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ORIGINAL ARTICLE **OPEN ACCESS**

Estimating Water Erosion Hazard by Using Remote Sensing and GIS Techniques Case Study: AL-Sheikh Bader Basin -Syria

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ABSTRACT

The RUSLE model integrated with GIS method has been used for the prediction of soil erosion hazard in AL-Sheikh Bader Basin -Syria. Therefor filed experiment has been taken to investigate about the study area, all the required maps were prepared using GIS V10.2. The results showed that, about 55% of the study area is classified as acceptable erosion risk (<20 t/ha/y) which considered as a stable area, while rest of the area is under moderate (22.2%) to high (18.6%) erosion risk which considered as unstable area, furthermore, about 4.2% of the study area is classified as under severe erosion risk (>100 t/ha/y).

Keywords: *Water Erosion Hazard; RUSLE; GIS; SYRIA.*

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INTRODUCTION

Soil erosion is the phenomenon of separation and transition of surface soil particles, by wind or water. Erosion is considered the most common reason for soil degradation which conceded a serious and continuous environmental problem all over the world. The average of soil water erosion is affected by the interactive between soil properties and the proportion of its planted coverage, climate factors and topographical characteristics. The removal of mountain forests, overgrazing and agricultural activities play a principal role in increasing the average of water erosion [1]. The effects of soil water erosion on soil fertility, and agricultural productivity and environmental ecology have been recognized as severe problems in every corners of the world [2].

Soil Water erosion is considered as one of the main environmental problems that Syrian Arab Republic suffers from. However, the Coastal Area, particularly the mountain areas, is classified as most vulnerable to such a problem. The high rainfall rates which vary between 750-1400 mm/y, in addition, the recurrence of rainstorms that falls after intense retentions. Also, long and high slopes and the nature of parent material, specifically on calcareous rocks, in addition, mismanagement of the soil. These reasons are mainly responsible for the increasing of water erosion averages [3]. According to field experiments in 1994, the soil erosion average in Lattakia and Tartous mountains was estimated by 200 t/ha/y [4].

The Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD) has developed a map of soil degradation which demonstrates that about 6% of the Syrian land is threatened by water erosion with varying degrees (85% of this land is exposed to slight degradation, 12% is exposed to moderate degradation, while 3% suffers from extreme degradation) [5]. There is also another map published by FAO in 2008 and United Nations Environment Programme, it clearly shows high rates of water erosion in the Coastal Area which goes over100 t/ha/y.

[6] studied the changes in the amount of soil erosion into three systems (forests, burned forests, and agricultural lands) -Lattakia. The study concluded to record erosion, it reaches 121.55 t/ha/y for cultivated lands, 47.5 t/ha/y in burned forests, and 10.55 t/ha/y in the forests. According to a study done by [7] in fifteen locations that have different slopes and land-use in The Coastal Area in Syria using field experiments, the rate erosion varies between 12 to 200 t/ha/y.
[8] studied soil erosion by using RUSLE and WEPP in AL-Sheikh Bader Basin, the result showed that soil erosion ranged from 1.4 to 125.8 t/ha/y by using RUSLE equation, while the soil erosion in the study area ranged between 2.04 - 288 t/ha/y calculated by WEPP model. Therefore, the objectives of this study are:
1) to investigate about the hazard of soil erosion at a catchment scale in in AL-Sheikh Badr basin by using remote sensing technique and GIS with Revised Universal Soil Loss Equation (RUSLE).
2) produce soil erosion risk map
3) Determining the percentage of Lands affected by soil erosion

METHODOLOGY

The Study Area:
The study was conducted in Al-Sheikh Badr area which located to the north-east of the city of Tartus as located about 35 km, the study covers an area 20279 ha (202.79 km^2). It goes between 35˚ 57′ 40″& 36˚ 15′ 40″ east and 34˚ 39′ 55″ north as shown in Figure (1), with Mediterranean climate that is characterized by hot and wet summer and rainy and moderate cool winter most of the time and sometimes little cold [9]. The annual rainfall rate reaches 1242.86 mm (1960-2013). Whereas, the average of minimum temperature was 12.5◦C and the maximum average was 21.69◦C (1960-2013). The arable lands are constituting of 13250 ha, while forests constitute 5018 ha [10].
Land-cover types vary from natural vegetation (forests) mixed with crop-land such as wheat, barley, and field crops (tomatoes, lentils, chick-peas, potato, tobacco), vines and olives.

