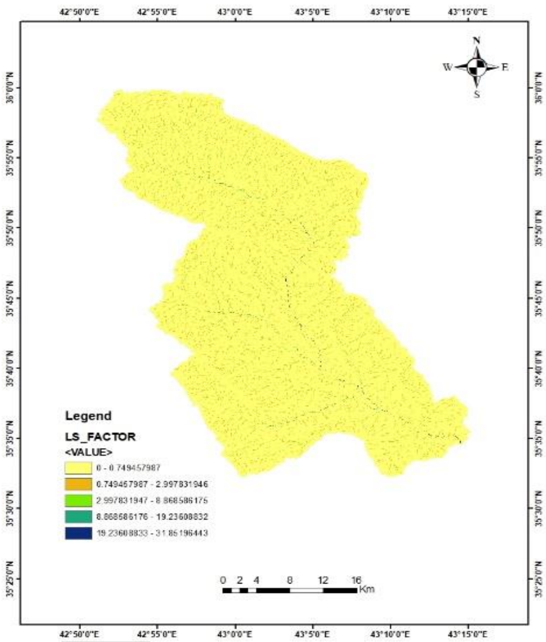

Fig. 18 LS-factor of Al-Jirnaf Valley Catchment.

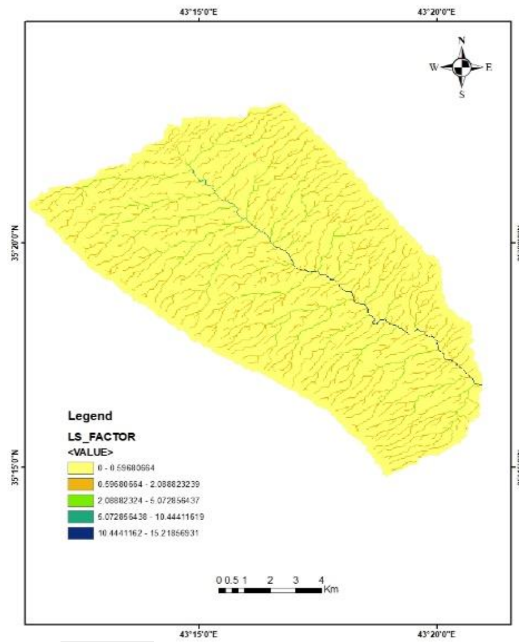

Fig. 20 LS-factor of Al-Qasr Valley Catchment.

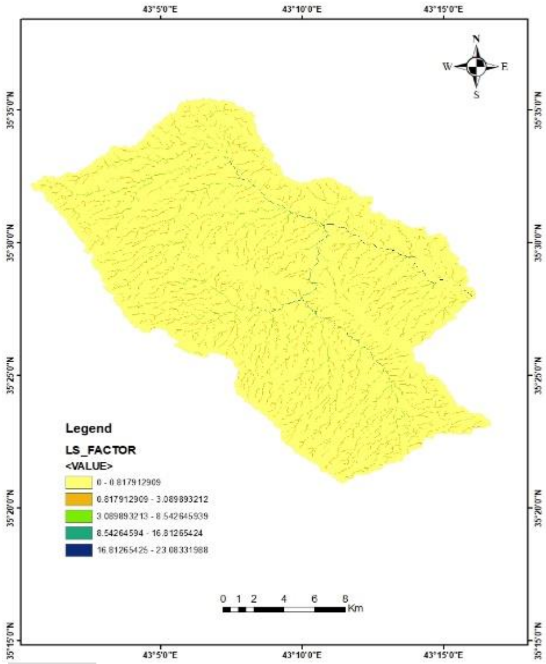

Fig. 19 LS-factor of Umm Al-Shababit Valley Catchment.

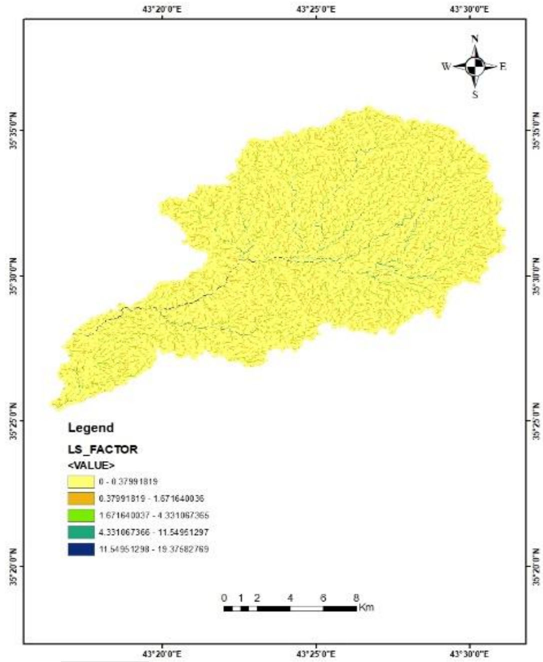

Fig. 21 LS-factor of Al-Shook Valley Catchment.

