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ESTIMATION AND MAPPING OF SOIL EROSION USING THE RUSLE MODEL AND GIS TOOLS: A CASE STUDY OF THE WAD EL HAI WATERSHED IN THE WESTERN AURÈS, NORTH-EASTERN ALGERIA

Abstract: Soil erosion is the main cause of siltation in dams, on the one hand, and it is one of the main causes of degradation of the agro-pedological heritage, on the other hand. In this context, this work aims to quantify the eroded soils and their spatial distribution in the watershed of Wad El-Hai (Aurès, Algeria), reaching the Fontaines des Gazelles dam located at the outlet of this basin. The work focuses on mapping and analyzing various thematic maps representing the key erosion factors, linking the Revised Universal Soil Loss Equation (RUSLE), with the goal of producing a synthesis map providing a quantitative spatial representation of the extent of the phenomenon in the watershed. From this map, we can confirm that the erosion phenomenon affects the entire watershed of Wad El Hai. The most severe erosion, affecting 11.60% of the expansive territory at rates exceeding 33.6 tons per year per hectare, is predominantly concentrated in mountainous regions marked by exceptionally steep slopes. Conversely, the majority, accounting for 64.23% of the entire expanse, is situated in the plains, where erosion rates are comparatively lower at 6.7 tons per hectare per year. The assessment of potential water erosion yields disconcerting outcomes, projecting an average annual loss rate of 15.38 tons per hectare throughout the entire catchment area. The results presented in this study will serve as a vital resource and a decision-making tool, supporting the management and preservation of natural resources by policymakers and stakeholders.

Key words: Watershed Wad El-Hai, erosion, RUSLE, siltation of dams, Fontaine des Gazelles dam

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Introduction

The phenomenon of erosion has long been a subject of interest to many researchers around the world, given its consequences, such as sedimentation in dams and watercourses, floods, and the degradation of agricultural lands, which can lead to significant economic costs. The Mediterranean region has traditionally been considered susceptible to erosion (Henin & Gobillot, 1950; Auzet, 1987; De Ploey, 1989; De Noni et al., 1997).

Erosion has become a major issue in the North African region, where water and soil potentials are seriously threatened (Heush et al., 1971; Demmak, 1982; Meddi, 1992; Lahlou, 1994; Touaibia et al., 2001; Terfous et al., 2003; Achite et al., 2005, Berghout, 2017). Algeria has a fleet of 64 operational dams, with a total (initial) capacity of 7745 hm^3. Bathymetric surveys of the dams in 2004 revealed that the storage capacity had been reduced to 6736 hm^3 due to siltation (Manser A, undate).

Various methods of combating the phenomenon of erosion, degradation of agricultural lands and siltation of dams have been developed and implemented in the field, and it has been proven that reforestation of part or all of the surface of a watershed, combined with torrential flow correction, can effectively reduce erosion and solid transport.

The construction of small sedimentation dams upstream of the dams to be protected proves very useful, if we refer to the experience gained in the watersheds of the Hamiz, K'Sob, Zardezas, Boughezoul and Ghrib dams. The implementation of these erosion control structures requires knowledge of the spatial distribution of erosion in the upstream basin of the dam (Rango & Arnoldus, 1987; Roose, 1996). Similarly, dredging in dam reservoirs and flushing by partial emptying can help reduce dam volume, as was the case with the CHEURFAS I dam in the 1959-1962 period and the Hamiz dam in the 1969-1972 period.

The Wad El-Hai watershed, recently equipped at the outlet of a dam commissioned in 2000, is a case in point. In this study, we will attempt to quantify erosion and identify erosion-prone areas within the watershed with the aim of developing a plan to protect the dam against the risk of silting.

Numerous researchers have developed relationships linking erosion or sediment transport to geomorphological, lithological, and climatological factors. One of the most widely used relationships for predicting water erosion at an annual scale is the Revised Universal Soil Loss Equation (RUSLE) by Wischmeier and Smith (1978). This equation takes the form of a product of five independent factors, each representing a parametric equation with multiple variables.

The objective of this study is to quantify the average annual sediment yield entering the Fontaines des Gazelles dam, as well as the spatial distribution of erosion risk in its watershed, 'Wad El-Hai,' belonging to the larger Chott Melghir watershed, by applying the Revised Universal Soil Loss Equation (RUSLE).

The results of this research can help to make the right decisions and choose the best strategies to increase the lifespan of the Fontaines des Gazelles dam, protect and restore agricultural land, and combat erosion and desertification.

Materials and methods

Study area

The Wad El Hai watershed is located in the southern foothills of the Aurès Mountains, between longitude 5° 30' to 6° 17' 36'' East and latitude 5° 35' to 35° 35' 21'' North; it is part of the large Chott Melghir watershed, with a total surface area of around 1660 km²; To the north, it is delimited by the watershed of the Constantine Plateau, while its eastern boundary is defined by the watershed of Wad Abdi. In the west, it is bordered by the watershed of Chott El-Hodna (Figure 1).

