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Risk of water erosion in coastal watersheds north of Tetuan (Internel Rif, northern Morocco): Evidences from GIS-based spatial approach

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ABSTRACT: In this study we estimate the risk of water erosion in coastal watersheds between M'diq and Fnideq located in northern Morocco, through using a new approach based on spatial cartography. Precisely, the methodology adopted here integrates a Geographic Information System (GIS) with the universal soil loss equation (USLE). The field data includes three major components namely, lithology, degree of slope and vegetation density. Each of these components is represented by a separate layer, in which 1 to 5 value expresses its lateral variability degree. The final map of water-erosion risk is obtained by the sum of superposed indices, separately assigned to three thematic layers (facies, slope and vegetation cover), and multiplied by the percentages of the contribution of each factor to determine the percentage of weighting. . Secondarily, a complementary table translates the cartographic values of each layer as percentage values expressing the impact exerted by the corresponding risk factor throughout the studied area. The risk map is deducted after validation of these weightings on the field by choosing checkpoints distributed throughout the watersheds of the site. This method would allow for the tracking and of course monitoring of water erosion on a larger scale and to better direct the administrations concerned to the priority of installations.

KEYWORDS: Water Erosion, Spatial GIS Approach, Watershed, M’diq and Fnideq, (Rif Region), Morocco.

1 INTRODUCTION

Soil erosion by water is a major cause of land degradation. It is estimated that 1/6 of the world's soils are affected by water erosion [1]. Land degradation induced by water erosion results not only in the loss of fertile soil and in the soil-productivity reduction. It also results in increasing the concentration of suspended sediment in the watercourse, and in carrying material to fill reservoirs. This two-fold physical risk reverberates medium to short-term consequences on the ecosystems equilibrium and on the civil engineering infrastructures

It is well known that the process of water erosion and sedimentation are influenced by biophysical and human factors, occuring at different intensities across the landscape. However, the spatial and temporal scales of processes are still misunderstood, which makes monitoring and evaluation of erosion and deposition a complex and cumbersome task with a considerable uncertainty.

Consequently, there is a need fora deep understanding of the erosion processes and the deposition on ground, in order to analyze their impact on the productivity of soil as well as their impact elsewhere (for example, sedimentation and water quality) [2], [3].

Problems related to water erosion are widespread in the countries of the Mediterranean and North Africa. [4] In Morocco, especially in the Rif region, a reputed still young chain, erosion in general and more particularly water erosion is today the basis of a series of economic and social problems. This is what makes it an important phenomenon in which the study is intensified due to the action of many teams in the world at large. Erosion of plots rate measurements were often used and have given successful results for a quantitative estimation [5]-[8]. However, they represent a lengthy and expensive approach because they require monitoring over many years. The punctual measurements of erosion on plots for many years allow us to compare well the risks in various soil conditions, slopes, land use, but not to spatialize risks on the watersheds because they (measurements) isolate the plots and thus eliminate the cumulative effects. Therefore, it appears more interesting to opt for techniques, allowing a quick estimation of erosion, capable of taking into account the temporal and spatial variations across the watershed and can be applied to the entire studied area.

The undertaken study, as part of this work on assessing the rate of erosion, was conducted across three coastal watersheds between M'diq and Fnideq, which are characterized by a quite high pluviometry, its large storm resources, and strong oscillations in the altitude and by the nature of its soil which promotes the development of a high risk of erosion. (and by the nature of the soil more or less favorable to the release of the processes of gullying, hydric erosion and landslides.) The approach adopted in the framework of this work is to develop a mapping method for a rapid, reliable and inexpensive diagnosis, making use of the limited data available for the identification, quantification and spatialization of the erosion in order to deduce the steps of anti-erosion controls

The method is to draw up a map of water erosion on the basis of lithological, topographic and land use indicators. The erosion map is obtained after the superposition of thematic layers, and it is then validated on the ground to determine the contribution percentage of each of the intervening factors in the erosion process to highlight thereafter the most influential factor in the area.

2 PRESENTATION OF THE STUDY AREA

2.1 LOCATION AND GEOLOGICAL SETTING

The study area is located in the northwest of Morocco, at the western north extremity of the Rif chain. It extends from the town of M’diq up to the north of Fnideq. It is limited in the east by the Mediterranean Sea, in the west by the chain of Haouz, in the north by the city of Fnideq and in the south by the city of M'diq. It includes three watersheds: Smir, Negro and Fnideq (Fig.1).

