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Estimation and cartography the water erosion by integration of the Gavrilovic "EPM" model using a GIS in the Mediterranean watershed: Lower Oued Kert watershed (Eastern Rif, Morocco)

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ABSTRACT

The lower Oued El Kart watershed, situated in the north of Morocco, on the Mediterranean side of the eastern Rif, is characterized by a semi-arid bioclimate and rare and irregular rainfall. The obtained result shows that the watershed loses an average of 14,7 t/ha/year. To evaluate this dynamic and the losses of soil it engenders, we have preceded the integration of the EPM model (Erosion Potential Method) of GAVRILOVIC in a GIS. The maximum loses are 138,8 t/ha/year and minimum are 0,01 t/ha/year. Total annual loses of the watershed of the Oued El Kart low an average of 205 800 t/year (Erosion in the plot). The results analysis of this model has permitted, also using a GIS, to determine the factors that control the water erosion and which are in order of importance: the soil protection (vegetation), erosion types, soil erodibility, the precipitations, the slope and temperature. It should be noted that the used methodology of EPM model applies to various types of erosion.

Keywords— *Watershed of the Oued El Kart Low, Degradation, soil, EPM model, GIS*

1. INTRODUCTION

The dominant geomorphological process in most of the globe is due in particular to water erosion (Toy et al. 2002). It is an environmental problem worldwide, with several physical factors (predominance of heavy slopes and vulnerable lithological formations, low natural cover and irregular rains) and anthropogenic (land use, high population density and deforestation) promoting the development and acceleration of the processes of this phenomenon.

Soil erosion by water considered is a serious problem in the Mediterranean region, is more pronounced in the Rif mountains than in the rest of Morocco. These areas are characterized by the predominance of friable geological formations (marls, marl-limestone, etc.). Human intervention is very important in the degradation of the environment through a number of interventions such as ploughing, etc. The consequences of these human actions are affected by intense erosion, the forms of water erosion (sheet erosion, rill, gully erosion, Badland, etc.). The quantification of the Soil erosion by water using a Geographical Information System (GIS), provides a better and consistent quantitative approach to estimating soil erosion through the application of mathematical equations, namely the Equation of Gavrilovic's EPM Model, which covers various types and forms of erosion and taking into account their adaptability to the study area.

2. STUDY AREA

Oued El Kart watershed low is located in the west of the Eastern region in Morocco, more precisely 15 km West of the Nador city's, between latitudes 698,000 and 716,000 north, longitudes 516,000 and 505,000 west. It is an area of approximately 140 km^2 that is limited to the west by the Amjaw massif and to the east by the Gourogou massif. The climate is semi-arid with a rainfall annual average of 300 mm. Geologically, the area is characterized by a quaternary deposit. Several soil types were identified such as poorly evolved soils and mineral soils with alluvial input.