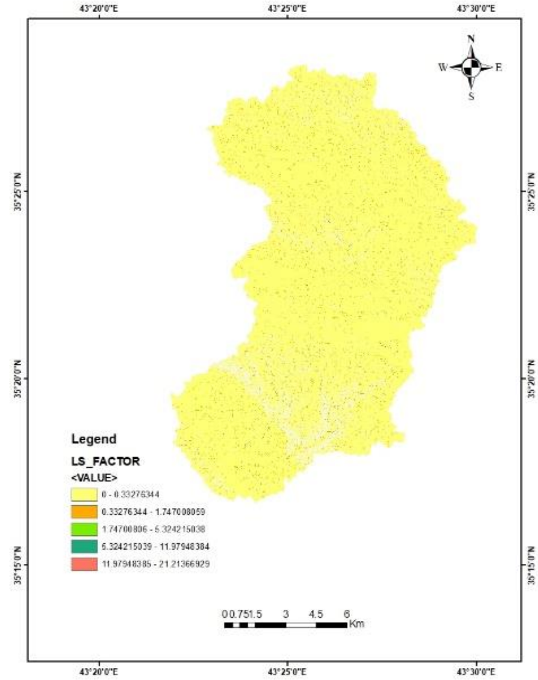

Fig. 22 LS-factor of Al-Rakhma Valley Catchment.

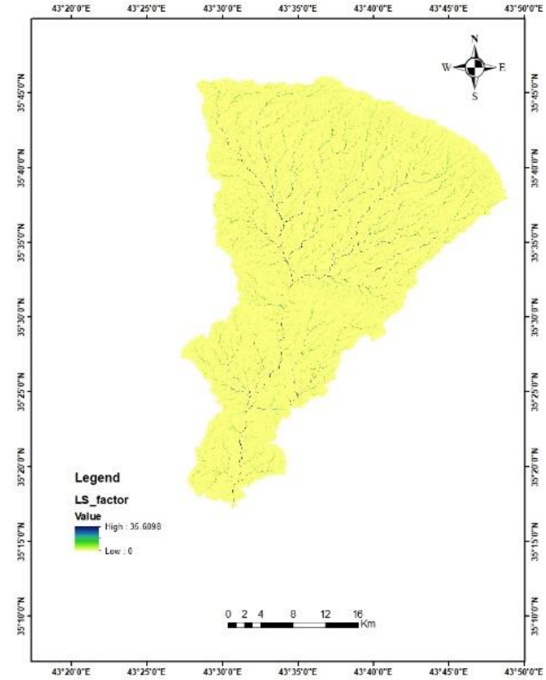

Fig. 23 LS-factor of Al-Fudha Valley Catchment.

4.5. Cover Management Factor (C)

Land vegetation and its management directly affect soil erosion in catchments, as plants resist the energy of raindrops and dissipate torrential floods. The C-factor value ranges between 0 and 1, depending on the type of soil vegetation cover; therefore, the less the effect of the vegetation cover, the closer the factor value is to (1), and the denser the cover or resistance to erosion, the closer the value is to (0). The C-factor value is (1) for barren or newly plowed soil and (0) for water bodies. Several equations were proposed to find the C-factor value based on the Normalized Difference Vegetation Index (NDVI) [12]. The NDVI vegetation map was produced after downloading the Sentinel-2 visual from the USGS website. Then, Eq. (5) was used and processed by the program GIS [15]:

$$C = e^{-\alpha * \frac{NDVI}{\beta - NDVI}} \qquad (5)$$

Figures (24-29) represent the C-factor map for all valleys catchments.

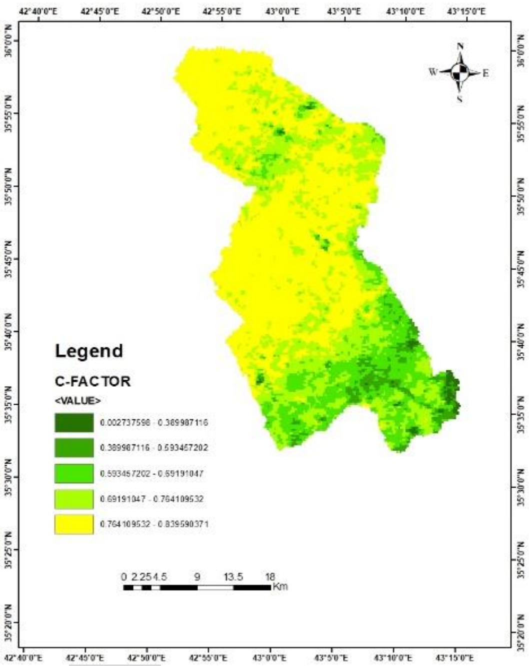

Fig. 24 C-factor of Al-Jirnaf Valley Catchment.

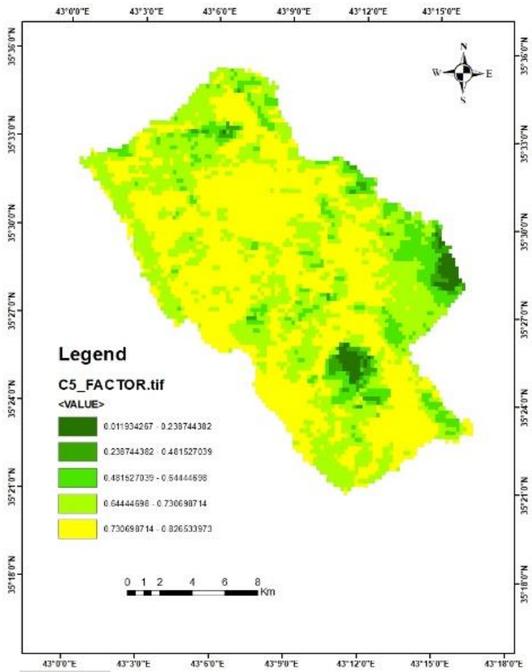

Fig. 25 C-factor of Umm Al-Shababit Valley Catchment.

