Leveraging Artificial Intelligence for Hydrological Response: Mapping Water Erosion in a Tunisian Context

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DOI: https://doi.org/10.51584/IJRIAS.2025.100700025

Received: 02 June 2025; Accepted: 06 June 2025; Published: 01 August 2025

ABSTRACT

This paper aims to map and quantify water erosion in the El Gouazine watershed using four empirical models integrated into a Geographic Information System (GIS). The models studied are the Universal Soil Loss Equation (USLE), its revised version (RUSLE), its development (MUSLE) and the FAO equation. Using these tools, a synthetic map of soil losses was created, providing an overview of the intensity and distribution of erosion. The results show that more than 74% of the basin suffers from low erosion, with losses less than 2.5 tons per hectare per year, while 20% of the area is affected by moderate erosion (2.5 to 10 tons/ha/year), and 13.74% by severe erosion (greater than 15 tons/ha/year). After the implementation of sustainable soil and water management (SWM) practices, a significant reduction in erosion was observed, illustrating the effectiveness of the interventions. The RUSLE and MUSLE models showed substantial reductions in soil losses, confirming their essential role in preserving natural resources and limiting erosion. Soil erosion is a major threat to agricultural land in Tunisia, affecting approximately 3 million hectares and posing a risk to the sustainability of small hilly lakes. In the El Gouazine watershed, located in central Tunisia, this phenomenon is amplified by a semi-arid Mediterranean climate, rugged topography, fragile soils, and increasing anthropogenic pressure.

Keywords: Cartography, geographic information system (GIS), sustainable management, water erosion, watershed

INTRODUCTION

Global climate change and anthropogenic pressures on natural environments have intensified concerns related to the management, protection and sustainability of ecosystems [1-3]. This study is part of this framework and highlights the importance of remote sensing and new sensors accessible to the scientific community to better characterize and predict certain natural risks, particularly water erosion, in the Mediterranean region. Recent research on climate vulnerability in the Mediterranean highlights an increase in aridity, accentuating water erosion [4-6]. This phenomenon is particularly widespread on slopes subject to torrential rains, fragile soils and steep slopes, often aggravated by human practices such as deforestation, overgrazing, uncontrolled urban development and quarrying [7-9]. According to FAO (1990), soils are severely degraded in several Mediterranean countries: 35% in Greece, 40% in Morocco, 50% in Turkey. In Tunisia, 45% of the surface area is threatened, or around 3 million hectares, mainly agricultural land, while in Algeria, 45 % of the Tell surface area, or 12 million hectares, is also affected [10-13]. In Tunisia, hill reservoir lakes play a crucial role in national Water and Soil Conservation (WSC) strategies, serving as water reserves for agriculture and protecting soils from erosion [14]. However, these infrastructures are particularly vulnerable to siltation caused by solid inputs from water erosion. To preserve these resources and ensure the sustainability of agricultural systems, it is essential to implement effective methods to combat erosion [15, 16]. Erosion modeling has emerged as a key tool for identifying risk areas and designing appropriate solutions [17, 18]. Empirical models, such as the

Universal Soil Loss Equation (USLE), its revised version (RUSLE), the amended equation (MUSLE) and the FAO method, are widely used. Combined with geographic information systems (GIS), these models allow for rapid and efficient mapping of vulnerable areas, including the costs and time required to plan interventions. In this context, this study focuses on the El Gouazine watershed, in central Tunisia, to quantify and map water erosion using USLE, RUSLE, MUSLE and FAO models integrated in a GIS. The objective is to better understand erosion dynamics and provide management tools to reduce risks, improve soil sustainability and protect critical water infrastructure [19-22].

Materials And Methods

Empirical soil erosion models: Principles, applications, and advanced innovations

Empirical soil erosion models play a central role in the assessment and management of soil loss, a major concern for natural resource conservation and sustainable agriculture. Among these models, the Universal Soil Loss Equation (USLE), developed by Wischmeier and Smith in 1978, provides a solid basis for quantifying erosion. This model, and its later versions such as the Revised Universal Soil Loss Equation (RUSLE) and the Modified Universal Soil Loss Equation (MUSLE), have expanded the understanding of factors influencing soil erosion at different scales of study, ranging from individual plots to regional scales [23-25].

