Nat. Volatiles & Essent. Oils, 2021; 8(5): 11417-11441

Quantitative Assessment Of Soil Loss Prediction Using The Revised Universal Soil Loss Equation (RUSLE) In A GIS Framework In Wadi Dhahban, Asir Region, Saudi Arabia

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ABSTRACT

This paper aims to estimate the amount of soil loss by water erosion basin for Wadi Dhahban, through the application of the global equation for soil loss (R * K * LS * C * P). Rainfall (R) was calculated by collecting monthly rainfall data for the period between1980-2020, Monthly Precipitation Datasets, World Clim. 2.1 (January 2020). The map of the aggressive rain factor, in addition to the map of soil erosion factor (K), has been prepared, through the results of the analysis of soil texture. Then, the map factor (LS) which is the gradient grade slope length is obtained through the ArcGIS program. Besides, a land use map of the (dimensionless) C-factor land management factor, which took into account the role of different types of vegetation cover and different methods of land use, has been prepared. The (dimensionless) conservation practice factor (P-factor) relies on soil conservation techniques and the data set to (Landsat 8, (ASTER) Global Digital Elevation Model Version 3 (GDEM 003), and the global land use/land cover (LULC) map). This shows that an extended part of the area is undergoing a severe loss. The mean annual soil loss is predicted as about 36.99 (t/ha-1 year-1) for some watersheds that show extended soil loss. The degrees of soil loss are classified into slight, moderate, high, very high, severe and very severe). Soil loss decreases not only agricultural productivity, but also reduces the water availability. In the current study, an effort to predict potential annual soil loss has been made. For the prediction, the Revised Universal Soil Loss Equation has been adopted in a GIS framework. The RUSLE factors were calculated (in the form of raster layers) for Wadi Dhahban to create soil erosion maps, which can serve as effective inputs in deriving strategies for land planning/management in the environmentally sensitive mountainous areas.

Keywords: Soil loss; Erosivity; Watershed; RUSLE model; RS; GIS

1- Introduction :

Soil erosion is a natural process driven by physical factors (rain or surface runoff). However, the occurrence of erosion processes and how intensive they are depending also on soil properties, topography, and vegetation cover (Drezewiecki, 2014, p.867). The soil detachment rate increases rapidly along with rainfall intensity (Jones et al., 2004).

Various approaches and equations for risk assessment or predictive evaluation on soil erosion by water are available in international literature. Wischmeier and Smith (1965, 1978) analyzed and assessed various dominating factors of soil erosion and introduced the universal soil loss equation (USLE). A revised version of this model (RUSLE) further enhanced its capability to predict water erosion (Renard and Freimund, 1994; Renard et al., 1997; Yoder and Lown, 1995).

Moreover, the combined use of GIS and erosion models has proved to be effective for estimating the magnitude and spatial distribution of erosion (Cox and Madramootoo, 1998; Erdogan et al., 2007; Fernandez et al., 2003; Fu et al., 2006; Gong, 2001; Lewis et al., 2005; Lim et al., 2005; Millward and Mersey, 1999; Mitasova et al., 1996; Molnar and Julien, 1998; Wu and Dong, 2001; Wu and Wang, 2007; Yitayew et al., 1999), though it has some drawbacks(Li et al. 2011) .

USLE remains the most practical method for estimating soil erosion potential (Dennis and Rorke, 2000). Soil erosion dynamic is influenced by spatial heterogeneity such as land use/land cover (LULC). Soil erosion estimation and prediction are relevant at a wide range of spatial scales (Vrieling, 2006), especially the larger scales (Bonilla et al. 2010). This is where remote sensing (RS) and GIS become more valuable. RUSLE is one of the most widely used (Wischmeier & Smith 1978; Renard et al. 1997;

Yuksel et al. 2008; Adediji et al. 2010; Prasannakumar et al. 2012) and has been applied in areas of different spatial scales and environmental conditions (Angima et al. 2003; Cohen et al. 2005; Prasannakumar et al. 2012).

Linking soil erosion models with RS and GIS rapidly produces input data to simulate different soil erosion scenarios and enables the massive catchments area (De Roo 1996). Areas can be simulated at a user-defined resolution (Xia & Clarke 1997; Qinke et al. 2002; Renschler & Flanagan 2002), and visualization displays a sequence of model output across time and space. Various studies show the potential use of RS and GIS in soil erosion mapping, soil, rainfall, vegetation cover and topography information (Narayana & Babu 1983; Dwivedi et al. 1997; Hill & Schütt 2000; Fu et al. 2005; Metternicht & Gonzalez 2005; Dabral et al. 2008; Kouli et al. 2009; Bonilla et al. 2010; Hasan et al. 2013).

2- The main purposes and research question:

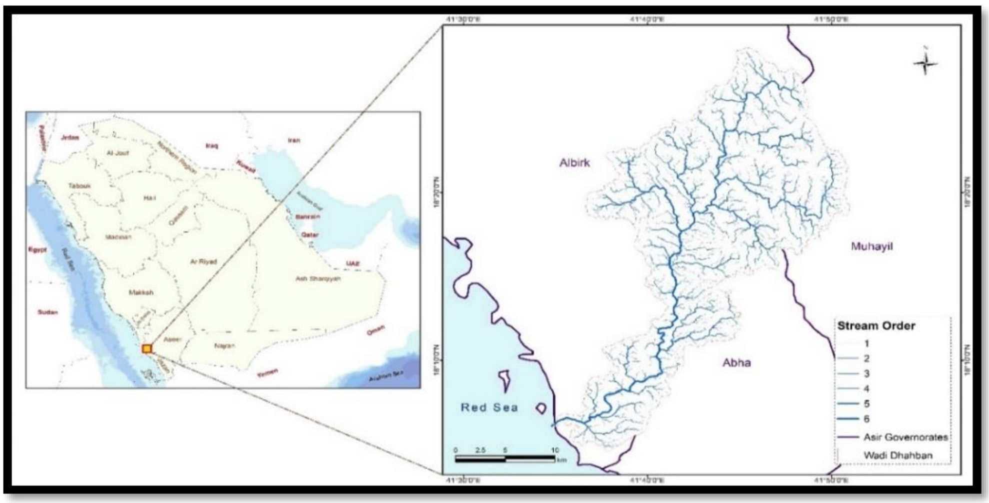
This research is to develop a framework for assessing soil loss using RUSLE based on the spatial data in Wadi Dhahban sub-watershed, to map its erosion magnitude and potential. This region has been subjected to intense deforestation since the early 18th century despite the recent limited efforts on soil conservation soil erosion. The results of the erosion map are utilized to identify the physical factors causing erosion and to plan soil conservation strategies for sub-watershed.

3-Physical Presentation of Wadi Dhahban:

3-1- Study area:

Wadi Dhahban is located in Al-Birk governorate. It combines the marine and mountainous nature, with a total length of watercourses 509.87 km², and circumference of 162.068 Km, Fig.1 and Plate.1. The tributaries of Wadi Dhahban are Wadi Lihad, Wadi Ash-Shijn, Wadi Sha`Ib Manghal, Sha`Ib Jabal Ash-Shufyanah, Sha`Ib Jabal Al Mudawwarah, Sha`Ib Jabal Ad-Dubayb, Sha`Ib Jabal `Azqah, Sha`Ib Dankan, Sha`Ib Baralan, Sha`Ib Al Qawz, Sha`Ib Al-Falakah, and Sha`Ib Al-`Udrut .

Fig.1: Location of the study area



Source: ArcGIS Pro 2.8.1, Spatial Analysis using (ASTER) Global Digital Elevation Model Version 3 (GDEM 003), Ministry of Economy, Trade and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA)

Plate. 1: Wadi Dhahban stream

Source: https://twitter.com/binsheqban/status/1207937298521829376?s=20

3-2- Geological Formation:

The watershed of Wadi Dhahban stems from the foothills area, which is the reason for its designation. It spreads by means of hills of volcanic and rift origin, and it is covered by alluvial soil gravel. Besides, the height of these hills decreases, and they have strong escarpments and slopes. Therefore, the inhabitants constructed agricultural terraces on their slopes wherever they were able to do so, and the numerous wadis whose upper streams coincide with the fault axes scattered in the region, are narrow gorges where erosion activates to deepen and widen their courses (Al-Zahrani, 2006, pp. 18- 19).