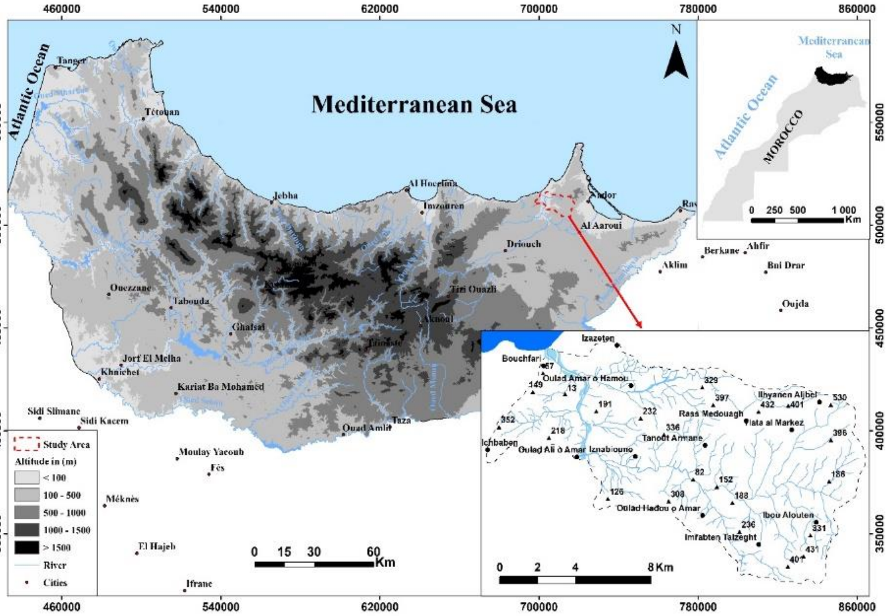

Fig. 1: Presentation of the study area

3. APPROACH AND METHOD

3.1 APPROACH

The EPM model 'Erosion Potential Method' (Gavrilovic, S., 1962; 1970; 1972), was developed in the 1950s by Gavrilovic in watersheds of the Morava River in Serbia (Ex Yugoslavia)[1]. The method aims to quantify Soil erosion by water and to develop suitable practices for reducing soil loss. It is applicable to various types of erosion (sheet erosion, rill, gully erosion, Badlands, ...) which differs from the Universal Soil Loss Prediction Equation (USLE, RUSLE) which applies only to sheet erosion. The EPM model is expected to combine the factors of water erosion depending on precipitation volumes and temperature, soil erodibilty, soil protection, types of erosion and slopes. Water erosion is linked to soil loss by the equations developed by Gavrilovic, S., 1962; 1970; 1972.

The application of the Gavrilovic model required the mapping and integration of the various parameters that are necessary for the operation of the EPM model in the Geographic Information System (GIS). This coupling makes it possible to evaluate the soil losses and to estimate the weight of each factor and their combined effects on the one hand and to disentangle their interdependence on the other. in a quick and efficient way, to unravel the complexity and interdependence of the factors responsible for erosion. The equation expresses erosion as the product of six factors representing: slopes, precipitation, temperatures, soil erodibility, types of erosion and soil protection :

$$\mathbf{W = \pi * T * H * \sqrt{Z^3}}$$

Where;
W: average annual soil erosion (m^3/km^2/year).
T: temperature coefficient.

$$\mathbf{T = (0,1 * to) + 0,1}$$

Where;
to : average annual temperature en ^{O}C.
H : is average annual precipitation (mm).
Z: erosion coefficient.

$$\mathbf{Z = y * Xa * (\delta + \sqrt{Ja})}$$

Where ;
y: Coefficient of soil erodibility. It depends on the rock, soil types and climate.
Xa: Soil protection coefficient against influences related to atmospheric phenomena.
δ: Coefficient that expresses the type and degree of evolution of visible erosion processes in the watershed.
Ja: slope angle (%).

Convert the results of this model from m^3/km^2/year to t/ha/year by applying the density equation (ρ):

$$\mathbf{\rho = m / V}$$

Where ;
m: the mass of the homogeneous substance occupying a volume V.

3.2 METHOD

This work was carried out according to the steps outlined in the following Organization chart (Figure2).

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[1]NevenaDragičević , Barbara Karleuša, NevenkaOžanić (2016).