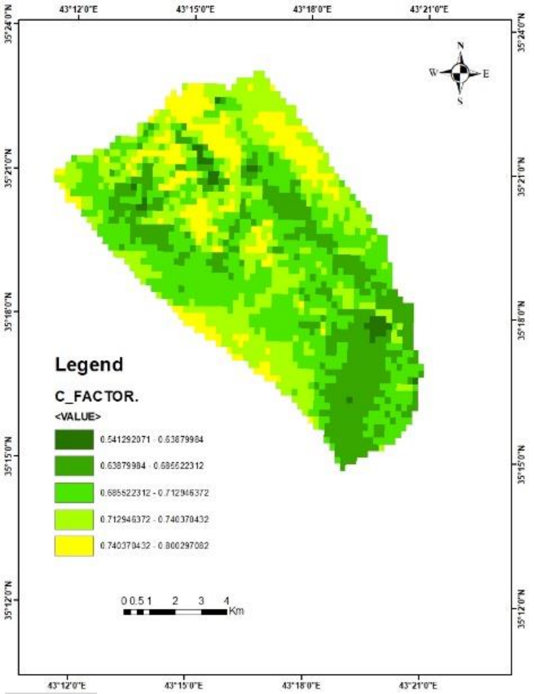

Fig. 26 C-factor of Al-Qasr Valley Catchment.

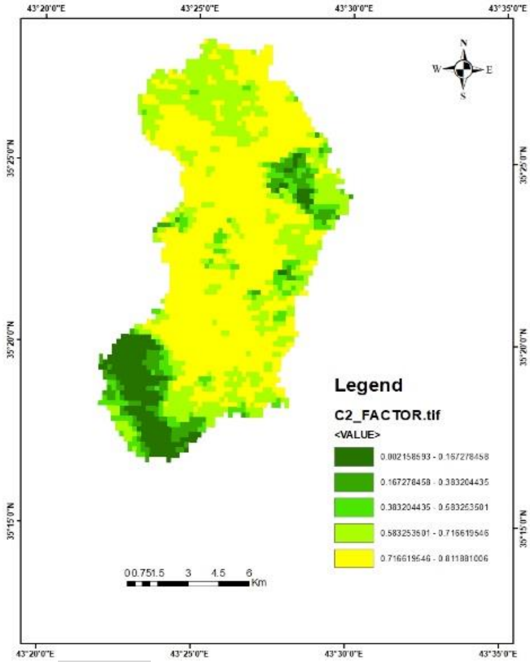

Fig. 28 C-factor of Al-Rakhma Valley Catchment.

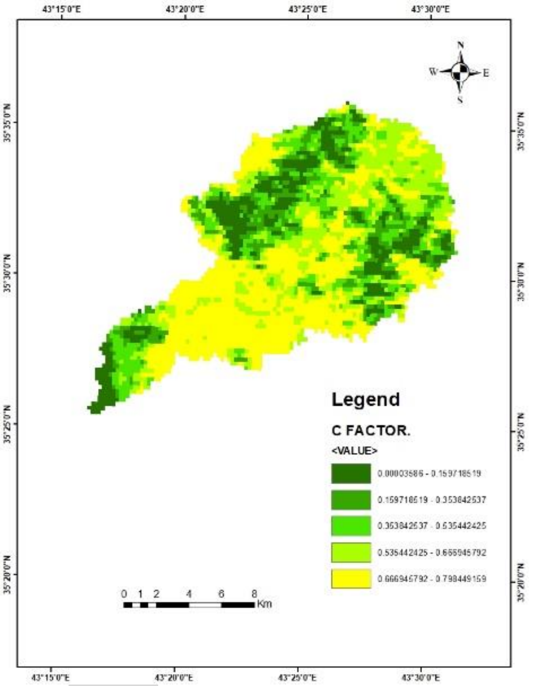

Fig. 27 C-factor of Al-Shook Valley Catchment.

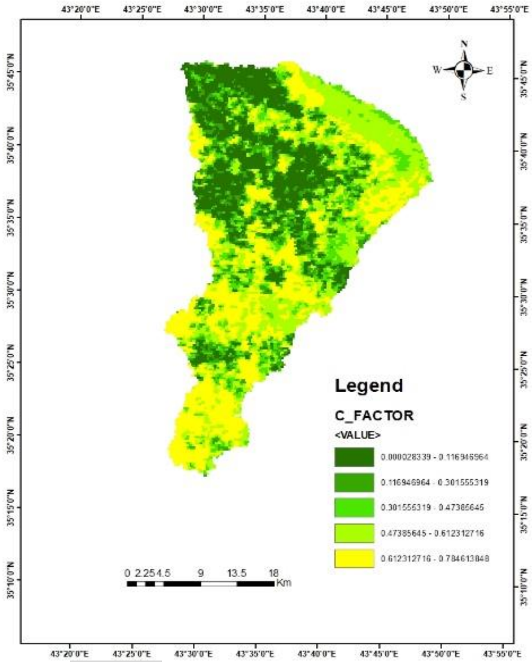

Fig. 29 C-factor of Al-Fudha Valley Catchment.