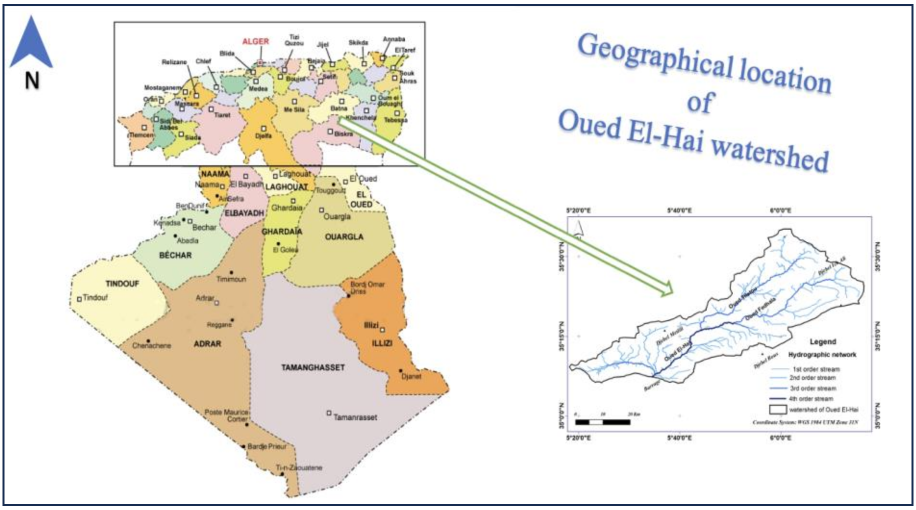

Fig. 1. Geographical location of Wad El-Hai watershed

The geological formations in the area exhibit considerable diversity primarily composed of sedimentary rocks. These include various degrees of hardness in limestone, occasionally dolomitic, as well as marly rocks that have undergone significant surface alterations, primarily due to the region's harsh climate. Throughout the fields, one can observe a succession of grey and green marl layers alongside prominent massive limestone formations, which are visible at Djebels Tuggurt, Ich Ali, and Metlili. Additionally, the 340-meter-thick El Kantara half-block, along with Djebels Bouss and El Malou, is predominantly characterized by massive limestone formations. In the northernmost part of the basin, there are hard sandstone and softer marl formations that contain gypsum crystals, notably exposed in the Jebel Tichao area (Bellion, 1973; Laffite, 1939; Rouahna, 2003; Yahiaoui, 1990).

The Wad El Hai watershed exhibits a pattern of NE-SW-oriented mountain ranges, with elevations gradually declining from the northern region, exemplified by the Belezma Mountains in the north, reaching their peak at an elevation of 2091 m. (DJ. Tuggurt), to the west is the summit of the Monts de Metlili at 1496 m a.s.l., to the south is the DJ. Bous 1789 m, to the east Ras Elkrouch 1508 m, DJ. El Malou 2091m and DJ. El Rherah 1865 m.

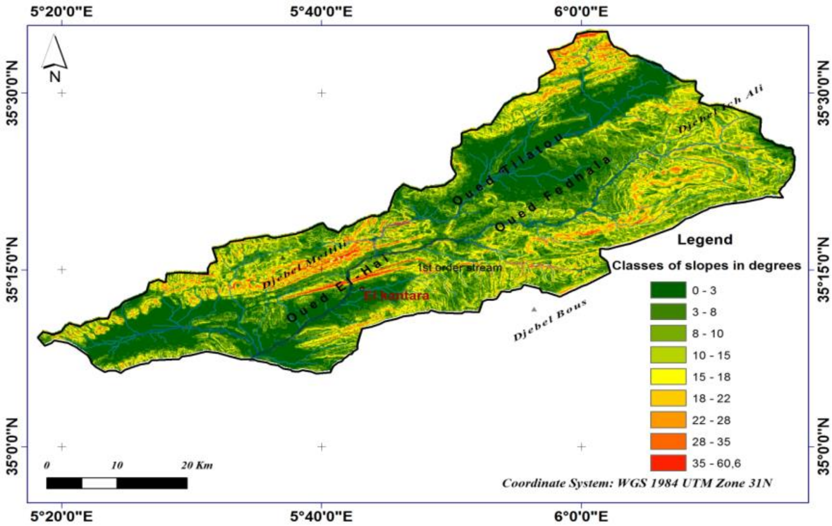

Fig. 2. Slope map of the Wad El Hai watershed

The slope map of the watershed developed from the digital terrain model (Figure 2) shows that low to moderate slopes (0-10°) are mainly concentrated in plains and river terraces, accounting for 66.97% of the watershed. High slopes (10°-28°) are primarily distributed in the central and northern parts of the basin, representing 28.40% of the total area. These areas are generally characterized by undulating hills and may consist of plateaus or hills. The remaining slopes, classified as very steep with more than 28 degrees and resembling mountain ranges, account for 4.63%.

The hydrographic network of the study basin is made up of one very important valley: Wad El Hai and its tributaries (Wad Fedhala and Wad Tilatou) (Figure 3).