Fig. 1. Landsat image with delimitation of the study area

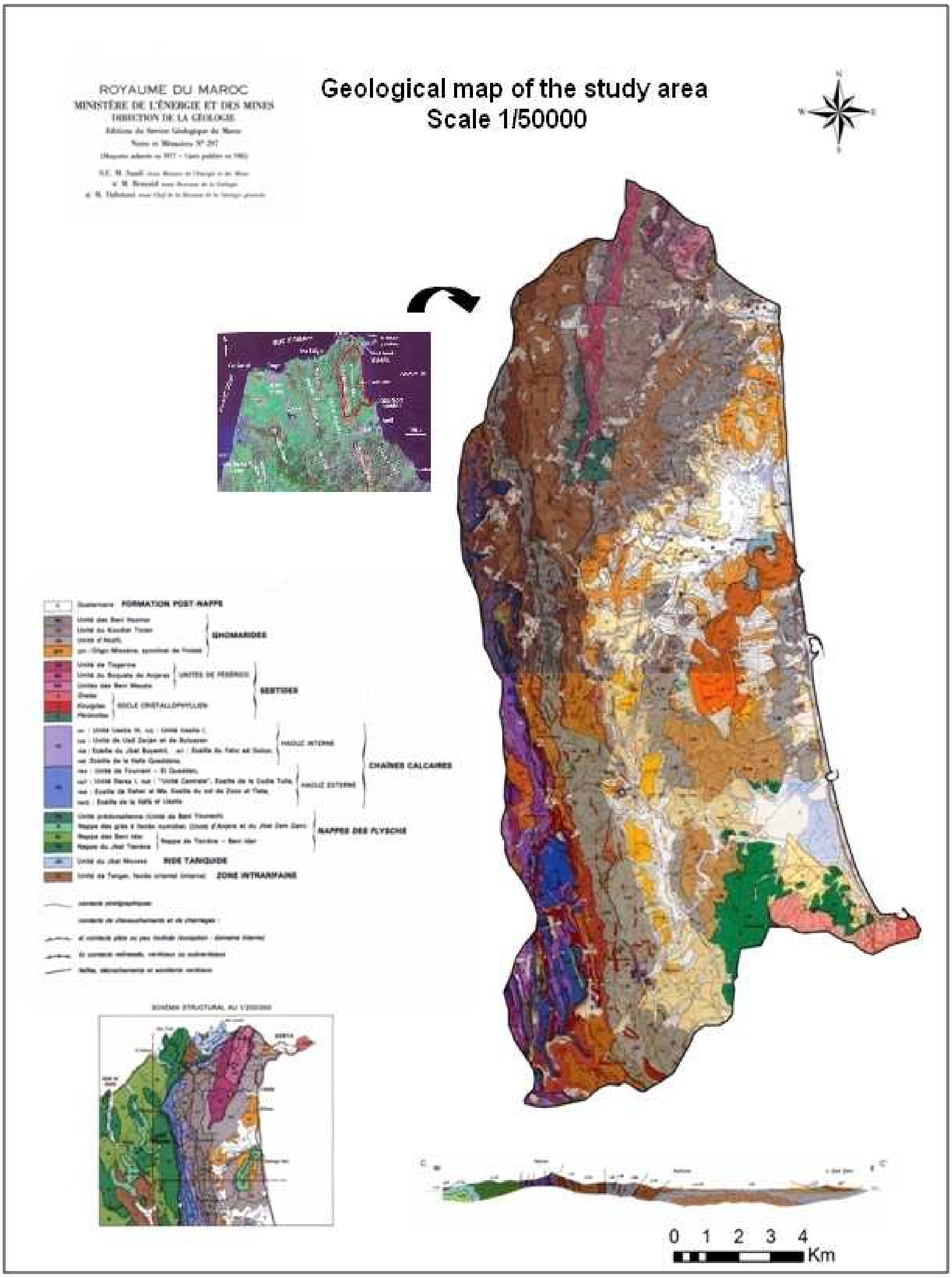

Fig. 2. Geological map of the study area 1/50 000 (from Kornprobst and Durand-Delga 1985). [17]

It belongs to the Rif internal zones and it is composed mainly of three units: *the calcaire chain of Haouz (Dorsale Calcaire)*, the Ghomarides and the Sebtides unites. The Sebtides are metamorphic landson Paleozoic series, diversely assumes a detrital clay, carbonated permo-triasic alpine coverage. The Ghomarides consist mainly of shale and sandstone Paleozoic rocks, but they assume more alpine coverage ranging from Triassic through the middle Burdigalien [9], [10] with quitely diverse carbonate and clastic facies. As its name indicates, The calcaire chain of Haouz, consist of units and / or of no metamorphic series napes essentially carbonated ranging from Triass to Early Miocene [11], [9] (Fig. 2).

2.2 GEOMORPHOLOGY OF THE SITE

Overall, the studied site is part of a chain topographically fragmented enough for structural reasons and which owes its allure to High Mountain for its character which is young and consequently of its relief. [11] Watersheds located between Fnideq M'diq, making object of this study, are limited in the west by the chain of Haouz reliefs, elongated along a north-south axis, and their high points are situated in the massive of Hafat Raouda (641m) in the North, and the massive Hafat Uestia in the South (838m). These high ridges and scales are characterized by many steep cliffs and a karstic morphogenesis. It is these ridges that define our watersheds in the West and thus form their lines divide Many travertineuses terraces with structures in staircases juxtapose these carbonated solid masses. These are the peaks which delimit our basins slopes in the West and form consequently their watersheds. At these ridges join in the Eastern foothills dominated by sandstones-pelitic facies of Paleozoic overcome locally (to the immediate north of the watershed of Smir) by the Numidian massive Jebel Zem Zem which forms only a small mountain little more than 400 m. With the exception of this massive, the most dominant altitudes often remain below 150m.

On the Paleozoic in low altitude are installed recent Quaternary alluvial formations forming the coastal plains of very low altitude developed on paléorias already shaped the Pliocene [12]. The downstream portion consisting of Paleozoic alluvial land and is often crossed by watercourse, the most important form the main Oueds in the region (Oued Smir Oued Negro etc ...). On the Paleozoic and lowland are installed recent Quaternary alluvial formations forming the low-lying coastal plains developed on paléorias which already shaped the Pliocene [12]. The downstream portion, consisting of Paleozoic alluvial land, is often crossed by watercourse of torrential character, the most important of which form the main Oueds in the region (Oued Smir Oued Negro etc ...).

Two coastal plains are distinguished in the study area.. They constitute the downstream termination of the main Oueds of coastline between Fnideq and M'diq, it is the plain of Restinga and Smir. They are bordered by rocky terraces of the ancient and medium quaternary, and they are often flooded during winter due to their low altitude, their proximity to the sea level and the torrential watercourse. [12]

The coastline between Fnideq and M'diq about 24Km long, is dominated by sandy beaches sometimes associated with cobbles/pebbles and gravel beaches. These gravel beaches are characterized by an average slope, a generally narrow width (50 to 150m) and a variable width as they develop downstream plains or river geographic torrential mouths [13].

2.3 CLIMATE

The climate of the study area is sub-humid Mediterranean type. In this sector the average rainfall is 600 mm / year (Fig. 3), which represents the double of the national average. The wet season runs from October to April and the rain is particularly abundant between November and January. The dry season is relatively short, resulting of low to null rainfall between June and September.

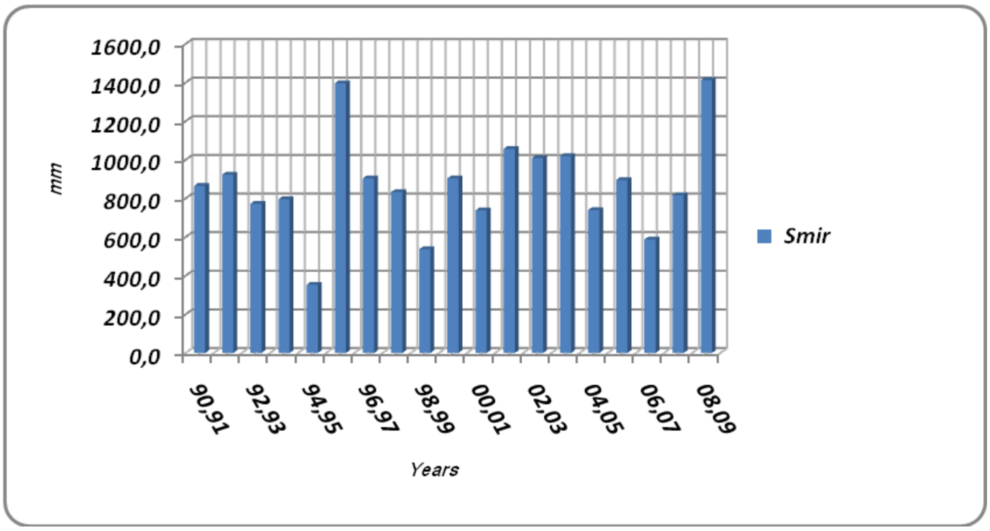

Fig. 3. The variation of the annual average of precipitation Source (Hydraulic Basin Agency of Loukkos)

