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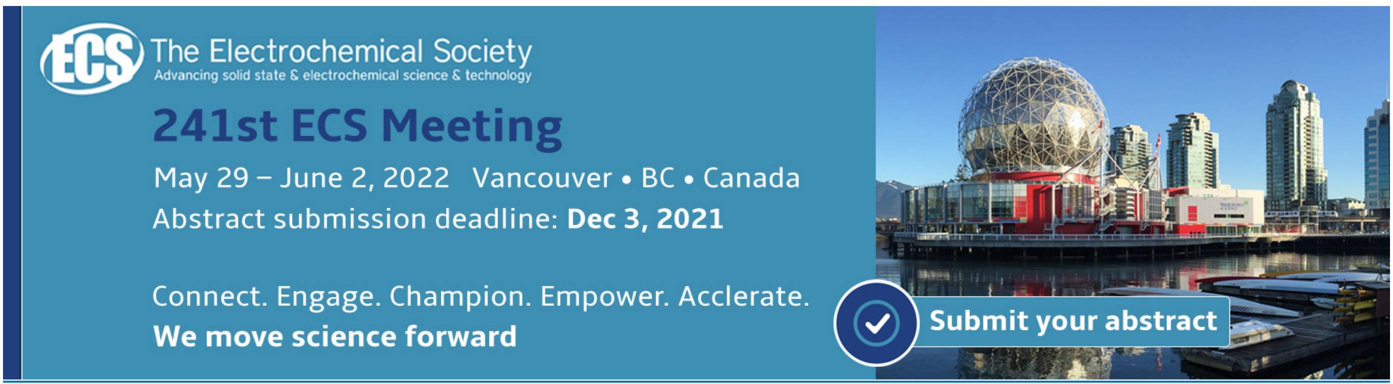

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Use of Revised Universal Soil Loss Equation (RUSLE) Model to Estimate Soil Erosion in Jibab Wadi Basin West of Iraq

A A M Alalwanya [1*], E T Abdel Ghani[2], K A Ali [3], A H I Al-Bayati [4]

[1] Center for Desert Studies
[2] Development Center of Upper Euphrates Basin, University of Anbar, Anbar, Iraq
[3] College of Education for Human Sciences, Department of Geography, University of Anbar, Anbar, Iraq
[4] Department of Soil Science and Water Resources College of Agriculture, University of Anbar, Anbar, Iraq

*Corresponding author's email: ds.dr.abdalkareem@uoanbar.edu.iq

Abstract. The study dealt with one of the most important environmental problems that leads to soil deterioration, increase in the degree of desertification and the loss of large areas of lands that suffer from dry and semi-arid areas. This study aims to calculate the amount of soil transported using the revised universal equation model of erosion RUSLE, and five representative surface samples were obtained. For all the watershed of the valley, analyses were carried out for the general equation of erosion, and the climatic data of the Anah meteorological station were used, whose values ranged between (0.0554 -0.4923), as well as the values of normalized difference vegetation index (NDVI) between its high and low values (0.10084 -0.645161). Maps were created from the general equation factors (RUSLE) and their units were classified according to water erosion rates to investigate the susceptibility of soil to erosion and the risk of soil erosion.

1. Introduction

Soil erosion is known as the process of separation and transfer of soil particles, whether by wind or water, which leads to their deposition in other places and the formation of new soil, water, and private water pools in water basins [1]. Water erosion of soil is considered one of the most dangerous manifestations of environmental degradation that afflicts productive pasturelands, and it is a process of continuous deterioration of the land (soil, vegetation cover), in dry and semi-arid areas, expensive investments [2].

The highest rates of soil erosion in the world occur in Asia (including Iraq), estimated at 74 tons.$h^{-1}.y^{-1}$ [3], and every year, about 75 billion tons are eroded from the soil, equivalent to 40 times the natural rate of erosion and erosion in the world [4].

Soil erosion has been the focus of researchers' attention since the thirties of the last century. Mathematical equations and models were used to represent the state of soil erosion [5]. For instance, several statistical and mathematical models were developed by the US Department of Agriculture, published for the first time in [6], and then several attempts and studies were made to update and modify models for estimating soil erosion until reaching the RUSLE equation, which was widely used to estimate the risk of soil erosion. This model has

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been applied in many regions of the world by many researchers and with different variables to suit the nature of the study area in which it was applied as a scientific method for monitoring the state of soil erosion and evaluating environmental degradation of agricultural soils for sustainable development. It is also one of the important applications that enable us to obtain approximate data to accurately estimate the volume of soil losses based on the conditions of the region, determine the model of soil erosion and the affected lands and draw the necessary maps for them[7],[8], [9]. Soil erosion causes the deposition of silt, especially in front of the dams, and thus affects the life of the dam and other uses such as irrigation of crops and the quality of vegetation in general [10].

The model of the revised universal equation of soil losses RUSLE has been used by [11] in GIS and remote sensing data depending on several factors and variables in Lebanon and Tunisia. For example, [12], [13] used the Digital Elevation Model (DEM) with remote sensing data in studying coastal soil degradation. Also, [14] produced maps soil erosion, estimating the size of erosion and rapid assessment of erosion risks, and the same method was used by [15] to produce a soil erosion map in Yeon District, Korea.

A soil erosion risk map was prepared by [16] for the soils of the Al-Thawra Dam Basin area in Lattakia Governorate using the Corine Model and the GIS program, 66 km^2, respectively. The study emphasized the importance of the vegetation cover in reducing the area or areas that suffer from severe erosion risk by 58.20%.

The current study aims to apply the RUSLE equation to estimate soil erosion and degradation using the soil susceptibility factor to water erosion, mapping soil degradation areas in Wadi Jibab within the dry environment in Anbar Governorate using RS and GIS data, and determining the spatial distribution of soil erosion patterns in a watershed the Wadi.

2. Materials and Methods

2.1. Study location

Wadi Jibab is located within the western plateau region, 305.8 km west of Baghdad, where it meets the delta Wadi Jibab in the Euphrates River west of the City of Ayah (Fig.1). It is located between latitudes (34°27'50",34°00'00") north and longitudes (41°23'00",41°43'00") east. The watershed of Wadi Jibab is extended from the southwest towards the northeast, and its course flows into Euphrates River, as it shares the water division line from the east with Wadi Al-Kasr and Wadi Al-Fahimi with a circumference of 216 km and an area of 986.6 km^2.