4.6.Soil Conservation Practices (P-Factor)

This factor shows the extent of soil loss due to reduced use of agricultural practices, such as contour plowing and terrace farming, and thus contributes only to a small percentage of subsistence agriculture. This factor was derived from maps of land use and slope ratio, and its value ranges from (0 – 1). The closer the value is to (1), the worse these practices are and their greater impact on the region. Its value decreases and approaches (0) whenever soil protection practices exist. After an on-site examination of the area and the studied catchments, no cases of soil protection practices were recorded in the sloping areas and plowing. Therefore, the P-factor value was considered (1) for all catchments [12].

5.ESTIMATION OF SEDIMENTS LOAD FROM WATERSHEDS

As indicated earlier, not all sediment load produced in an erosion process in the watershed is transported out of the catchment in real-time. Due to the loss of momentum of the conveying mechanism, considerable deposition occurs mostly in areas of the catchment with low slope, high roughness, or very low velocities due to large expansion of flow area. The ratio of sediment yield to the gross erosion in the watershed, called sediment delivery ratio (SDR), is an important parameter in quantitative estimation of sediment Load. The average annual (SDR) values vary in a wide range as this parameter depends on several parameters. Out of the many parameters, the significant ones are:

(1) The size of the watershed.
(2) The channel density.
(3) The relief length ratio.

The watershed size is key in determining the opportunities for depositing eroded sediment load. The larger the area, the greater the chance that the sediment load will be deposited in the catchment and, thus, the lower the (SDR).

If (USLE) is used, the sediment delivery ratio (SDR) should be estimated. The sediment load is obtained by multiplying gross watershed erosion by (SDR) [11]. The drainage area method is most often and widely used in estimating sediment delivery ratios in previous research. Williams (1975) developed an equation relating (SDR) with the drainage area. It is based on Maner's (1962) equation and the sediment yields observed in 14 watersheds in the Blackland Prairie Area in Texas. The model shows a good relationship between (SDR) and the drainage area (R^2 = 0.92). The model can be written as follows:

$$\log(SDR\%) = 1.7935 - 0.14191 \log(A) \quad (6)$$

where A is the drainage area in km^2

Vanoni (1975) used the data from 300 watersheds worldwide to develop a model by the power function. This model is considered a more generalized one to estimate (SDR).

$$SDR = 0.42\, A^{-0.125} \quad (7)$$

where A is the drainage area in square miles.

The USDA SCS (1979) developed an (SDR) model based on Blackland Prairie, Texas data. A power function is derived from the graphed data points:

$$SDR = 0.51\, A^{-0.11} \quad (8)$$

where A is the drainage area in square miles [16].

6.RESULTS AND DISCUSSION

After finding factors for the universal equation of soil losses (USLE) (Eq. 1) in the previous paragraphs, these factors were processed using the GIS program to obtain a soil erosion map for the six studied valleys. The model was applied to each of the six catchments, and an independent map was extracted, showing the extent and degree of soil degradation for each catchment. Figures (30-35) represent a soil degradation map for all valley catchments.

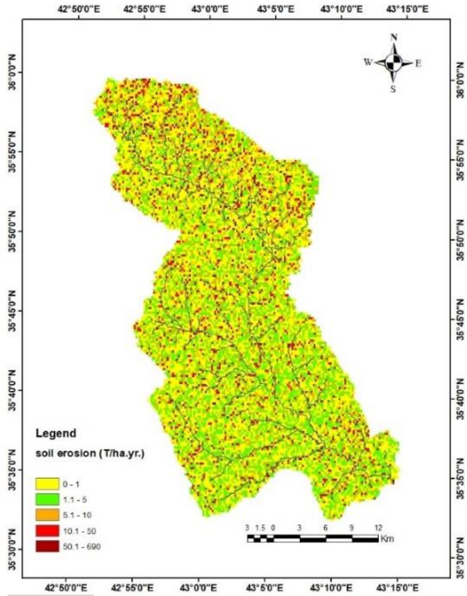

Fig.30 Soil Erosion of Al-Jirnaf Valley Catchment.

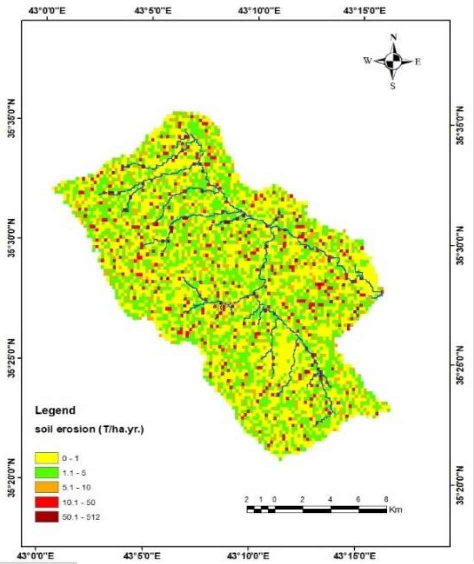

Fig.31 Soil Erosion of Umm Al-Shababit Valley Catchment.