2.4 VEGETATION

The vegetation of the site is quite varied, like the diversity of habitus. Climatic conditions, the heterogeneous terrain, and the presence of wetlands «lagoon-marsh complex and retaining dam (Smir dam)», located on the Smir River, are the main factors responsible for this diversity.The vegetation is characterized by the presence of a large number of species, about 375 species belonging to 236 genera and 94 families. [14]

Spontaneous species, the most common of which are Thuya, Lentisque and Kermès Chêne, grow on limestone bedrock, the cork oak on siliceous bedrock and oleander along rivers, on the banks of Oueds and the introduced species from reforestation which are mainly the pine and eucalyptus**.**

2.5 HYDROGRAPHIC NETWORK

The Smir Watershed, with an area of about 97 Km^2, is drained by the Smir River which collects water of the four main tributaries: Oued Zarjoune, Oued El Lille, Bayine and Belouazene. Secondary tributaries which we also find are: Kof el Fouki and Kof Essefli. It is essential to note that all watercourses in the watershed of the Smir river originate from sources that appear as resurgence at the contact zone between the limestone ridge and Paleozoic schists ghomarides..

Oued Negro "Aswad" feeds Merja de Negro directly in freshwater. It leads to the sea water collected in the watershed Negro. The watershed of the Oued Negro is bounded on the east by the Mediterranean Sea, in the west by the limestone ridge, south by Jebel ZemZem and to the north by Fnideq watershed, it is drained by a series of tributaries where the principal ones are: Oued Ailiyine, Oued Heddadine and Hofret Zeitoune. It covers an area of about 71 Km^2, with a maximum altitude of 641 m and a minimum of 5 m.

The Fnideq Watershed extends over an area of 35 Km^2, is drained by the Oued Bayssa which collect water of the four major tributaries: Oued Laimouna, Oued sfayh, oued Kahndeq and Oued Assalas (Fig. 4).

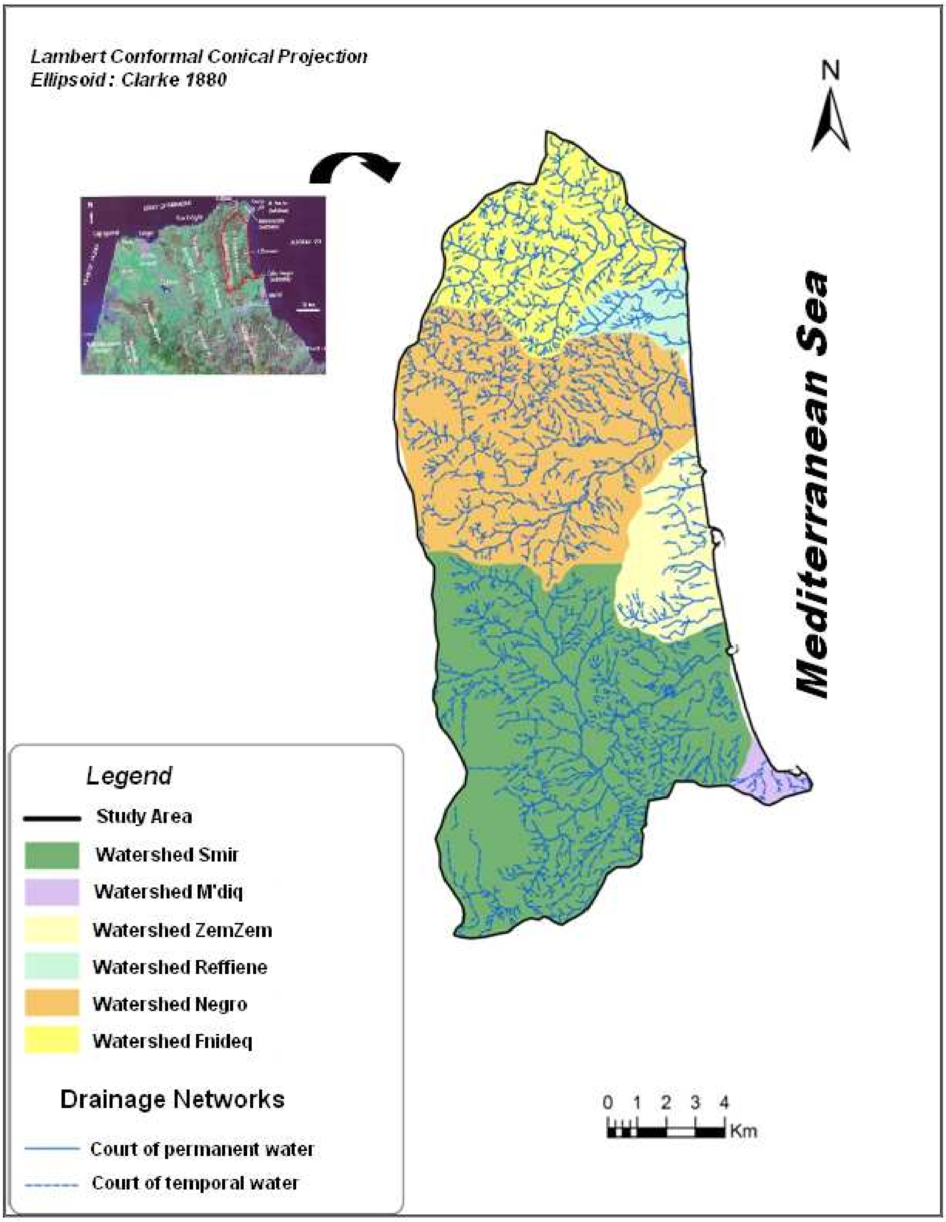

Fig. 4. Map of the hydrographic network of the three watersheds Smir, Negro and Fnideq

3 METHODOLOGY AND PURPOSE OF WORK

The approach adopted in this study is to integrate a Geographic Information System (GIS) to the universal soil loss equation (USLE) [15], which would allow for the monitoring of water erosion in a largest scale. The method used to develop the map of risk is based on the degree of influence of three parameters of the equation [15] namely, slope, lithology and vegetation cover. The application of the erosion model has established the thematic maps for the studied area.

The proposed methodology is applied to three watersheds; Smir, Negro and Fnideq. The erosion model plays a prediction by identifying and evaluating all participants in order to determine parameters of the model, namely the slope, lithology and vegetation cover

The USLE is an acronym for "Universal Soil Loss Equation" [15]. It is the mathematical model most used for evaluating and calculating the loss in soil. It has been tested for many years in North America. The main method is to estimate erosion across parcels in order to intervene and not to exceed the threshold limit for the tolerable erosion rate which vary from 1 to 12t/ha/an [16].