RUSLE, introduced by Renard et al. in 1997, represents a major advance over the original USLE by incorporating additional factors such as soil erodibility (K), slope and slope length (LS), vegetation cover (C), and conservation practices (P) [26, 27]. These parameters are calculated from empirical field and laboratory data, providing an accurate estimate of soil losses for various agricultural land management scenarios. RUSLE is particularly suited for application at the plot scale, where it can simulate average annual erosion in complex agricultural systems, influenced by diverse cropping systems and soil management techniques. MUSLE, on the other hand, is an extension of the RUSLE model, designed to quantify sediment generated during extreme abstraction events, such as storms. Rather than relying solely on the erosivity of abstractions, MUSLE integrates variables such as the maximum instantaneous flow and the total runoff volume. This adaptation allows for more precise estimation of the volumes of sediment generated during specific water erosion events, thus improving the ability of the models to meet the needs of post-event analyses and specific interventions. The combination of RUSLE and MUSLE models with geographic information systems (GIS) offers a significant advance in spatial analysis and optimization of erosion management. The integration of digital elevation model (DEM) data allows for visualization and assessment of net soil movements at the sub-watershed scale, thus enabling more effective planning of soil conservation and restoration practices. In addition, the methodology developed by the Food and Agriculture Organization of the United Nations (FAO) in 1979, which is based on the USLE approach, provides a global vision of the interactions between climatic, pedological and anthropogenic factors influencing soil erosion. This generalization allows application in various geographical contexts and better adaptation to local specificities, contributing to sustainable and sustainable soil management in the face of contemporary environmental challenges [28-30].

Characterization of the El Gouazine lake watershed

The El Gouazine Lake watershed, located in the semi-arid central region of Tunisia, covers an area of 17.08 km² and belongs to the Nebhana watershed as shown in Figure 1. It is characterized by a specific geological environment, belonging to the syncline with intercalated calcareous marls from the Bartonian to the Lutetian. These calcareous formations have a strong pendant, thus influencing the morphology of the watershed. The upstream part of the basin, covered with sub-horizontal calcareous crusts, shows a geomorphological complexity, while the valley bottoms are relatively undeveloped in comparison [31, 32].

Land use in this region varies considerably. A coexistence of several types of landscapes is observed, ranging from semi-forested plots to land exclusively dedicated to agriculture. Cereal crops alternating with fallow land represent 32.1% of the total area, while degraded forest covers 35%, and dense forests 11.02%. Fallow land covers 2.1%, scrubland 4.12% (carob and mastic trees), herbaceous steppe with esparto grass 3.44%, and arboriculture (olive and almond trees) represents 3%. Deep ravines cover 3% of the area, while mixed units reach 4%. A small dam built in 1990 marks the outlet of the basin, as well as the bed of the wadi and the hillside

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue VI June 2025

lake occupying 1.6% of the total area. Specific developments have been carried out, in particular benches before the contour lines in 1996 and 1997, covering 40% of the agricultural land and orchards. This type of development aims to reduce erosion by maintaining soils in place while improving agricultural productivity [33].

The climate of this region is of the semi-arid Mediterranean type, marked by a hot summer season and a cool winter season. The thermal contrasts are accentuated by the continentality and the relief, accentuating the summer drought. The average annual rainfall amounts to 400 mm, although this average is subject to great spatial and temporal variability. During the observation period from 1994 to 2004, the annual collections varied between 253 mm and 577 mm. The coordinates of Lake El Gouazine are precisely located at 35°54'30" North, 9°42'13" East, with an altitude variation between 383 and 586 meters, and a slope index of 11.75 m/km, influencing the dynamics of erosion and deposition in the watershed [34, 35].