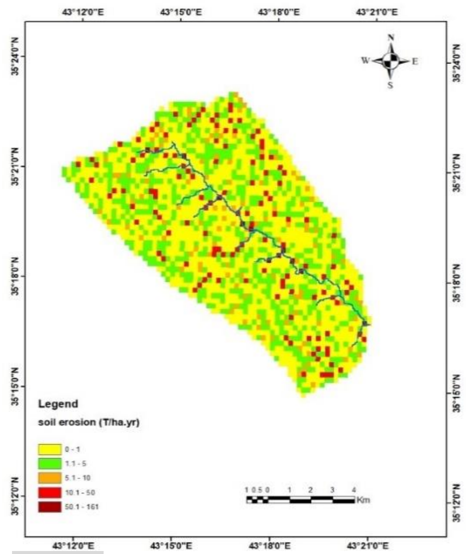

Fig. 32 Soil Erosion of Al-Qasr Valley Catchment.

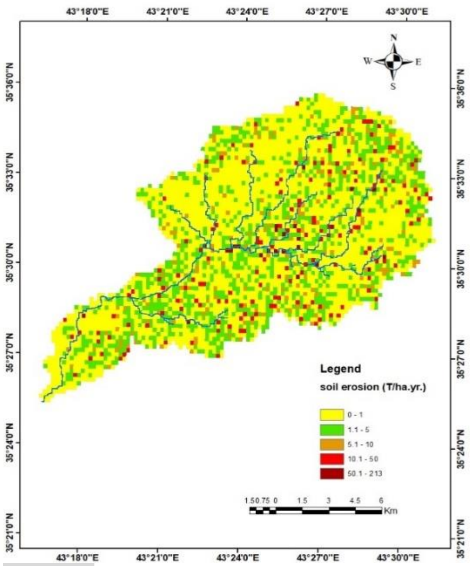

Fig. 33 Soil Erosion of Al-Shook Valley Catchment.

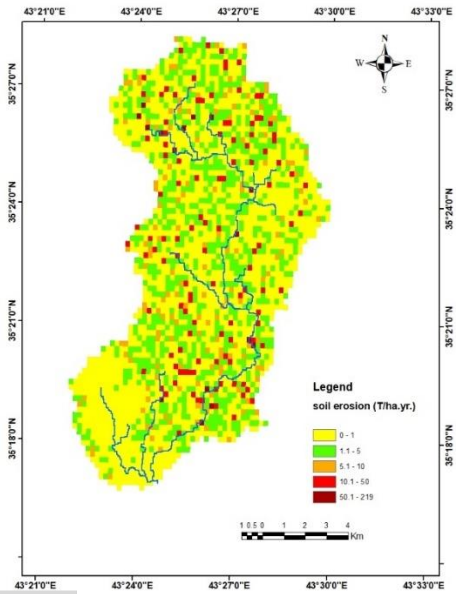

Fig. 34 Soil Erosion of Al-Rakhma Valley Catchment.

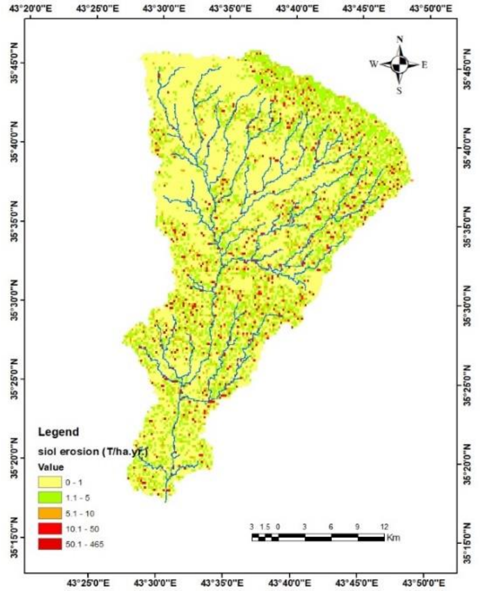

Fig. 35 Soil Erosion of Al-Fudha Valley Catchment.

The maps produced for soil erosion in the six valleys showed spatial variation in erosion values for each catchment. Table 5 was adopted to evaluate the degree of erosion [17]. Table 6 summarizes what was deduced from the catchment soil erosion maps and shows the erosion classification for each valley. Table 7 shows the SDR values for each valley after applying Eqs. (6)- (8) to obtain the percentage of sediment load reaching the reservoir from eroded soil from each valley and then calculate the sediment load, as shown in Table 8 and Fig. 37.

Table 5 Soil Erosion Classification [17].

No.	Level	Soil loss (ton /ha.year)
1	Very low erosion	0-1
2	Low erosion	1-5
3	Medium erosion	5-10
4	High erosion	10-50
5	Extreme erosion	>50

Table 6 Total Annual Soil Erosion from Valleys and Classification of Erosion Severity.