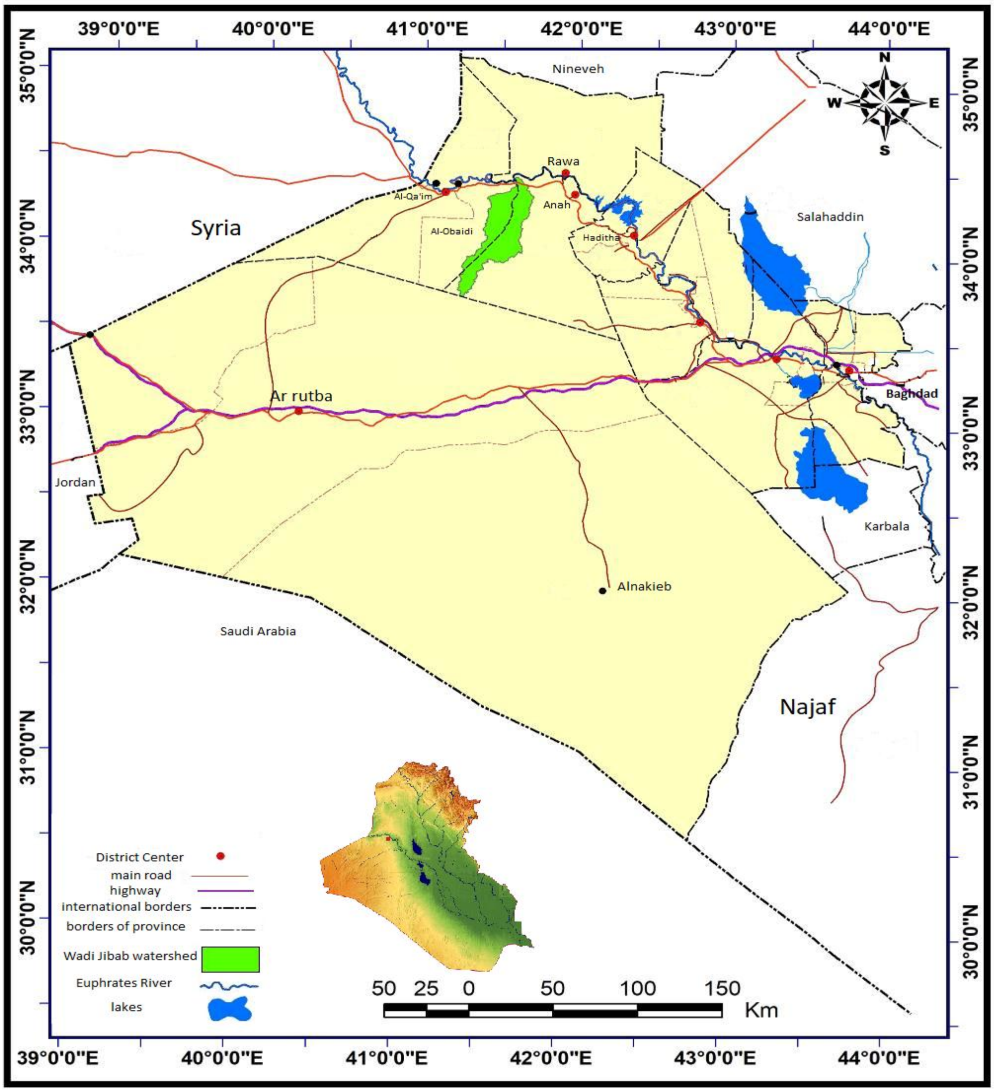

Figure 1. A detailed map for the study area (Wadi Jibab)

2.2. Soil sample collection

A survey of the area's soil was conducted through several field visits from 2012 to 2013. The visits stopped due to the security conditions in those areas during this period and resumed in the year 2019. Five pedons were excavated, 50 samples were collected, and 150 auger holes were drilled from several sites to include all the watershed of Wadi Jibab and transferred to the laboratory of the Center for Desert Studies - University of Anbar, air-dried and sieved with a sieve with a diameter of 2 mm to obtain soil used for physical and chemical analyses, organic matter, cation exchange capacity, use of soil texture triangle, and all required analyses according to [17].

2.3. Climate

Temperature: It is one of the important climatic elements in the formation and distribution of plant communities on the surface of the earth. The study area is characterized by the presence of two main seasons, the first in hot dry summer and the second is a cold winter, in addition to two variable seasons, spring and autumn. The month of July recorded the highest average temperatures, reaching 33 Cº for a station, and the lowest average temperature was in January, the coldest month for the winter season, figure 2.

Rainfall: Rain is one of the most important forms of precipitation in the study area, and it has a significant impact on soil erosion and the growth of vegetation, as well as the role of groundwater recharge and high humidity. The rainy season begins in the region from the beginning of October until the end of May, whose fall is associated with the beginning of the passage of air depressions over the country during the second half of October, as few showers occur at first and then increase during December, January, and February while decreasing in the months of March and April, and their passage stops at the end of June. The amount of rain falling on the region varies from season to season, as well as during rainy years. It is clear to us that the total annual precipitation amounted to 167.4 mm (Table 1 and Figure 2 show the monthly rates of rain (mm) for the station of the study area).

Humidity: It is the percentage between the amount of water vapour that is present in a certain volume of air and the amount that the same volume of air can bear to reach the degree of saturation at the same temperature and pressure. The relative humidity rate has reached 26%. As for the highest rate of relative humidity, it was in January, when a station recorded 78%, the decrease in relative humidity in the basin area had a reflection on the lack of soil moisture in the area, which led to the lack of vegetation cover (figure 2 shows the distribution curve for maximum and minimum temperatures). The range, and rate (Cº) and figure 3 wind rose show the gusts of wind from the indicated direction and figure 4 is a summary of the climatic elements, while map 5 shows the amounts of rain in the study area in Anah station.