The surface of Wadi Dhahban basin was created by various surface formations in terms of composition and structure of rock and geological age. The rocks are igneous and metamorphic that belong to the Pre-Cambrian era. Besides, fuses of modern volcanic rocks are present at the end Cliffside Mountain sedimentary rocks above the base rocks. The study area consists of seven surface geological formations as follows Fig. 2 and Table.1:

Qsb: Sabkhah deposits—Salt-impregnated sediment along the Red Sea coast

Qal: Alluvial deposits—Sand and gravel in wadis, reworked loess, and wadi flood-plain silt deposits

Qs: Sand, Silt, and Gravel—Mainland: pediment and sand deposits; some eolian sand and silt; linear dune ridges

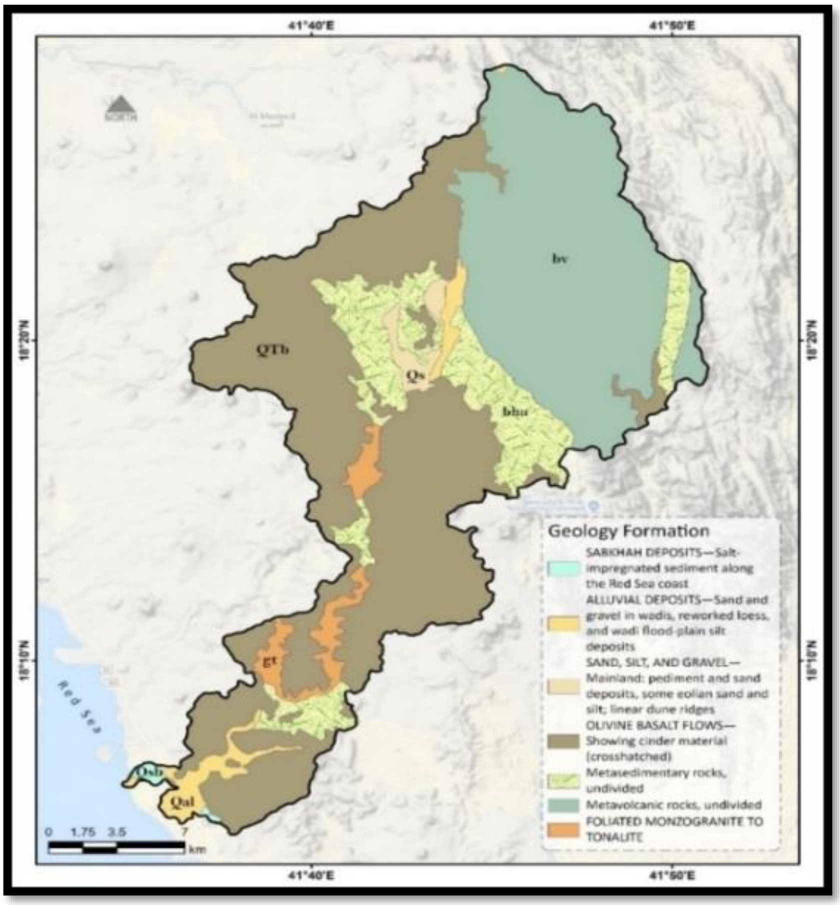
QTb: Olivine Basalt Flows—showing cinder material (crosshatched)

bhu: Meta-sedimentary rocks, undivided

bv: Meta-volcanic rocks, undivided

gt: Foliated monzogranite to tonalite

Fig. 2: Geology formation of Wadi Dhahban



Source: ArcGIS Pro 2.8.1, Data Visualization using Saudi Geological Survey (SGS), 250k, Ministry of Energy and Mineral Resources, Deputy Ministry for Mineral Resources, Sheet of Wadi Haliy

Table.1: Geological formation groups and area (km²)

Classification	Formation	Time	Area (km2)	%
Qsb	SABKHAH DEPOSITS—Salt-impregnated sediment along the Red Sea coast	Quaternary	1.84	0.36
Qal	ALLUVIAL DEPOSITS—Sand and gravel in wadis, reworked loess, and wadi flood-plain silt deposits	Quaternary	13.86	2.71
Qs	SAND, SILT, AND GRAVEL—Mainland: pediment and sand deposits, some eolian sand and silt; linear dune ridges	Quaternary	7.06	1.38
QTb	OLIVINE BASALT FLOWS—Showing cinder material (crosshatched)	Proterozoic	245.13	47.91
bhu	Meta-sedimentary rocks, undivided	Proterozoic	69.45	13.62
bv	Meta-volcanic rocks, undivided	Proterozoic	159.36	31.11
gt	FOLIATED MONZOGRANITE TO TONALITE	Proterozoic	14.74	2.91
	Total		**511.44**	**100**

Source: Excel, Summary Statistics, Saudi Geological Survey (SGS), 250k, Ministry of Energy and Mineral Resources, Deputy Ministry for Mineral Resources, Sheet of Wadi Haliy

In addition, the gradual weakening of the granite basement is explained by the old erosive action preceded by a long period of mechanical and chemical weathering associated with a high density of faults and cracks.

3-3- Morphometric Analysis of the Hydrography of the Streams and Basins of Wadi Dhahban:

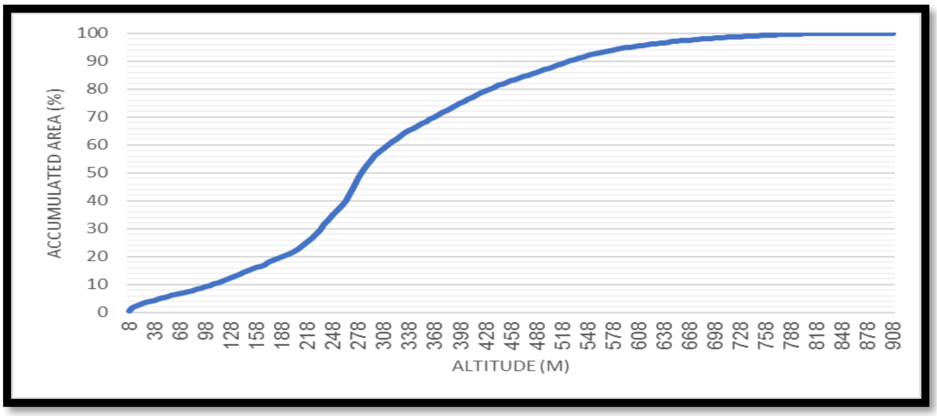
The morphometric and hypsometric indices as well as the competence of the hydrographic network are among the primordial factors intervening in the current erosive dynamics. As a result, the watershed shows significantly favorable morphometric and topographic conditions for the concentration of runoff estimated as 12 hours and 30 minutes. Thus, the concentration of runoff can turn into a real flood in a considerably short period of time. By referring to the general hypsometric curve, the difference and the specific difference in level, the average altitude and the overall slope index, this watershed shows a powerful relief and a clearly gathered shape with a compactness index of the order of 2.03 (Table.2 and Fig.3). A disadvantage of RUSLE is that it does not consider the water and hydrological aspects involved in the manifestation of erosive processes, yet they determine the violent behavior of some watercourses.