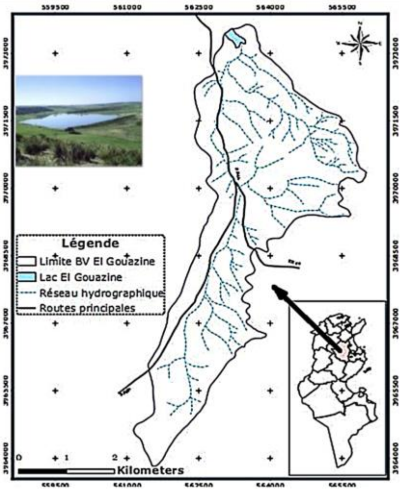

Figure 1. Location map of the study area

The main hydrologic characteristics of the watershed and from its reservoir downstream are listed in Table 1.

These data illustrate the hydrological complexity of the El Gouazine watershed, directly influencing water resource management and erosion prevention practices.

Table 1. Hydrologic characteristics of El Gouazine

Characteristics of the catchment	
Aria (ha)	1708
Perimeter P (Km)	26.69
Index of compactness Ic	1.8
Length of the rectangle L(km)	11.91
Width of the rectangle l(km)	1.41
Maximum Altitude Hmax (m)	590
Minimum Altitude Hmin (m)	383
Index of slope Ig (m/km)	11.75
Specific Rapids Dsp (m)	48.57

ISSN No. 2454-6194 | DOI: 10.51584/IJRIAS |Volume X Issue VI June 2025

Characteristics of the reservoir	
Year of construction	1990
Volume to the spill Vi (m^3)	237030
The Surface spill As (ha)	9.597
Report Vi/As	2.47
Height of the dike (m)	10.63
Length of the dike (m)	232
Nature of the weir	Concrete, trapezoid
Spout height (m)	8.28
Width of the spillway (m)	20.6

Description Of Erosion Factors

To analyze water erosion in the El Gouazine watershed, several empirical models were adopted: the Universal Soil Loss Equation (USLE), its revised version (RUSLE), developed by Fox et al. in 1991, its modified version (MUSLE) and the equation proposed by FAO [36].

These models make it possible to predict and quantify soil losses based on various factors such as precipitation, soil characteristics, topography and vegetation cover. Their integration into a Geographic Information System (GIS) made it possible to carry out precise and detailed analyses on the entire watershed.

The GIS was used to digitize the maps, analyze and combine data from the different erosion factors, and produce synthetic maps representing the risk of water erosion. This approach makes it possible to locate priority areas for soil management and the implementation of effective conservation practices.

Factor of rainfall aggressiveness (R)

The index of aggressiveness takes into account the interactions between the height, the intensity and duration of the rains on the solid transport over a long period [37]. This climate index is calculated, for a heavy downpour, and is cumulative per episode, per month, or per season.

The climatic erosivity of rainfall is considered constant for the whole river basin that is to say it has not used a layer of this factor under a GIS, but it was considered a single value.

Factor of rainfall erosivity R according to USLE

This index takes into account the three conditions: energy, intensity of peak and duration of rainfall. Thus the index of rainfall aggressiveness is calculated by Eq. (1) where:

$$R = E_T \times I_{30} \qquad (1)$$

I_{30} is maximum intensity of the rain in 30 min of duration for the downpour considered (mm h^{-1}). E_T is kinetic energy total of rain (MJ $ha^{-1}mm^{-1}$).

The kinetic energy of the rainfall is given by Eq. (2):

$$E_T = 210 + 89\log(I_{30}) \qquad (2)$$

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Factor of rainfall erosivity R according to MUSLE

This factor results from the following equation:

$$R = 11.8(V \cdot Q_P)^{0.5} \qquad (3)$$

With V is the volume of runoff water (m^3) and Q_P is peak flow (m^3/s).

Factor of rainfall erosivity R according to RUSLE

R monthly (of Arnoldous 1980): R is called factor rain or index of rain erosivity. The factor R can be defined as the potential capacity of the rain to produce erosion. This potential capacity is often attributed to its physical characteristics to know the quantity, intensity, the dimension of the rain drops, the distribution size of these drops and the speed of the fall which are connected between them.

In fact, several methods are presented for the determination of the factor R in which the one cited in Table 2.

