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PREDICTING THE POTENTIAL ANNUAL SOIL LOSS USING THE REVISED UNIVERSAL SOIL LOSS EQUATION (RUSLE) IN THE OUED EL MALLEH CATCHMENT (PRERIF, MOROCCO)

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Key words : Erosion, GIS, Idrisi, Oued El Mellah, Fez Morocco.

Abstract. This paper presents the results of our study on mapping the spatial evolution of the land from the modeling process of erosion. This contribution aims at determining rapid changes in land cover and land use and modeling of soil erosion in the study area where we have little data. Analysis of satellite data has identified six main types of land (Land severely degraded, cereal, mix cereal and tree crops, trees, and reforestation) in the watershed of Oued El Mellah north the city of Fez (Morocco). After the loss of soil have been estimated by the RUSLE module integrated into the GIS Idrisi, the results allowed the identification of sectors across the basin where interventions are needed to limit the process of land degradation.

Introduction

Soil erosion is a growing problem in the north of Morocco, particularly in the Pre-Rif domain. It negatively affects agricultural productivity, reduces water infiltration, underground water resources and water availability.

Previous studies of erosion and soil loss quantification in the Moroccan Rif and Prerif mountains were essentially qualitative and apprehended erosion processes and the resulting landforms (Heusch et al. 1970, Benmoussa et al. 1993, Daghmoumi 1994, Ait Fora 1995, Rahhou 1999, Al Karkouri 2003, Siteri et al. 2003). The scientific quantification of erosion and soil loss in Morocco is still lacking. The model usually adopted over the world to achieve such evaluation was the universal equation of soil loss by USLE (Wischmeier and Smith, 1978). However, in the Moroccan context, the application of the model may be problematic and should be tested to apprehend its effectiveness mainly in the Rif and Prerif region. This area is mountainous, with very steep slopes, and the

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development of gullies and even badlands is frequent. The previous applications of the model had been operated on sheet erosion, with hilly landforms and slope inclination less than 20%.

The present study aims to apply this model to the Oued El Mellah watershed, in the Prerif, where conditions are most suitable (agricultural land, slopes do not exceed 20%). The mapping approach was used to apprehend the factors involved in erosion processes: the aggressiveness of rainfall, slope, slope length, the soil erodibility, vegetation cover and tillage practices.

In the current study, an effort to predict potential annual soil losses has been conducted using the Revised Universal Soil Loss Equation (RUSLE) adopted in a Geographical Information System framework. It is used for the prediction of sheet erosion depending on the distribution of the aggressiveness of rainfall, the erodibility of soil, topography, land use practices and crop management.

GIS (ArcGis 9.3, Idrisi Andes) and remote sensing data are both used for modeling of soil erosion in the Oued El Melleh watershed. Results are illustrated in a map that allows the prioritization of the action across the watershed.

1. Study site

The Oued El Malleh catchment (fig. 1) is located at the North of Fez city and extends on the Prerif domain.

Its area is approximately 34 km². It is bordered in the East and North by the Oued Sebou valley, in the West by the Oued Mekkes catchment and in the South by the Saiss plain, with altitudes varying between 250 m and 900 m (Jbel Zalagh).