The following equation expresses this model:

A = R x K x LS x C x P

Where:

A = Annual soil loss from sheet and rill erosion in tons/acre
R = Rainfall erosivity factor
K = Soil erodibility factor
LS = Slope length and steepness factor
C = Cover and management factor
P = Support practice factor

Due to a lack of data to assess and calculate the parameters of the method (USLE), we approach the study of erosion in our area from another view. Thus, we thought to introduce Geographic Information System software in ArcMap. This latter will allow us at first to produce a database for creating maps, and then to overlay these thematic maps in which the factors intervene directly in the estimation of potential erosion in the three basins (Fig. 5). Another advantage of this method is that it allows developing risk maps of erosion over large areas by minimizing the cost and time of work, something that is not evident with the conventional method (USLE) which is feasible only on land parcel which eliminate the cumulative effect.

The model shows water erosion resulted of rain, which is considered as the main driver of soil loss.

Thus, in an ArcMap environment, the calculation of classes of erosive potential is obtained from the sum of the indices assigned to different classes of parameters which are: lithology, slope and vegetation cover. Each index is multiplied by the contribution (weight) percentage of the corresponding thematic layer (parameters). The result is classified into five equal classes:

Pe = (IV x A) + (IFR x B) + (C x IPT)

Pe: erosive potential. IFR: Index friability.

IV: Index of vegetation density. IPT: Index degree slope.

A, B and C: Percentage of contribution (weights).

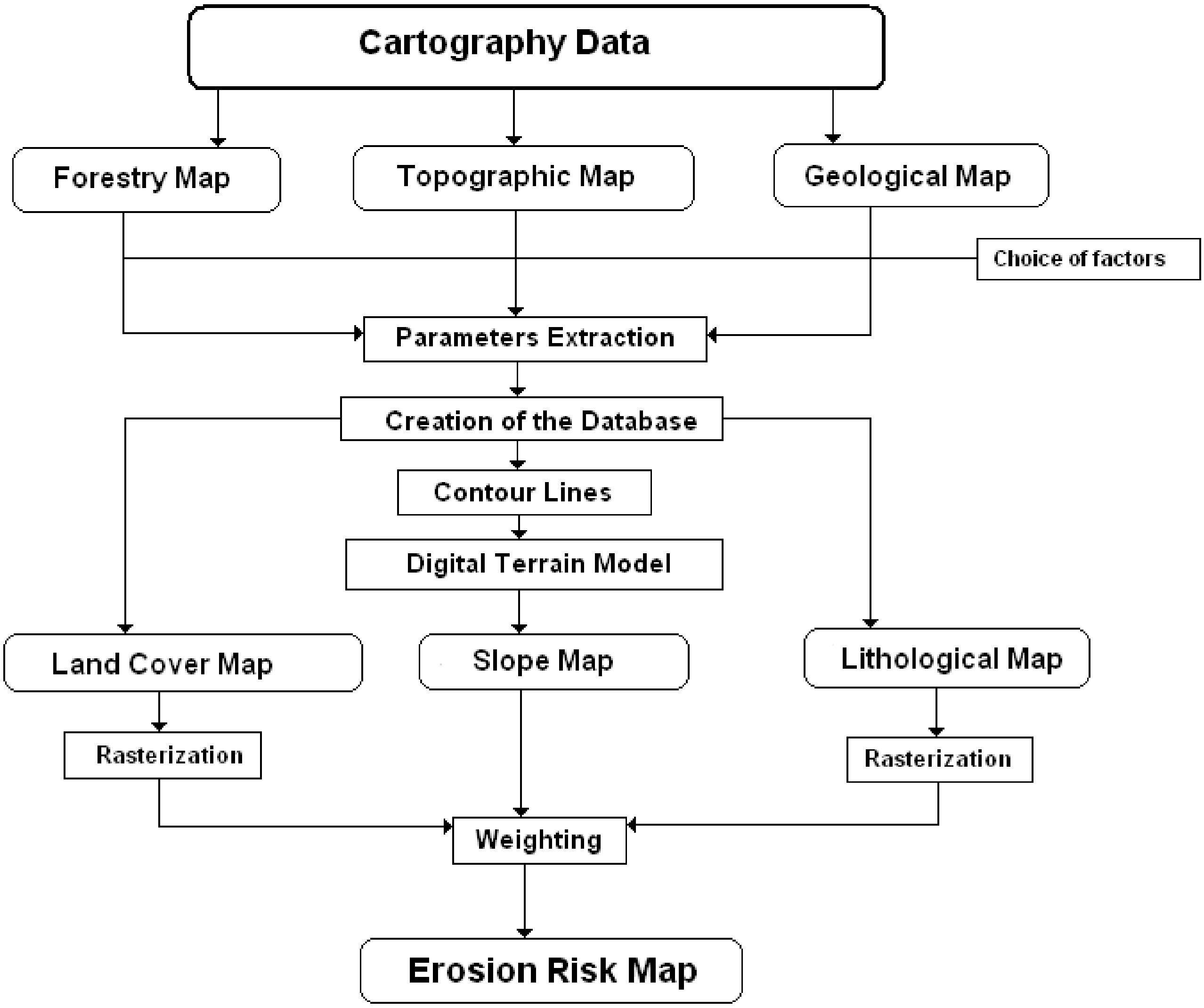

Fig. 5. Scheme showing the different steps of the adopted methodology

3.1 PREPARATION OF MAPS

The slope map (Fig. 6) is obtained by digitalizing contour lines on topographic maps: *Tlat Taghramt, Fnidq M'diq, Port Tanger Méditerranée* (Tangier Mediterranean Port), Dam of Smir 1/25 000th and then treatment with ArcGIS software. The slope derived from this model is classified according to the contribution of slope erosion and this as shown in Table (1).

The vegetal cover Map (Fig. 7) is extracted from the forest map Tétouan NI-30-XIX-4, 1:100,000 (Inventaire Forestier National Deuxième Cycle, 2003). Vegetal communities were classified according to their density, a recommendation made by an official of the "*service des eaux et forêts"*. Table (1) summarizes the different classes of the vegetal cover based on density.

Lithological facies Map (Fig. 8) is synthesized from the geological maps of the Rif (RAS MAZARI-Tétouan and Ceuta, 1/50 000 [16]. The lithofacies were then classified and grouped according to their degrees of friability, we distinguish five classes are then selected (see Table 1).

Table 1. The different classes of land cover, facies and degree of slope and the contribution index.