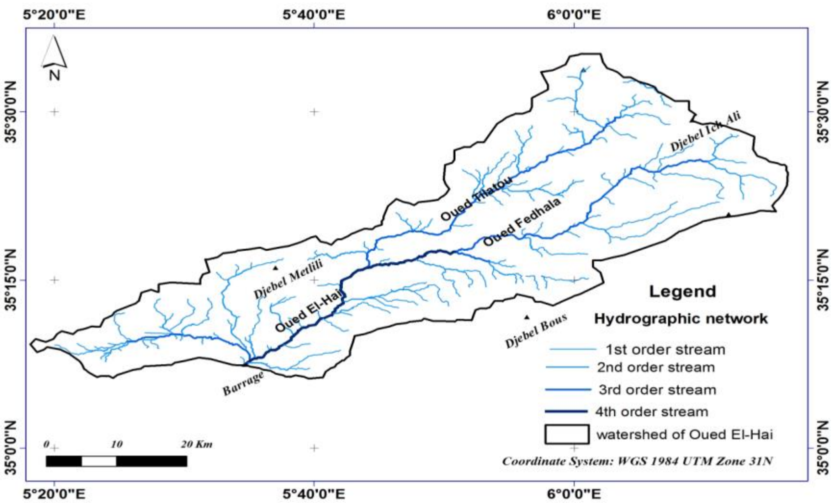

Fig. 3. Hydrographic network of Wad El-Hai watershed

The study area a climate that transitions from semi-arid conditions upstream to arid conditions downstream, featuring cold winters and hot, parched summers. Seasonal precipitation in the upper basin is mainly concentrated in autumn and spring. Unlike the lower sub-basins, precipitation is concentrated in the autumn and winter seasons, while the study area shows a decrease in precipitation and an increase in monthly, seasonal and diurnal temperatures up to 15°C.

Biological levels are highly degraded on the upper slopes, with cedar, Aleppo pine, holm oak and juniper. On the lower slopes, non-agricultural areas are covered by esparto grass and scrub. The valley floor is gently sloping and occupied by a modest cereal crop.

In summary, the rock formations in the region display moderate to low resistance against erosion. Additionally, the soils are characterized by a lack of mineral resources and are inadequately protected by degraded to severely degraded vegetation, including shrubs. The area experiences a semi-arid to arid climate with low precipitation, a significant lack of liquid water in the soil, and high temperatures. Collectively, these factors underscore the issue of erosion within the study area.

Methodology

Methodological flowchart of the applied RUSLE model

The RUSLE model of soil erosion risk is based on several natural and anthropogenic factors. It is a multiplicative function of the five factors that control water erosion: climatic aggressiveness, soil erodibility, slope and slope length, land use, and anti-erosion practices Wischmeier and Smith (1978). It is expressed as:

$$A=R * K * LS * C * P \qquad (1)$$

where:
A= Soil loss rate t/ha/year
R = Rainfall erosivity (MJ.mm/ ha.h.year),
K = Soil erodibility (t.h/ha. MJ.mm),
LS = Topographical factor (L in m, S in %),
C = Vegetation cover,
P = Agricultural activities and practices and anti-erosion projects.

To this end, satellite data (vegetation cover, land use and occupation), lithological data morphology and climatic data into a geographic information system (GIS).

Input data

The primary input factors employed in this research encompass precipitation, soil composition, and land usage. The goal is to construct an extensive database that facilitates the manipulation, continual updating, and visualization of these data sets (Table 1).

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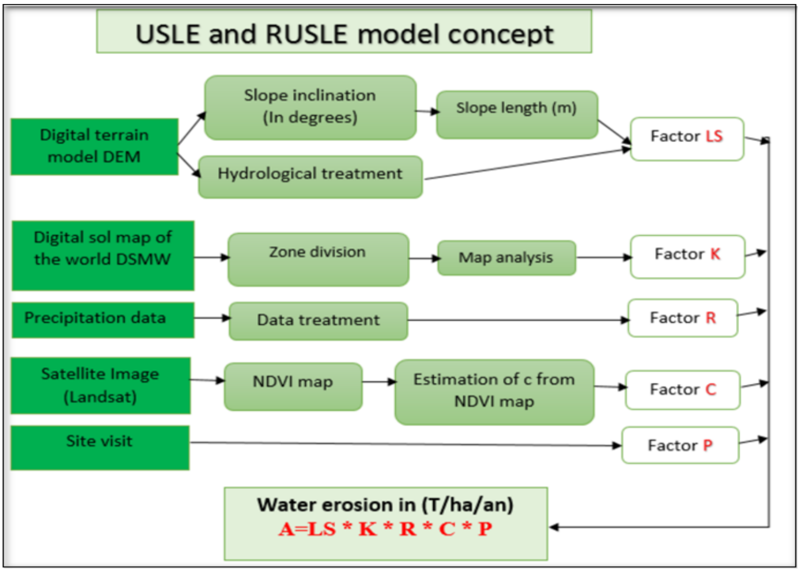

Fig. 4. Methodological flowchart of the applied RUSLE model

Tab. 1. Data source and description

Factor	**Data type**	**Source**	**Description**
Rainfall erosivity	Precipitation data	National Water Resources Agency ANRH, 2020	Precipitation data for 38 years (1970-2009) from seven rainfall stations
Soil erodibility	soil data	Digital soil maps of the world (DSMW)	Extracting the soil map of the study area
Topographical factor	SRTM–DEM	Earth explorer	LC08_L1TP_194035_20190717_20190721_01_T1 LC08_L1TP_194036_20190717_20190721_01_T1 Resolution 30 m
Vegetation cover	Land use	Satellite image (Landsat) Vegetation cover map	Extracted from satellite image and Vegetation cover map
Agricultural activities and practices and anti-erosion projects	Field survey		

Calculation and mapping of RUSLE model parameters

Rainfall erosivity factor R

The R factor incorporates into its calculations the intensity of rainfall, the energy delivered during precipitation and the quantity of water that can be mobilized for runoff. To consider this factor, it is necessary to know the total rainfall and the maximum 30-minute intensity of a rainfall event over a 30-year period. As this second parameter is rarely available, it is generally not possible to calculate R using the method described in RUSLE. (Renard & Freimund, 1994) have proposed an alternative based on the relationship between R and mean annual rainfall. Table 2 summarizes the various erosivity results in MJ.mm/ ha.h.year.

$$R = 0.04830 * P^{1.610} \quad (2)$$

where:

R is the Erosivity in (MJ.mm/ ha.h.year);

P is the annual precipitation in (mm), calculated using the average annual rainfall in (mm) measured at various stations located in or near the study area.