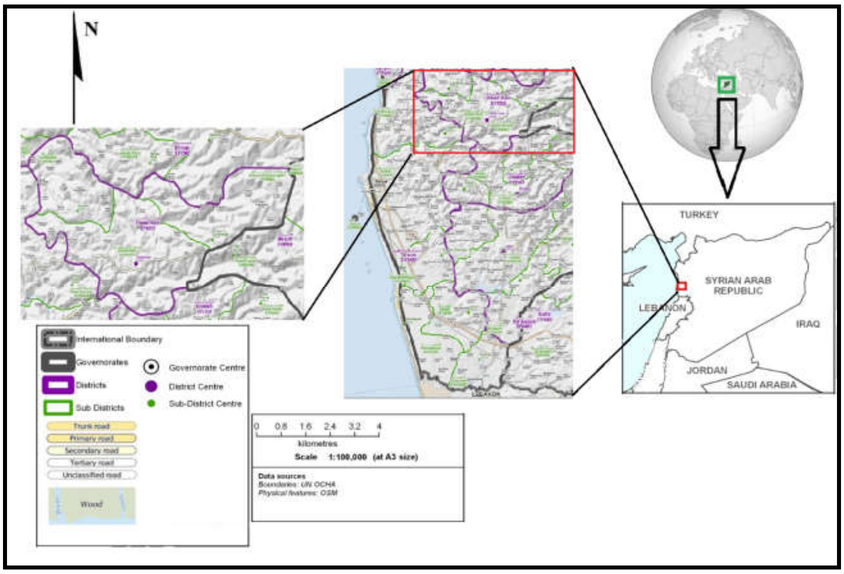

Figure 1. Location of the study area on the map of Syria

Soil sampling:
Field visits have been made to the study area and getting 15 samples as shown in figure (2) that cover most of it. Samples were taken by putting a wooden frame 1*1m and then samples were collected from the outskirts of the frame in addition to the center of it at a depth of 2.5 cm, after that samples were mixed with each other and form a homogeneous sample, furthermore, samples site were chosen based on the slope and land use of the study area, the sampling sites were identified using a GPS (Global Position System) as shown in table 1. After that, samples were transported to the soil physics laboratory in the College of Agricultural Engineering-Tishreen University, then some tests were conducted: partical analysis using at hydrometers method [11], and determine the Texture of the soil using the texture triangle - American classification (USDA), the percentage of organic matter OM% [12], the Cation Exchange Capacity CEC (m.mq./ 100 g.soil) [13].

TABLE1: LOCATIONS AND LAND USE

Location	X	Y	Land use
Qamsieh	35 °34′3	35 °58′2	Fruit Tree
Tareck 1	35 °13′8	36 °60′7	Shrubs
Sorani	35 °12′9	36 °71′	Fruit Tree
Namreh	35 ° 12′	36 °12′5	Olive
Tareck 2	35 °13′8	36 °60′ 7	Shrubs
Wardieh	35 °02′2	36 °32′1	Olive
Brmanh	35 °31′	36 °13′3	Potato
Shikh-Badr	35 °91′7	36 °41′9	Olive
Drti	35 °43′2	35 °58′2	Wheat
H.Qanieh1	35 °32′	36 °13′37	Fruit Tree
Brisen	34 °41′	36 °19′	Fruit Tree
Ghbh	35 °12′5	36 °54′2	Closed Forest
H.Qanieh2	35 °11′	36 °2′	Wheat
Mokbleh	35 °12′ 1	36 ° 10′2	Potato
Kamso	35 °1′45	35 °59′5	Wheat