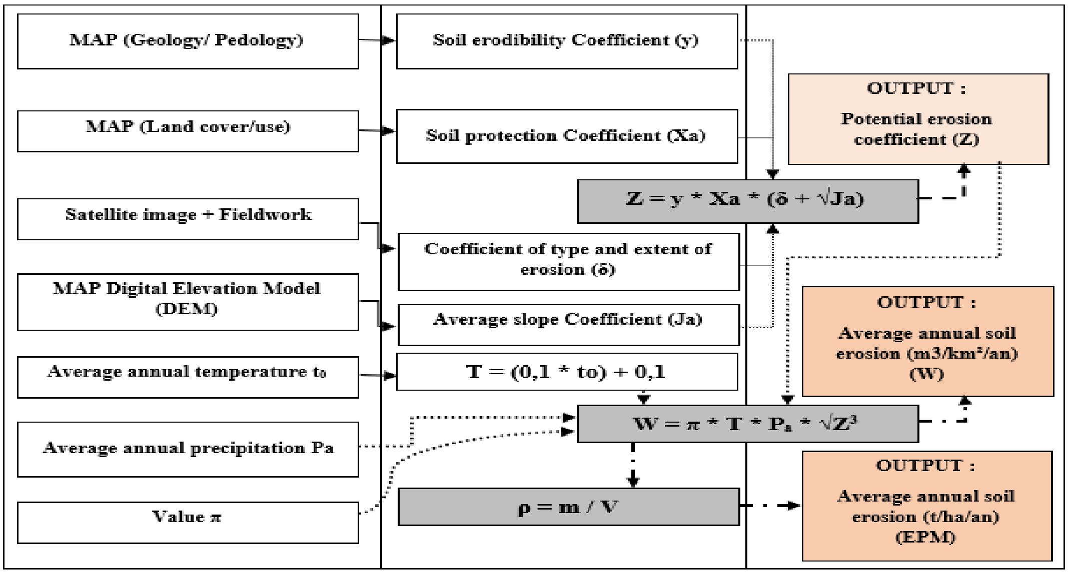

Fig. 2: Organization chart of the methodology adopted

4. PARAMETERIZATION OF EPM MODEL FACTORS

4.1 AVERAGE SLOPES COEFFICIENT (JA)

Slopes are one of the most important factors in the EPM model. The biggest relief parameters which determine the intensity of the water erosion in the watershed is the slope gradient. The increase in flow velocity under the effect of slopes strongly causes erosion. The spatial distribution of slopes in the Oued El Kart low catchment area generally depends on the lithological nature of the substrates.

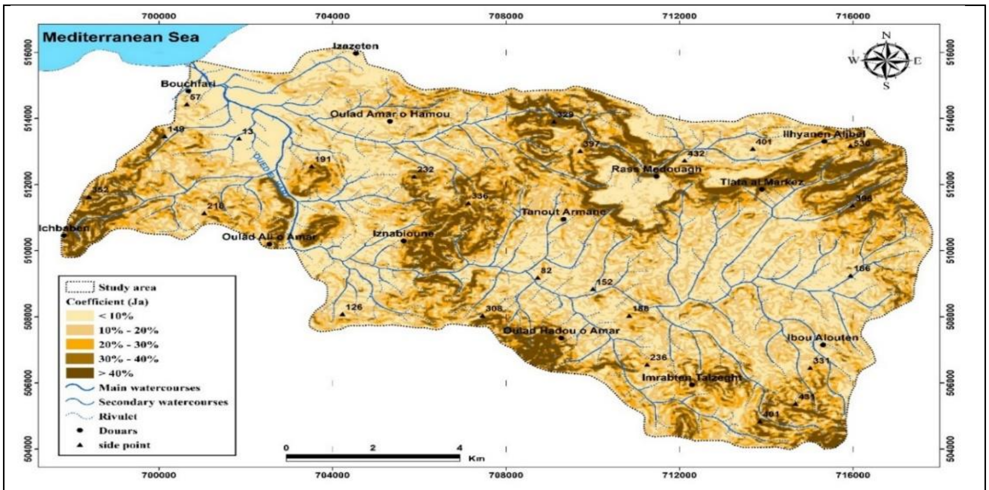

Fig. 3: Average slopes coefficient map

The distribution of slope classes shows that those in general very low to moderate (<30%) are dominant, they represent more than 85% of the total surface area. The high to very high slopes represent a percentage of 15% for classes over (>30%), are concentrated in the southwestern and northeastern parts.

Table 1: Average slopes coefficient

Classes of (Ja)	The area in (ha)	The area in (%)
Very low (< 10%)	5044,4	36,2
Low (10% - 20%)	4568,5	32,8
Moderate (20% - 30%)	2122,2	15,2
High (30% - 40%)	1107,5	7,9
Very high (> 40%)	1120,4	7,9

Source: Dragicevic & al., 2016

4.2 AVERAGE ANNUAL TEMPERATURE COEFFICIENT (T)

Temperature characterization was conducted using satellite imagery data, using different seasonal data from the 3 years (2015, 2016 and 2017), due to lack of data. To calculate the temperature map we use the USGS formulas using the equation :

$$\textbf{Land surface temperature} = BT / 1 + w * (BT / p) * \ln(e) \qquad (3)$$

Avec :
BT: satellite temperature.
w: wavelength of emitted radiance (11.5µm).
p : h * c / s (1.438 * 10^{-2} m k).

h : Planck constant (6.626 * 10^{-34} Js).
s: Boltzmann (1.38 * 10^{-23} J/K).
c : speed of light (2.998 * 10^{8} m/s).