The calculated R-values were then interpolated using an IDW interpolation method.

Tab. 2. Erosivity in (MJ.mm/ ha.h.year) in the oued El Hai watershed

Stations	**Altitude (m)**	**Lon (°)**	**Lat (°)**	**Pmoy annual (mm)**	**R(MJ.mm/ ha.h.year)**
N'gaous	750	5.611	35.562	250.59	35.18
T-elabed	1390	6.193	35.255	259.60	37.24
Djemoura	400	5.842	35.072	147.94	15.06
Batna	1040	6.167	35.565	358.97	62.75
Biskra	130	5.744	34.855	111.30	9.52
Bouhmar	1275	6.407	35.434	318.15	51.67
Menaa	1005	6.005	35.179	247.31	34.44
Barrage at-touta	471	5.413	35.408	222.70	29.09
Ain Touta	917	5.898	35.391	251.50	35.34
Oued Chelih	1180	6.007	35.539	317.90	51.60
Merouana	1000	5.913	35.637	447	89.32
Tazoult	1200	6.249	35.494	346	59.14
Hamla	1174	6.088	35.565	318.50	51.76
Bouzina	1350	6.108	35.281	279.20	41.87
El Kantara	513	5.718	35.223	230	30.64

Figure 5 shows the erosivity map synthesized from the spatialization of hydrological stations, showing that the value of the R factor varies from 28 (MJ.mm/ ha.h.year) to 58 (MJ.mm/ ha.h.year). The highest values are recorded in the north-east, while the lowest values are recorded in the south-east of the wad El Hai watershed.

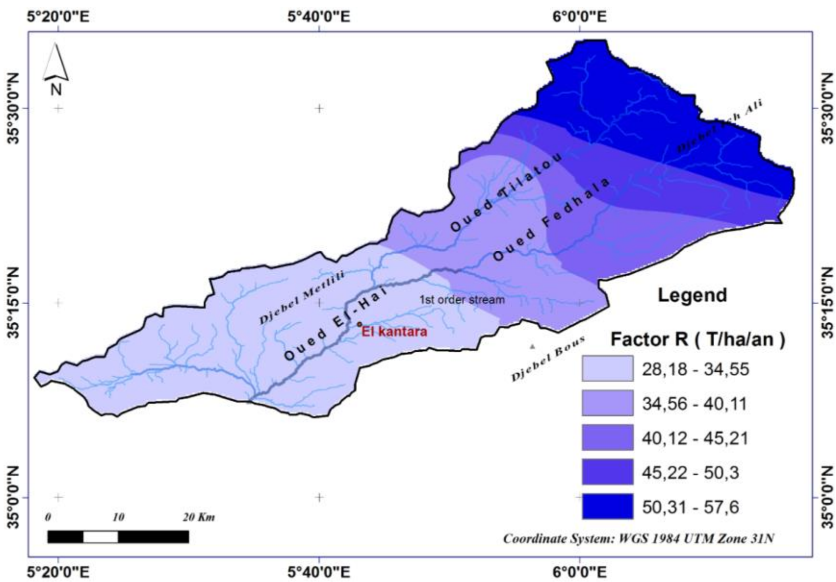

Fig. 5. Erosivity factor R in the Wad El Hai watershed

Soil erodibility factor K

To estimate the K factor, we used equations from (Williams, 1995) and the DSMW (Digital SoilMap of The World) map. Processing this map with Gis software gave us all the granulometric parameters of the soils, i.e. the percentage of organic carbon, sand and clay. The soil erodibility factor was calculated using Williams (1995) formula 3.

$$K = F_{Csand} \times F_{cl\text{-}si} \times F_{Orgc} \times F_{hisand} \times 0{,}1317 \tag{3}$$

where:

K: the erodibility factor;
OrgC: the percentage of organic carbon;
Csand: the percentage of coarse sand;
cl-si: the percentage of clay and silt;
hisand: the percentage of sand.

$$F_{Csand} = \left(0{,}2 + 0{,}3 \times \exp\left[-0{,}256 \times m_{Csand} \times \left(1 - \frac{m_{silt}}{100}\right)\right]\right) \tag{4}$$

$$F_{cl\text{-}si} = \left(\frac{m_{silt}}{m_c + m_{silt}}\right)^{0{,}3} \tag{5}$$

$$F_{OrgC} = \left(1 - \frac{0{,}0256 \times OrgC}{OrgC + \exp(3{,}72 - 2{,}95 \times OrgC)}\right) \tag{6}$$

$$F_{hisand} = \left(1 - \frac{0{,}7 \times \left(1 - \frac{m_{Csand}}{100}\right)}{\left(1 - \frac{m_{Csand}}{100} + \exp\left[-5{,}51 + 22{,}9 \times \left(1 - \frac{m_{Csand}}{100}\right)\right]\right)}\right) \tag{7}$$

where:
mc: the clay fraction content (<0.002 mm diameter) [%];
msilt: the silt fraction content (0.002-0.05 mm diameter) [%];
mCsand: the sand fraction content (0.05-2.00 mm diameter) [%];
orgC: the organic carbon (SOC) content [%].

From these equations, the K factor was calculated; the results are represented in figure 6.