Erosion level	Valleys	Al-Jirnaf Valley	Umm Al-Shababit Valley	Al-Qasr (Al-Jafr) Valley	Al-Shook Valley	Al-Rakhma Valley	Al-Fudha Valley
Total area	km²	945	319	113	197	152	902
Total erosion	ton/year	518700	128726	36338	52299	42415	232198
Very low erosion	Area (sq. km)	463.6	156	63.5	125	91	604
	Erosion (ton/year)	278	518	1636	1650	800	7125
	Erosion%	0.05%	0.4%	4.5%	3.15%	1.9%	3%
Low erosion	Area (sq. km)	284.5	117	35.6	52.3	44.8	222.2
	Erosion (ton/year)	96593	33479	9605	15073	13367	63040
	Erosion%	18.6%	26%	26.4%	28.8%	31.5%	27.14%
Medium erosion	Area (sq. km)	104.3	22.6	6.14	10	8.4	38.3
	Erosion (ton/year)	77488	16867	4593	7472	6299	28521
	Erosion%	14.9%	13.1%	12.64%	14.28%	14.85%	12.28%
High erosion	Area (sq. km)	75.34	19.68	7.14	8.3	6.46	31.3
	Erosion (ton/year)	155289	43939	14956	16733	15888	65283
	Erosion%	29.94%	34.1%	42.16%	31.99%	37.45%	28.1%
Extreme erosion	Area (sq. km)	17.22	3.56	0.61	1.28	0.91	5.59
	Erosion (ton/year)	189051	33921	5547	11370	6060	68227
	Erosion%	36.44%	26.35%	15.26%	21.7%	14.28%	29.4%

Table 7 SDR Values for Each Valley.

Valley	SDR1	SDR2	SDR3	Average SDR
Al- Jirnaf valley	0.235102	0.200901	0.266524	0.2341757
Um Al-Shababit valley	0.274276	0.230111	0.300342	0.268243
Al Qasr (Al-Jafr) valley	0.317795	0.261985	0.336662	0.305481
Al-shook valley	0.293692	0.244401	0.316696	0.2849297
Al-Rakhma valley	0.304701	0.252453	0.32586	0.2943382
Al Fudha valley	0.236661	0.202074	0.267892	0.2355426

The valley's annual sediment load productivity is calculated by multiplying the (SDR) value with the erosion value extracted from the (USLE) Universal Soil Loss Equation.

Sediment Load of valley (ton/year) = total erosion of valley (ton/year) * SDR **(9)**

The following is a review of the results obtained for each of them:

As shown in Fig. 30, the erosion values for Al-Jirnaf valley varied from (0 to 690) tons/ha.year. It achieved the highest annual rate of soil erosion from the valley, as 518,700 tons would be washed away annually, and the amount of sediment load reaching the reservoir would reach 121,467 tons, at a rate of 48.7% of the total sediment load arriving from the valleys annually. Figure 31 shows a map of soil erosion for Umm Al-Shababit Valley. This catchment's highest erosion value was 512 tons/ha.year. The total erosion from this valley amounting to 128,725 tons/year, as well as the amount of sediment load that will flow into the reservoir, amounting to 34,529 tons/year, which constitutes 13.85% of the total amount of sediment load from the six valleys. Figure 32 shows a map of soil erosion for Al-Qasr valley. The highest value of erosion in this catchment was 161 tons/ha.year, and the total expected amount of erosion for the catchment was 36,328 tons/year. This valley's total annual sediment load was 11,100 tons/year or about 4.45% of total sediment load. Figure 33 shows a map of soil erosion for Al-Shook Valley. The highest value of erosion in this catchment reached 213 tons/ha.year, and the total expected amount of erosion for the catchment reached 52,299 tons/year; the total annual sediment load from this valley was 14901tons/year or about 5.96% of total sediment load. Figure 34 shows a map of soil erosion in Al-Rakhma Valley. The soil erosion of this valley varied from (0 to 219 tons/ha.year). So, the total expected amount of erosion for this catchment was 42,415 tons/year, and the total sediment load that would flow into the dam reservoir from this valley was 12,470 tons/year, or about 5.01% of the total sediment load. The soil erosion map for Al-Fudha Valley, Fig. 35, shows that the soil erosion value varied from (0 to 465) tons/ha.year. Therefore, the total expected amount of erosion for the catchment was 232,198 tons/ year, and this valley's annual sediment load production was 54692 tons/year or 21.95% of the total sediment load. Figure 36 shows the five classifications for each of the six valleys. This figure and Table 6 show that the largest percentage of eroded soil comes from the two areas classified as highly eroded and areas with extreme erosion, indicated in the maps and the figure in red and brown due to the high slope and lack of vegetation. It is noted that these areas are concentrated near the water courses of the valleys, which causes them to be easily eroded by runoff. Also, from the slope maps, it is clear that high-erosion areas are concentrated in high-slope areas. A smaller percentage of areas with low erosion are shown in green in the maps and figures due to their large area. Therefore, appropriate measures must limit or reduce soil erosion from these areas. Figure 37 and Table 8 show each valley's total annual amount of sediment load.