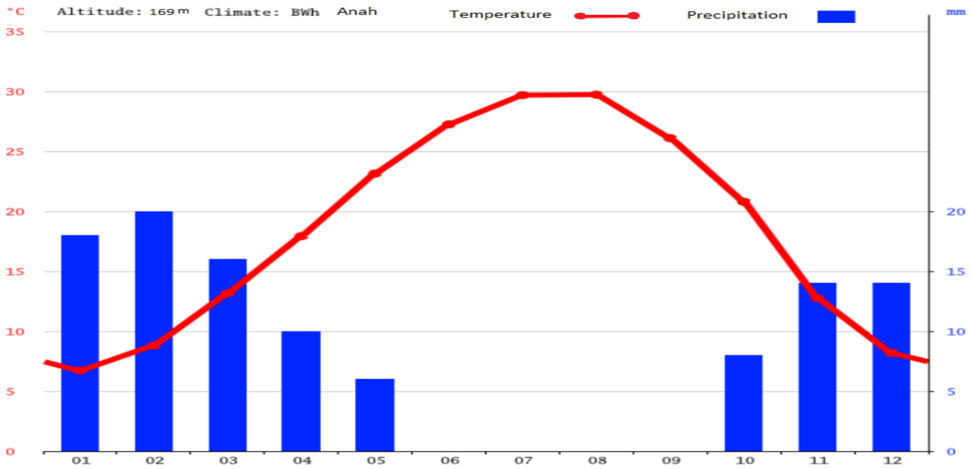

Figure 2. Monthly temperature and precipitation of ANAH

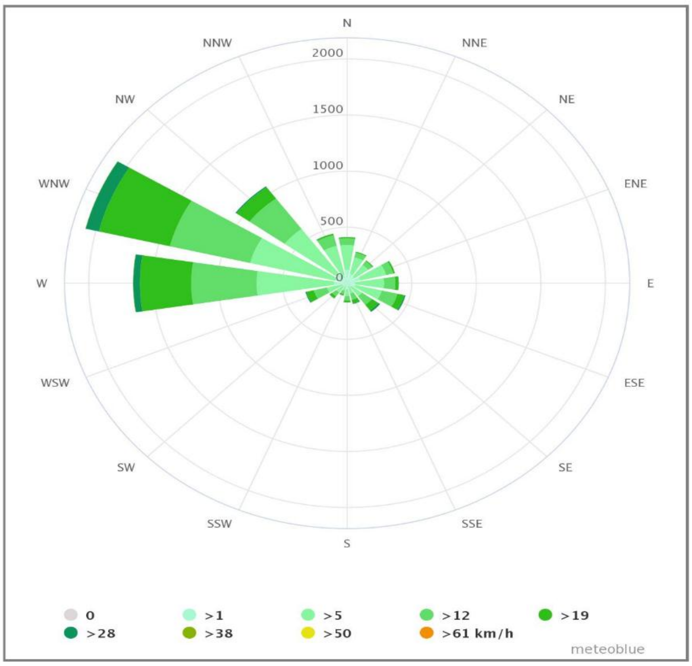

Figure. 3. The wind rose for Anah shows how many hours per year the wind blows from the indicated direction (source: metoblue[18])

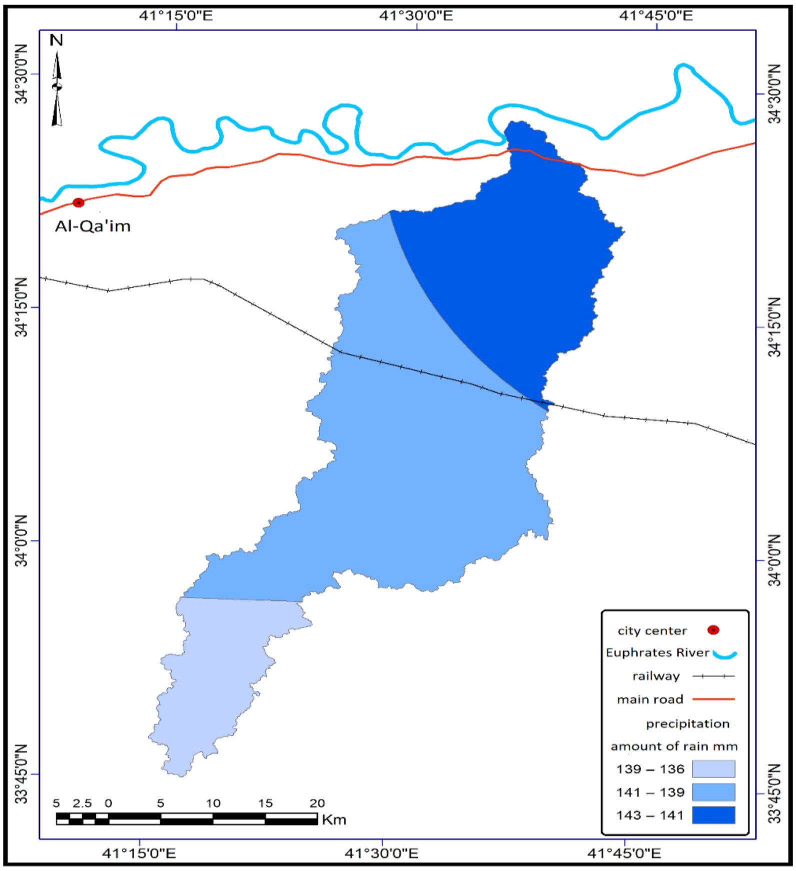

Figure. 4. Distributions of rain amounts in the study area for the period 1979-2015

Table 1. Amount of annual rainfall in the Upper Euphrates region (Anah station) 1979 - 2015

years	rain rate
1979	91.7
1980	155.6
1981	121.9
1982	297.1
1983	152.0
1984	111.0
1985	73.6
1986	60
1987	29.9
1988	213.0
1989	119.9
1990	54.5
1991	124.9
1992	130.1
1993	153.9
1994	149.5
1995	173.5
1996	212.8
1997	221.7
1998	97.5
1999	81.0
2000	123.2
2001	96
2002	132.3
2003	48.1
2004	94.9
2005	96.4
2006	195.2
2007	22.5
2008	68.0
2009	144.9
2010	114.6
2011	131.6
2012	98.201
2013	169.8
2014	119.7
2015	33.4
average	121.9

2.4. Geology

The study area is located within the Arab Nubian shelf or what is known as the stable *shelf*, specifically within the Anah belt - Al-Baaj. The occurrence of torsion in the sedimentary cover led to the formation of landforms such as refractive plateaus, ground depressions, and rift valleys, including the Wadi Jibab basin area [19]. Among the most important of these existing formations, according to their ages, from oldest to newest, are:

Anah Formation: This formation appears to the west of the study area in the middle of the axis of its anticline fold. The main detectors are submerged in the Qadisiyah dam reservoir, and its basic components are limestone of soft, crystalline cream colour that contains very solid fossils.

Euphrates Formation: Euphrates formation is one of the most widespread geological formations in western Iraq, as this formation is exposed in the Al-Baghdadi area and extends to the Iraqi-Syrian border. The study area is near the downstream area. This formation also appears in the western parts of the study area.

Fatha Formation: It appears in several areas of the study area, especially in the central and southern parts. The rocks in this formation consist of overlapping gypsum with layers of limestone, and these rocks are fragile and have a great ability to dissolve, which negatively affected the quality of groundwater in the region. Within this formation, layers of the Nafayl formation are revealed, which are found in the formations of some hills and plateaus, such as Tal Al-Ghader and Tal Al-Madwarah located to the west of the study area.

Quaternary Deposits: The Quaternary period is the latest geological time unit representing the last 1.88 million years of the Earth's life. The origin of the deposits is traced back to the Pleistocene and Holocene. It is difficult to separate between the Quaternary and Tertiary deposits due to the repetition of the process of sedimentation and erosion, as they are deposited in the valleys beds of valleys and rocky depressions that were affected by the movement of the faults, as well as at the high areas and their slopes [20], as shown in Figure (5).

2.5. Geomorphology

The geomorphic units in the region were classified by [21] based on the factors causing their formation (the origin of its formation) and included the following: Units generated by erosion factors and by a structural effect, including terraces and plateaus.

-Units produced by differential erosion factors (climatic factors such as rain and floods such as the Pediment and Hills units.

- Units resulting from erosion and sedimentation factors for surface waters (rivers and valleys), including the flood plain, river terraces, and valley fill sediments and depressions.
- Units resulting from physical and chemical erosion of rocks by surface water (units of valleys and depressions).
- Units of evaporative origin with climatic influence such as salt crust and sabkha.