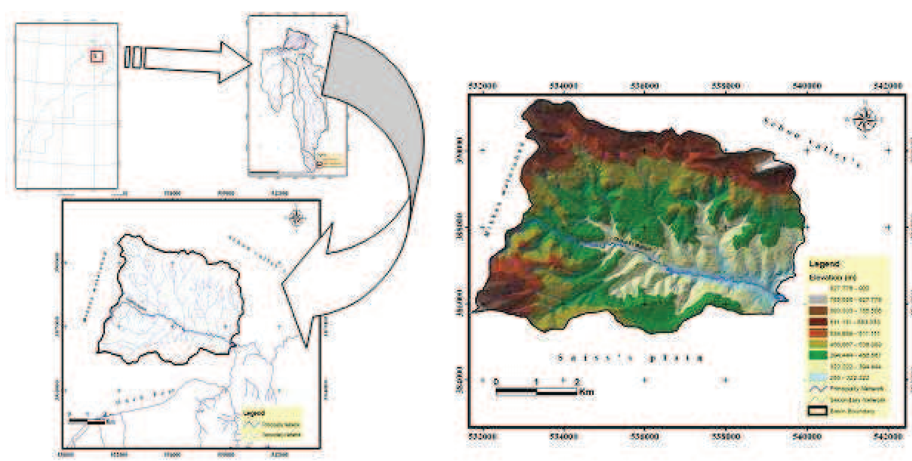

Fig. 1 - Localization and Digital Elevation Model of the El Malleh catchment

2. Physical environment

2.1. Slope. The map of the spatial distribution of topographic slope of the Basin of Oued El Malleh was generated from a Digital Elevation Model with 5m resolution. This map shows a very abrupt relief with slopes exceeding 80% along Jabal Zalagh (fig. 2).

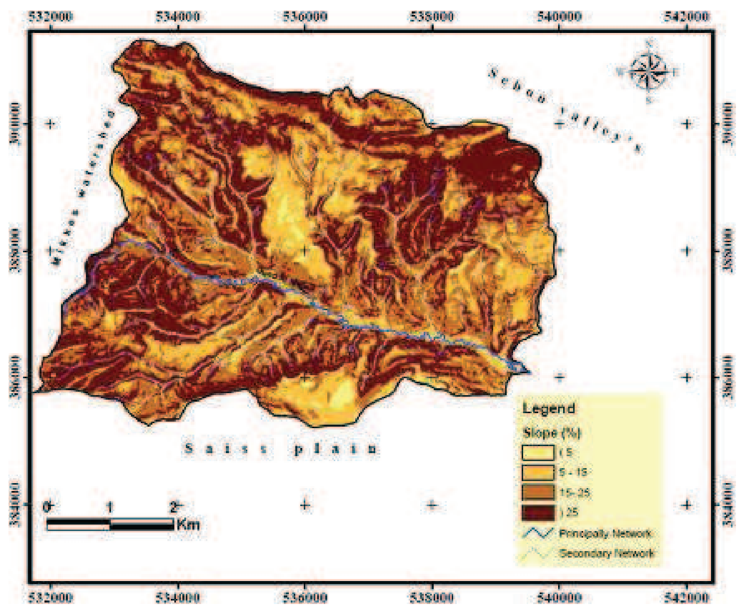

Fig. 2 - Slopes of the El Malleh catchment

2.2. Geology. The study area belongs to the Pre-Rif domain where several geological formations appear at the catchment scale. We observe different sedimentary deposits of different ages (fig 3):

- Gypsiferous clays and salt Triasic in age at the North-West basin (Essahlaoui et al., 2001),
- Calcareous sandstone which is Liasic in age at the Jbel Tghat and Jbel Zalagh;
- Miocene marls with interbedded sandstone;
- Pliocene conglomerates at he Merinids site;
- The quaternary travertine supporting the Medina of Fez;

The basin is crossed by Oued El Malleh and oriented from the West to the East. There are several springs in the basin but their discharge is low.

2.3. Soil types and textures. Four different types of soil textures are observed in the area:

• the sandy texture for aerated soil, with a high nutrient content - 10 and C2 units;

• the silty texture, for a fairly solid ground, rich oozes, and poor physical properties - 4, 15, 16 and C1 units;

• the clay texture, in soils rich in clay, poorly ventilated, impervious and difficult to cultivate - 17 unit;

• the balanced texture corresponding to the optimal texture, with all the qualities of the previous types - 3 and 19 units.