K-factor values between 0.140 and 0.224 show the apparent fragility of the soil and its susceptibility to erosion. The map in figure 6 shows the spatial distribution of the different K-factor categories in the watershed, distributed across the study area according to different homogeneous units. Representing more than half of the total catchment area (64.88%), followed by an average erodibility of 0.206 and 4.25% and a surface resistance of 0.224 and 30.86%.

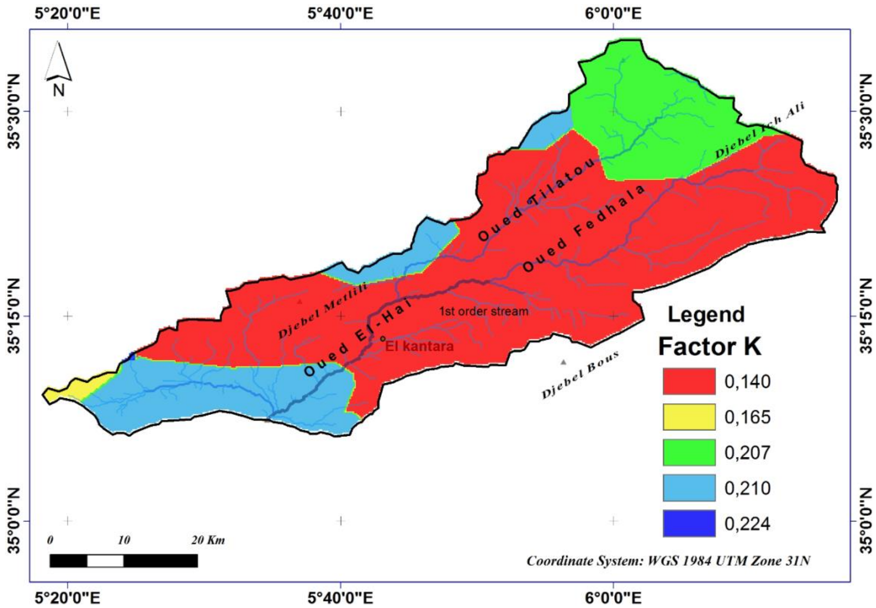

Fig. 6. Erodibility factor K in the Wad El Hai watershed

Topographical factor LS

Topography is an important factor in water erosion. Runoff is usually strong and rapid on steep slopes, causing very dangerous water erosion (Arnoldus, 1980). The topographical factor (LS) is determined from the length of slopes (L) and their inclination (S), calculated from the digital terrain model (DTM).

In our work, L and S are determined by the Gis software (Field Calculator) using the following formulas (Desmet et al., 1996):

$$LS=\left[0.065+0.0456(\text{slope})+0.006541(\text{slope})^2\right]\left(\frac{\text{slope length}}{\text{constant}}\right)^{NN} \quad (8)$$

where:
slope = slope inclination (%)
slope length = length of slope in m (ft)
constant = 22.1 in metric unit; (72.5 in imp. unit)
NN = see table 3

Tab. 3. NN values

slope	< 1	1≤ slope ≤ 3	3≤ slope ≤ 5	≥ 5
NN	0.2	0.3	0.4	0.5

The distribution diagram of the topographical factor LS (Figure 7) shows that the highest values are logically found at the highest altitudes in our study area.

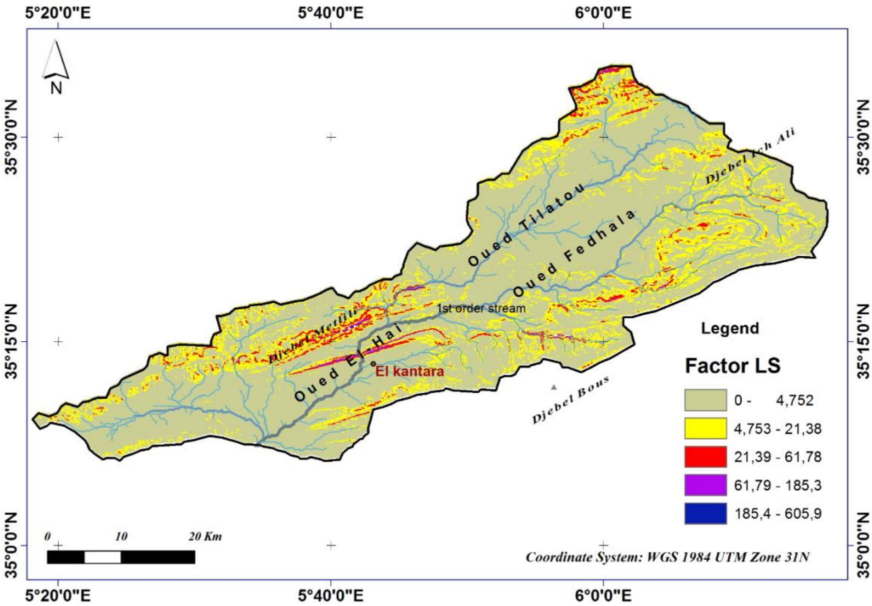

Fig. 7. LS topographic factor map in the wad El Hai watershed

Reading the map generally reflects the topography of the terrain. Values between (4.75 – 605.90) are generally located to the north, northeast, east and northwest of the watershed, coinciding with areas of high slopes, and values between 0 and 4.75 are scattered throughout the study area.

This distribution shows that 20.74% of the watershed is Class 4.75 to 605.9 consequently; a significant part of the watershed is at high risk of erosion.

Canopy factor C

The value of the C factor changes between 0 and 1, depending on land use. Given the NDVI values linked to the C factor, many researchers use regression analysis to estimate the value of C factors in the land use/land cover category in erosion assessment (Ouallali et al., 2016; Kouli et al., 2009; Zhou et al., 2008; Berghout, 2017).