According to the geomorphological description, the study area was characterized by a hilly surface surrounding the main valley course and a wide plain, interrupted by several valleys with the seasonal flow, some of them are permanent flowing due to the flowing artesian water throughout the year. Based on the differences in erosion factors and their effects, the geomorphic phenomena in the region varied as follows:

Plateau: The hills are located on both sides of the valley mainstream at a number of steps from sea level, ranging from 119-90 meters on both sides of the valley as well as the diversity of wadis drainage systems.

Rocky terraces: rocky terraces are located in the area of the gypsum plateaus, as they are cut off from the original plateaus by the erosion factors of the running water.

Plains: Within the study area there is a part of the valley of Al-Qasr Wadi. The sediments of these plains consist of gravel, sand, clay, and rock-like mineral components; plain permeates large areas of sabkhat lands, as shown in the geological map of the study area.

Alluvial Terraces: located within the study area, which are the landforms resulting from the succession and repetition of erosion and sedimentation carried out by the valley on the sediments in the valley plain of sedimentary basins. There are different levels of river terraces along the wadi.

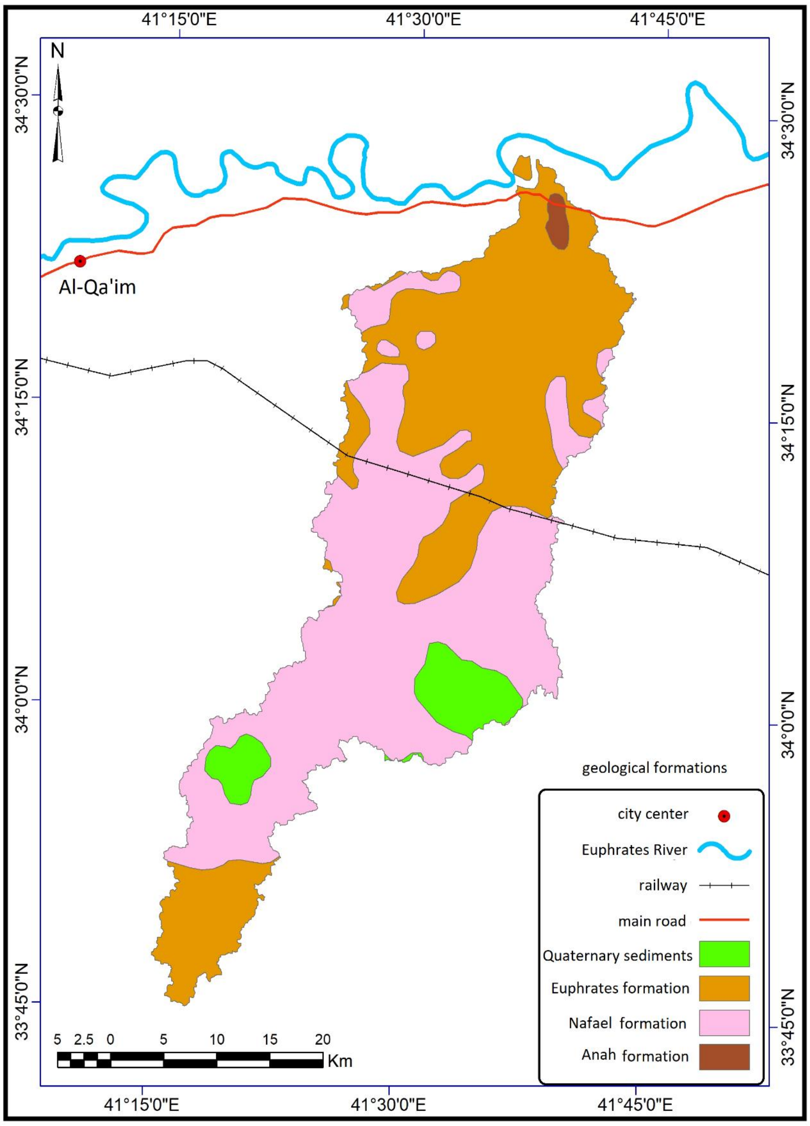

Figure 5. The geological formation of the study area

2.6. Work plan

The flowchart below illustrates the steps of applying the RUSLE equation model and matching it with soil maps and agricultural soil uses using GIS applications and remote sensing, Figure 7.

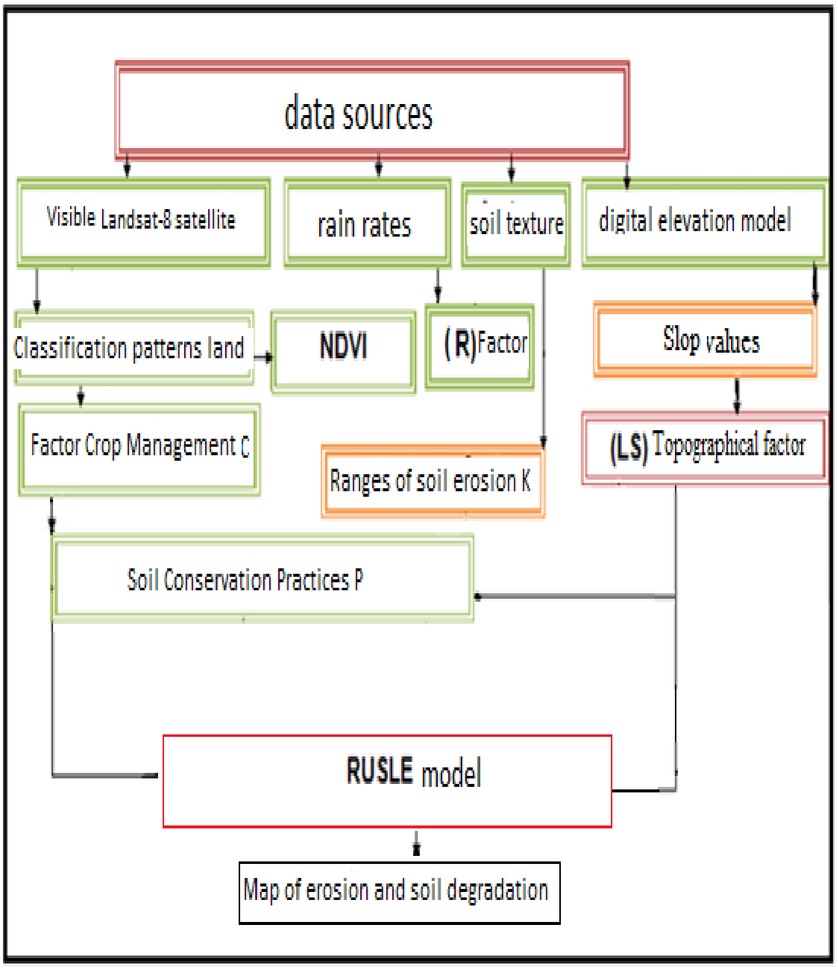

Figure 6. Steps in the estimation of soil loss using RUSLE

2.7. Data collection
Satellite images of (Landsat-8) for the year 2016 was used from the site (USGS) [22], with a resolution of 30 m and a false-color (R, NIR, G), and then corrected to determine the coordinates from the topographic map at a scale of 1: 5000. The satellite images were calibrated to ensure that they were free of clouds and atmospheric disturbance, then a cut-off was made for the study area based on soil units. The digital elevation model DEM, Fig.7, was also used, from which the gradient map of Wadi Jibab was derived.