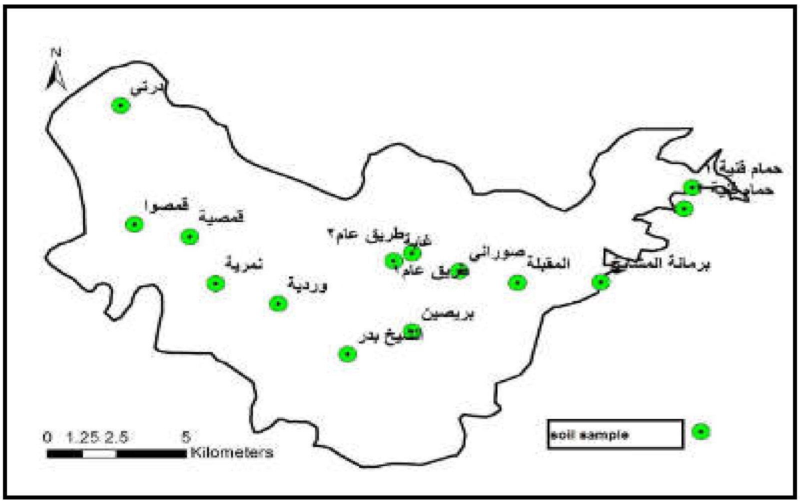

Figure 2. Map showing points of collection of soil samples in the study area

Soil erosion estimation by RUSLE:

There were many models for estimating soil erosion such as the Universal Soil Loss Equation (USLE) [14] and its revised (RUSLE) and its modified (MUSLE) [15], There were other soil erosion models range in various degrees of complexity such as WEPP- Water Erosion Prediction Project [16], CORINE-COoRdination of Information Environment [17] and SWAT- Soil and Water Assessment Tool [18].

Now a day, RUSLE model in assessment with remote sensing technique (RS) and GIS technology has been used to predict the annual soil loss which has many advantages like parameters of this model can be easily integrated with GIS for better analysis, less time consuming and low coast.

The RUSLE model using five factors is expressed as:

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

Where:

A: soil loss (t .ha-1/y) R: rainfall-runoff erosivity factor (MJ.mm. ha-1h-1.y-1)

C : cover management factor K: soil erodibility factor(t.ha.h.ha-1.MJ-1 mm-1)

P : support practice factor LS : slope length- steepness factor (72.6-ft, 9%)

L and S factors stand for the dimensionless impact of slope length and steepness, and C and P represent the dimensionless impacts of cropping and management systems and of erosion control practices.

In the present study, annual soil loss rates and severity were computed based on RUSLE in GIS environment using Arc GIS 10.2, ERDAS Imagine 8.5, and the associated GIS packages. Land use/cover information for the study area was obtained from LANDSAT ETM+ 2010, and revised by site visiting, while rainfall data was obtained from the Ministry of Agriculture all factors are computed as fallow:

Rainfall Erosivity Factor (R)

To compute R factor, max rainfall in 30 minutes of 10 years were collected from Safita metrological station (25km east of the study area), using the formula [19]:

$$R = \frac{\sum_{i=1}^{j}(EI_{30})_i}{n}$$

$$E = 916 + 331\log_{10} i$$

E: kinetic energy (ft.ton.acre-1.in-1)
I_{30}: is maximum 30-min rainfall intensity (in.h-1)
$(EI_{30})i$: EI_{30} for storm i, j number of storms in (n) years period.
The rainfall erosivity (R) was 481.4 (MJ mm h-1 h-1 yr-1), after that it converted into raster layerin ArcGIS software (Figure 3).