Table. 2: The morphometric and hydrological characteristics of the watershed of Wadi Dhahban

Basin	Area	Perimeter	Compactness Factor	Length L	Width W	Drainage texture	Tc	Flow rate (m/s)	slope index	Average altitude (m)	Hydrographic density (Streams/km2)	Drainage density (km/km2)	Total length of water courses (km)	Number of streams
Wadi Dhahban	**509.87**	**162.07**	**2.03**	**40.89**	**12.47**	**6.48**	**750**	**0.89**	**17.34**	**305.60**	**0.56**	**2.14**	**1092.18**	**1345**

Source : EXCEL & ArcGIS Pro 2.8.1, Statistical Analysis, (ASTER) Global Digital Elevation Model Version 3 (GDEM 003), Ministry of Economy, Trade and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA)

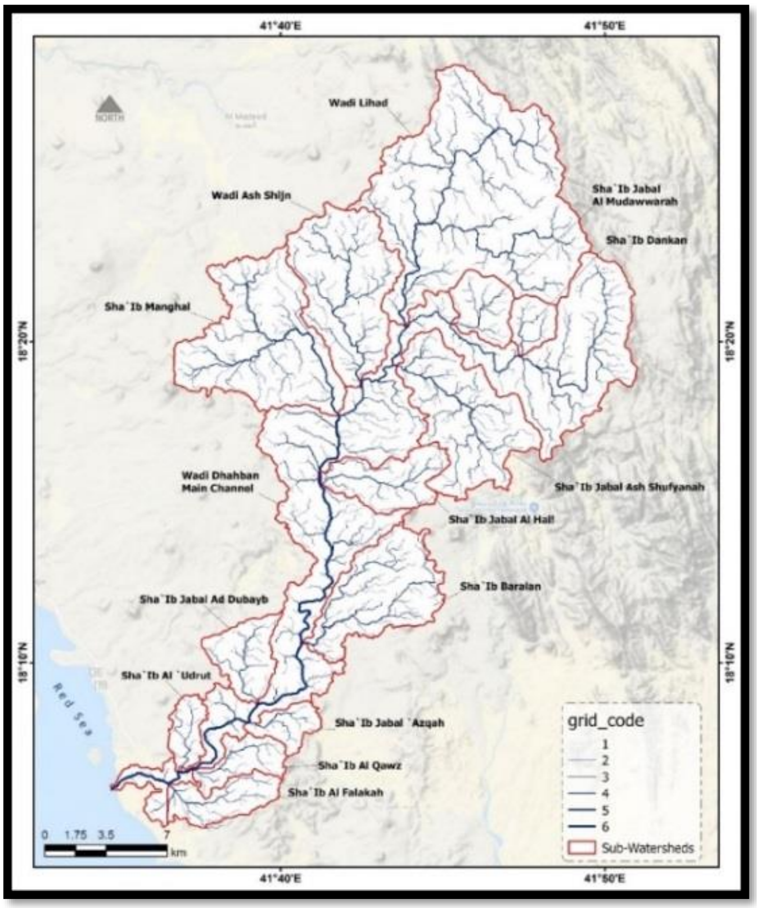
Fig. 3: Hypsometric curve of the watershed of Wadi Dhahban



Source : SAGA GIS (2.3.2), Summary Statistics, (ASTER) Global Digital Elevation Model Version 3 (GDEM 003), Ministry of Economy, Trade and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA)

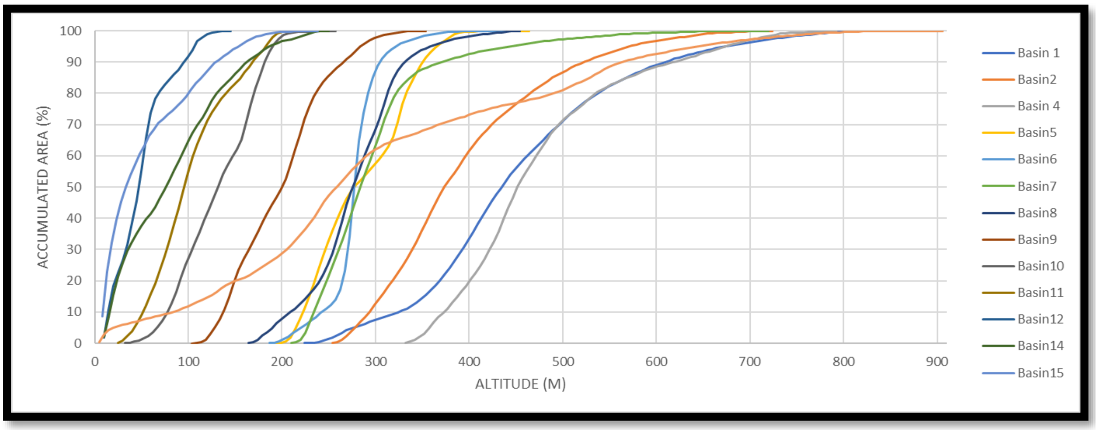
The situation is more complex if we consider the sub-watersheds (Fig.4). A more detailed study of the different tributaries will allow for the determination of the part of each sub-watershed in the mobilization of sediments along the impluvia. Two groups clearly specifying sub-basin slopes were cleared. The first group includes the two upstream sub-watersheds having a rigorous hypsometric curve. These conditions are capable of generating waterfalls and torrential flow, especially during occasional heavy rains. The second group includes four sub-basin slopes in the middle and downstream are less varying, less rugged and more elongated (Fig 5 and Table. 3).

Fig. 4: Sub-watersheds of Wadi Dhahban



Source: ArcGIS Pro 2.8.1, Spatial Analysis using (ASTER) Global Digital Elevation Model Version 3 (GDEM 003), Ministry of Economy, Trade and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA)

Fig. 5: Classification of the hypsometric curves of the sub-watersheds of Wadi Dhahban



Source : SAGA GIS (2.3.2), Summary Statistics, (ASTER) Global Digital Elevation Model Version 3 (GDEM 003), Ministry of Economy, Trade and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA)

Table. 3: Morphometric and hydrological characteristics of the sub-watersheds of Wadi Dhahban

Basin	Area	Perimeter	Compactness Factor	Length L	Width W	Drainage texture	Tc	Flow rate (m/s)	slope index	Average altitude (m)	Hydrographic density (Streams/km2)	Drainage density (km/km2)	Total length of watercourses (km)	Number of streams
Sha`Ib Al-`Udrut	6.67	13.19	1.44	4.60	1.45	1.14	150	0.72	10.54	49.22	2.70	2.13	14.20	18
Sha`Ib Al-Falakah	12.34	20.53	1.65	6.28	1.97	1.46	240	0.64	10.08	52.54	3.16	2.62	32.36	39
Sha`Ib Al-Qawz	9.58	18.15	1.65	5.19	1.84	1.05	150	0.89	14.96	81.36	2.51	2.19	20.93	24
Sha`Ib Baralan	31.75	31.31	1.57	9.51	3.34	2.08	210	0.65	9.97	197.64	2.55	2.47	78.30	81
Sha`Ib Dankan	6.69	10.66	1.16	3.59	1.87	1.31	90	1.16	26.75	473.58	2.70	1.94	12.95	18
Sha`Ib Jabal `Azqah	6.86	13.42	1.45	4.06	1.69	1.12	180	1.04	20.72	101.88	2.77	1.98	13.56	19
Sha`Ib Jabal Ad-Dubayb	13.08	17.78	1.39	5.64	2.32	1.46	180	0.88	14.65	130.69	2.67	2.04	26.70	35
Sha`Ib Jabal Al-Hal!	16.79	21.81	1.50	7.06	2.38	1.60	210	0.79	13.13	276.27	2.56	2.44	40.90	43
Sha`Ib Jabal Al-Mudawwarah	11.06	14.53	1.23	3.88	2.85	1.51	90	1.16	26.21	393.35	2.62	2.06	22.74	29
Sha`Ib Jabal Ash-Shufyanah	39.72	38.40	1.72	9.59	4.14	2.29	210	0.90	17.22	297.12	2.95	2.21	87.61	117
Sha`Ib Manghal	52.83	40.27	1.56	11.26	4.69	2.63	360	0.61	9.95	276.30	2.57	2.22	117.00	136
Wadi Ash-Shijn	41.93	32.80	1.43	10.85	3.86	2.80	270	0.79	12.95	284.60	2.84	2.14	89.66	119

Main Channel of Wadi Dhahban	**150.23**	**176.25**	**4.06**	**40.89**	**3.67**	**1.71**	**750**	**0.93**	**18.31**	**301.34**	**2.54**	**2.07**	**311.01**	**382**
Wadi Lihad	**110.32**	**58.72**	**1.58**	**15.34**	**7.19**	**3.76**	**345**	**1.09**	**24.16**	**452.80**	**2.58**	**2.03**	**224.22**	**285**

Source: EXCEL & ArcGIS Pro 2.8.1, Statistical Analysis, (ASTER) Global Digital Elevation Model Version 3 (GDEM 003), Ministry of Economy, Trade and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA)

3-4- Aspects of the vegetation cover :

The vegetation cover in Wadi Dhahban is characterized by its diversity, inconsistency and density. It has a lot of crops, seasonal annuals and perennial trees, and it is occupied by degraded forests: dense on the high slopes and sometimes in the form of bushy tufts of two meters high. It consists mostly of Juniperus procera trees, Ficus Sulicifolia, Olea Chrysophylla, and Dodonea Viscosa. Part of the land has turned into cultivated plants including almonds, apricots and apples. The most important types that exist are Acacia Seyal, Acacia tortilis and Acacia Flasciculata. Some types are of terminal trees, including Tamarix gallica, Tamarix aphylla, Salvadora persica, Zezyphonus spina Christi, Mistletoe, Contourea sp., Plam, Hyphaene thebica and Lawsonia inermis Plate 2.