The NDVI vegetation index is calculated as a ratio between the red infrared (R) and close-in infrared (NIR) bands, and reflects the synthetic active optical radiation score.

NDVI= (PIR - R) / (PIR + R)

For Landsat 8 images:

NDVI = (Band 5 - Band 4) / (Band 5 + Band 4)

The NDVI value changes between -1.0 and 1.0. The higher value indicates dense green vegetation and the lower value indicates exposed soil or water bodies.

NDVI values <0 become 0

In order to estimate the values of factor C in the study region, we used regression for five pairs of values (Berghout, 2017). These values are taken from the experimental diagram of Guitas represented in Figure 8 (Gitas et al., 2009).

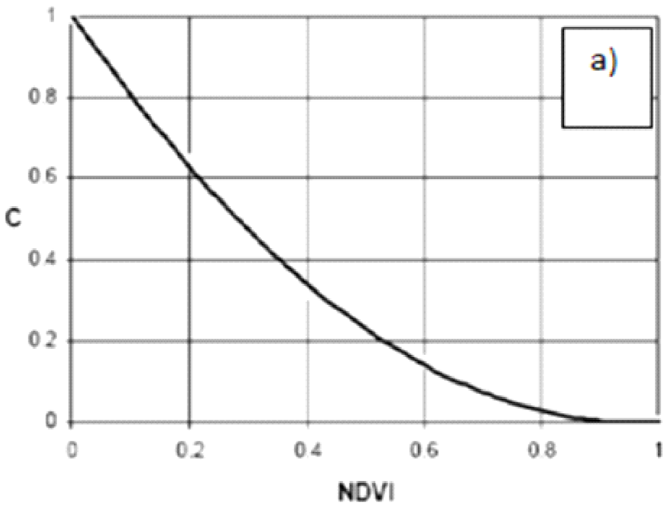

Fig. 8. Experimental diagram for estimating factor C (Gitas et al., 2009)

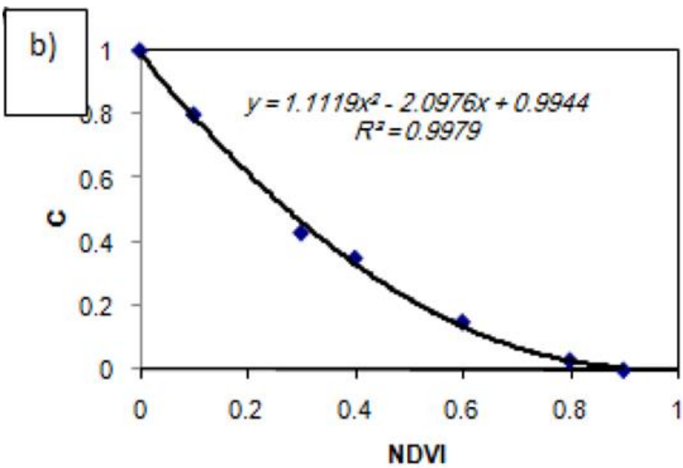

Fig. 9. Relationship between the "C" factor and the NDVI (Berghout, 2017)

To avoid inter-annual variations in the C factor, the NDVI was averaged over an 11-year period from 2002 to 2012. In addition, the dates of satellite image acquisition coincide with the four seasons of the year. The factor generated from the NDVI index gives an average value of 0.39, placing the study site in an area of low to medium vegetation cover.

The C-factor map (Figure 10) shows values ranging from 0.2 to 0.99. Referring to Figure 8's map, we can identify five prominent land occupation categories within the watershed. The lowest occurrence, with a value of 0.2, corresponds to wetland areas, while the highest occurrence, scoring 0.79, pertains to regions adorned with thinly dispersed forest cover. The highest coefficients 0.99 correspond to bare soil.

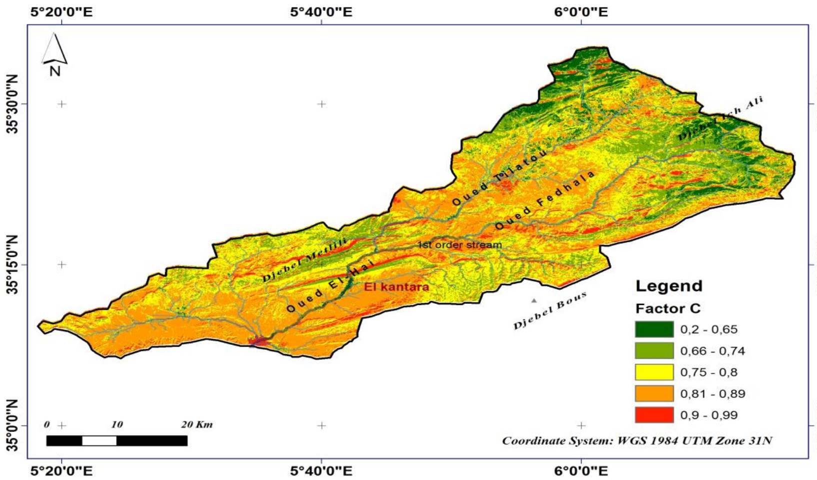

Fig. 10. Vegetation cover factor C in the wad El Hai watershed

Anti-erosion practices factor P

The P factor (Figure 11) represents soil protection and erosion control practices that reduce runoff and thus the risk of water erosion. It all depends on the measures taken. In the case of the Wad El Hai basin, values for this factor generally range from 0.55, indicating very good practices for resisting artificial erosion, to 1, representing no resistance to erosion caused by human activity.