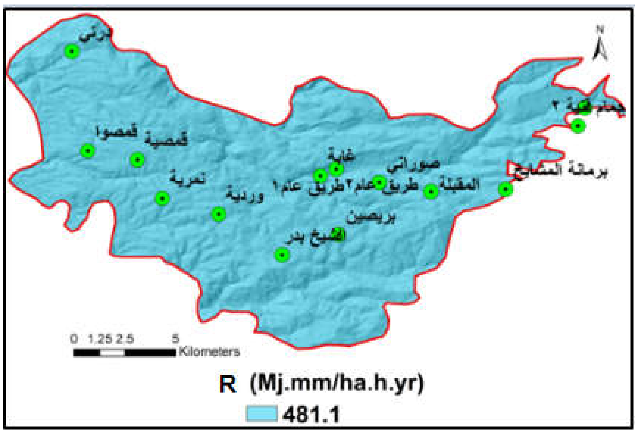

Figure 3: Rainfall Erosivity Factor (R) map in the study area

Soil Erodability Factor (K)
The K-factor is a numerical value varies from 0 to 1 and to determine it, soil samples were brought to the soil physics laboratory in the College of Agriculture-Tishreen University to carry on the following tests: sand%, silt% and clay% then soil texture, the percentage of organic matter OM%, and cation exchange capacity CEC (m.mq/100g.soil). The corresponding K-values for the soil types were identified from [20] table. The results showed in table (2). Furthermore, K-factor map was generated by using K-values from table (2) by applying the logarithm of Kriging, as is shown in figure 4.

TABLE2: CHEMICAL ANALYSES AND K-FACTOR IN THE STUDY AREA

Location	%Sand	%Clay	%Silt	Texture	%O.M	C.E.C(m.mq./100g.soil)	k
Qamsieh	21.95	27.159	50.884	Silty Loam	0.5745	22.4	0.48
Tareck 1	32.36	47.970	19.667	Clay	1.1495	29.13	0.42
Sorani	6.347	16.753	76.899	Silty Loam	1.6696	19.8	0.2
Namreh	21.95	58.376	19.667	Clay	2.8727	33.12	0.2
Tareck 2	32.36	47.970	19.667	Clay	2.8227	30.22	0.23
Wardieh	16.75	42.768	40.479	Silty Clay	1.8579	19.88	0.2
Brmanh	27.15	47.970	24.87	Clay	0.402	26.12	0.2
Shikh-Badr	11.55	37.565	50.88	Silty Clay Loam	1.1415	22.6	0.32
Drti	16.75	32.362	50.88	Silty Clay Loam	2.8787	24.57	0.2
H.Qanieh1	32.36	42.768	24.8	Clay	3.4474	26.88	0.23
Brisen	11.55	42.768	45.68	Silty Clay	1.7232	21.12	0.23
Ghbh	6.347	42.768	50.84	Silty Clay	1.1415	24.33	0.48
H.Qanieh2	6.34	27.159	66.49	Silty Clay	2.876	23.16	0.23
Mokbleh	32.36	47.970	19.66	Clay	3.159	28.675	0.2
Kamso	27.15	37.565	35.27	Clay Loam	0.5745	26.956	0.23

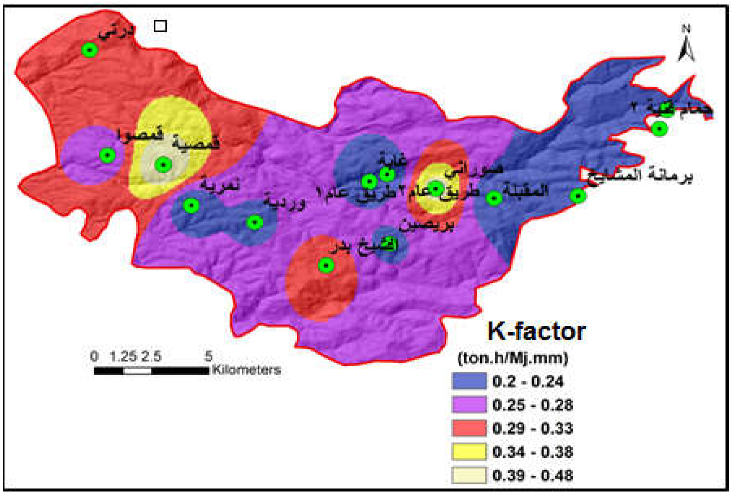

figure 4. Soil Erodability Factor (K) map in the study area.