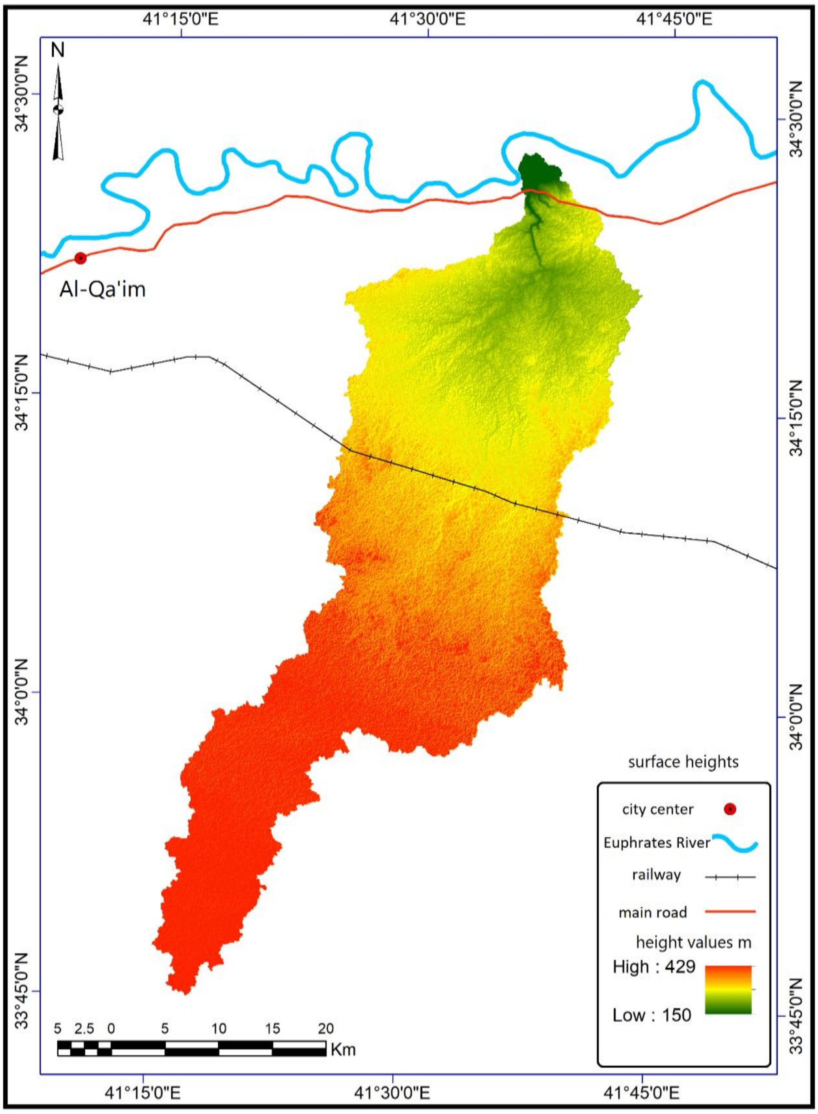

Figure 7. DEM digital elevation model for Wadi Jibab watershed

To apply the RUSLE model, it is necessary to derive many variables and factors based on data on rainfall rates, slope values, land uses, and soil texture, in addition to applying the NDVI index, then converting all vector data to digital Raster so that it is easier to deal with. The data of the average rainfall R for the period from 1985-2015 for the weather station in Anah was used to produce a rain distribution map according to Thyson distribution, produce a map (k) for soil texture, extract the slope degrees and calculate the slope length coefficient (LS) from the digital elevation model, and produce a land cover map and its uses from the Landsat satellite visible on May 8, 2015, and extract the NDVI index as input to the RUSLE model.

2.8. Description of the General Revised Soil Loss Equation (RUSLE)
The mathematical model consisting of many factors and variables was used to evaluate sites for planning purposes and to assist in the decision-making process, and choose the necessary measures to control soil erosion. This equation was applied through GIS tools and the values of factors and variables were extracted according to the following equation [23]:

$A = R \times K \times LS \times C \times P$ ……………… 1
A = Amount of annual soil loss in hectares (m.g. ha^{-1}. y^{-1})
R = Rain and runoff rates (mm)
K = susceptibility to soil erosion (m.g. ha^{-1})
LS = slope factor and slope length
C = crop management factor
P = soil maintenance factor

Factor R: annual rainfall (mm)
The rainfall and runoff estimation factors were calculated by deriving annual rainfall rates for Anah Weather Station, table1, using the Kriging method from spatial analysis tools in ArcGIS 10.3 [24] and then applying the following equation [25]:

$$R=23.61\times e^{(o.oo8p)}$$ …………………2

Applying Equation 2, the value of R = 23.0

Factor (K): Erodibility factor

This factor is related to the properties of the soil, the most important of which is the soil texture. A map was extracted showing the soil types based on their spatial distribution depending on their texture after taking 5 models of the surface stress at the mouth, middle and source of the Wadi, Fig.8. Chemical and physical properties were estimated Figuer8, as well as the soil types of the study area, and then the following equation was used to estimate the value of the factor K [26].

K= 27.66 X M1.14 X 10-8 X (12-a)+(0.0043)+(0.0033x(c-3)) ....(3)
M: the proportion of silt + very fine sand (%)
a: organic matter (%)
c: permeability (cm. h-1)

Factor (C): Crop management factor and land cover

It is used to clarify the extent of the impact of agricultural land uses on soil erosion through a classification of land uses in the valley basin in addition to extracting the NDVI (Normalized Difference of Vegetation Index) vegetation cover index, Figuer10. Table 2, shows the values of factor C for each type of land use, where it is noted that the highest value of this factor, was 0.61 in the uses of irrigated agriculture, but in the barren areas, the value was 0.1, and the lowest value was (-0.8) because it is devoid of vegetation cover.