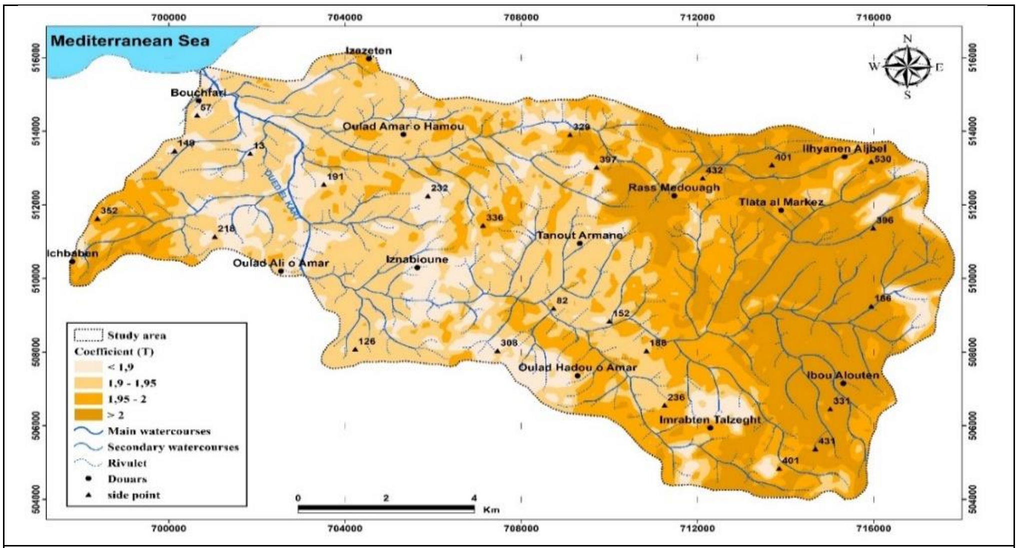

Fig. 4: Average annual temperature coefficient map

The annual averages of the temperatures at the lower watershed level after the calculation according to the following equation ((0.1 * Temperature) + 0.1) are between 1.7°C and 2.1°C, they are distributed according to a North-South gradient.

4.3 AVERAGE ANNUAL PRECIPITATION (P_A)

Precipitation plays a primary role in causing water erosion. It depends mainly on the intensity of the rain (Le Bissonnais and Papy, 1997). Over the period from 1970 to 2010, the distribution of average precipitation is based on a rainfall gradient from East to West and more locally North-East at the level of the Oued El Kart watershed low.

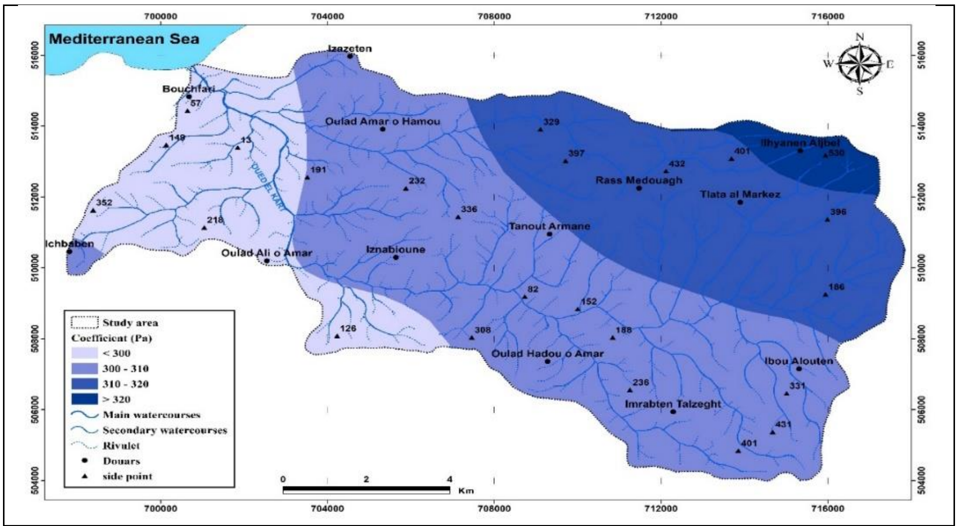

Fig. 5: Average annual precipitation map

The isohyets map was constructed using the Thiessen method, which considers that there is a precipitation gradient between the different stations in the study area (3 stations). In the west, the annual average rainfall exceeds 300 mm, increasing towards the east by 320 mm due to the effect of altitudes and slopes that form barriers against Mediterranean influences.