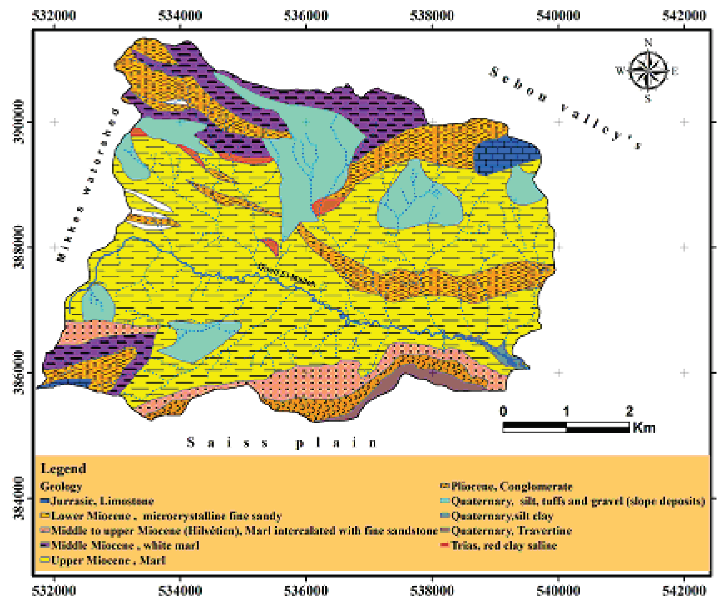

Fig. 3 - Geology of the El Malleh catchment

Complementary analyses were made on these soils (Fig. 4) and show that:

- Equivalent humidity is very high for the undeveloped soil (5-11%) the lowest values are found in the calcimagnesic soil (from 2% to 4%).

- pH is moderately basic (between 7.89 and 9.88).

- $CaCO_3$ levels vary between 37% and 68% for the undeveloped soil and 40% for calcimagnesic soils.

- organic matter content is very high for Vertisols (5.83), and minimum values are observed for calcimagnesic soils (between 0.67% and 1.29%).

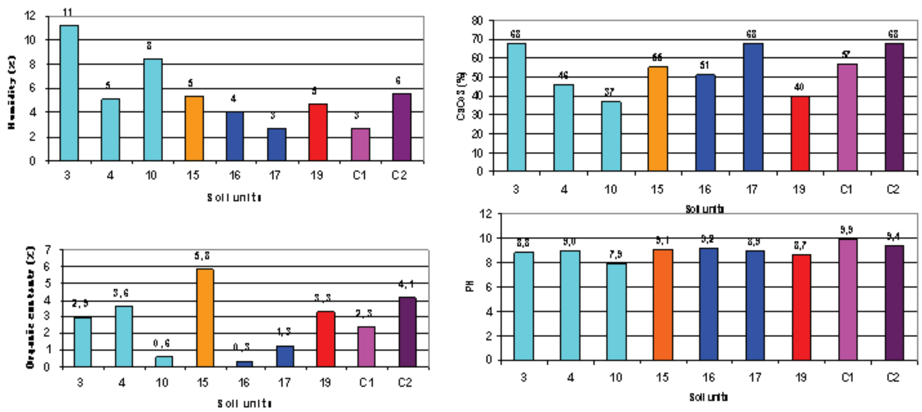

Fig. 4 - Soil humidity, calcimetry, organic matter content and pH

Following these results, the Oued El Malh catchment is a fragile context that favors erosion, considering its topographic, geologic and pedologic characteristics.

3. Potential soil loss estimation

3.1. Methodology and measurements. The RUSLE module was integrated in the Idrisi software. This module not only calculates soil losses for each pixel of the grid but also for groups of pixels into homogeneous polygons, based on the slope criteria, orientation and slope length which can be adjusted by the user (Wall et al., 2002; Sadiki et al., 2004; Chen et al., 2008).The model combines empirical RUSLE factors affecting the extent of erosion and is as follows (Fig. 5):

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

where:

A = estimated average soil loss in (t/h/yr),
K = soil erodibility factor,
LS = topographic factor integrating gradient and slope length,
C = Cover-management factor,
P = Support practice factor.

The RUSLE factors were calculated (in the form of raster layers) for our watershed in the basis of the soil and land use map (Fig. 5). The R-factor was calculated from monthly and annual precipitation data. The K-factor was estimated using soil maps available from the Soil Geographical Data Base of Europe at a scale of 1:25,000. The LS-factor was calculated from a 25 m digital elevation model. The C-factor was calculated using image from Google Maps and field observations (Fig. 6). The P-factor in absence of data was set to 1.