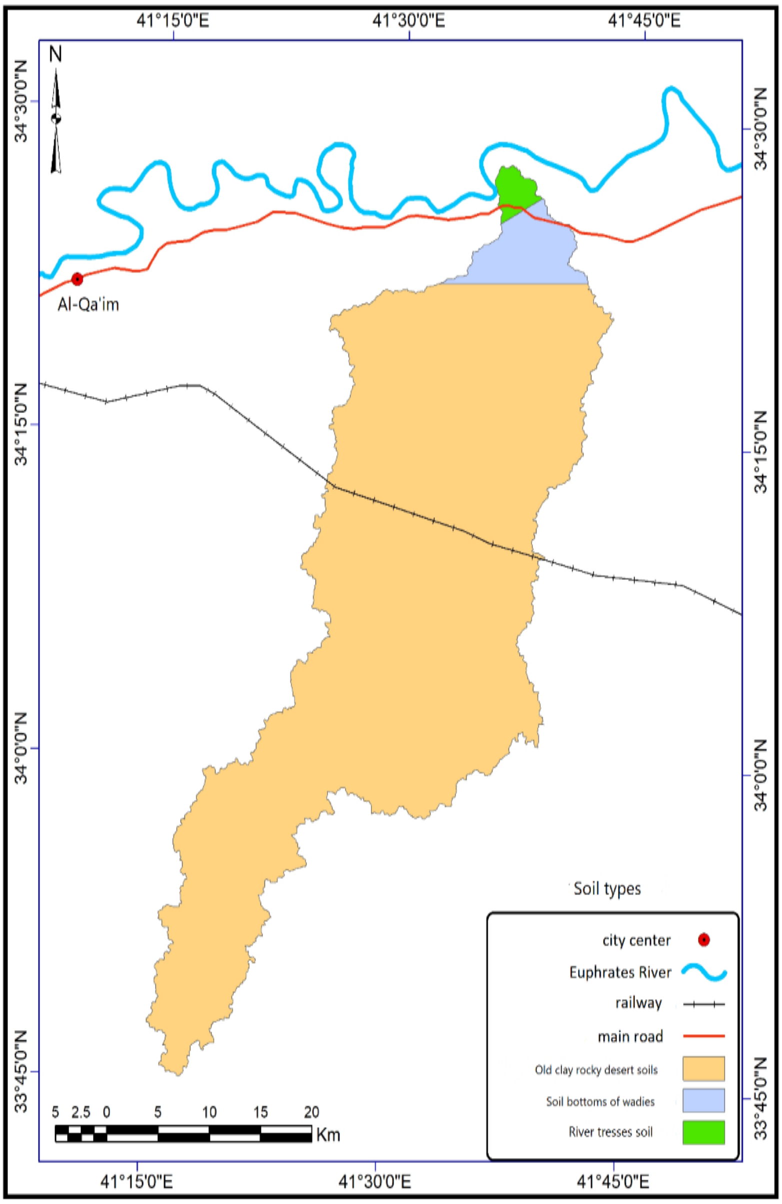

Figure 8. Soil types of the study area

Table 2. Values of the crop management factor for each type of land use

No.	land use	Crop management coefficient values C
1.	irrigated agricultural land	0.61
2.	pasture	0.3
3.	barren lands	0.1
4.	Built-up areas	0.8

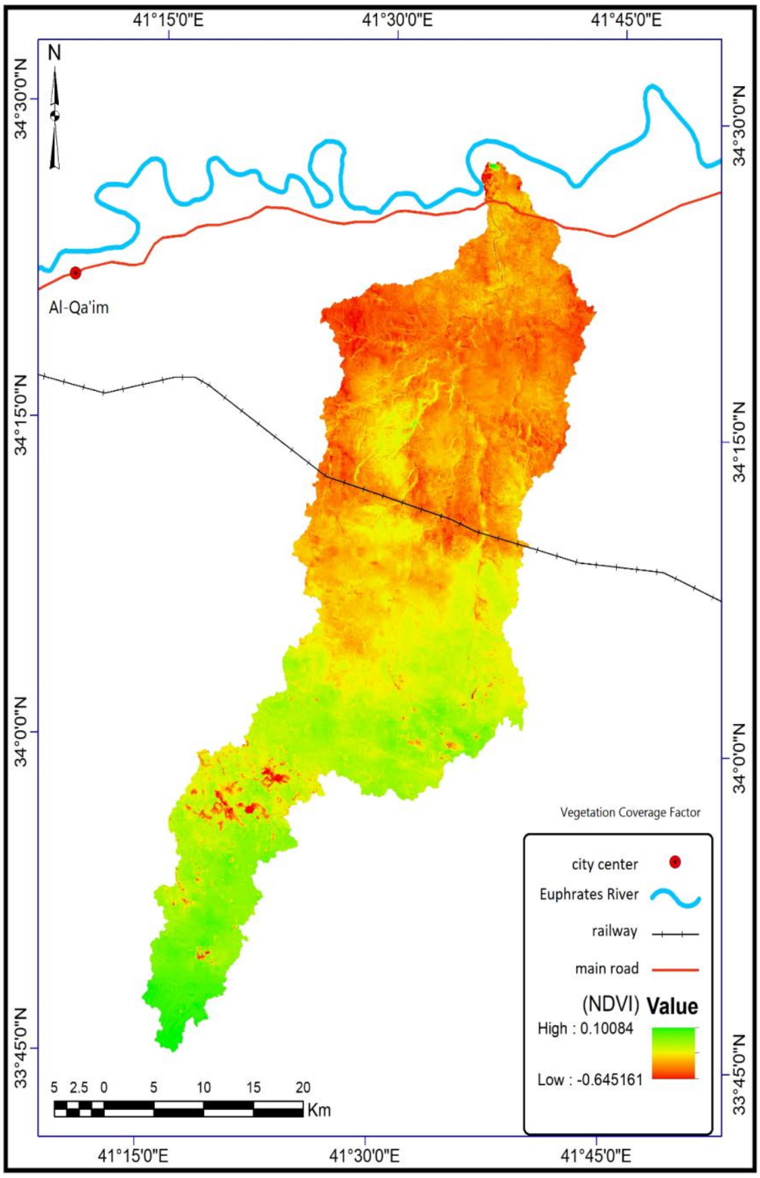

Figure 9. Distributions of the NDVI vegetation factor

Factor P: Soil Management Practices:

This factor shows the extent of soil loss because of reducing agricultural practices, such as contour plowing or terraces, etc., and thus its contribution to the contour lines is at night. This factor is derived from land-use maps and regression ratios, and its value ranges from 0 to 1, Figure 10, Distribution of land cover varieties, Figure 12, Distributions of slope degrees in the study area.