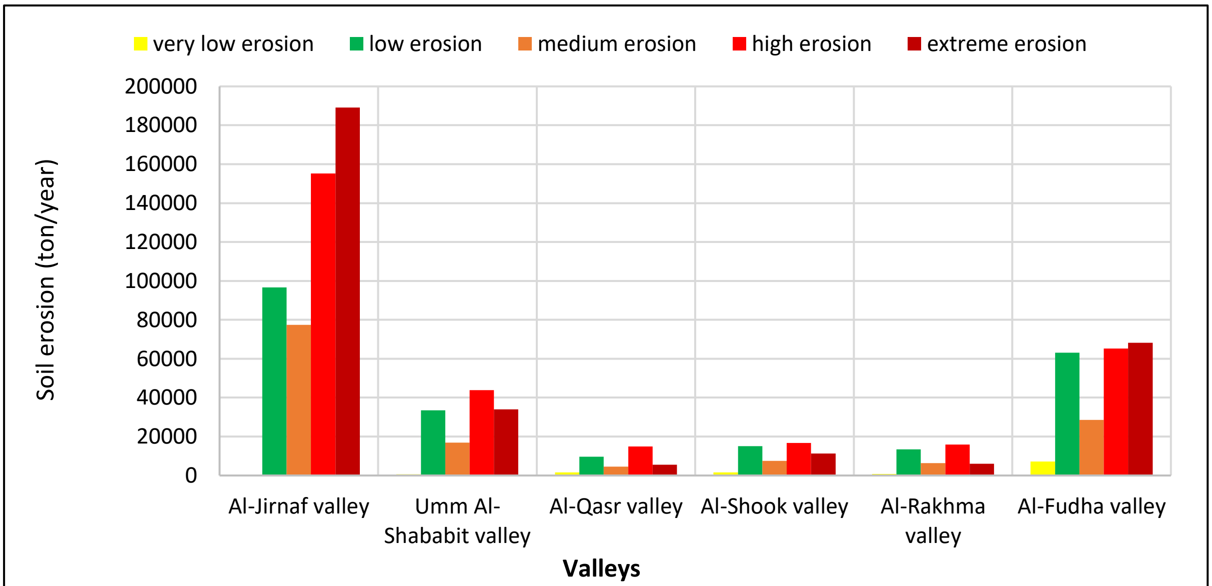

Fig. 36 The Amount of Soil Erosion for Each Valley.

Table 8 Sediments Load Arriving from Each Valley Annually.

Valley	Area (km²)	Valley Total Erosion (ton/year)	Valleys Sediments Load (ton/year)
Al-Jirnaf valley	945	518,700	121466.9253
Umm Al-Shababit valley	319	128,725	34529.84651
Al-Qasr (Al-Jafr) valley	113	36,328	11100.57027
Al-Shook valley	197	52,299	14901.5358
Al-Rakhma valley	152	42,415	12484.35312
Al-Fudha valley	902	232,198	54692.51161

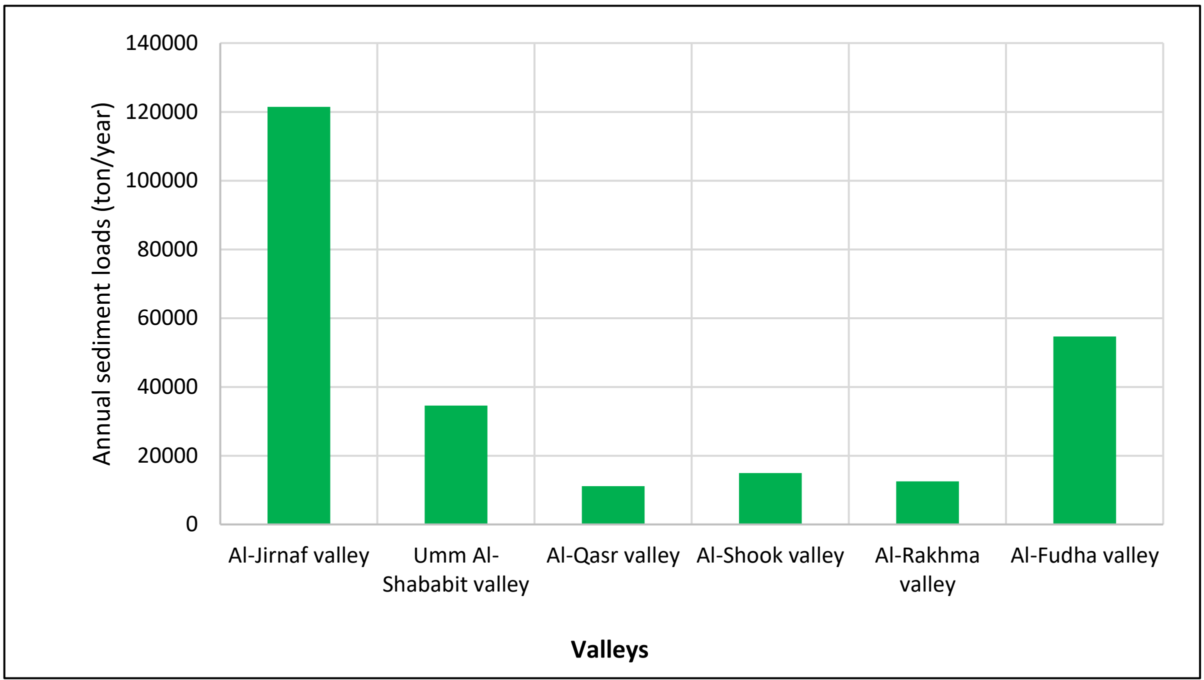

Fig. 37 Annual Sediment Loads Came from the Six Valleys.