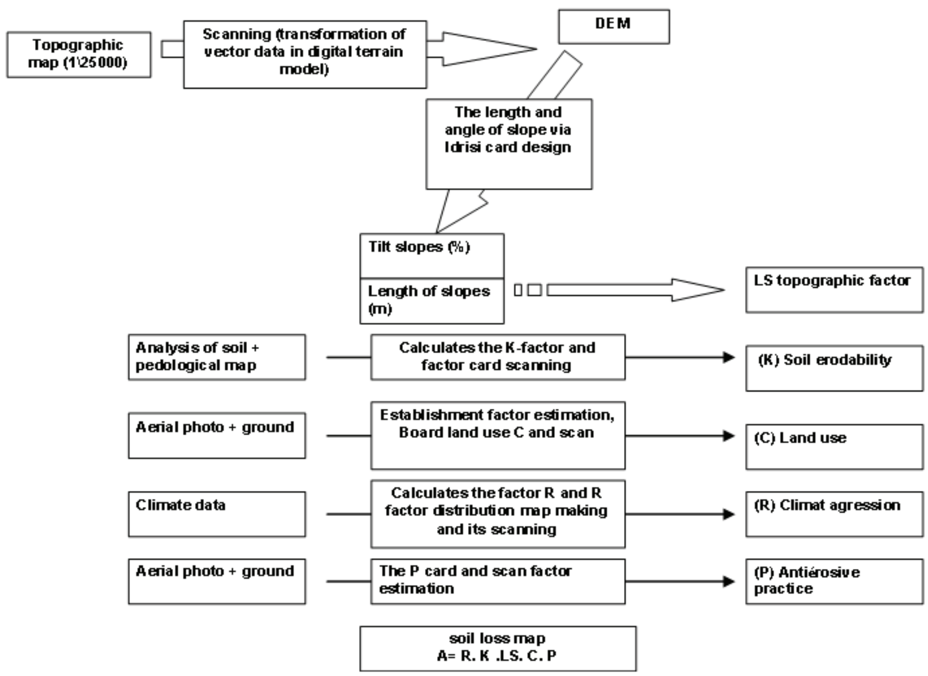

Fig. 5 - RUSLE schematic approach used

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3.2. Results. More than 90% of the total basin area of Oued El Mellah is covered by cereals, olives, or a mixture of both cultures, while other land (badland, irrigated agriculture, dump, and reforestation) represents only 7% of the basin area.

Given the complexity and diversity of geological facies several soil types occurs in the region. There are eight soil units (raw minerals, little change erosion, little change colluvial input, Vertisol rounded surface, Calcimagnesic, Isohumic, Complex units 2 , 3, and 4, Complex units 3 and 16).