Plate. 2: Natural vegetation cover of Wadi Dhahban

Source: (A field study in May 2021).

The most important crops are in agricultural terraces: wheat, barley, maize, all kinds of vegetables and leafy vegetables, pomegranates, peeled almonds, peaches, grapes, figs, prickly pears, apricots, citrus fruits, rose plantations, palm and watermelon .

However, this plant cover is seriously degraded due to the persistence of long dry periods and the irresponsible behavior of the inhabitants who have largely exploited its wood in the construction of the roofs of traditional houses. The slaughter and devastation of herds have also led to frequent drying out of the old forest cover, which has experienced a notable reduction in its area in the recent decades. This has prevented any regeneration of this natural plant cover. The proofs of this observation are the predominance of slopes strewn with dried junipers, even in the areas protected by the State.

3-5- Developments located on the main Wadi Dhahban:

The dry-stone cords and retaining walls are found in the places biologically supported through certain plant species, notably Acacia, Tamarix and Juniperus. Those ancestral works aim to preserve the agricultural terraces which run along the watercourse of Wadi Dhahban against the resumption of certain erosive phenomena. Such slope techniques have a dual function, both productive and preservative, and they act positively against the harmful effects of torrential rains. The terraces allow for the absorption and the good internal transfer of water. The retaining walls promote the continuous fattening of the terraces by settling overflow silt without preventing the flow of excess water downstream during occasional heavy rains, Plate. 3.

Plate. 3: Example of the slopes of Wadi Dhahban in the form of agricultural terraces

Source: (https://twitter.com/AbdulelahAlfars/status/1094699245351944194?s=20) and a field study in May 2021

4- Materials and Methods:

There are many methods that take into account soil erosion in watersheds, and these methods range from simple to more complex and vary in their need for data entry and ability to predict erosion. The universal soil loss equation (USLE) represents a soil erosion estimation model designed to calculate the quantity of soil removed by erosion. The USLE is empirically designed to compute the average of soil losses from the agricultural land (Wischmeier and Smith, 1978): was the most widely used model in predicting the loss of soil. It is described by the following Eq.:

$$A = [R] * [K] * [LS] * [C] * [P]$$

where :

A= the soil loss, expressed by the annual average rate of erosion (t/ha/y)

R= the rainfall erosion factor (MJ mm/h ha/y)

K= the soil erodibility factor (t ha h/MJ mm)

LS= the topographical factor (slope-length and slope-steepness) (dimensionless)

C= the land cover and management factor (dimensionless)

P= the factor of the works for erosion prevention and control (dimensionless)

After much research and application, the USLE was improved, which led to the development of the Revised Global Soil Loss Equation (RUSLE) which has the same formula as the USLE but with many factor-checking improvements. Agriculture Guide No. 703 (Renard et al. 1997) published by the United States Department of Agriculture (USDA) describes this equation in detail. Its developments include:

- Introduction of new algorithms for calculation, and new erosivity values of rainfall-runoff (R).
- In addition to new method to calculate the cover-management factor (C), using the sub-factors that include prior land use, crops, soil cover (including rock fragments on the surface) and roughness ground.
- Moreover, new forms of estimating factors slope length and steepness (LS) which consider the erosion percentages grooves and inter-grooves.

- The ability to adjust the LS factor for variable shape slopes; and new conservation practices values (P) for crops in alternating strips, use of grasslands and underground drainage. Therefore, the use of the RUSLE method is mostly suitable for watersheds in Wadi Dhahban.

5- Application of the Revised Universal Equation to the watershed of Wadi Dhahban in terms of quantification of soil loss:

It is arduous to separate the action of diffuse erosion from that of erosion concentrated in the watershed of Wadi Dhahban due to the interaction of multiple factors. The objective of this application is a rough approximation of the surfaces affected by degradation.

The state and behavior of cultivation terraces as per the rate of water erosion to the extent that they constitute a real threat heritage are highlighted. A drawback of this model is that it does not allow for the lobes of convex meanders of streams. The Revised Universal Equation of Land Losses is expressed by the multiplication of 6 factors related respectively to the potential erosion of rainfall (R), soil erodibility (K), the slope acting by its length and its value (LS), land Cover (C) and anti-erosion facilities (P). In order to be integrated into the GIS, this equation is frequently modified .

5-1- Rainfall-runoff erosivity factor (R-factor) :

Factor R expresses the rainfalls intensity, and it represents the local value of rainfall erosion index. It reflects the effect of rainfall intensity on soil erosion derived by Wischmeier (1959), according to the following formula:

$$\mathbf{EI} = E \times I_{30}$$

EI= the rainfall erosion index (MJ/ha) .

E= the total kinetic energy of the rainfall (t/ha) .

I_{30}= the maximum intensity of rain in 30 minutes (mm/h).

Rainfall average was calculated through the rainfall data for the period 1980-2020 through climatic stations and Spatial Analysis using Monthly Precipitation Datasets, World Clim. 2.1 (January 2020).

Changes were made to factor R's method of determination. The values of the coefficients expressing rainwater erosion are calculated by some mathematical relations using various climate data. The rainwater aggression exerted on the soils from Wadi Dhahban has been assessed as per modified Fournier index (FM) (Arnoldus, 1980) determined by the following equation:

$$FM = \sum_{i=1}^{12} \frac{Pi2}{P}$$

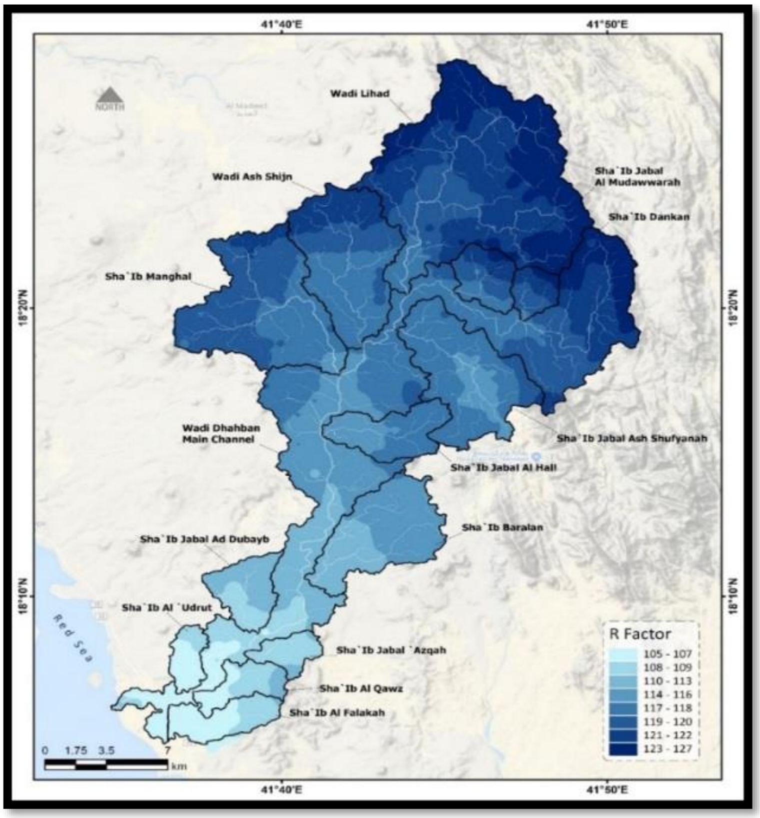
where :

Pi = the average amount of rainfall for the month i (mm);

P= the annual average amount of rainfall (mm) .

The map representing factor R of RUSLE equation (fig.6) shows the altimetric distribution of pluvial aggressiveness, with high values for highlands and low values in lowlands.

Fig. 6: Factor R of RUSLE equation calculated for Wadi Dhahban



Source: ArcGIS Pro 2.8.1, Spatial Analysis using Monthly Precipitation Datasets, World Clim. 2.1 (January 2020), 1980-2020

5-2- Soil erodibility Factor (K-Factor):

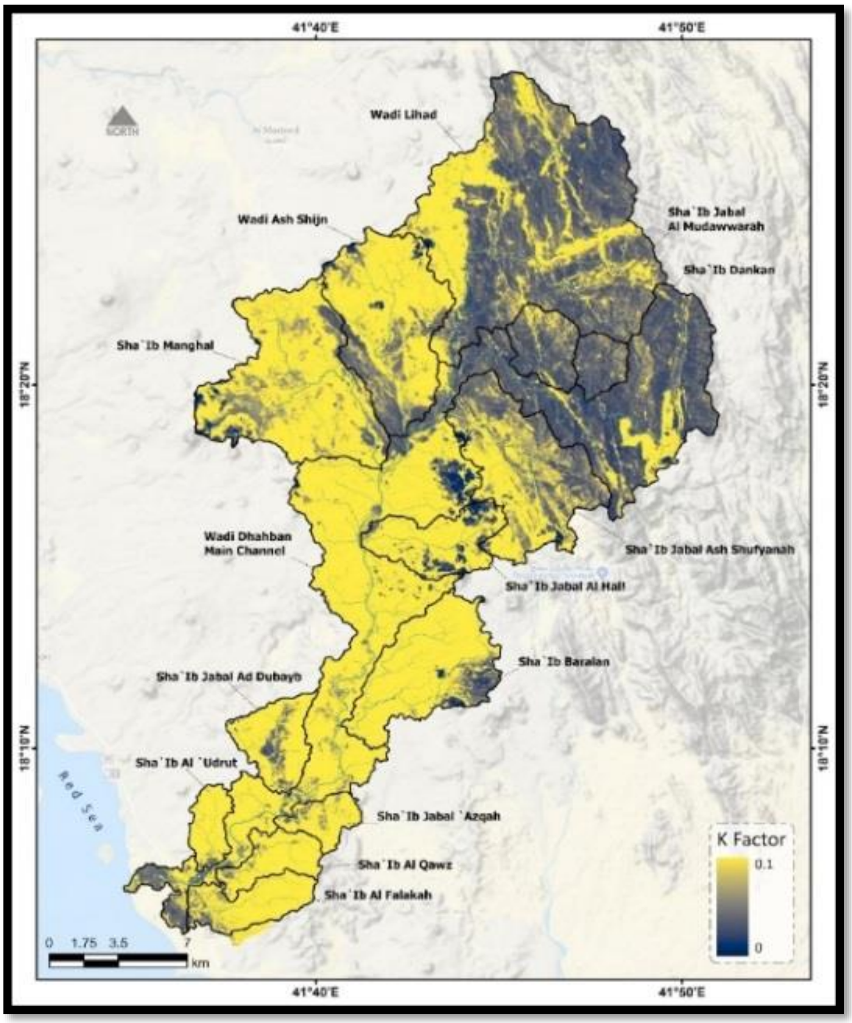
The most accurate method for determining the values of **factor K** is to perform measurements directly on the field. The soil-erodibility nomograph made by Wischmeier et al. (1971) is mostly used as the direct measurement is financially unfeasible. Within this nomograph, there are four soil parameters including texture, organic material content, soil coarse quantity, structure and permeability .

The values of **factor K** for the agricultural land of the study area are presented in Table.4, depending on the soil texture type. Fig.7 shows the map of factor K. A relatively low variation of soil erosion susceptibility exercised by precipitation and water runoff on slopes is noticed. The values are between 0.006 and 0.0513. This fact is due to the high homogeneity of soil granulometry composition. The biggest values appear in soils with high compaction. The soils with a high total porosity present an increased water infiltration capacity.

Table. 4: Factor K values according to soil texture

Soil texture	Factor K
Sandy loam	0.0389
Loamy sand	0.0584
Clay silt	0.0363
Silty clay	0.0690

Fig. 7: Factor K of RUSLE equation calculated for Wadi Dhahban



Source: ArcGIS Pro 2.8.1, Spatial Analysis using MEWA, Land Investment Department, Saudi-American Committee, 1984, 250k

5-3-Slope steepness and length (SL-Factor):

Factor LS is the topographic factor or Slope Length, and Steepness Factor (LS): a slope gradient factor (S) and a slope-length factor (L); both of which are determined by the Digital Elevation Model (DEM). In the calculation the transport capacity of overland flow (Surface runoff) (Morgan et al, 1984, pp.245-253), L represents the effect of slope length on erosion. The soil loss per unit area increases as the slope length increases (Ganasri et al, 2016, pp.953–961). S represents the effect of slope steepness on erosion where soil loss increases more rapidly with slope steepness than it does with slope length. The LS factor represents erodibility due to combinations of slope length and steepness relative to a standard unit plot. Simultaneously, Mitášová et al. (1996) propose also a formula for implementing this equation in ArcGIS software by which the map of factor LS can be obtained:

LS= Pow [(flow accumulation) × cell size / 22.1, 0.6] × Pow [Sin(slope) × 0.01745/ 0.09, 1.3]

Final, LS = L∗S

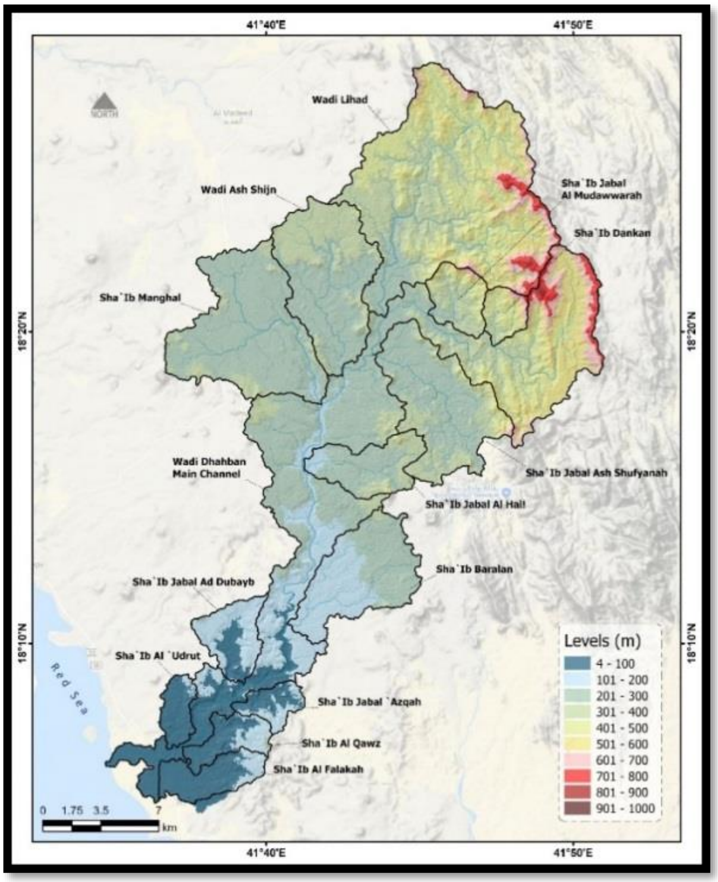
Where:

Flowacc (flow accumulation) = the flow accumulation, derived from DEM .

slope = the slope in degrees, derived from DEM after conducting fill, flow direction and flow accumulation processes in ArcGIS. Cell size is the size of the cells being used in the grid-based representation of the landscape. Finally, the LS factor map was derived using the above formula in ArcGIS spatial analysis raster calculator function.

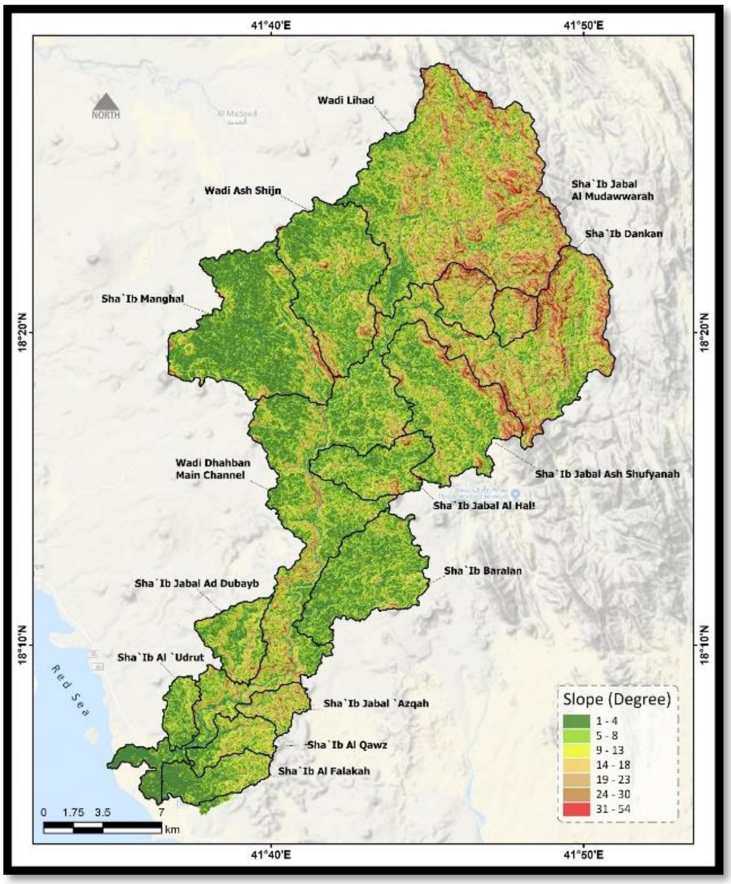
The slopes gradient and slope length factors were calculated from the DEM and combined to result in the topographical factor grid. The DEM for Wadi Dhahban (Fig.8, 9) was the foundation for developing the LS factor and defining the extent of the bounds of the analysis area (Wadi Dhahban). The watershed has an average slope of 18°. Almost 70% of the total area is marked by steep slopes that vary between 24 ° and 55°. However, 20% of the area having very steep slopes is between 0 ° and 55 °, while the weakest slopes with values less than 9 ° are significantly unrepresentative on the upstream course of Wadi Dhahban (Fig. 10).

Fig. 8: Digital Elevation Model of Wadi Dhahban



Source: ArcGIS Pro 2.8.1, Spatial Analysis using (ASTER) Global Digital Elevation Model Version 3 (GDEM 003),
Ministry of Economy, Trade and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA)

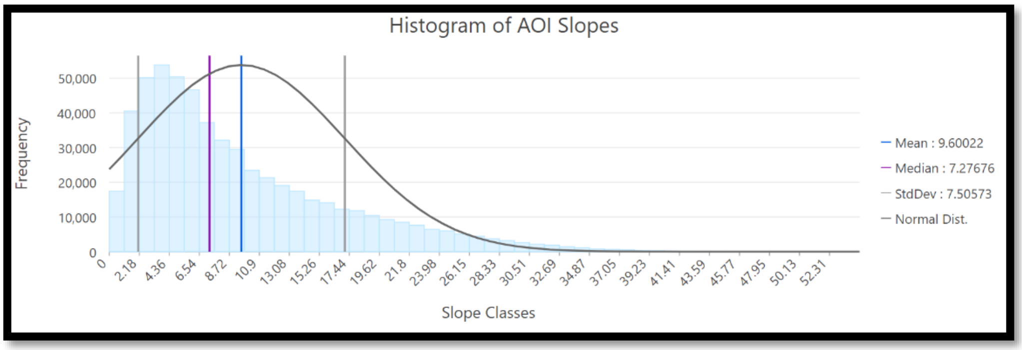
Fig. 9: Slope classes of Wadi Dhahban



Source: ArcGIS Pro 2.8.1, Spatial Analysis using (ASTER) Global Digital Elevation Model Version 3 (GDEM 003),

Ministry of Economy, Trade and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA)

Fig. 10: Histogram of AOI Slopes of Wadi Dhahban



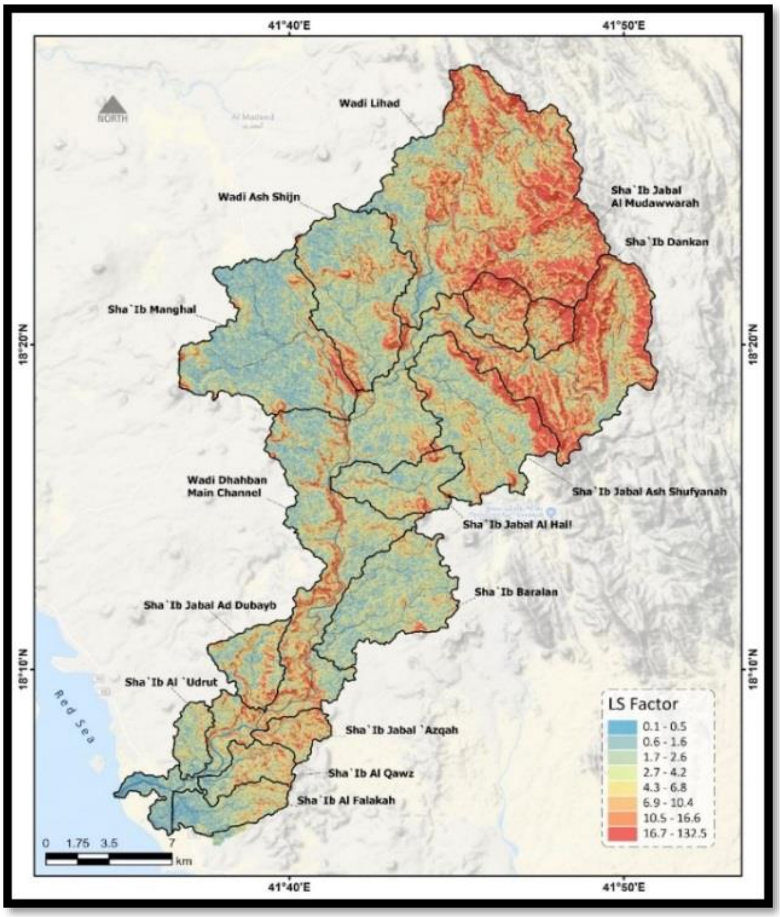
Source: ArcGIS Pro 2.8.1, Spatial Analysis using (ASTER) Global Digital Elevation Model Version 3 (GDEM 003),

Ministry of Economy, Trade and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA)

Importantly, the slope acts not only by its rigor but also by its length and, above all, by its shape. The slopes with a convex slope, particularly without a sufficiently thick colluvial mantle, are among the most privileged sectors for the opening of multiple channels and the development of small gullies.

The map of factor LS (Fig.11) reveals high values for more elevated areas on the, but also on some steeper slopes from the eastern side, where the relief is highly fragmented. The low values characterize the major riverbeds of the main wadi in the area. The map shows that the values of the factor of the degree and length of the regression (LS) range from zero in the flat areas and 132.5 in the areas of the steep, especially over the northeast and southwest slopes which stand out in the form of separate and scattered units in the central and northern parts of the basin of wadi Dhahban.

Fig. 11: Factor LS of RUSLE equation calculated for Wadi Dhahban



Source: SAGA GIS (2.3.2), Spatial Analysis using (ASTER) Global Digital Elevation Model Version 3 (GDEM 003),
Ministry of Economy, Trade and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA)

4-5- Crop/vegetation and land cover factor (C-Factor):

Factor C is probably the most important in RUSLE equation because it represents the conditions that can be most easily modified for reducing soil erosion. The parameters with the highest impact for C are represented by the vegetation coverage degree of the soil, the trees canopy, the land roughness and the previous mode of land use (Renard et al., 1997). The vegetation cover is the second most important factor next to topography that controls soil erosion risk. The land cover intercepting rainfall increases infiltration and reduces rainfall energy. Otherwise, the C factor is normally assigned by a simple assessment of the vegetation cover. In this study, the produced Land Use/Land Cover was used for preparing a C-factor map (Koirala et al, 2019, p.7).

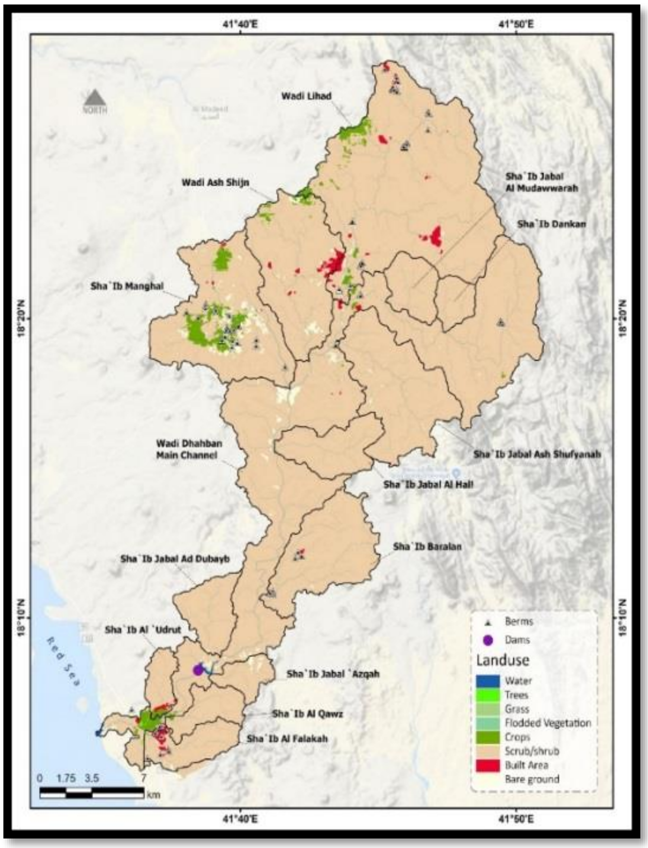
First, the raster map was converted to a polygon and the attributes with the same land use type were merged in ArcGIS are presented in table 5, and Fig. 12. The C factor ranges from 0 to approximately 1, where higher values indicate no cover effect and soil loss comparable to that from a tilled bare fallow, while lower C means a very strong cover effect (Erencin, 2000). The coefficients of factor C adapted for wadi Dhahban are presented in Fig. 13 shows the factor C of RUSLE equation determined for the study area.

Table 5: Land use of Wadi Dhahban

Land use	Area (km2)	%
Water	0.453	0.089
Trees	0.166	0.033
Grass	0.005	0.001
Flooded Vegetation	0.006	0.002
Crops	11.007	2.155
Scrub/Shrub	485.46	95.21
Built Area	4.583	0.90
Bare Ground	8.190	1.61
Total	**509.87**	**100**

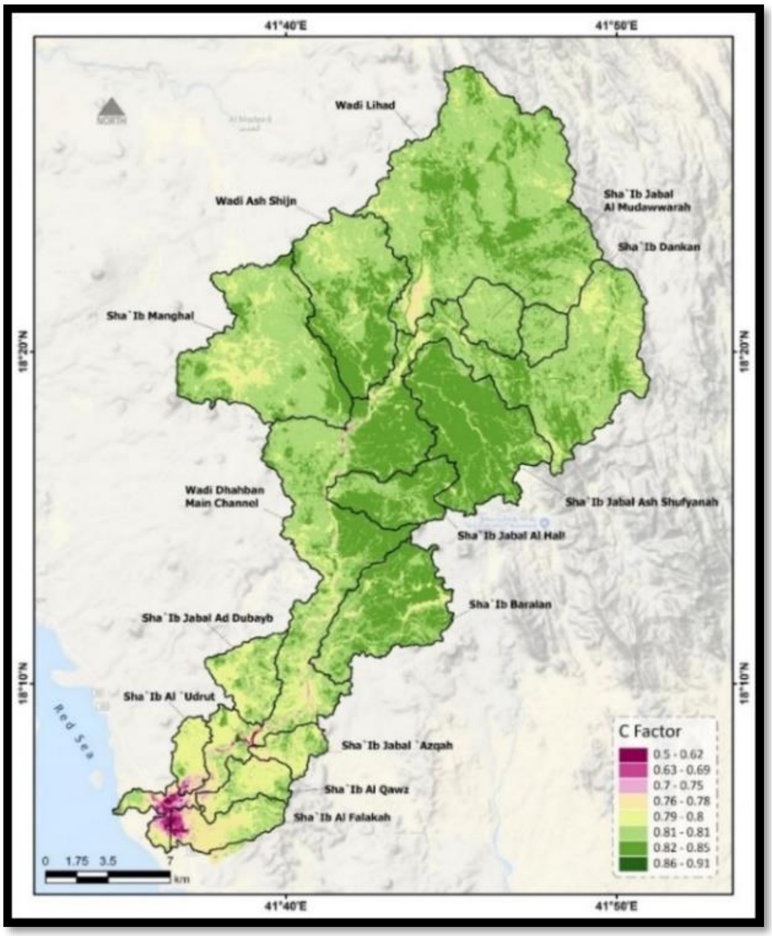
Source: EXCEL & ArcGIS Pro 2.8.1, Data Visualization using global land use/land cover (LULC) map, the Dynamic World Project by National Geographic Society in partnership with Google and the World Resources Institute, 2020, 10m Cell Size

Fig. 12: Land use of Wadi Dhahban



Source: ArcGIS Pro 2.8.1, Data Visualization using global land use/land cover (LULC) map, the Dynamic World Project by National Geographic Society in partnership with Google and the World Resources Institute, 2020, 10m Cell Size

Fig. 13: Factor C of RUSLE equation calculated for Wadi Dhahban

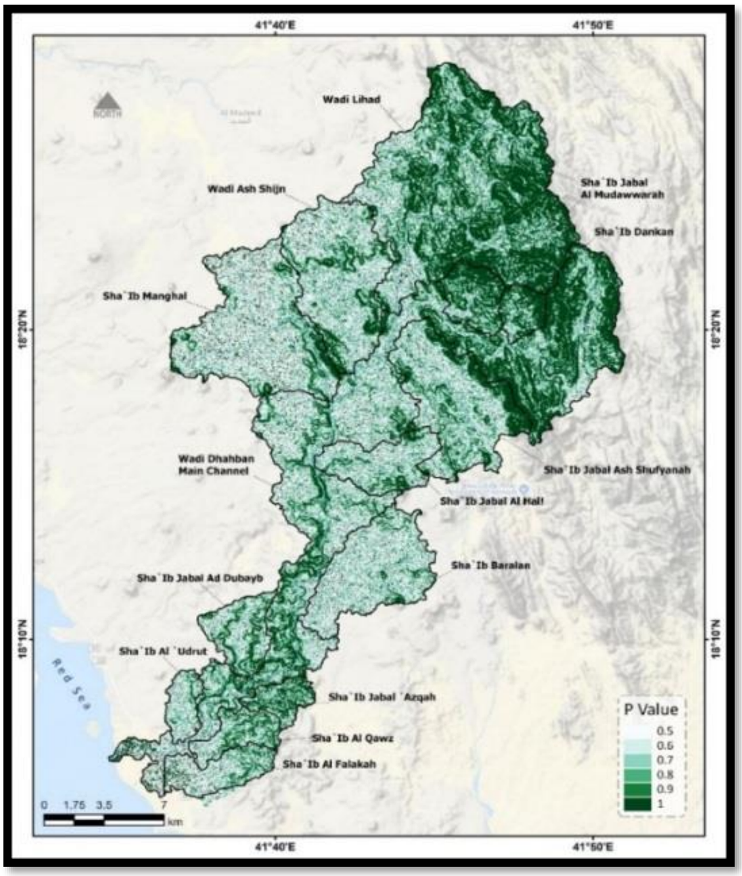


Source: ArcGIS Pro 2.8.1, Spatial Analysis using Landsat 8, OLI, 14 June 2012, WRS:168047

5-5- Support or Erosion Control Practice (P-Factor):

Factor P: the support practice factor indicates the rate of soil loss according to the various cultivated lands. Its methods encompass contours, cropping, and terrace. It can control erosion (Shin, 1999). Its values are 0 to 1, where 0 represents a very good anthropic erosion resistance facility and 1 indicates a non-anthropic resistance erosion facility in Wadi Dhahban. Embankments are farming conservation means and a support practice Fig.14 shows factor P of RUSLE equation calculated for Wadi Dhahban.