Table 2. Factor of rainfall erosivity (R)

Case	**Reference**	**R and P or F relationship**
Case I	Arnoldus-linear (1980)	R= (4.17F-152) /17.02
Case II	Arnoldus (1980)	R= 4.17F – 152
Case III	YU and Rosewall (1996)	R=3. 82 F1.41
Case IV	Arnoldus-Exponential (1977)	R = 0,302 F1.93
Case V	Renald and FREIMUN -F (1994)	R= 0.739F1.847
Case VI	Renald and Freimun (1994)	R=0.0483 P1.61
Case VII	Roose (1994)	R=P * 0.5
Case VIII	Kassam & al. (1992)	R=117.6 (1.00105^{MAR}) for MAR< 2000mm
Acc IX	Singh & al. (1981)	R = 79+ 0,363 F

Or F is index of Fournier, P is annual precipitation, MAR is precipitation annual average and R is factor of rainfall erosivity.

In reality, it has not used a layer of this factor under a GIS, but it was considered a single value for the entire watershed.

The factor of rainfall erosivity is calculated from several formulas proposed by Weischmeir and Smith (1970), and then by the method of Arnoldus (1980) based on the monthly precipitation or of the index of Fournier [38].

To calculate this factor, we used the data of the monthly of the rain, and the annual rainfall by using the formula of Arnoldus (1980) which is presented in the form:

$$\log R = 1.47 \times \log\left(\frac{Pi^2}{P}\right) + 1.29 \qquad (4)$$

R is rainfall erosivity in (MJ/ha.mm/h), Pi is rain's monthly i (mm) and P is annual rainfall (mm).

The data used in this work are from the direction of water resources (1994-2009).

R (15 min) and R (30 min) of RUSLE: This factor is calculated using the data from the instantaneous rainfall which gives the values of cumulative rains every 15 minutes in the same manner for R (30) which presents the values of cumulative rains every 30 minutes. The data used are from the database DGACTA/IRD.

This index takes into account the three conditions: energy, intensity of peak and duration of rain. E is a function of the kinetic energy of the rain E and maximum intensity of the rain in duration of 15 minutes I15 or 30 minutes at I30.

The R value adopted in the equation of RUSLE is the average of those subpoenaed during a hydrologic year during a multi-year period representative:

$$R = (EI)_{15} = \sum_{j=i}^{n} I_{15j} \left[\sum_{j=1}^{m} (\Delta hij, i)\, E_{i,j}\right] \qquad (5)$$

Has each not of time, measure the height rushed and the kinetic energy (E_i) generated in (MJ/ha.mm) depending on the intensity of precipitation (**I**) in (mm/h). In the equation of RUSLE, the kinetic energy, for each interval of uniform intensity in the downpour, is given by the following formula:

$$E_i = 0.29 \times [I - 0.72e^{-0.05I}] \qquad (6)$$

With I is intensity of rain in mm/h, E_i is kinetic energy of a amounted-phase and Δhi is height of the amounted phase in mm.

Factor of soil erodibility also occur throughout the ground (K)

The card of the factor K is obtained from the soil map (agricultural map, 2000). A bibliographic study allows us to determine the values of the factor soil erodibility also occur throughout K of each soil unit of the watershed as shown in Table 3.

Table 3. Factor soil erodibility also occur throughout K (reported by Cormary, 1964)

Pedological Units	**Index K (RUSLE)**	**Index K (USLE/MUSLE)**
Complex of sol	0.05	0.041
Rendzines	0.013	0.054
Soil raw minerals	0.036	0.042
Vertisols	0.01	0.01
Little Soil advanced to contribution	0.08	0.05

Factor of vegetation cover C

This factor is used to express the effect of vegetation cover present in the watersheds. In effect, because of lack of data necessary to calculate the values of the factor C there has recourse to studies conducted on the neighboring areas in our study area.

The spatial distribution map of the vegetation cover factor is obtained directly from the card of occupation of the soil made from satellite images from Google Earth. In fact, the indices of C deductions are chosen in referring to the work of Cormary and Masson (1971) in Tunisia and the applications of the RUSLE model, especially on the hilly lake Abdessaddok [39].