7.CONCLUSIONS

1- The total soil erosion from the six valleys reached 1,010,677 tons annually, and it is expected that 249,175 tons/year of it will reach the Makhool reservoir annually as a sediment load.
2- Al-Jirnaf catchment achieved the highest annual rate of soil erosion from the valley, followed by the Al-Fudha catchment in second place. Umm Al Shababit catchment came in third place, the Al-Shook catchment came in fourth place, the Al-Rakhma catchment fifth, and the Al-Qasr catchment sixth.
3- The Sediment Delivery Ratio (SDR) values for the studied valleys, i.e., Al-Fudha, Al-Rakhma, Al-Shook, Al-Qasr, Umm Al-Shababit, and Al-Jirnaf, were 0.2355426, 0.2943382, 0.2849297, 0.305481, 0.268243 and 0.2341757, respectively.
4- The estimated sediments load from the six valleys that will flow into the dam reservoir amounted to 249,175 tons per year, including 121,467 tons per year from Al-Jirnaf Valley, 54,692 tons per year from Al-Fudha Valley, 34,529 tons per year from Umm Al-Shababit Valley, 14,901 tons Al-Shook Valley, 12,484 tons per year from Al-Rakhma, and 11,100 tons per year from Al-Qasr Valley.

LIST OF SYMBOLS

A	The soil loss per unit area in unit time. Usually, the units of *A* are metric (tons/ha/year)
R	Rainfall erosivity factor (MJ.mm/ha. h. year)
K	Soil erodibility factor (t. ha. h/MJ.ha.mm)
L	Slope length factor (unitless)
S	Slope-steepness factor (unitless)
C	Cover management factor (unitless)
P	Support practice factor (unitless)
MAR	Annual precipitation (mm)

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REFERENCES

[1] Fadhil RMS. **Estimation of Sediment Load from West Bank Valleys to Mosul Dam Reservoir**. *Al-Rafidain Engineering* 2013; **21**(5):28-40.

[2] MARTÍN-ROSALES W. **Sediment Yield Estimation and Check Dams in a Semiarid Area (Sierra de Gádor, Southern Spain)**. *Integrating Methods and Techniques (Proceedings of symposium)* 2003; IAHS Publ. no. 279 :51-58.

[3] Karami H, DadrasAjirlou Y, Jun C, Bateni SM, Band SS, Mosavi A, Chau KW. **A Novel Approach for Estimation of Sediment Load in Dam Reservoir with Hybrid Intelligent Algorithms**.

Frontiers in Environmental Science 2022; **10**: 821079, (1-16).

[4] Devatha CP, Deshpande V, Renukaprasad MS. **Estimation of Soil Loss using USLE Model for Kulhan Watershed, Chattisgarh- A Case Study**. *Aquatic Procedia* 2015; **4**:1429-1436.

[5] Mohammad ME, Al-Ansari N, Knutsson S. **Application of SWAT Model to Estimate the Annual Runoff and Sediment of Duhok Reservoir Watershed**. *Scour and Erosion* 2016; Taylor & Francis Group; p. 1129-1136.

[6] Alshraifat H. **Assesment of Soil Erosion Susceptibility in Wadi Rajeb Basin using RUSLE**. *An-Najah University Research Journal (Human Sciences)* 2023; **37**(5):981-1002.

[7] Ghumaid A, Abo Sammor H. **Assessment of Soil Erosion Risk in the Azraq Basin Using Soil and Water Assessment Model, GIS, and Remote Sensing**. *An-Najah University Research Journal (Human Sciences)* 2023; **37**(4):739-774.

[8] Al-Mohamed HA, Al-Belbeisi HH. **Estimating Soil Degradation in Al Arab Valley Catchment Using Geographic Information Systems and Remote Sensing Techniques. Studies**. *Humanities and Social Sciences* 2019; **46**(1):125-139.

[9] Mohammad EM, Sami RM, Al-Ansari N, Knutsson S. **Sediment Delivery from Right Bank Valleys to Mosul Reservoir, Iraq**. *Journal of Ecology and Environmental Sciences* 2012; **3**(1):50-53.

[10] Khaleel MS, Mahmood MQ. **A Computer Program for Estimating the Sediment Load Entering the Right Side of Mosul Dam Reservoir**. *Tikrit Journal of Engineering Sciences* 2018; **25**(1):60-68.

[11] Subramanya K. ***Engineering Hydrology***. 3rd ed., New Delhi: Tata McGraw-Hill; 2014.

[12] Tagung T, Kumar S, Singh P. **A Review on Assessment of Soil Loss through Erosion using Revised Universal Soil Loss Equation (RUSLE) Model**. *The Pharma Innovation Journal* 2022; **11**(8):486-493.

[13] Al-Kenani MNA. **Daily Rainfall Recorded in Iraq (Synoptic Study)**. *Journal of Education College Wasit University* 2018; **1**(8):145-169.

[14] Almughari B. **Application of RUSLE Model for Estimating Soil Erosion in Gaza Strip in Palestine Using Geographic Information System**. *An-Najah University Journal for Research-A (Natural Sciences)* 2021; **35**(1):1-21.

[15] Van der Knijff JM, Jones RJA, Montanarella L. **Soil Erosion Risk Assessment in Europe**. *EUR 19044 EN, Office for Official Publications of the European Communities 2000;* Luxembourg: 34. 2000.

[16] Ouyang, D. and Bartholic, J. **Predicting Sediment Delivery Ratio in Saginaw Bay Watershed**. *Proceedings of the 22nd National Association of Environmental Professionals Conference* 1997; Orlando: p. 659-671.

[17] Pham TG, Degener J, Kappas M. **Integrated Universal Soil Loss Equation (USLE) and Geographical Information System (GIS) for Soil Erosion Estimation in A Sap Basin: Central Vietnam**. *International Soil and Water Conservation Research* 2018; **6**(2018):99-110.