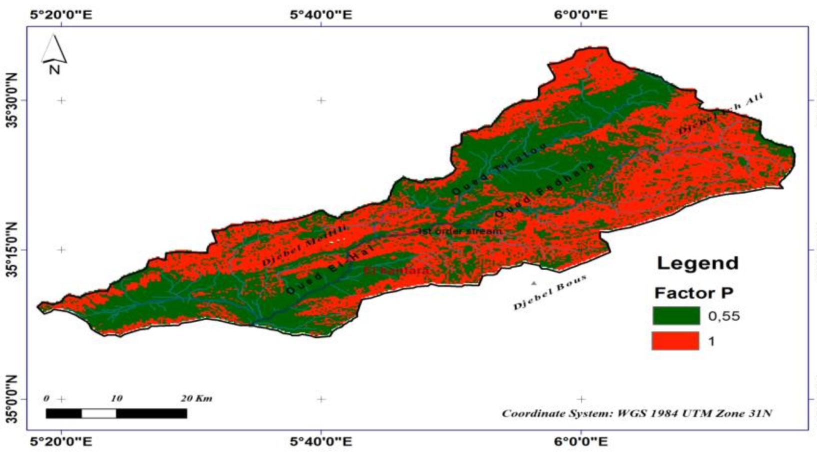

Fig. 11. Anti-erosion practices in the wad El Hai watershed

Results and discussion

Through this study, we conclude that the watershed of Oued El-Hai is characterized by elements that favor the appearance of all forms of erosion. Elevations decrease from upstream to downstream with a vertical drop of 1,714 meters, moderately steep slope, moderately low erosion resistance, semi-permeable and dynamic terrain characteristics. Drainage density is moderate to high; soils are skeletal, poorly converted to virgin minerals, and unprotected by degraded to highly degraded vegetation. All of these factors indicate that erosion in the study area is very likely. From a geological point of view, the watershed indicates that it is an area surrounded by low mountains (up to 2091 m from the Bellezema Mountains), forested on the north side and rocky and bare on the south side, both with steep slopes at the foot; there is a lot of gravel. This area is the wettest part and the El Hai wad drains it. In the study area, the rate of total vegetation cover which has a protective effect of the vegetation stratum on the ground is relatively low, particularly in the Al Hai wadi basin, whose degradation or discontinuity is characterized by the steppe grassland, which does not provide soil protection. The flora that protects the soil at only one time of the year, is found more during the flood months (September, October), so if the water arrives in the form of sudden showers, it will not be able to be absorbed and these showers will become excessively erosive.

These elements are summarized in the RUSLE model by five parameters. These parameters vary as follows:

- Erosivity factor map (R): from 28 to 58 with an average of 39.6 throughout the watershed;
- Soil erodability map (K): from 0.140 to 0.224 with an average of 0.162;
- Topographic factor map (LS): from 0.0 to 605.9; with 79.3% of values below 4.75 and an average of 3.834 throughout the watershed;
- Land use map (C): from 0.20 to 0.99 with an average of 0.78.
- Anti-erosion practices map (P): 2 values, 0.55 and 1.0.

By multiplying these parameters using a Geographic Information System (GIS), we obtain the erosion risk map (Figure 12 and Table 4), showing the erosion potential in t/ha/year throughout the watershed of Wad El Hai.

The values of the synthetic index obtained through multiplication range from 0.0 to 879.0 t/ha/year with an average of 15.38 t/ha/year as presented in table 4 and figure 12.

Tab. 4. Distribution of soil loss classes is mainly presented on the wad El Hai watershed

Soil loss class	Interval	Area (%)	Area (Km²)	Quantity (tons)
Tolerable	0.0 – 6.7	64.23	1121.1	1951
Low erosion	6.7 – 11.2	8.78	151.3	1333
Moderate erosion	11.2 – 22.4	10.56	184.3	2966
High erosion	22.4 – 33.6	4.82	84.1	2298
Most severe erosion	33.6 – 879.0	11.60	202.5	18296
Total	0.0 – 879.0	100.00	1745.3	26845

According to the classification established in the Canada based on the tolerance of agricultural soils to losses (McKague, 2023), we can classify erosion in the basin into five main categories:

Category 1 - Tolerable (very low erosion): The soil loss rate is between (0,0 - 6,7) t/ha/year and covers the largest area of the watershed, where its surface area reaches 1121.1 km², at a rate of 64.23% of the total surface area, and this is due to the gentle slope of the Kantara and Ain Touta plains. In addition to its location beneath the dense forests of Dj.Tuggurt.

Category 2 - low erosion: The loss is limited to (6,7 -11,2) t/ ha/year and covers an estimated 153.3 km² at a rate of 8.78% of the watershed area. Moreover, this is due to the gentle slope of the Kantara and Ain Touta plains. In addition to its location beneath moderately dense forests and low vegetation.

Category 3 - Moderate erosion: The rate of soil loss ranges between (11,2 – 22,4) t/ha/year; it covers an estimated area of 184.3 km², at a rate of 10.56% of the total area. It is associated with areas of steep slopes and low vegetation, as well as on hill slopes. These areas move between steep cliffs and plains.

Category 4 - High erosion: The rate of soil loss ranges between (22,4 – 33,6) t/ha/year; it covers an estimated area of 84.1 km², at a rate of 4.82% of the total area. It is generally located to the north, northeast, east, and northwest of the watershed around areas with steep slopes and low vegetation cover.