Classes	Land cover	Facies	Degree of slope	Index
1	Dense Forest > 66%	Limestone	0-5°	1
2	Moderately Dense Forest 33% -66%	Sandstone	5-15°	2
3	Low Dense Forest 10% - 33%	Schists	15-30°	3
4	Mattoral	Flysh	30-35°	4
5	Non Wooded Ground	Alluvium	35-90°	5

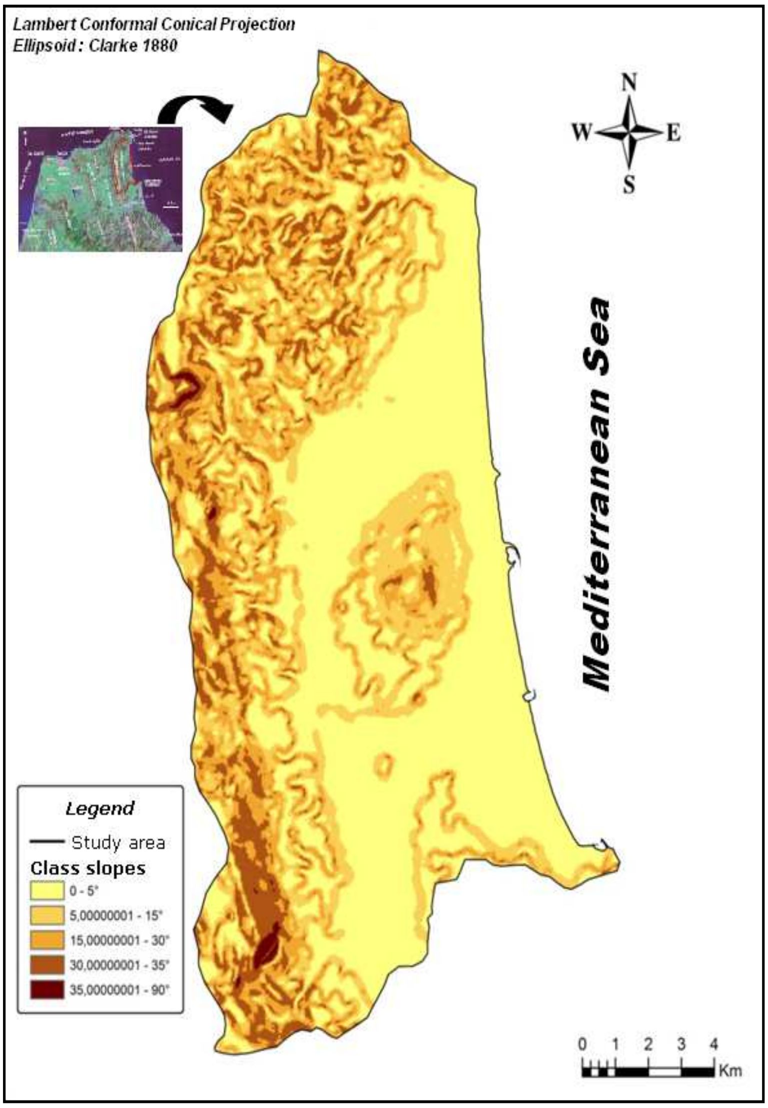

Fig.6. Slope map

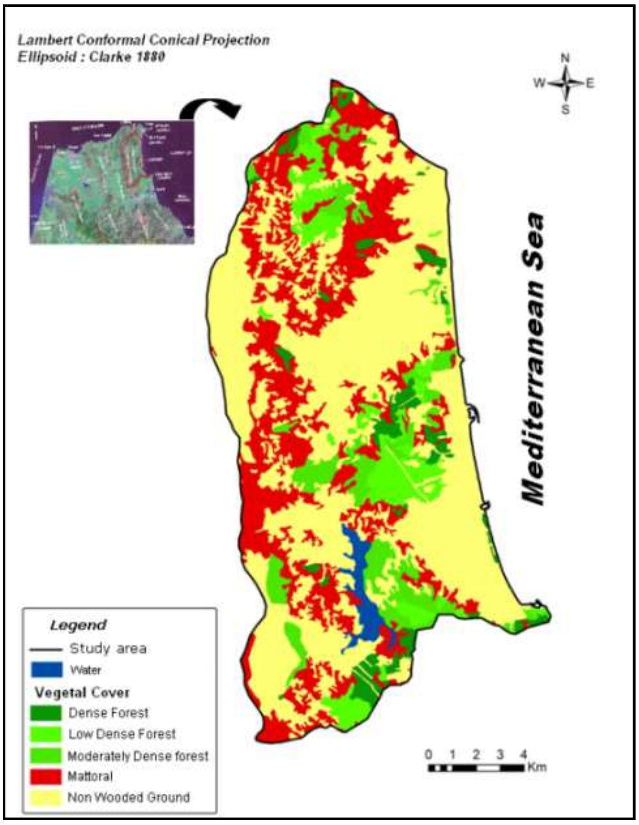

Fig.7. Land cover map

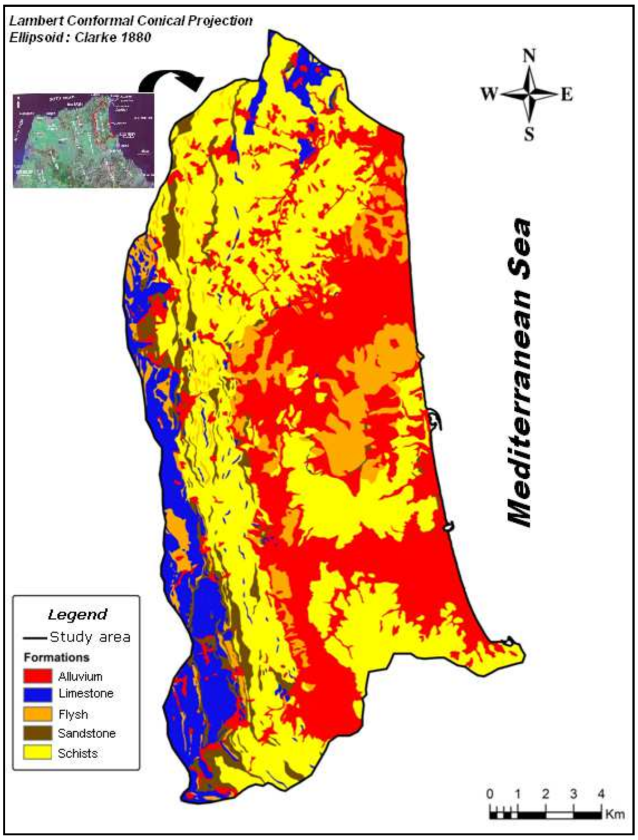

Fig.8. Map of lithologic facies

3.2 ELABORATION OF THE RISK MAP

Having rasterized the three thematic maps of parameters involved in the risk of erodibility, we preceded to the superposition of three layers, namely: the slope map, the vegetal cover map and lithological map in order to use them for mapping weights.