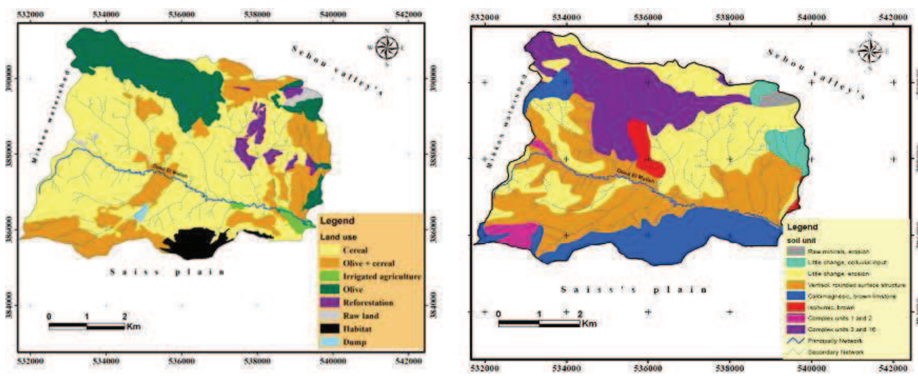

Fig. 6 - Soil units and land use

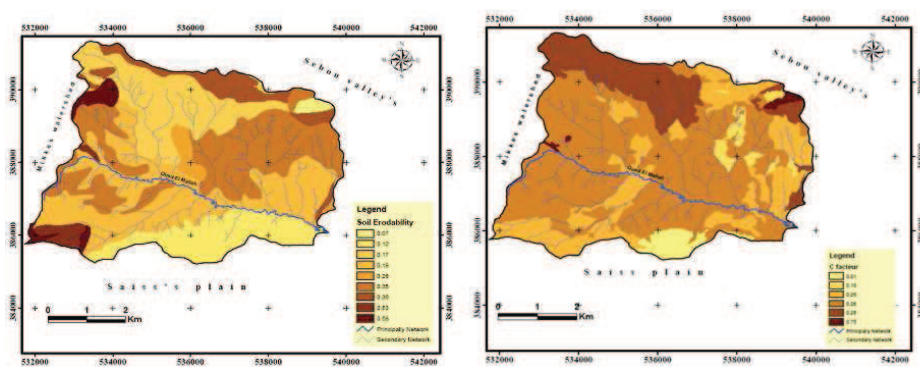

Fig. 7 - Soil K-Factor and C-Factor

The K and C factors of each soil and land use unit are reported in the Table.1.

The average soil losses determined by RUSLE vary between 5.6 t / ha / yr as the minimum value measured in the urban areas and 150.7 t / ha / yr as the maximum value recorded at the badland areas, which are generally unprotected Regosols located on steep slopes. The areas occupied by annual crops also show a high susceptibility to soil erosion, with annual losses of 41.6 t / ha / year (Tab. 2).

Tab. 1 - K-Factor and C-Factor for each Soils and land use units

Soil Units	K metric t/ha
Raw minerals	0.07
Little change erosion	0.18 to 0.36
Little change colluvial input	0.35
Vertisol rounded surface	0.18 to 0.35
Calcimagnesic	0.12
Isohumic	0.26
Complex units 2 , 3, and 4	0.53
Complex units 3 and 16	0.17
Land use Unit	**C factor**
Habitat	0.01
Reforestation	0.15
Olive + Cereal	0.25
Dump	0.26
Irrigated agriculture	0.26
Cereal	0.28
Olive	0.75

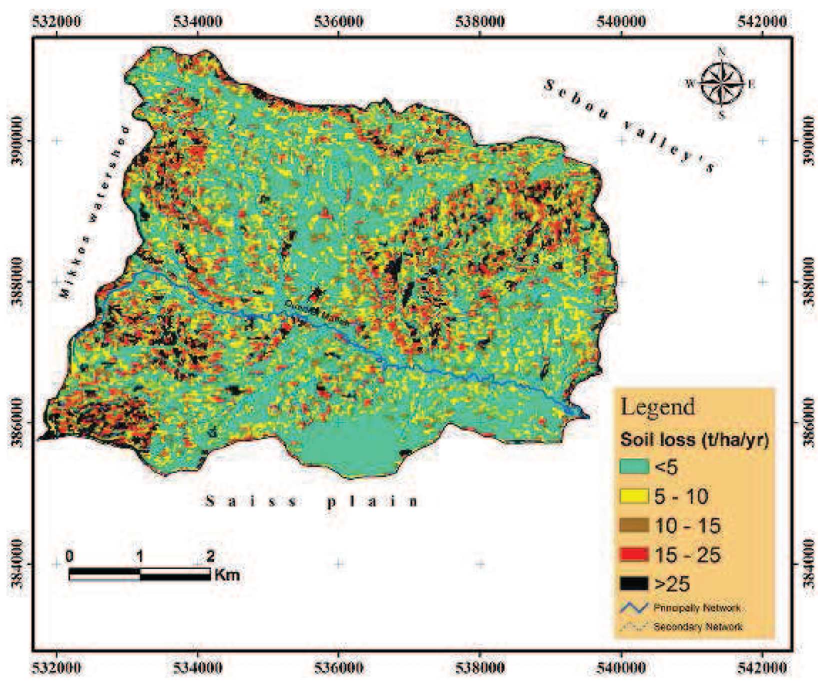

Fig. 8 - