التنبؤ بكمية التربة المنجرفة في منطقة حوض نهر الابرش باستخدام GIS وRUSLE

Predicting the Soil Erosion Quantity in AL-Abrash River Basin by Using GIS and RUSLE

د. منى بركات [1] د. محمد العبد [2] د. عزالدين حسن [1] م. علي جوهرة [3]

Dr. Mona Barakat[1] Dr. Mohammad AL-Abed[2] Dr. Ezaldeen Hasan[1] Eng. Ali jouhra[3]

(1) قسم علوم التربة والمياه، كلية الزراعة، جامعة اللاذقية، اللاذقية، سورية.

(1) Department of soil and water sciences, Faculty of Agriculture, University of Tishreen, Lattakia, Syria.

(2) الهيئة العامة للاستشعار عن بعد، دمشق، سورية.

(2) General Organization of Remote Sensing (GORS), Damascus, Syria.

(3) طالب دكتوراه، قسم علوم التربة والمياه، كلية الزراعة، جامعة اللاذقية، اللاذقية، سورية.

(3) Ph.D student, Department of soil and water sciences, Faculty of Agriculture, University of Tishreen, Lattakia, Syria.

الملخص

أجريت الدراسة في حوض نهر الأبرش الواقع في محافظة طرطوس غرب سورية، تغطي الدراسة مساحة قدرها 368.46 كم^2، وجرى التنبؤ بخسارة التربة باستخدام المعادلة العالمية المعدلة RUSLE وGIS. تم حساب عامل الهطل المطري (R) بالاعتماد على بيانات هطول الامطار الشهرية للفترة 2007-2020 ، كما حُسب عامل قابلية التربة للانجراف (K) لكل عينة ترابية بعد تحديد (القوام ، البناء، الناقلية الهيدروليكية، المادة العضوية)، أما عامل الميل (LS) فقد حُسب بالاعتماد على DEM بدقة 30م ، وعامل الغطاء النباتي (C) فقد حسب بالاعتماد على مؤشر ال NDVI. أظهرت نتائج الدراسة أن قيم العامل R تراوحت بين 31.48 - 40.32 ، و قيم العامل K تراوحت بين 0.03 -0.26 اذ تركزت الترب ذات القيم المنخفضة في الجزء الجنوبي من منطقة الدراسة، في حين تراوحت قيم العامل LS بين 0 - 43.93، اما قيم العامل C بين 0.28 - 1.11. صنفت نتائج كميات التربة المفقودة المحتملة في منطقة الدراسة إلى ثلاثة صفوف على النحو التالي: منخفض حيث تراوح فقدان التربة بين (0-27 طن /هكتار/ سنة) ومتوسط (27-60 طن/ هكتار/ سنة) وشديد حيث تجاوز فقدان التربة (180 طن/ هكتار/ سنة).

الكلمات المفتاحية: الانجراف المائي، المعادلة العالمية المعدلة لفقد التربة، نظم المعلومات الجغرافية، حوض نهر الأبرش.

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Abstract

The study was conducted in Al Abrash river basin which is located in the Tartous Governorate in the west of Syria. The study covers an area of 368.46 km^2. Soil lost was predicted by using the Revised Universal Soil Loss Equation RUSLE and GIS . Erosivity factor (R) was calculated based on the monthly rate of rainfall over the period 2007-2020, Soil edibility factor (K) of each soil sample was calculated after determination of (texture, structure, hydrolic conductivity and organic matter), Slope factor (LS) based on the Digital elevation model (DEM) up to 30m accuracy, and Land Cover factor (C) depending on the Normalized Difference Vegetation index (NDVI). The Results showed that values of R factor were between 31.48-40.32, values of K factor ranged between 0.03- 0.26 , Soil with low values were concentrated in the southern part of the study area, values of LS factor were between 0 –43.93, while the C factor values were between 0.28-1.11. The results indicated that quantities of soil loss in the study area were classified into three classes as follows: low in which soil loss ranged between (0-27 tons/ha/year), Moderate (27-60 tons/ha/year), and High in which soil loss exceeded (180 tons/ha/year).