4.4 SOIL ERODIBILITY (Y) :

The soil erodibilty factor (Y) is defined by Renard et al (1997) as the influence of soil properties on soil losses during rainfall events, and established its sensitivity to water erosion by its intrinsic properties, namely geological characteristics, soils and land use. They are calculated according to the following formula (Wischmeier W. H. and Smith D. D. (1978)):

$$Y = 2{,}1 * M^{1{,}14} * 10^{-4} (12 - MO) + 3{,}25 (B - 2) + 2{,}5 (C - 3) / 100 \qquad (4)$$

With:
M= (% Fine sand + silt) * (100 - % Clay);
MO: percentage of organic matter;
B: soil permeability code (1 to 6);
C: permeability class of the profile;

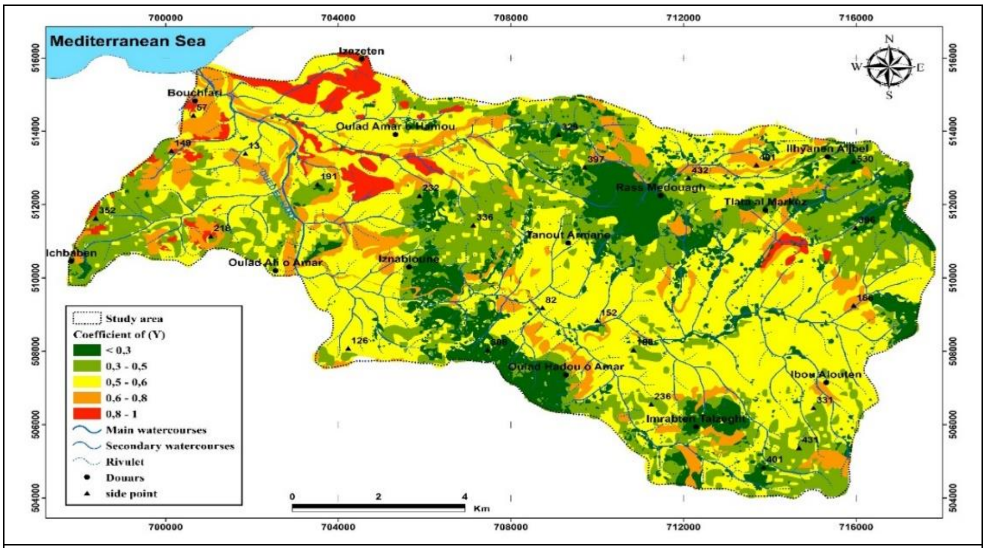

Fig. 6: Soil erodibilty coefficient map

Figure 6 and Table 2 show the distribution of soil erodibility as a function of the soil sensitivity equation (Wischmeier W. H. and Smith D. D. (1978)). The most dominant coefficient in the lower part of the watershed is the Weak rock, schistose, stabilised represents an area of 6920.9 ha (50%), and then Rock with moderate erosion an area 3237.9 ha (23.5%).

Table 2: Soil erodibilty coefficient

Soil erodibilty coefficient	Classes (Y)	Area (ha)	Area (%)
Hard rock, erosion resistant	< 0,3	1936,6	14,1
Rock with moderate erosion resistance	0,3 – 0,5	3237,9	23,5
Weak rock, schistose, stabilised	0,5 – 0,6	6920,9	50,1
Sediments, moraines, clay and other rock with little resistance	0,6 – 0,8	1426,3	10,1
Fine sediments and soils without erosion resistance	0,8 – 1	441,3	2,2

Sources: Gavrilovic S., 1962; 1970 and Dragicevic & al., 2016

4.5 SOIL PROTECTION (XA)

The soil protection coefficient (Xa) directly related to the vegetation cover which plays an important role in reducing erosion by protecting the soil during rainfall and increasing soil permeability. The surface condition varies according to the seasons and agricultural work. The classes of Soil Protection Coefficient (Xa) are varied according to land use between "Xa" from 0.1 (for dense forests) to 1 (for badlands).