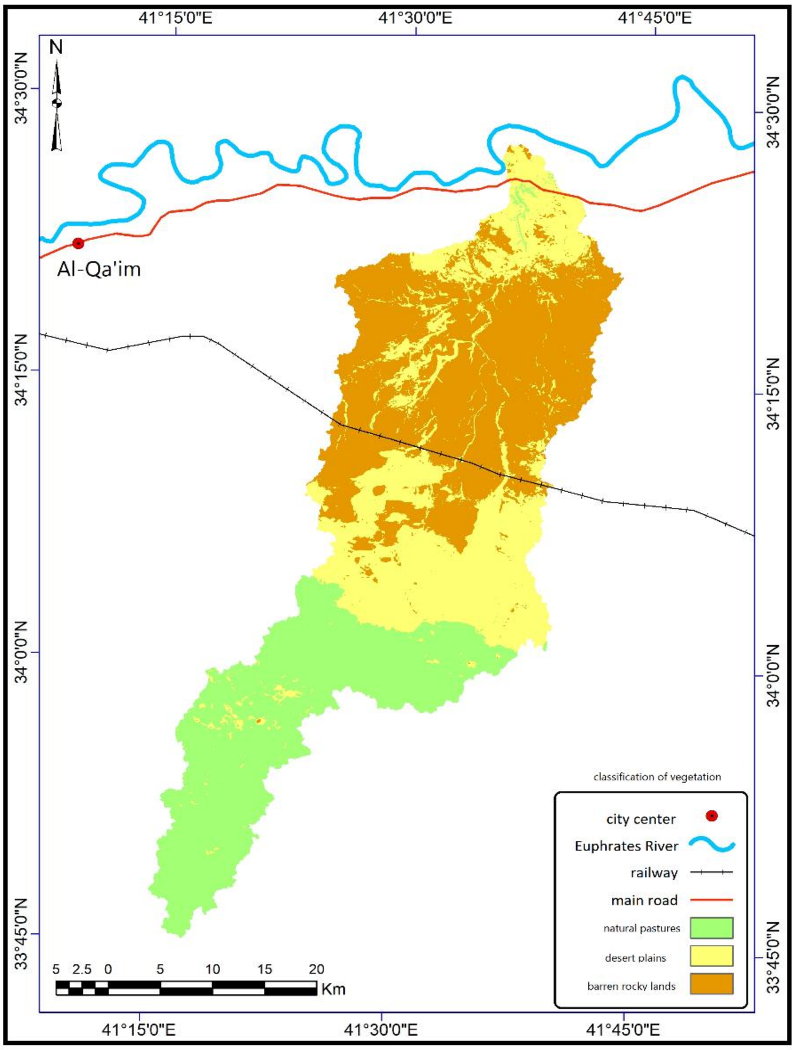

Figure 10. Distribution of land covers varieties in the study area

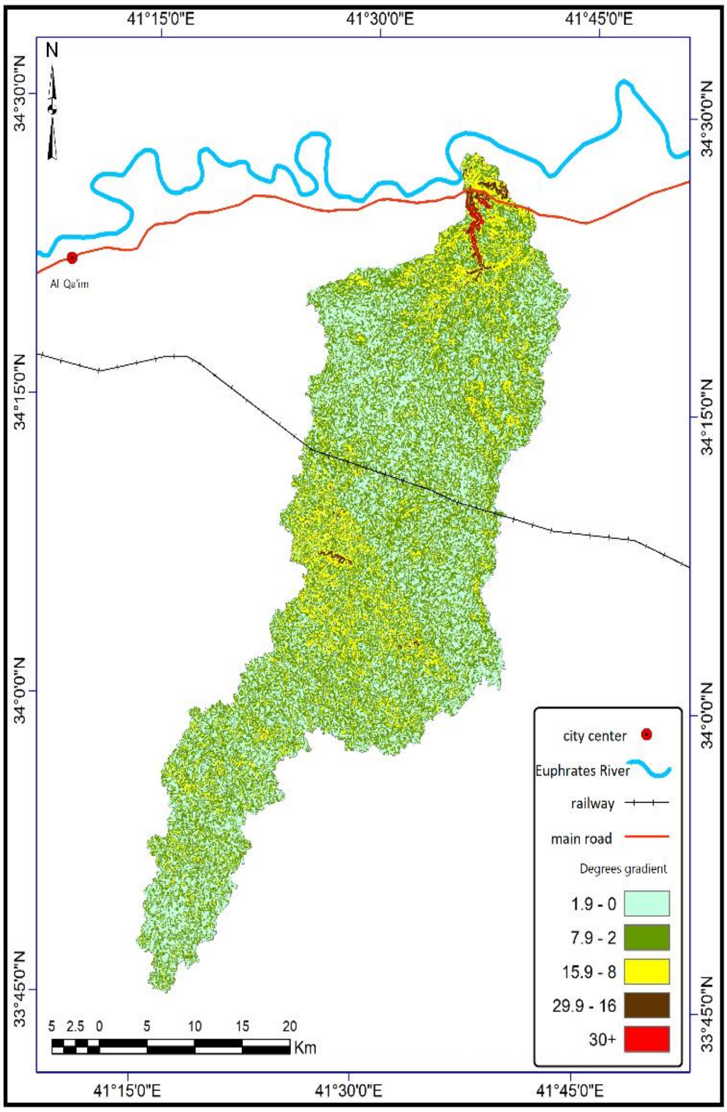

Figure 11. Distributions of slope degrees in the study area

3. Results and discussion

The water soil erosion map was derived after matching the above-mentioned layers overlays and transforming them into a Raster grid form. Samples were calculated and taken, and a water soil erosion map was extracted.

Five types of soil susceptible to erosion were estimated (k-factor), which appropriately expresses the size of soil degradation in the study area using GIS technologies and soil characteristics within the studied sites distributed within the valley watershed according to [27]. As shown in the table, the values were between (0.05541-0.4925), figuer13, Soil erosion classification map, table3, Areas, and rates of water erosion.

A map of erosion risks was created by integrating all the estimated factors for the characteristics of the soil and the environment according to the RUSLE equation to create a map of erosion and soil erosion using k-factor values. The map shows the risks of soil erosion, a distribution of erosion susceptibility differences for the study area where the severe erosion case is shown Within the middle region of the wadi watershed with values ranging between 0.3827-0.4923, while the same slight erosion level was within the delta of the valley and its tributaries with the Euphrates River. This region is characterized by the availability of dense vegetation cover as well as the presence of agricultural areas and the values of soil erosion susceptibility were between 0.05541 - 0.1599. The rest of the varieties were distributed in the beginnings of the southern valley and some other areas depending on the characteristics of the soil and the characteristics of the ecological environment of the wadi system, Figure.14, Soil erosion risk distributions, Figure 15. Statistical distributions of the severity of soil erosion in the study area.

The natural distribution function indicating the standard estimation in the NDVI values indicates that most of the values are close to the zero value in the cultivated areas with a density of natural vegetation, which is less dangerous in terms of the possibility of erosion. As for the large values from areas with scattered vegetation cover and bare land, which are exposed to erosion and water erosion, they appear in the figure vegetative. The close investigation of the P factor within the RUSLE equation revealed that there are more positive values that indicate the organic content in some of the studied soil sites.