Keywords: Water Erosion, Revised Universal Soil Loss Equation, Geographic Information System, AL-A brash River Basin.

Introduction

Erosion is a natural process, as old the earth's existence, which usually does not cause any major problems unless accelerated by human activities. It becomes a difficulty when human activity causes it to occur much faster than under ordinary conditions. (Kassie *et al*.,2020)

Soil erosion is one of the global environmental issues which is gradually increase throughout the world (Nasir and Selvakumar., 2018), it is causing great economic losses every year and threatening natural resources, agriculture and the environment (Addis et al 2019). Soil erosion can also cause severe environmental problems, including soil and water degradation, a decrease in land productivity, eutrophication and sedimentation of waterbodies. (Haregeweyn *et al*.,2017) . Erosion occurs as a combined effect of such factors as climate characteristics, soil type, topography (slope and slope length), vegetation cover, and conservation practices (e.g., contour farming, terrace, etc.) (Ekinci 2005; GDF 2017). It is estimated that the land area affected by soil degradation due to the erosion to be 1100 M ha by water erosion and 550 M ha by wind erosion in the world.(Ganasri and Ramesh 2016; Devatha *et al*.,2015). Therefore, a precise assessment of soil erosion by water at watershed scale is needed and mapping of soil loss susceptible area. The Mediterranean countries are particularly prone to erosion, have the highest soil loss rates due to special climatic conditions with prolonged dry periods followed by heavy rainfall combined with steep slopes (Panagos *et al*.,2015). Mapping and estimating soil erosion ore is often difficult due to the complex interplay of many factors such as climate, land cover, soil, topography, and human activities (shoman., 2019).

Researchers have developed many Soil erosion models for estimating soil loss, such as the Soil and Water

Assessment Tool (SWAT), the Water Erosion Prediction Project (WEPP), the Universal Soil Loss Equation (USLE), the Revised Universal Soil Loss Equation (RUSLE), etc. (Pham *et al*.,2018).

Gaubi *et al*.,(2017) noted that nowadays the (RUSLE) which is prepared by Renard *et al.* (1997) is the most used equation in determining the spatial distribution of soil erosion in the Mediterranean Such proliferation can largely be because of their simplicity and flexibility in use as compared to other models and needs less data than most of the other erosion estimation models (Zhu.,2015; Ostovari *et al*.,2017). Revised Universal Soil Loss Equation Models is easy to use in integration with GIS and remote sensing (Phinzi and Ngetar, 2019).

The use of remote sensing (RS) and geographical information system (GIS) data seems necessary for the analysis and estimation of erosion, erosion intensity mapping make soil erosion estimation, and its spatial distribution feasible with reasonable costs and better accuracy in larger basins (Bahrawi *et al*, 2016).

The main objective of this paper is to predict the annual rate of soil erosion and determining its spatial distribution by using RUSLE model through GIS in Al-Abrash basin.

Materials and Methods

1-Study area:

The study was conducted in the Al Abrash river basin which is located in Tartous Governorate west of Syria as shown in Fig1. The study covers an area of 368.46 km^2. AL Abrash river basin extends wide starts from north east in the mountainous area and ends in the South West at the sea line between the latitudes of 34.91” and 34.69” North and longitudes of 36.27” and 35.95”East. The climate in the study area is a Mediterranean climate with warm, rainy winters and hot dry summers, The annual rainfall ranges from 700 to 1400 mm More than 90% of the annual rainfall occurs in the winter from October to April, with no rain falls during the summer. The mean monthly temperatureis 13.5 to 28.5 °C. June, July, and August are the hottest months of the summer time. the main dominant land use and vegetation types are : agriculture field-forests-groves of citrus and olive trees and other fruits).