Fig.14: Factor P of RUSLE equation calculated for Wadi Dhahban



Source: ArcGIS Pro 2.8.1, Spatial Analysis using (ASTER) Global Digital Elevation Model Version 3 (GDEM 003),
Ministry of Economy, Trade and Industry (METI) of Japan and the United States National Aeronautics and Space Administration (NASA)

The RUSLE equation implemented in ArcGIS Pro 2.8.1software supposes the multiplication of the five involved factor maps, using Raster calculator tool:

RUSLE = R * K * LS * C * P

These raster maps were integrated within the ArcGIS environment using the RUSLE relation to generate composite maps of the estimated erosion loss in the study area. The soil loss rate of Wadi Dhahban is classified into 6 erosion classes, (Table.6). The areas with very severe erosion values have been recognized as 1st priority and so on. From the study, 11% of the areas need conservation strategies as they have very severe erosion rates.

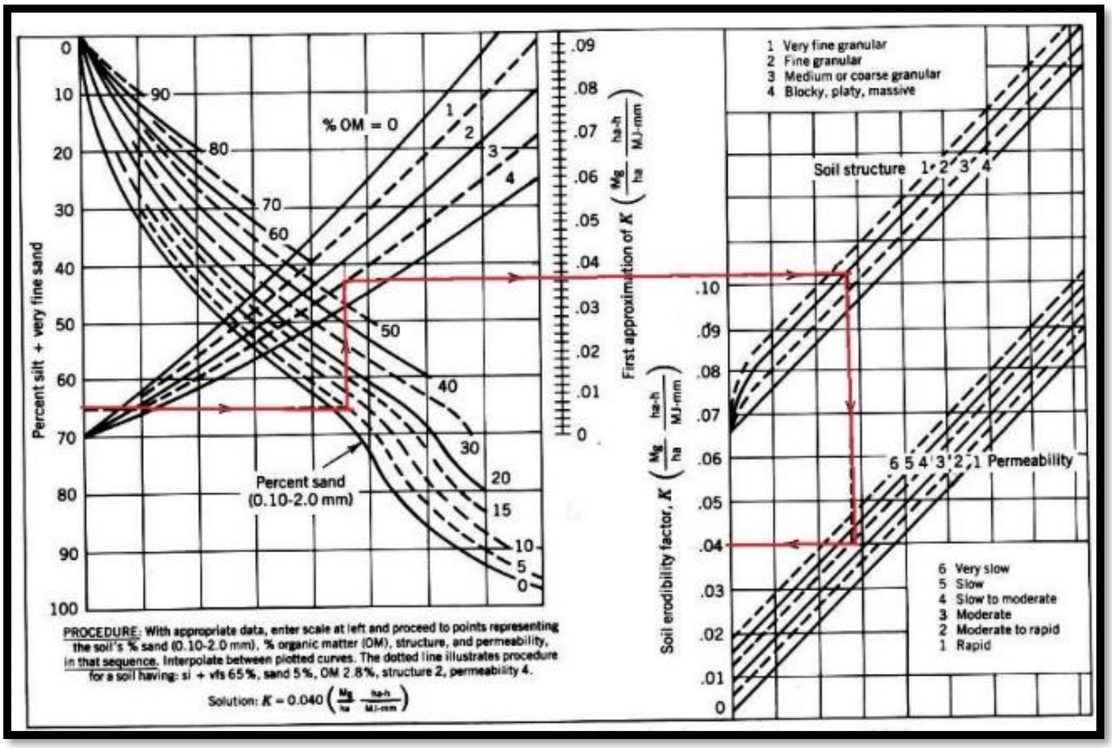
Table. 6: Soil loss classes as per severity and conservation priority

Erosion Rate (t ha^{-1} yr^{-1})	Class	Conservation Priority
0-5	Slight	6
5-10	Moderate	5
10-20	High	4
20-40	Very High	3
40-80	Severe	2
80 <	Very Severe	1

After: (Koirala et al., 2019)

The graph set by Wischmeier helps to directly calculate the soil erosion coefficient in order to avoid resorting to complex mathematical methods. It is practical, especially for research that does not depend on the results of soil analysis. A practical example of a sample of soil samples is those containing 65% of delicate sand, 5% of coarse sand and 3% of organic matter. Moreover, their permeability index is within 5 (slow) and the index is as much as the soil structure within 2. The end of the red arrow on the graph represents the soil erosion coefficient, which is within 0.04, Fig.15.

Fig.15: Soil-Erodibility Nomograph in SI units

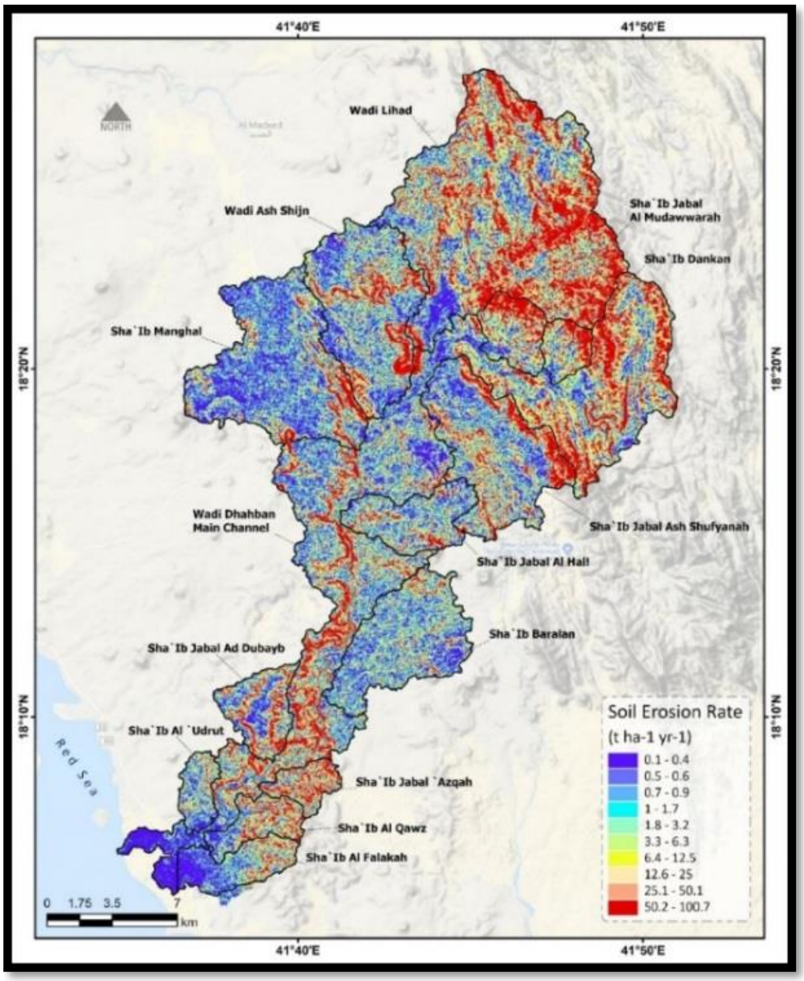


Source: (Wischmeier and Smith, 1978)

6- Results and discussion of soil loss:

The degrees of soil erosion risk in the study area were classified into six degrees in terms of soil loss values, Table .6. The highest values of soil erosion loss (Very Severe) reach the 80 < tons/ hectare /year during normal rains. The results of map (Fig. 16.) are the closest to reality because it is based on average rainfall limits of 100.7 tons/ hectare /year during normal rains. Referring to the map, the northeastern parts and the mouth of the valley are the most vulnerable parts to erosion. The bottom of the watercourse (near the estuary), the concentration of running water, the high soil erosion coefficient and the intensity of rain are among the reasons, although the slope (LS) in this part of the basin is weak.

Fig. 16: The annual average soil loss of Wadi Dhahban



Source: ArcGIS Pro 2.8.1, Spatial Analysis using Different Sources

7-Conclusions:

The importance of the study is to produce the spatial distribution of soil loss in Wadi Dhahban located in Al-Birk governorate, Asir region. The mean potential soil erosion rate for Wadi Dhahban is estimated as 36.99 t ha−1 yr−1. This study shows that 65% of the study area needs conservation attention Therefore, this research disentangles the utility of the RUSLE model to manage and preserve grounds.

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