The used model allows to impose percentages of relative weighting on each parameter and to deduce different maps of erosive potential (see Table 2).

Four erosion risk maps were obtained using the sum of weights. It should be noted that only one risk map is selected and this is according to the percentage of validation deduced from observations on the ground (ground truth). This allowed us to identify areas at erosion risk by the percentage weighting assigned to each parameter which is reported in Table (2).

Table 2. Table weighting coefficients or contributions used in the model.

	% Weighting		
Sum of Weighting	**Map of lithologic facies**	**Map of slopes**	**Land cover**
A	50	30	20
B	40	40	20
C	33,3	33,3	33,3
D	25	25	50

- **Obtained Maps and validation of the model on the ground**

The four maps obtained by weighting are shown in Figures 9, 10, 11 and 12 (maps A, B, C, and D).

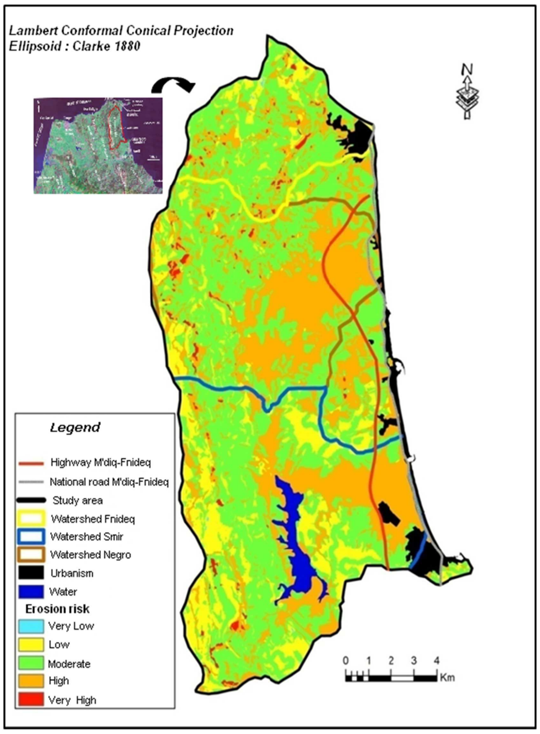

Fig.9. Map A

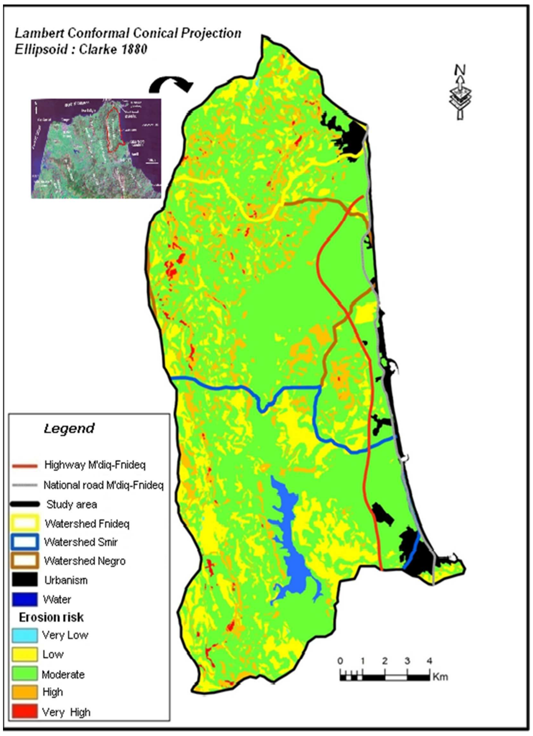

Fig.10. Map B

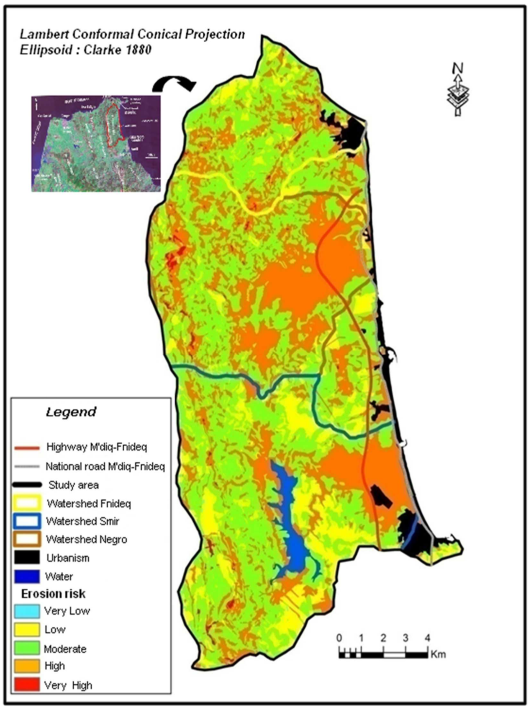

Fig.11. Map C

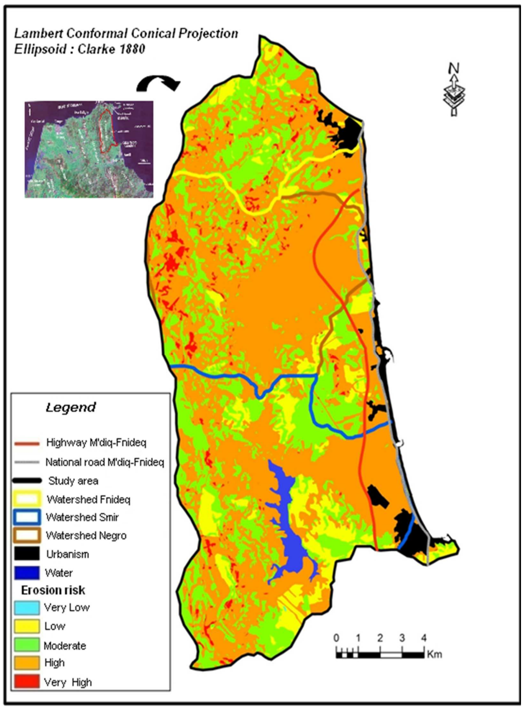

Fig.12. Map D

The rapid spatial analysis of the map generated by the model shows high rates of erosion in areas where there are low slopes with more or less consistent formations.

To ensure the validity of the model, we compared the results with field data. Criteria and forms of erosion considered on the ground are those reported in Table 3. For this purpose, we selected 16 checkpoints which are distributed in each river basin out of a total of 48 checkpoints across three watersheds forming the studied area, and which concern all classes of potential erosion (Fig. 13) (see also Annex 1 Picture 1 and 2). A table of erosion rates based on events of erosion on the ground is then established (see Table 3).