Category 5 – Most severe erosion: The rate of soil loss ranges between (33,6 – 879,0) t/ha/year; it covers an estimated area of 202.5 km², at a rate of 11.60% of the total area. It is located to northeast, east, and northwest of the watershed around areas with very steep slopes and very low vegetation cover, as well as on the riverbanks and vegetation-free areas.

In the watershed, only a fraction of the eroded soil will reach the outlet of the system. This portion of sediment is referred to as the sediment delivery ratio (SDR). It is generally estimated using the soil conservation service method (USDA Soil Conservation Service, 1983).

$$SDR = 0.417762\ A^{-0.134958} - 0.127097 \tag{9}$$

where:
SDR: Sediment Delivery Ratio (%);
A: Watershed area (mi²).

$$SDR = 4.64\%$$

It can be concluded that 95.54% of the sediments are trapped in the traps between the generation point and the outlet of the watershed, and the fraction reaching the Fontaine des Gazelles dam is approximately 4.64%, which corresponds to 1245.6 tons per year.

If we consider that the solid inputs reaching the dam are those measured at the El-Kantara hydrometric station located upstream of the dam at a distance of about 10 km (1362.7 x 103 tons/year) (Attoui & Hadji, 2022), we will have the relative error between the measured and simulated quantities by RUSLE: Er = 8.53%.

This error demonstrates good agreement between the RUSLE simulation results and field measurements on an annual scale; therefore, the application of this model can lead to good results as long as representative data is available.

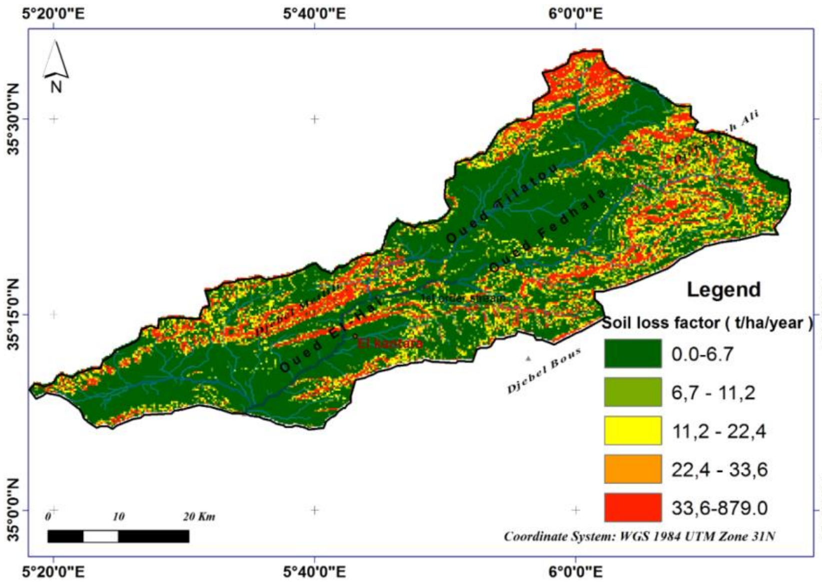

Fig. 12. Soil loss in (t/ha/yr) in the wad El hai watershed

Conclusions

Through our research efforts, we have successfully computed the outcomes of implementing the Revised Universal Soil Loss Equation (RUSLE) via a Geographic Information System within the Wad El-Hai watershed. These findings underscore the watershed's susceptibility to and significant impact from soil erosion. If soil erosion rates persist at their current pace, it is probable that this will result in substantial land degradation and, additionally, accelerated siltation of the Fontaine des Gazelles dam.

The watershed experiences an annual average soil loss rate of 15.38 tons per hectare. This figure reflects erosion levels that exceed the soil's natural tolerance, aggravated by the region's harsh climate characterized by low but sporadic rainfall. These conditions, marked by localized and intermittent storms, do not permit pedological adjustments to offset the soil loss. The fact that 16.42% of the area falls under the high and most severe soil erosion category is a concerning signal, emphasizing the urgent need for effective soil erosion management in this region.

The gravity of this situation is further heightened by additional erosion catalysts, which collectively intensify the erosion process. These factors include steep terrain, soils highly prone to erosion, and the alarming deterioration of vegetation cover. Nonetheless, the integration of the model into a Geographic Information System (GIS) presents several advantages. It enables the systematic management of a vast array of qualitative and quantitative data pertaining to various soil degradation factors, culminating in the creation of a comprehensive map illustrating the distribution of erosion sensitivity levels across different regions within the watershed.

While the applicability of soil loss calculations using the Revised Universal Soil Loss Equation (RUSLE) in a SIG has yielded good results compared to measurements from the

El-Kantara hydrometric station (relative error of 8.53%), the exploration of other models is necessary to enhance and compare results within our specific study area.

The results obtained from this model (in terms of the quantity and spatial distribution of erosion) prove invaluable for decision-makers and planners. It aids in devising erosion control strategies and preventive measures based on soil erosion data. Additionally, it facilitates the selection of suitable agricultural practices and erosion mitigation techniques, taking into account the risk level (low, moderate, or high), and allows for monitoring the impact of land use and development.

Furthermore, the integration of Geographic Information Systems (GIS) with the RUSLE model technique can be extended to other regions in Algeria to estimate and monitor soil erosion on a larger scale. Moreover, the utilization of data at the seasonal or monthly scale can provide information on the spatiotemporal variation of erosion in the watershed.

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