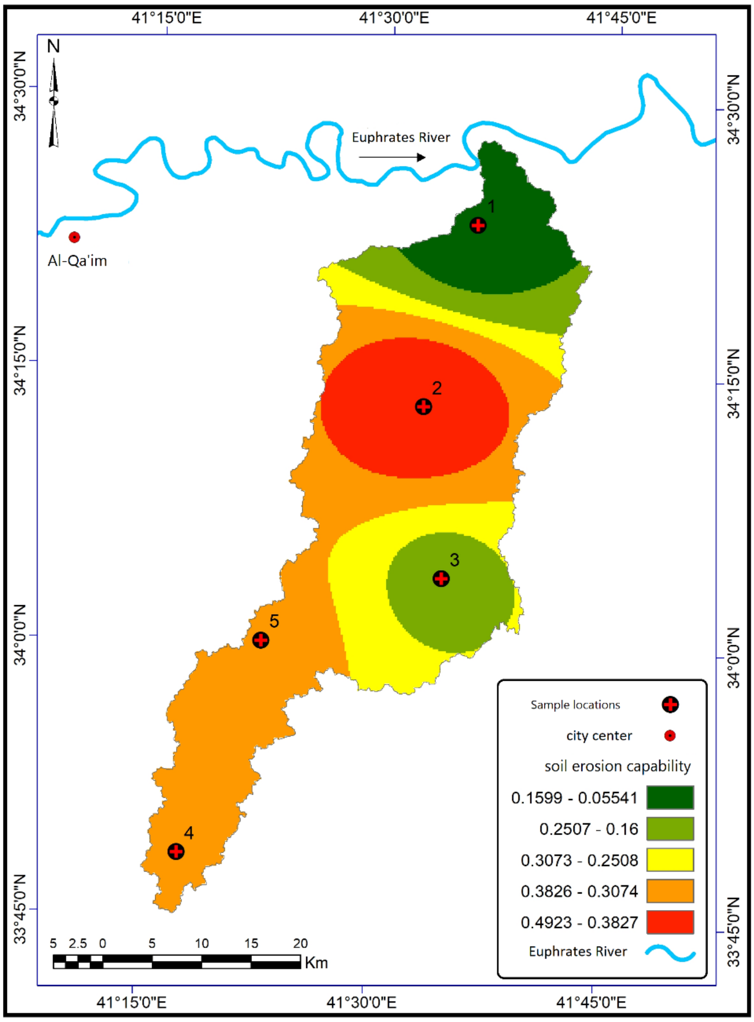

Figure 12. Soil erosion classification map.

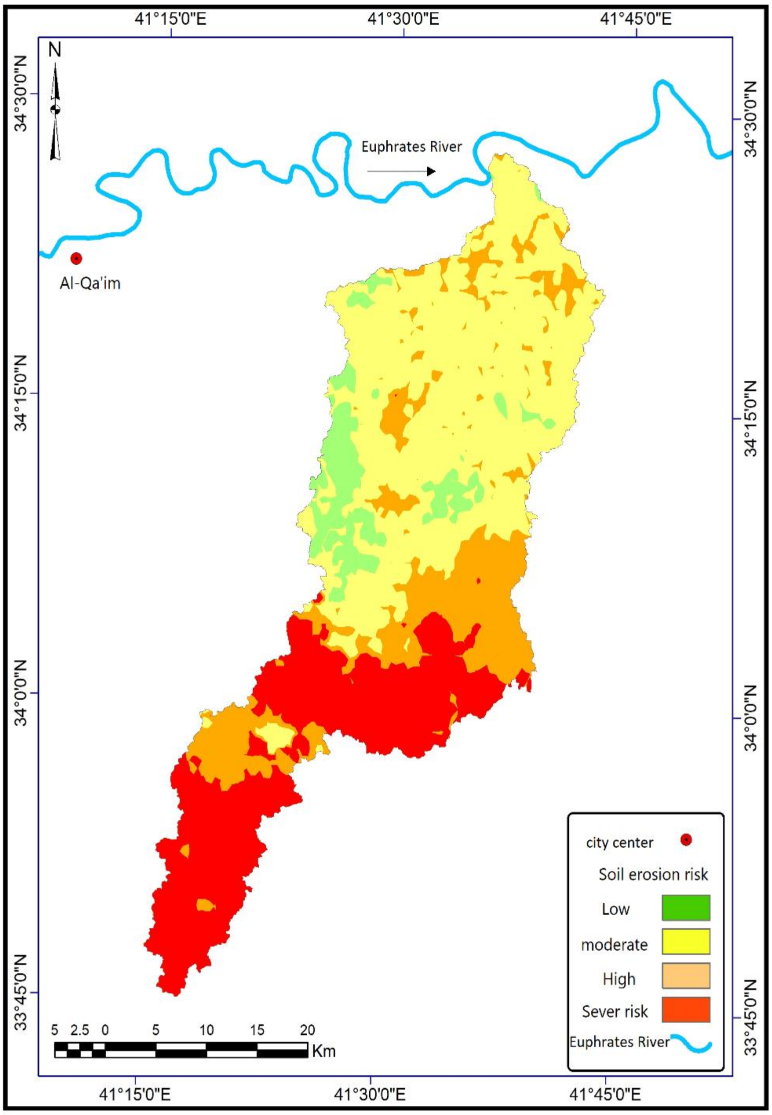

Figure 13. Soil erosion risk distributions

Table 3. Areas and rates of soil erosion

erosion hazards	Area km^2	%
Low	91.20	7.00
moderate	604.10	46.40
High	250.30	19.22
Severe	356.40	27.37
Total	1302	100.00

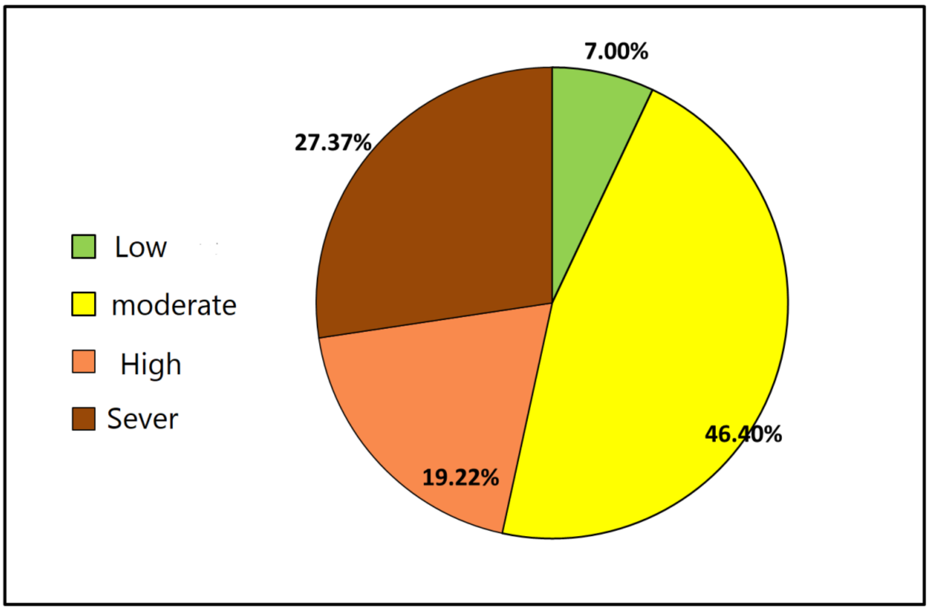

Figure 14. The severity of soil erosion in the study area

4. Conclusions

The values of soil erosion susceptibility were in the range 0.0551-0.4923. The areas of the severe actual risk of erosion with high values were concentrated in the central areas of the watershed of the wadi, while the low values of soil erosion were within the valley delta and the average values of erosion susceptibility were distributed mostly within the southern locations of the valley formation. The average values of the soil erosion risk were distributed over an area of 604.10 km2 with a rate of 46.40%, while the low values of soil erosion were distributed over an area of 91.20 km2 at a rate of 7.0%.

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