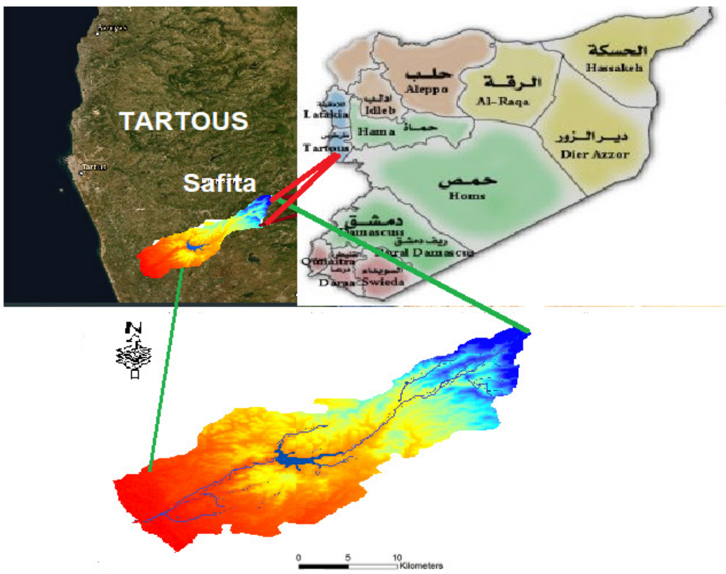

Fig .1. The location of study basin.

2- RUSLE factors calculation:

This model illustrates the effect of climate, soil, topography, and land use on soil erosion in sloping terrain caused by raindrop and surface runoff impact. The (RUSLE) is the most appropriate model that can be utilized to predict soil erosion loss based on the available data in Syria generally and Tartous specifically. With the RUSLE model the average annual rate of soil loss can be estimated and the spatial distribution of the soil erosion risk map can be established. by multiplying several factors in raster data format as follows (Renard et al. 1997):

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

Where:

A: = Average annual soil loss in in tone/ha/year

R: = Rainfall/runoff erosivity

K = Soil erodibility

LS = Slope Length and Steepness Factor

C = Cover-management

P = Support practice factor

1-2 Rainfall erosivity (R-factor):

Rainfall is an important natural factor influencing water-borne erosion partly through the detachment power of raindrop striking the soil surface and partly through the contribution of rain to runoff (Ganasri and Ramesh 2016).

The rainfall erosivity factor R was calculated by applying the following equation (Lenard and Freimud,1994):

$$R=3.85+0.35p$$

where R is a rainfall erosivity factor; P is monthly rainfall (mm).

The R factor value of each climatic station adjacent to Al-abrash river basin was calculated for the period of 14 years (2007-2020) using the above equation, and the R factor map of the study area was produced with the spatial interpolation techniques in a GIS environment.

2-2 Soil erodibility (K-factor):

The Soil erodibility factor represents both susceptibility of soil to erosion and the amount and rate of runoff. (Devatha *et al*., 2015).

The method for indirect estimation of K factor was based on the equation, which utilized the soil physical properties (texture and organic matter content, soil structure, permeability rate, etc.) ,as input data (Addis and Klik., 2015).

Therefore, using the Equation developed by (Londhe *et al*.,2010) soil erodibility factor (K-value) for each soil sample was calculated and soil erodibility map was generated as a raster data through interpolation by ‘Kriging’ method.

$$K=2.1*10-6*M^{1,14}*(12-OM)+0.0325*(D-2)+0.025*(4-P)$$

Where:

M: (%vfs +% silt) * (100 - % clay)

Where: clay % is clay fraction content (< 0.002 mm); silt % is silt fraction content (0.002–0.05 mm); vfs% is very fine sand fraction content (0.05-0.1 mm); OM = is the organic matter content, D = is the average row of weighted granular diameters which are calculated by using the sieves with graduated diameters (0.25-0.5-1-2-3-5-8-10 mm) and the following Equation:

$$\mathrm{MWD} = \sum_{i}^{n} Wi.Xi$$

where n is the order number of samples sizes, Wi is the weight of the secondary granules on the sieve as a percentage in the case of total drought, and Xi is average of diameter on the sieve. Then, the mean weighted diameter was classified into four rows, as in Table 1.

Table: 1 Average row of weighted granular diameters (Wischmeier and Smith 1978).

Row	1	2	3	4
Average weighted diameter (mm)	1>	1- 2	2- 10	10<

p is the saturated hydraulic conductivity of soil which calculated using soil water characteristics calculator program depending on the percentage of individual granules involved in soil composition and soil content of organic matter. The saturated hydraulic conductivity was classified as six rows (Table 2).

Table: 2 Rows of hydraulic conductivity (Wischmeier and Smith1978).

Row	1	2	3	4	5	6
Hydraulic conductivity (cm/day)	<1	1-10	10-40	40-100	100-300	<300

3-2 Slope length and steepness (LS-factor):

Topography is the main factor affecting soil erosion and the effect of measures for conserving soil and water (Koo *et al*. 2016).

In the present study, Determines the slope steepness degree inclination using digital elevation model (DEM) with 30 m, then LS factor was mapped through the following Equation proposed by Kumar and Kushwaha (2013):

$$LS(r) = (m + 1)\,[A(r) / 22.13]^{m}\,[\sin \beta(r) / 0.09]^{n}$$

where m and n are empirical exponents (m = 1.3 and n = 0.6), $\beta(r)$ is the slope steepness in percent, In ArcGIS, $\beta(r)$ is calculated the function of the Surface – Spatial Analyst Tool "slope" and A(r) the accumulated upslope contributing area for a given cell size, 30 m.

4-2 Cover management factor (C)

This factor estimates the amount of soil surface protection from erosion by vegetation. The Vegetation factor or C factor is the most important parameter in soil loss in RUSLE model.

the Remote sensing technology provides a lot of information about the land surface through the Normalized Difference Vegetation Index (NDVI) which is positively correlated with the amount of green biomass and gives an indication of differences in green vegetation coverage.

NDVI was calculated from Landsat 8 image taken at May 2020 using the following equation (Sellers and Canopy, 1989):

NDVI = (NIR-RED) / (NER+RED)

Where: NIR is the near-infrared band and RED is the red band.

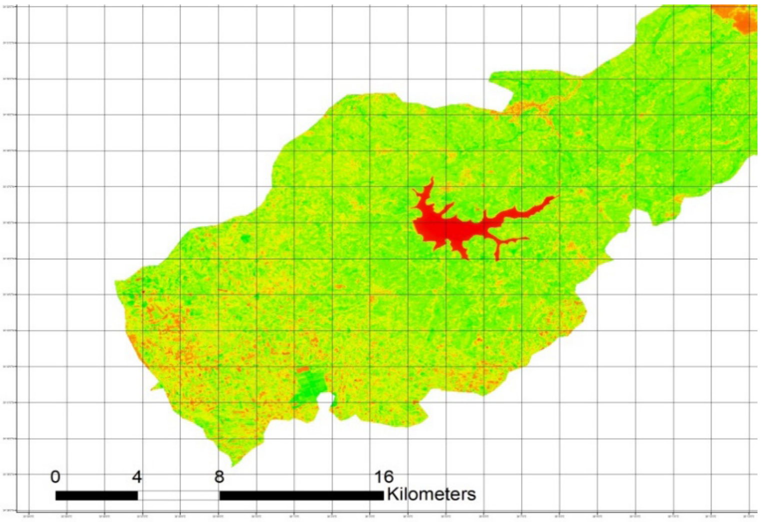

Fig .2. Spatial distribution of NDVI values in May 2020.

Due to the close relationship between the cover management factor (C) and vegetation coverage (Zhou *et al*.,2006) the Researchers established a formula for estimating the cover management factor by using the Normalized Difference Vegetation Index (NDVI) and vegetation coverage. In this study, calculated C-factor through the following equation: (Karaburun.,2010; Das *et al*.,2018):

C factor = 1.02 – 1.21 * NDVI

5-2 Conservation support practice factor (P):

The P-factor values ranges from 0 to 1, the value approaching to 0 indicates good conservation practice while the value approaching 1 indicates poor conservation practice (Ganasri and Ramesh, 2016). According to field observations, there are no significant conservation support practices, therefore it can consider P factor value is equals to 1 for entire the study basin.

Results and Discussion

1- Rainfall erosivity (R-factor):

Using rainfall data from four rainfall stations (Tab 3), R factors values of each station were estimated. Subsequently, R factor values of the entire watershed were interpolated using Ordinary Kriging interpolation within GIS.

(Figure 3) The spatial distribution of rainfall erosivity shows that the values of R factor vary from 31.48 to 40.32 .The lowest R values were recorded in the central and southern parts of the watershed and the highest were recorded in Some parts of the northwest, northeast and central parts of the study area.

Table: 3 Climatic stations used in the study with R factor values for each station.

Climatic station	Al basil	Safita	Almashtia	Sifsafi
R factor	32.34	37.18	39.54	35.99

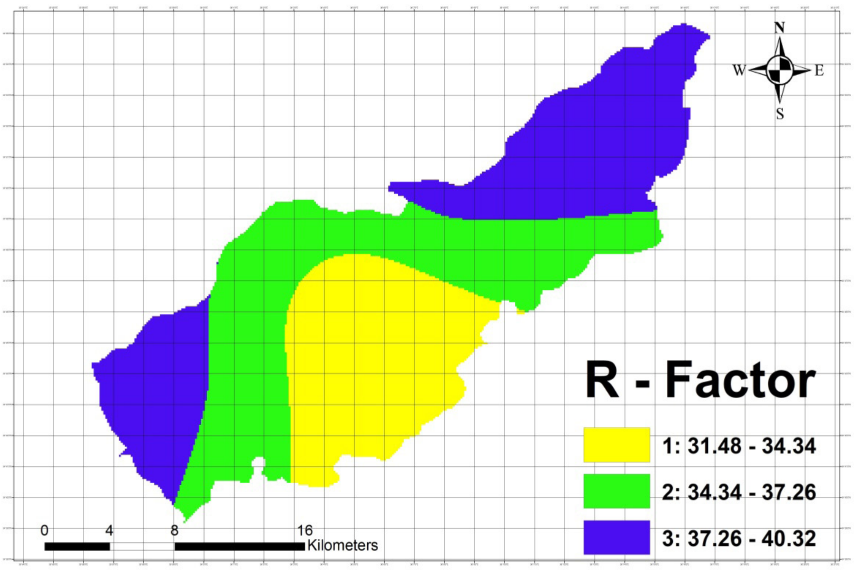

Fig .3. Spatial distribution of R factor values.

2- Soil erodibility (K-factor):

in this study the factor K values range from 0 to 0.26 as shown in the Figure. 4

The values are higher in the middle, northwest, and northeast parts of the study area (0.18-0.26), where the soils are higher in silt contents which are the most susceptible to erosion. They could be easily dispersed, causing surface crusts, and decreasing water infiltration.

Otherwise the southern parts where soils are rich in clay contents possess low K values, varied from 0.03–0.14, since they are resistant to detachment and have a high infiltration rate and thus reduced runoff. While Moderate K values range from 0.14–0.18 were observed with loamy clay soils, because of their susceptibility for detachment.

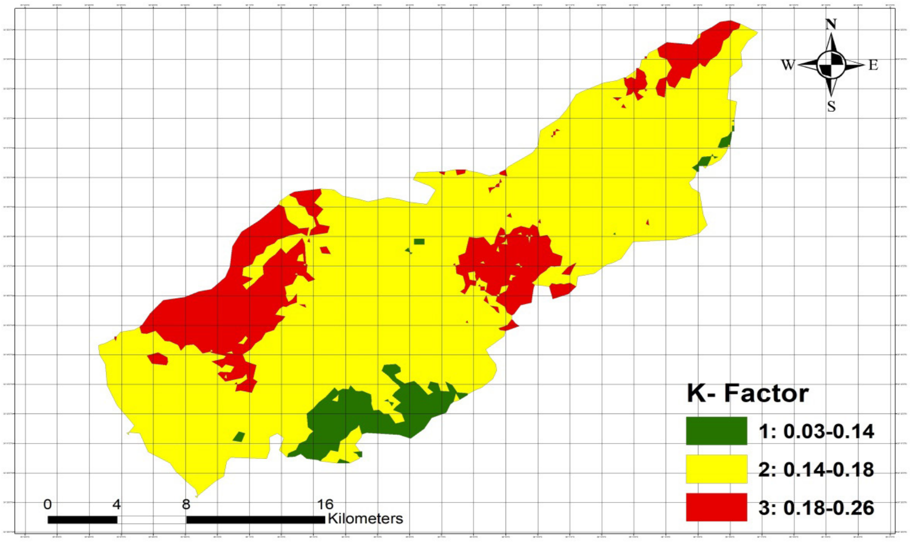

Fig .4. Spatial distribution of K factor values.

3- Slope length and steepness (LS-factor):

Figure 5 shows the steepness map, in which the values of the slope degree vary from 0 to 92.84%. the low values of the steepness are found on the west corner and southwestern part of the study area, either high values of the steepness were also obtained in the northeastern corner of the study area.

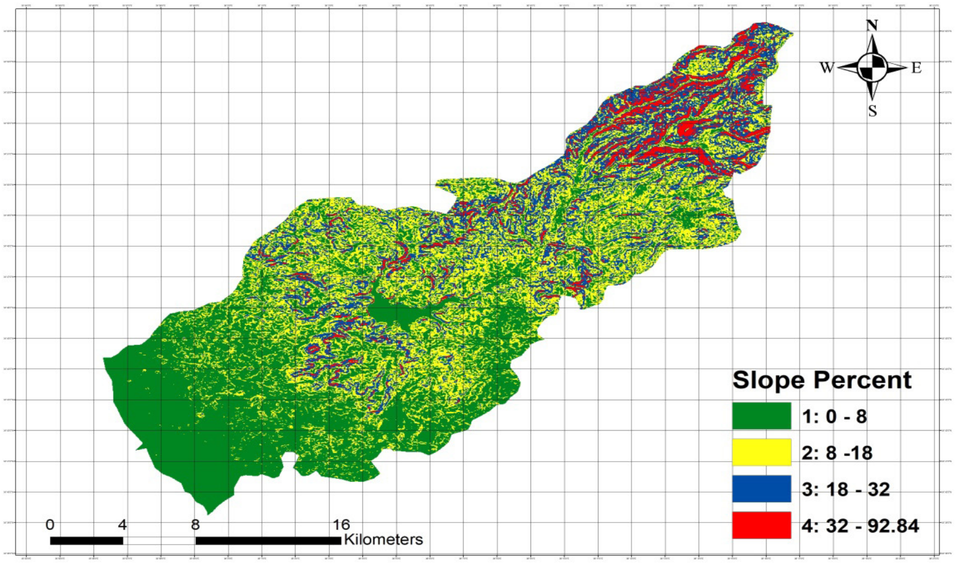

Fig .5. Spatial distribution of slope degrees values.

Whil the lS values ranged in study area from 0 in flat areas and 43.93 in steep areas, they were grouped into four classes (figure 6). The map shows the complexity of the topography, which make it vulnerable for soil erosion. Since this parameter characterizes the functioning of the surface, it is therefore a good indicator of soil erosion in the watershed.