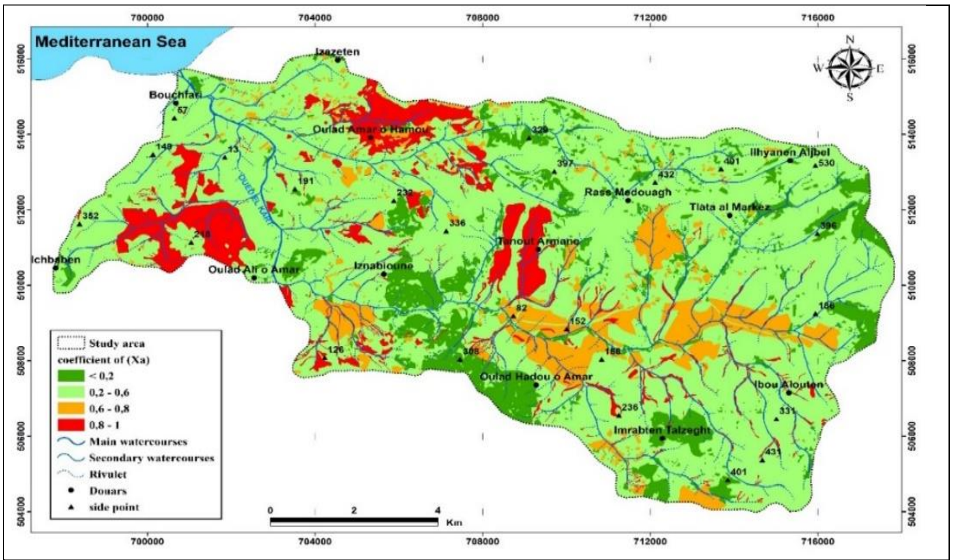

Fig. 7: Soil protection Coefficient map

The following table represents the land cover condition of Oued El Kart low watershed in 2019. As shown in the land cover map, Coniferous forest with little grove, scarce bushes, bush prairie & damaged forest and bushes, pasture is the most widespread category in Oued El Kart low watershed with 9787 ha, which means 70.4% of the total area, followed by Mixed and dense forest & low-density forest with grove, while Damaged pasture and cultivated land is the least spreading category (Table 3).

Table 3: Soil protection Coefficient

Soil protection Coefficient	Classes of (Xa)	Area (ha)	Area (%)
Mixed and dense forest & low density forest with grove	< 0,2	1597,6	11,4
Coniferous forest with little grove, scarce bushes, bush prairie & damaged forest and bushes, pasture	0,2 – 0,6	9787	70,4
Damaged pasture and cultivated land	0,6 – 0,8	1284,6	9
Areas without vegetal cover	0,8 – 1	1293,8	9,2

Sources: Stefanidis & Kalinderis, 2008; Zorn & Komac, 2008 and Dragicevic & al., 2016

4.6 TYPE AND EXTENT OF EROSION (Δ)

The map of erosion types is obtained by superimposing the map of soil sensitivity to erosion and the map of soil protection levels with field observations. The EPM erosion process coefficient table was used to determine the "factor (δ)" (Gavrilovic, 1988). Erosion process coefficients are classified into 5 categories, ranging from 0.1 to 1.0 (Table 4).

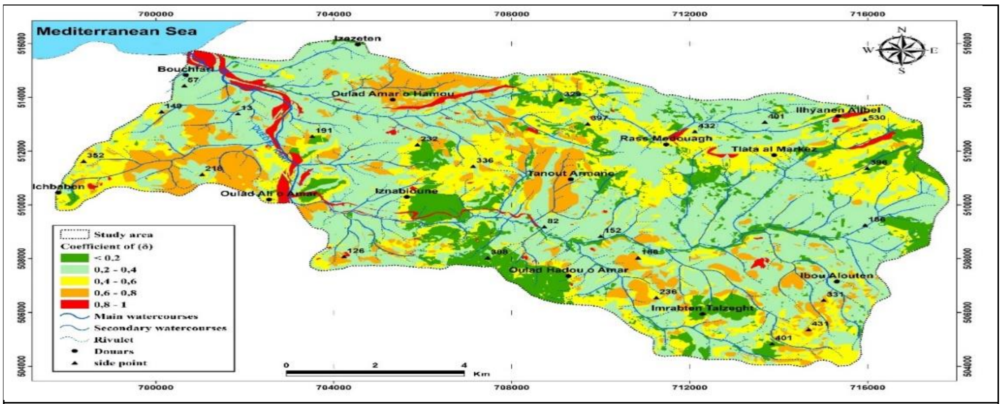

Fig. 8: Coefficient of type and extent of erosion map

According to Figure 8 and Table 4, it can be seen that a large part of the lower watershed occupies by the erosion in waterways on 20–50% of the catchment area (7562.36 ha or 54.2%). Followed by erosion in rivers, gullies and alluvial deposits, karstic erosion with an area of 2960.16 ha (21.2%). Indeed, classes of more than 0.6 occupy 13% of the total area in the lower watershed.

Table 4: Coefficient of type and extent of erosion

Coefficient of type and extent of erosion	Classes of (δ)	Area (ha)	Area (%)
Little erosion on watershed	< 0,2	1619,7	11,6
Erosion in waterways on 20–50% of the catchment area	0,2 – 0,4	7562,36	54,2
Erosion in rivers, gullies and alluvial deposits, karstic erosion	0,4 – 0,6	2960,16	21,2
50–80% of catchment area affected by surface erosion and landslides	0,6 – 0,8	1528,95	11
Whole watershed affected by erosion	0,8 – 1	279,26	2

Source : Stefanidis et Kalinderis, 2008 ; Zorn et Komac, 2008 and Dragicevic & al., 2016

5. RESULTS & DISCUSSION

5.1 POTENTIAL EROSION (Z) :

The potential erosion coefficient (Z) indicates the probability of erosion at the Oued El kart low catchment area, whose value of (Z) defines the erosion class according to the Gavrilovic table (Table 5).

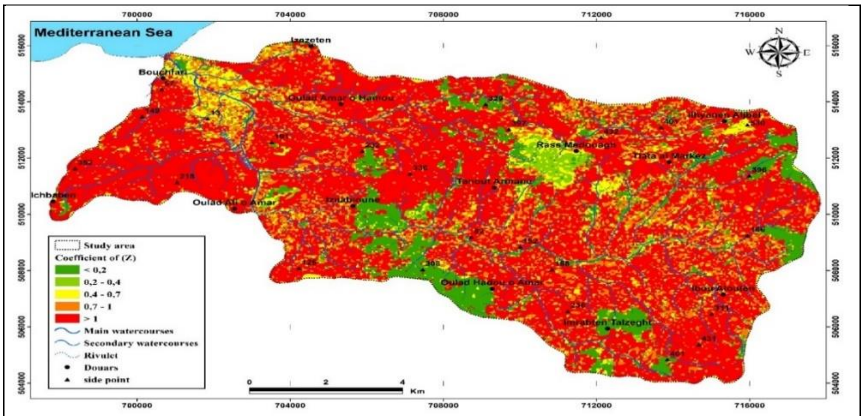

Fig. 9: Potential erosion coefficient map

The results obtained show that most of the potential erosion occupies excessive erosion areas (>1), occupying 8051.06 ha or 57.6% of the total surface area. Followed by the severe potential erosion coefficients of 2682.29 ha or 19.2%, then very slight potential erosion (9.8%), medium (9.7%) and slight occupy 505.46 ha (3.7%) (Table 5).

Table 5 : Potential erosion coefficient

Potential erosion coefficient	Classes of (Z)	Area (ha)	Area (%)
Very slight erosion	< 0,2	1373,96	9,8
Slight erosion	0,2 – 0,4	505,46	3,7
Medium erosion	0,4 – 0,7	1348,83	9,7
Severe erosion	0,7 – 1	2682,29	19,2
Excessive erosion	> 1	8051,06	57,6

Source des classes: Ostric et Horvat, 2008 and Dragicevic & al., 2016

5.2 ESTIMATION OF SOIL LOSSES ACCORDING TO THE EPM MODEL

The combination of the various factors that make up Gavrilovic's EPM equation produced the map of average soil losses by water erosion, which is estimated at 14.7 t/ha/year. The maximum loses are 138,8 t/ha/year and minimum are 0,01 t/ha/year. Total annual loses of the watershed of the Oued El Kart low an average of 205 800 t/year (Erosion in the plot). The rate of erosion, therefore, differs from one area to another depending on the influence of the various physical and anthropogenic factors that control the erosive dynamics.