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The values of the factor C obtained are represented in Table 4.

Table 4. Factor of the vegetation cover C (reported by Masson (1971) & Zante et al. (2003))

Occupation	C (RUSLE)	C (USLE/MUSLE)
Dense Forest	0.01	0.1
Degraded Forest	0.05	0.1
Annual Crop	0.7	0.55
Olive Trees	0.104	0.9
Journey	0.55	0.45
Garrigues	0.3	0.36
Mixed Unit	0.37	0.72
Vivid Gullies	0	0

Factor practices of anti-erosive P

This factor reflects the effects of practices that reduce the amount of runoff water and the runoff rate and which reduce to this fact the importance of erosion.

The protection index P used in the USLE model is a report without dimension obtained by comparison of erosion measured on plots where the work is done in the direction of the greatest slope (P = 1) and the erosion of plots variously protected and or P < 1, all other factors being equal.

The practices anti-erosive the most used at the watershed of El Gouazine are the benches.

The indexing of this factor is derived primarily from experimental results of Masson (1971), Heusch (1970) in Mediterranean area as well as of various compilations (FAO, 1993, WSC Tunis, 1995).

Table 5 presents the weighted values of the P index as a function of slope, illustrating the effect of anti-erosion practices on reducing soil erosion. This factor is essential in the USLE, MUSLE and RUSLE models, where it reflects the effectiveness of practices aimed at limiting the impact of runoff and stormwater.

Table 5. Weighting of the index P according to the slope

Slope (%)	Index P (USLE/ MUSLE)	Slope (%)	Index P (RUSLE)
1-2	0.6	0 -5	0.1
2-7	0.5	5 - 15	0.12
7-12	0.6	15 - 25	0.16
12-24	0.8	25 - 35	0.18
> 24	0.9	> 35	0.28

Topographic factor handset (LS)

This factor results from the combination of the tilt factor S and length L of slope. The action of the angle of the slope on runoff is amplified by the length of the slope, even if the impact of the latter remains limited.

The steep slopes with a fast flow are in general at the origin of major erosion whose importance depends on the geology, of the nature of the soil, and the protection by the vegetation cover. The LS factor is a function of the length and the angle of the slopes.

Factor of practices LS according to USLE/MUSLE

Several studies have been carried out for the determination of this factor in our case we are going to work with the equation of (Smith & al., 1996) presented in Eq. (7) [39]:

$$LS = 1.4 * (\frac{A_S}{22.1})^{0,4} * \frac{\sin(\theta * 0,01745)^{1,4}}{0,09} \qquad (7)$$

With θ is the angle of the slope in degrees and A_S is the specific surface writing under a GIS in the following manner (Moore and Burch, 1986):

$$A_S = \text{Flow Accumulation} * \text{Cell Size} \qquad (8)$$

The surface map (A_S) is determined by multiplying the card of the runoff accumulation (Flow accumulation) by the pixel size (resolution).

Factor of practices LS according to RUSLE

In the framework of our study, we used the formula developed by Wischmeier and Smith (1978) which has been used by several authors [40].

$$LS = (\text{folow accumulation} * \frac{\text{resolution}}{22.1})^{m} * (0,065 + 0,045 * S + 0,0065 * S^2) \qquad (9)$$

With S is the slope (%) and m is a parameter such as Table 6.

Table 6. Value of ‘m’ relative to each class of slope

Slope (%)	m
> 5	0.5
3-5	0.4
1-3	0.3
< 1	0.2

Table 6 presents the values of the parameter m according to the slope classes, a key element in the calculation of the LS factor according to the RUSLE method. This parameter m m translates the relationship between the slope inclination and the flow length.

Map of soil loss

The crossing of the cards of the major factors involved in soil erosion by water allows you to get the card of losses in soil at any point in the watershed (Figure 2).

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Method of food and agriculture organization (FAO)

The FAO has developed in 1979 a methodology at the national level to both parametric and empirical. This methodology is a generalization of USLE. This formula depends on the following characteristics: the climatic erosivity of rainfall, the nature of the soil, the slope of the land and the occupation of the land.