Topographic Factor (LS Factor)

The combined LS-factor was computed for the watershed by means of ArcInfo ArcGIS Spatial analyst extension using the DEM following the equation [21; 22;23]:

$$LS = (Flow\ accumulation * {}^{Cell\ size}/_{22.1})^{0.4} * ({}^{Sin\ slope}/_{0.0896})^{1.3}$$

where flow accumulation is the number of cells contributing to flow in to a given cell and derived from the 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 (Figure 5).

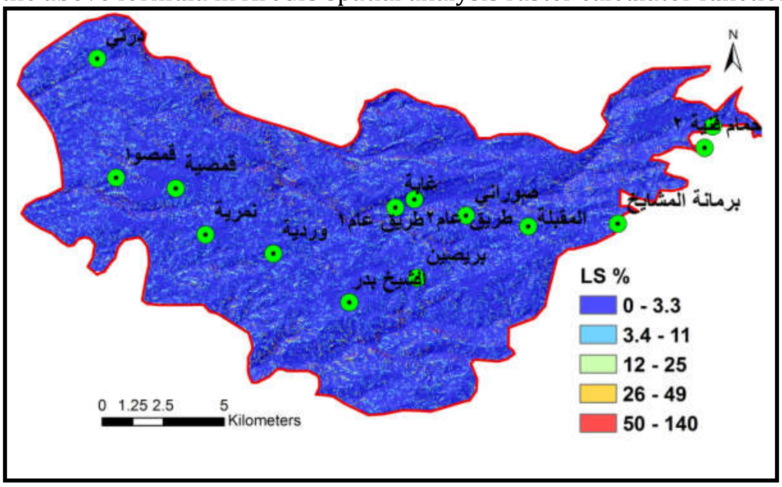

figure 5. Topographic Factor (LS Factor) map in the study area.

Cover Management Factor (C)

Due to the big size of the study area, and the complexity of vegetation cover, a remote sensing data was used to estimate the factor (C) [24; 25], so, a Landsat image of the study area was carried out, and analyzed by using the tool Image classification- supervised classification and divided into two zones (Soil) and (Vegetation) [26], after classification Soil attributes were multiplied by 0.29 [27] and Vegetation attributes were multiplied by 0.01.

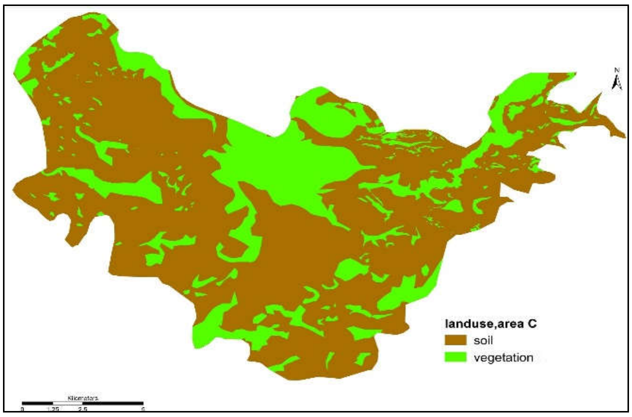

figure 6. Cover Management Factor (C) in the study area.

Conservation Practice Factor (P Factor)
The P-value ranges from 0 – 1, in our study P-value=1 because there are no conservation practice measures in the study area.

RESULT
After preparing the five factors layers according to the relationship in RUSLE model, they were multiplied to generate soil erosion hazard in the study area. The soil erosion hazard was classified into four different soil erosion risk levels as presented in Table 3, where Figure 7 shows the estimated erosion risk in the study area.