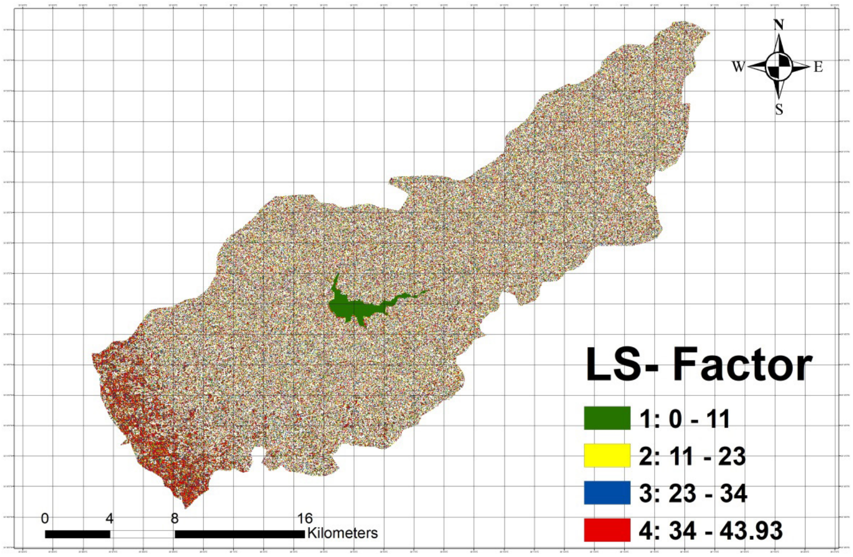

Fig .6. Spatial distribution of LS factor values.

4- Land Cover management factor (C):.

This factor estimates the amount of soil surface protection from erosion by vegetation and other land changes. Values of C factor ranges between 0 to 1. When value of C factor approach to 0 this means the area possess a good vegetative cover, while when value of C factor approach to 1 this means the area is a barren land.

In this study, the (C) factor value was low in the eastern part of the study area where the forest is dominant, it ranged between 0.28 to 0.53 while the high value of (C) factor was about 0.73 to 1.11, was found in the southwestern and some northern parts of the study area which represents to urban zones. The moderate values of (C) factor were concentrated in most of the study area, especially in the central parts around the Lake of the Basil Al-Assad Dam, the regions of olive and citrus agriculture permit a moderate protection of soil, the moderate values were 0.53 to 0.73 as shown in Figure 7.

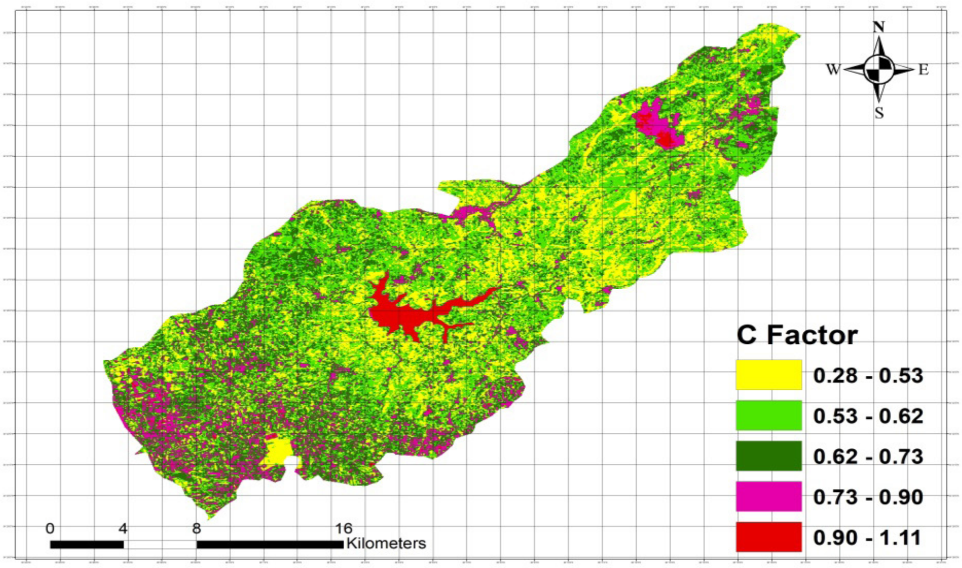

Fig .7. Spatial distribution of C factor values based on NDVI Index.

5- Spatial assessment of soil Erosion:

The soil loss map was produced by multiplying the raster of the R, K, LS and C factors in ArcGIS, as shown in Figure 8.

Results showed that the estimated annual soil lost for AL abrash basin ranged between 0 and 180 ton/ha/yr .

We noted that the spatial distribution of high values of soil lost were located at the Western and far eastern parts of the study basin that was because of high values of Soil erodibility factor which was high due to the low content of clay and organic matter in the area previously mentioned. Another reason for high values of soil lost was the high rainfall values in that area. The areas with low erosion rates were in the central and Southern parts of study basin, because of low rainfall values and moderate vegetarian coverage in those parts.

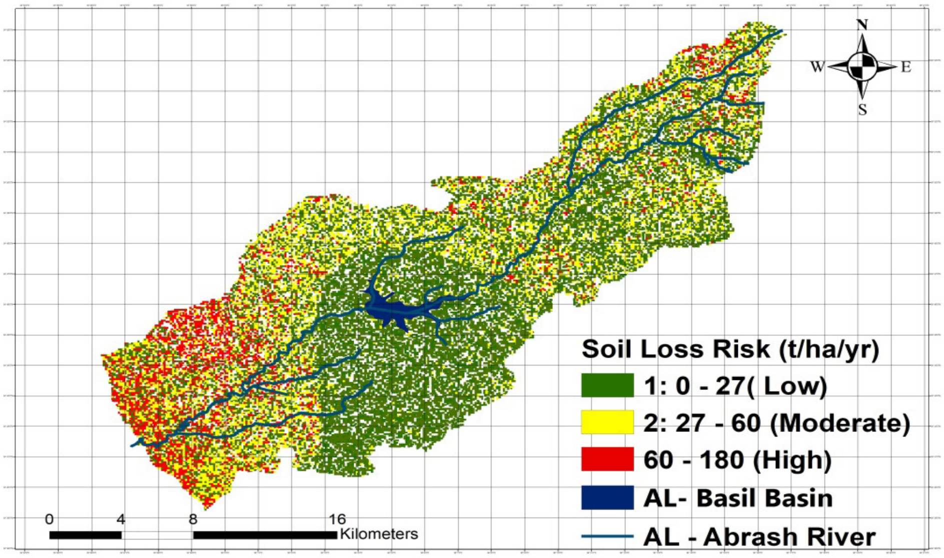

Fig .8. Soil erosion map in Al-Abrash basin based on RUSLE model.

The soil erosion zone in the study area was classified into 3 classes, low, moderate and high (Table 4). Results showed that about 81.34% of the area was classified as low erosion zone. While, The lands with high soil erosion were 6.33% of the study area. This Results Corresponds with a study carried out by the United Nations Environmental Protection Program in cooperation with the General for Remote Sensing (UNEP 2004) which it was indicated that Tartous region erosion was from a low to moderate erosion risk.

Table: 4 Classification of soil erosion in study basin.

Soil erosion class	Soil loss ($t\ ha^{-1}\ year^{-1}$)	Area (km^2)	Percentage (%)
Low	0-27	299.73	81.34
Moderate	27-60	45.41	12.33
High	60-180	23.32	6.33

Conclusions

The results show that the rate of soil loss in AL-Abrash river basin varies spatially from 0(t/ha/year) to 180 (t/ha/year). Generally, such methodology provides a simple framework that can easily be implemented in data-poor locations in Syria and elsewhere in the world, particularly in rural areas where there is much reliance on subsistence agriculture, limited financial resources and are vulnerable to soil erosion.

Finally, for long term sustainable soil resources management and erosion control particularly in steeper parts of the basin, conservation of existing vegetation cover and replanting appropriate vegetations should be done.

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