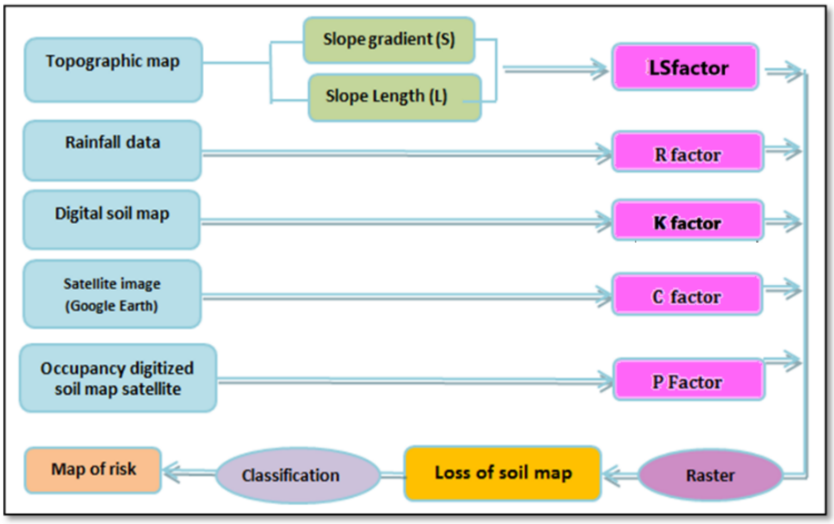

Figure 2. Flowchart methodological

She made an estimate of annual erosion Es (t/ha/year) according to the following formula:

$$Es = Fm \times C1 \times C2 \times C3 \qquad (10)$$

With Fm is index of Fournier amended characterizing climatic erosivity of rain;

$$Fm = \frac{\sum_{i=1}^{12} Pi}{P} \qquad (11)$$

Where Pi being the rain average of the month i (mm), P is rain annual average (mm), C1 is the coefficient of soil texture which depond of its nature and between 0.5 and 1, C2 is the coefficient which topographic depond of the slope and ranging from 0.5 to 1.5. C3 is the operating ratio of soils which vary according to the occupation of soils ranging from 0.4 to 1.

C1 is determined from the soil map of the watershed depending on the nature of the ground (Table 7).

Table 7**.** Value of the coefficient C1 [41]

Nature of the soil	**Coefficient C1**
Sandy-loam	0.5 to 0.6
Silty	0.7 to 0.8
Silty-clay	0.9 to 1.1
Clay	1.1 to 1.2

Source: Guide WSC (Cherif et al., 1995).

C2 is determined from the slopes map of the watershed (Table 8).

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Table 8. Value of the coefficient C2

Class C2 of	0 - 8 %	8 - 30%	> 30 %
Slope	0.5-0.7	0.8-1.0	1.2-1.5

Source: Guide WSC (Cherif et al., 1995).

C3 is determined from the map of occupation of the soil of the catchment (Table 9).

Table 9. Value of the coefficient C3

Occupation of ground	Cereal crop	Arboriculture	Journey	Brushland	Forests
C3	0.8-1	0.7	0.6	0.5	0.4

Source: Guide WSC (Cherif et al., 1995).

This work has allowed us to characterize the various parameters of the universal equation of the soil loss by consultation of former research and professional studies on the study area. These settings have been distributed on the totality of each watershed. The climatic erosivity of rain is assumed constant throughout the basin for each lake hilly, whereas the other parameters will be presented subsequently in the form of thematic maps.

ASSESSMENT OF EROSION

The application of the USLE model

The superposition of the maps of the various factors involved in water erosion soil to get the card of losses in soil at the catchment. In effect the application of the formula of Wischmeier & Smith (1978) taking into account the numerical values of the five factors given the loss in soil for each point of the catchment. This treatment allows you to divide the territory of the watershed in separate units. Each unit has the values of homogeneous factors of the USLE, with a loss in soil average of all pixels of the unit expressed in (tone/ha/year).

Masson (1971), on the basis of experiences in the semi-arid Tunisian, proposed a soil loss tolerable of approximately 2.5, 5 and 10 tones/ha/year. In fact, on the basis of classification of Masson, we adopted a new classification which better reflects the spatial distribution of soil loss. It has been calculated the erosion on two periods (before management water conservation and soil and after development).

1st scenario: Map of erosion before the management WSC

The spatial distribution of the land loss of catchment basin El Gouazine before the works of WSC in applying the USLE model is presented in Figure 3.

The examination of Figure 3 shows that the sharp erosion in the order of 52.08 t/ha/year is located at the level of high altitude. While the low erosion (less than 2.5 t/ha/year) is located at the level of areas of low altitude and at the level of the plains. The total losses of the annual basin are of the order of 53787 t/year with a rate of average erosion of 2.041 t/ha/year.

The spatial distribution of different classes of soil loss is presented in Table 10.

Table 10. Class of soil loss determined by the USLE model

Class (tone/ha/year)	Area (ha)	% Surface
0 2,5	1304,31	76.36 %

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2.5 - 5	176.15	10.31 %
5 - 10	143.3	8.38 %
10 - 20	56.9	3.33 %
20 - 52.08	12	0.69 %

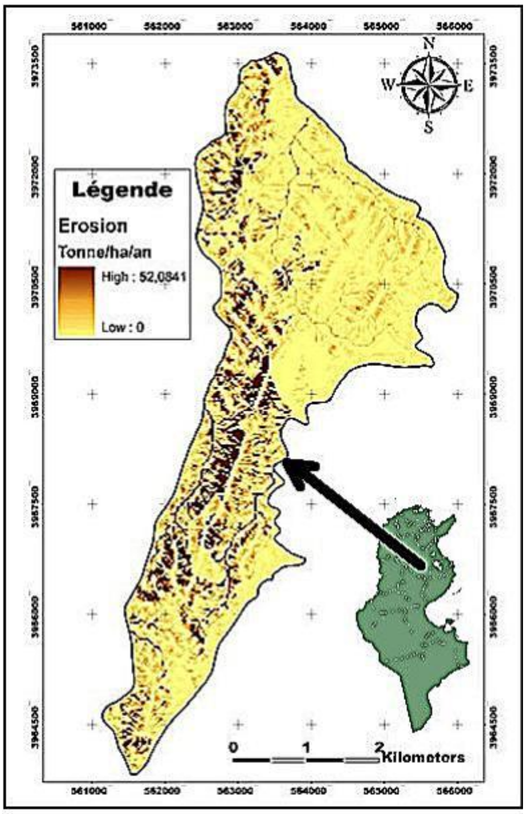

Figure 3. The spatial distribution of soil losses from the watershed El Gouazine before the WSC management with the USLE model

Table 10 shows that 76% of the basin is characterized by a loss of ground low (less than 2.5 t/ha/year). While approximately 19% of the basin have a loss of average ground varying from 2.5 to 10 t/ha/year. While only 4 per cent of the basin have a strong soil loss (greater than 10 t/ha/year).

2nd scenario: Map of erosion after the management WSC

The crossing of the different maps of factors LS, K, C and P of the RUSLE model with the climatic erosivity of rain obtained by the USLE model allows you to get the card of losses in soil at any point in the watershed after development. The results are illustrated by Figure 4.

From Figure 4, it is found that the average loss by water erosion in tablecloths for all the homogeneous units is approximately 1.46 t/ha/year. The maximum loss and minimum per unit in the watershed are respectively of 43.56 t/ha/year and 0 t /ha/year. The total losses of the annual basin are of the order of 38511,17 t/year. The erosion rate differs from one area to another of the watershed, according to the influence of different factors which control the erosion.

The distribution of the surface on the classes of soil loss adopted is presented in Table 11.

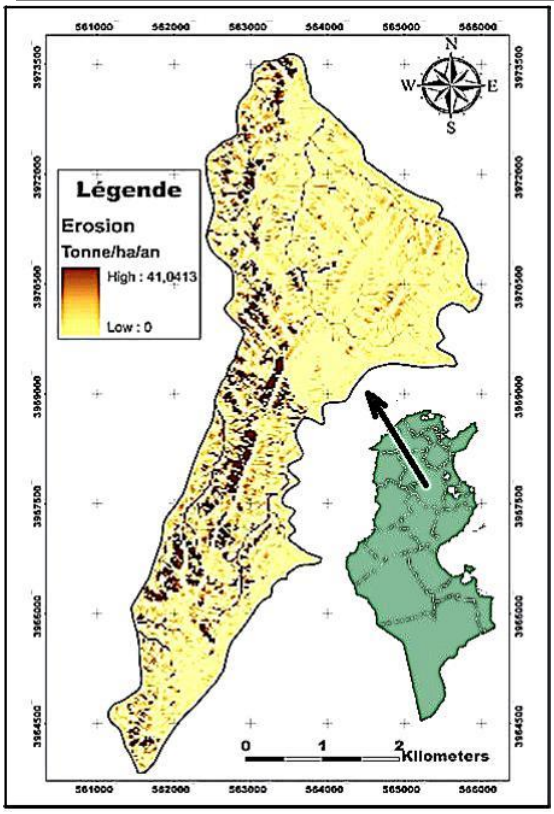

Figure 4. The spatial distribution of land loss of El Gouazine after the management WSC for the USLE model

Table 11. Class of soil loss determined by the USLE model after the management WSC

Class (tone/ha/year)	Area (ha)	% Surface
0-2.5	1426,77	90.31 %
2.5-5	26.52	1.68 %
5-10	96.65	6.11 %
10-20	26.52	1.71 %
20-43.56	2.96	0.19 %

The analysis of Figure 4 and Table 11 shows that 90% of the basin is characterized by a loss of ground low (less than 2.5 t/ha/year). While approximately 8 % of the basin have a soil loss average of 2.5 to 20 t/ha/year. When less than 2 % of the surface of the catchment of El Gouazine have a strong loss of soil (greater than 20 t/ha/year).

By comparing the results obtained by the USLE model before the management WSC and those obtained by the same model after then, we found that:

The total loss of the soil decreases of 40%; of 53787.28 t/year before planning up to 38511.17 t/year after development.

The value the average of the annual erosion declined by 40 %; of 2.04 t/ha/year (before construction) to 1.46 t/ha/year (after development).

The maximum value of the erosion decreases of 52.08 t/ha/year up to 43.56 t/ha/year.

While the minimum value remains constant equal to 0 t/ha/year.

The % of surface occupied by a strong erosion decreases of 4.02% up to 1.9% while the surface which presents an erosion low (< 2.5 t/ha/year) increased by 76.36 per cent up to 90.3 per cent of the total surface area with rates of increase of 15%.

CONCLUSION

The main objective of this work is to map and quantify water erosion in the El Gouazine watershed using four empirical models integrated into a Geographic Information System (GIS). These models, namely the Universal Soil Loss Equation (USLE), its revised version (RUSLE), the amended version (MUSLE) and the FAO equation, have made it possible to obtain a detailed synthesis of the distribution and intensity of erosion. The results show that more than 74% of the basin is characterized by low soil loss, less than 2.5 tons per hectare per year, while 20% have moderate erosion between 2.5 and 10 tons per hectare per year. On the other hand, about 13.74% suffer from significant erosion greater than 15 tons per hectare per year. After the application of soil and water management (WSC) practices, including features such as benches, there was a significant reduction in erosion, with the average annual soil loss decreasing from 6.18 tonnes per hectare per year to only 1.07 tonnes per hectare per year for the RUSLE model. Similarly, for the MUSLE model, the average soil loss decreased from 5.49 tonnes per hectare to 3.36 tonnes per hectare per year after the application of the management practices. In addition, these interventions reduced the area affected by high erosion from 7.31% to only 2.7%, while the area affected by low erosion increased from 59.28% to 66.35%. These results highlight the significant benefits of sustainable soil and water management practices on erosion reduction, as well as the preservation of natural resources, while suggesting new research perspectives to integrate the interconnection of groundwater with surface runoff in order to improve overall watershed management.

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