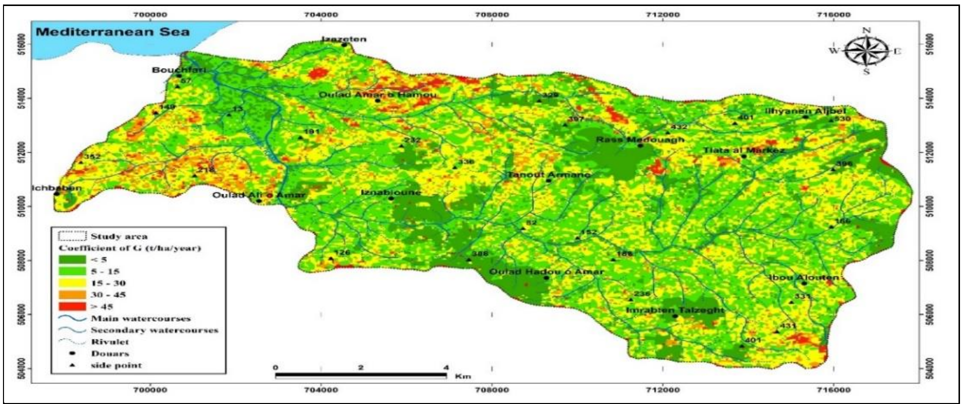

Fig. 10: Annual average soil loss map of Oued El Kart watershed low (by EPM)

According to Figure 10 & the table below, shows that land losses of 15 t/ha/year or less come from 57.3% of the lower watershed area. This indicates the low spread of the phenomenon. The medium intensity class soil losses between 15 and 30 t/ha/year, is the second-largest in terms of area and accounts for 33.7% of the study area. 9% of the total area generates losses of more than 30 t/ha/year.

Table 6: Annual soil loss in Oued El Kart Watershed low

Annual soil loss	Classes of G (t/ha/year)	Area (ha)	Area (%)
Very low erosion	< 5	2485,41	17,8
Low erosion	5 – 15	5523,76	39,5
Moderate erosion	15- 30	4702,73	33,7
High erosion	30 – 45	957,86	6,9
Very high erosion	> 45	293,23	2,1

Source: Alkarkouri, 2003

5.3 THE INFLUENCE OF EROSION FACTORS ON SOIL LOSS

The unequal distribution of soil losses in the watershed is a result of the wide variability in the effects of each erosion factor. The statistical relationship between the various factors and the erosive dynamics reveals fairly significant trends.

Table 7: Correlation matrix between Annual soil loss and erosion parameters

	G	Z	Y	Ja	δ	Xa	P_a	T
Annual soil loss G	1	0,81	0,37	0,30	0,46	0,49	0,35	0,07
Potential Erosion (Z)	0,81	1	0,45	0,41	0,49	0,49	0,36	0,01
soil erodibilty (Y)	0,37	0,45	1	-0,28	-0,02	0,31	-0,27	-0,03
Slopes (Ja)	0,30	0,41	-0,28	1	0,26	-0,16	0,10	-0,03
Erosion types (δ)	0,46	0,49	-0,02	0,26	1	0,42	0,02	0,08
Soil protection (Xa)	0,49	0,49	0,31	-0,16	0,42	1	-0,10	0,06
Precipitations (Pa)	0,35	0,36	-0,27	0,10	0,02	-0,10	1	0,52
Temperatures (T)	0,07	0,01	-0,03	-0,03	0,08	0,06	0,52	1

According to Table 7, it is important to note the strong correlation between the EPM map data and soil erosion protection, the latter seems to be the most decisive in the erosive dynamics with a correlation coefficient of the order 0.49 (24%). They are followed by erosion types parameters (22.5%), soil sensitivity to erosion (18.1%), precipitation (17.1%) and slope system (14.7%). In contrast, Soil erosion protection is itself related to erosion types with a correlation coefficient of 0.42. The types of erosion are rather strongly related to slope systems (correlation coefficient = 0.26). Temperatures are rather in good correlation with precipitation.

6. CONCLUSION

The implementation of Gavrilovic's EPM Equation using a geographic information system allowed a quantitative estimate of soil losses. This work presents the first maps on erosion risks in the Oued El Kart low, the results obtained show that average soil losses by water erosion, which is estimated at 14.7 t/ha/year. The maximum loses are 138,8 t/ha/year and minimum are 0,01 t/ha/year. Total annual loses of the watershed of the Oued El Kart low an average of 205 800 t/year (Erosion in the plot).

Subsequently, the statistical analysis in results of this model to determine the decisive causal factors that control erosion by water, which are in order of importance soil protection, types of erosion, soil sensitivity to erosion, precipitation, slopes and temperature.

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