From these field observations, it is possible to calculate the total accuracy of the model and choose the amount of weight (the porch to the reality on the ground or a percentage of the highest validation). Table (4) gives us an idea of the percentage of validation calculated from the following formula:

$$Pt = PCV / PCt$$

Pt: Total accuracy.

PCV: Number of checkpoints valid to confirmation on the field.

PCt: Total number of control points/checkpoints.

For the observation of erosion on the field we developed a table linking the form of erosion to a rate of erosion to assign an index.

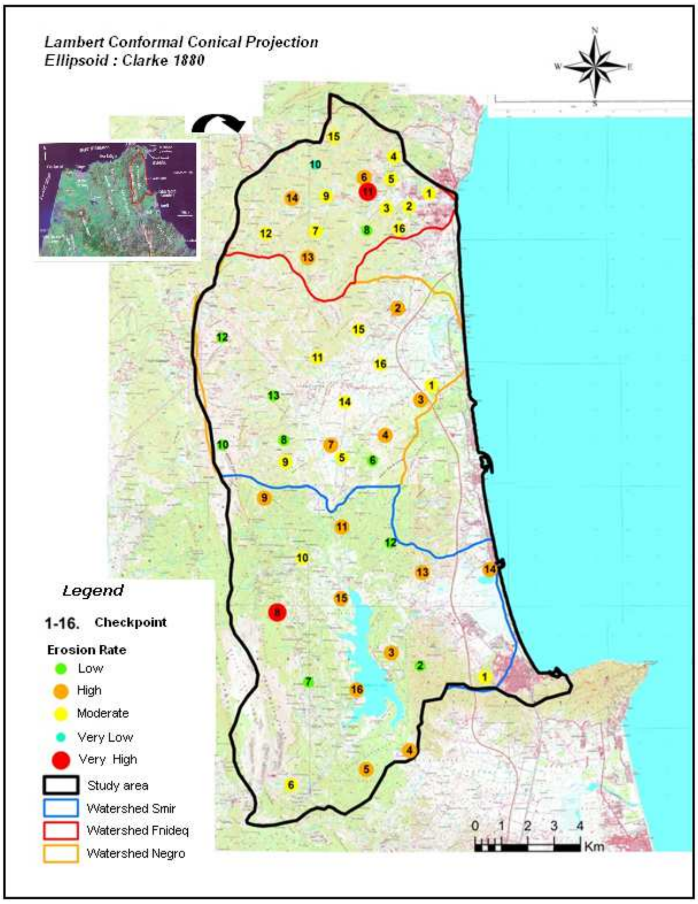

Fig.13. Distribution of checkpoints with their erosion rate in three watersheds of the study area rates.

Table 3. Percentage validation of checkpoints in the three watersheds for each map.

Watershed	Checkpoint	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	% de Validation
Negro	Map A	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	93.75
	Map B	1	0	0	1	1	0	0	0	0	1	0	1	0	1	1	1	50
	Map C	1	1	0	1	1	0	1	0	1	1	1	0	1	1	1	1	75
	Map D	0	1	1	1	0	1	1	0	1	0	1	0	1	0	0	0	50
Smir	Map A	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	93.75
	Map B	1	1	0	0	0	1	1	1	1	0	1	1	1	1	0	0	62.5
	Map C	1	1	1	1	0	1	1	1	1	1	0	1	1	1	1	1	87.5
	Map D	1	1	1	1	0	1	0	1	1	1	1	0	1	1	1	1	81.25
Fnideq	Map A	1	1	1	1	1	0	1	1	1	1	1	1	0	1	1	1	87.5
	Map B	1	1	1	1	1	0	0	1	1	1	1	1	0	1	0	1	75
	Map C	1	1	1	0	1	1	0	1	1	0	1	1	1	1	1	0	75
	Map D	0	1	1	0	1	1	0	1	1	0	1	0	1	1	1	0	62.5

1	Validé
0	Non validé

4 RESULTS AND DISCUSSIONS

- Case 1: Sum of weights D:

In this case, the weights are set as follows: 25% for lithology, slope 25% and 50% for the vegetal cover.

The map obtained based on these weighting coefficients is displayed in the Figure 12.

The rapid spatial analysis of the map generated by the model shows strong erosion rates in areas where there are slight slopes with more or less consistent formations. In this case, the percentage of map validation D would be 62.5% for the Fnideq watershed, 81.25% for the Smir watershed and 50% for watershed Negro. The average validation percentage would be then 64.58% (see Table 4).

- Case 2: Sum of the weighting C:

In this case, the weights coefficients are set as follows: 33.3% for the lithology, 33.3% for the slope 33.3% for the vegetation cover.

The obtained map based on these weighting coefficients is displayed in the Figure 11. The average validation coefficient in this case would be 79.16% (see Table 4).

- Case 3: Sum of weights B:

In this case, the weights are set as follows: 40% for the lithology, 40% for the slope 20% for the vegetal cover

The obtained map based on these weighting coefficients is displayed in the Figure 10.

Spatial analysis of the map B generated by the model shows the distributions of classes of low erosive potential to medium with a large percentage in area where there are high slopes with a friable substrate and a low density of vegetation cover. This result is not consistent with the reality on the ground. The average validation percentage in this case is 62.5%. (See Table 4).

- Case 4: Sum of weighting A:

In this case, the weights coefficients are set as follows: 50% for lithology, 30% for slope and 20% for the vegetal cover

The obtained map based on these weighting coefficients is displayed in the (Fig. 9).

Analysis of the spatial map generated by the model shows the class distributions of the erosive potential more or less favorable to the first contribution of lithology and slope and then the vegetal cover.

The average percentage of validation in this case is 91.58%. (See Table 3).

5 CONCLUSION

Based on average validation percentages calculated for the entire studied zone in each case weight given to various factors (lithology, slope and vegetal cover), it is clear that it is in the case of the map A where the weights are distributed in this way: 50% for the lithology, 30% for slope and 20% for vegetal cover where the coefficient of average validation is the strongest, which is 91.58%. Therefore, it should be noted that this is the map A (Fig. 14) that would be chosen as representative model of the risk of erosion of the entire watersheds of our studied area. In Morocco, especially in the Rif region, the water erosion is today the basis of a series of economic and social problems. This kind of map should already be taken into account in the institutions in charge of regional planning. It is an essential tool for decision which should be consulted during the implementation of works, the management of agricultural land etc... And especially that our country is currently undertaking a fairly significant economic development in many areas.