TABLE3: SOIL EROSION RISK LEVELS

Class	Soil erosion (t/ ha/y)	Percentage in the study area	Erosion hazard
1	0-20	55%	acceptable
2	20-35	22.2%	moderate
3	35-100	18.6%	high
4	>100	4.2%	sever

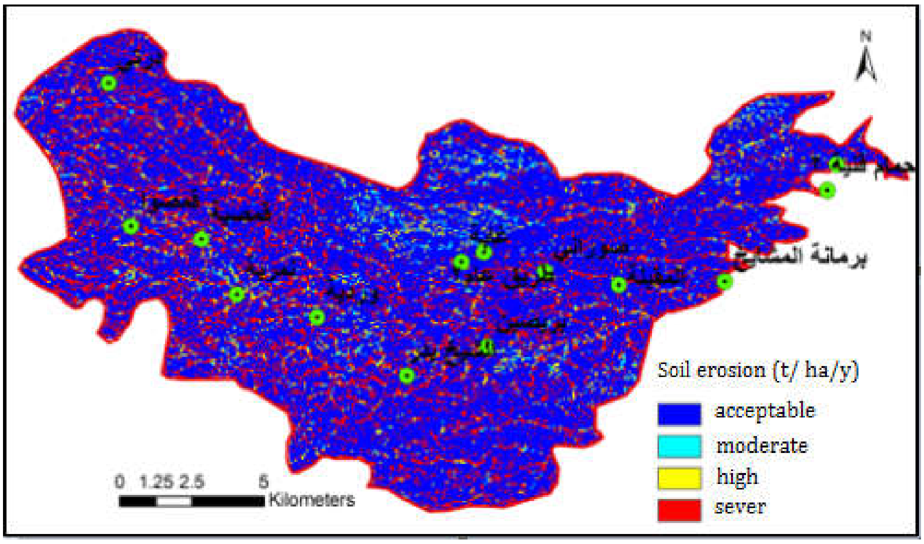

figure 7. Soil Erosion Hazard.

DISCUSSION
The results presented in Table 6 show that about 55% of the study area is classified as acceptable erosion risk (<20 t/ ha/y) which considered as a stable area, while rest of the area is under moderate (22.2%) to high (18.6%) erosion risk which considered as unstable area, furthermore, about 4.2% of the study area is classified as under severe erosion risk (>100 t/ ha/y), [28] pointed out that the amount of soil loss may exceed 100 (t/ ha/y) in some watershed in coastal region in Syria and this is due to severe slope and low vegetation, while [29] noted that the amounts of soil erosion up to more than 100 t/ ha/y, due to lower vegetation density and soil structure stability in the Syrian coastal region. So, we can say that more than 45% of the study area is considered under soil erosion hazard, due to one or more of these reason:

1. Agricultural cycle: planting wheat crop in fall season which begin in September is considered one of the most factors that affected soil erosion, because when rain storm began in the study area, most of the soil is coverless furthermore, the rain drops destroy soil aggregates which increase erosion rate, [30]; while [31] mentioned that high erosion rate in wheat fields caused by heavy rain storm which happened under coverless soil, while [32] pointed that the amount of eroded soil from wheat fields is significantly higher when compared with eroded soil from potatoes and corn fields due to the difference in soil cover. More ever, the nature of the climate in the Mediterranean region cause high erosion [33].
2. Physical properties of the soil: where, in the study area the domination of heavy textures, as showed in table 2, highly clay percentages reduce the infiltration rate which is considered as the first step in soil erosion.

CONCLUSION

Using the RUSLE method integrated with GIS techniques indicates that more than 45% of the study area is considered under soil erosion hazard, so It is important, avoiding tilling lands in the slope direction as much as possible to reduce the phenomenon of runoff and soil erosion, spatially where slope steepness is more than 8%, which contributes to ease of surface erosion, furthermore we need to look for alternative land use and crop rotation or mulching the soil in rainy season.
However, using GIS tools is considered as a good technique that save time and help decision maker to clarify vulnerability zones of soil erosion, and decide which kind of soil conservation should be taken. Finally, In Syria, soil erosion map is still at a local scale, which need more national efforts to produce a soil potential erosion risk map at national scale.

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