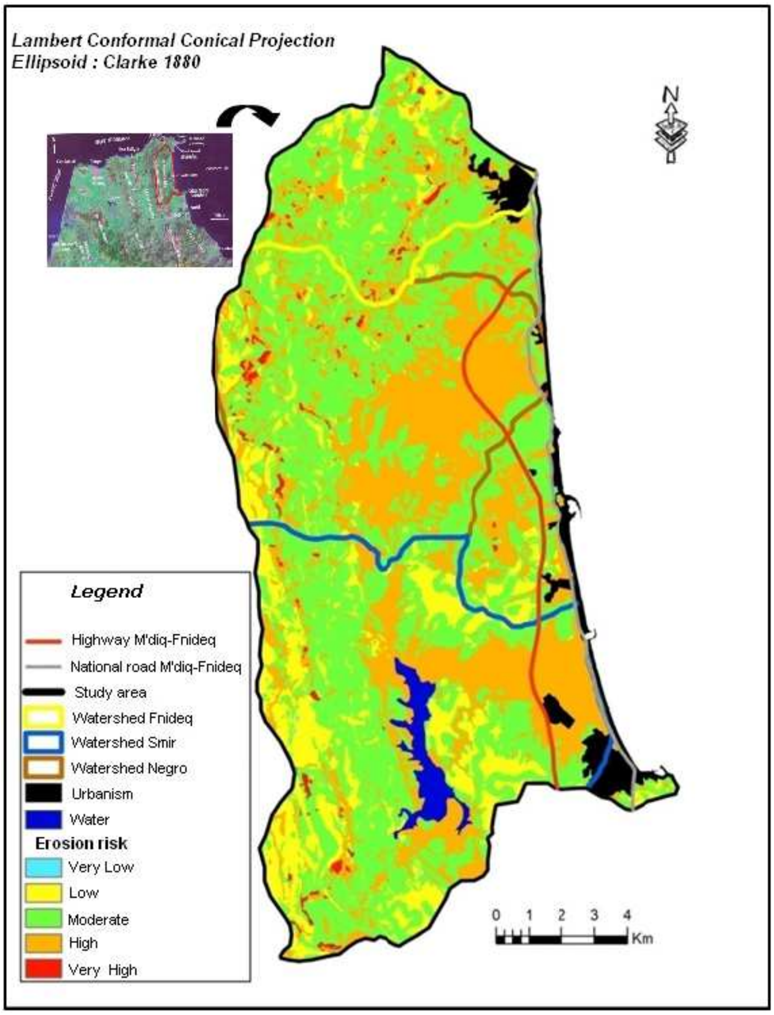

Fig. 14: Map of the risk of erosion obtained with a weighting coefficient A.

References

[1] Carlos Saavedra, B. Schultz, M. Mannaerts, T., 2005. Estimating spatial patterns of soil erosion and deposition in the Andean region using geo-information techniques A case study in Cochabamba, Bolivia

[2] Wickenkamp, V. Duttmann, R. and Mosimann, T., 2000. A multiscale approach to predicting soil erosion oncropland using empirical and physically based soil erosion models in a geographic information system. In: J.Schmidt (Editor), Soil Erosion: Application of Physically-based Models. Springer, Berlin, Germany, pp. 109-133.

[3] Romero, C.C. and Stroosnijder, L., 2002. A multiscale approach for erosion impact assessment for ecoregional research in the Andes., Proceedings SAAD-III, Lima, Peru.

[4] Éric Roose, Mohamed Sabir, Mourad Arabi, Boutkhil Morsli et Mohamed Mazour (2012) : Soixante années de recherches en coopération sur l'érosion hydrique et la lutte antiérosive au Maghreb, Physio-GeoV.6, p. 43-69

[5] Heusch B. (1970) - L'érosion du Pré-Rif (Maroc). Annales de la Recherche Forestière au Maroc, vol. 12, p. 1-176.

[6] Moukhchane M., bouhlassa S et Bouaddi K. (1998) - Évaluation de l'érosion des sols du BV El Hachef, par le Césium 137 (Tanger, Maroc).Bulletin du Réseau Érosion, vol. 18, p. 106-118.

[7] Moufaddal K. (2002) - Premiers résultats des parcelles d'érosion dans le bassin de Nakhla, Maroc. Bulletin du. Réseau Érosion, vol. 21, p. 244-254.

[8] Naimi M., Tayaa M., Ouzizi S., Choukr-llah R. et Kerby M. (2001) - Estimation du ravinement dans le bassin versant du Nakhla, Rif occidental, Maroc. Bulletin du Réseau Érosion, vol. 21, p. 232-243.

[9] Hlila R. (2005) : Evolution tectono-sédimentaire au front ouest du domaine d'Alboran (Rif interne septentrional, Maroc). Thèse de doctorat d'état. Université de Tétouan, 379p

[10] Hlila et al, 2008) Hlila R, Chalouan A, El Kadiri K, Sanz de Galdeano C, Martín-Pérez J.A, Serrano F, López Garrido, A.C, Maaté A & Guerra-Merchán A. 2008: New stratigraphic data of the Oligo-Miocene transgressive cover of the Ghomaride

units (Northern Internal Rif, Morocco) : Implications on tectonosedimentary evolution. Revista de la Sociedad Geológica de España, 21(1-2.).
[11] HLILA R. (1994): Etude des déformations miocènes dans la chaîne calcaire du Haouz (entre Tétouan et le col du Drauy). D.E.S. de 3ème cycle, Univ. de Tétouan, 155 p.
[12] El Gharbaoui A, (1981) : la terre et l'Homme dans la péninsule tangitane. Etude sur l'homme et le milieu naturel dans le Rif occidental. Trav. Inst. Sci. Rabat, Ser géol. Et géog. Phys., 439p.
[13] Boughaba A. 1992. Les littoraux meubles septentrionaux de la péninsule de Tanger (Maroc). Géomorphologie et effet de l'intervention anthropique sur leur environnement. Thèse de Doctorat, Fac. Lettres, Nantes, 413 p.
[14] Nabil L. (2005) : Pour un développement durable du Nord du Maroc. Revue d'Association Forum de Nord du Maroc 119p.
[15] Wischmeier, W.H. et Smith, D.D., 1978: Predicting rainfall erosion losses: a guide to conservation planning. Agricultural Handbook, 537. U.S.D.A.-S.E.A, Washington DC, 58 p.
[16] Roose E. (1994) : Introduction à la GCES; Bulletin Pédologique FAO, Rome, n070, 420 p.
[17] Kornprobst et Durand-Delga, 1985. Cartes géologiques de Tétouan et de Sebta au 1/50000.

ANNEX 1

Picture Planche

Picture 1 : vegetation density at the location of the checkpoint 1 in the Negro watershed .

Picture 2 : Gully at the location of the checkpoint 2 in the Fnideq watershed indicating a relatively stronger erosion than the previous case in the Negro watershed.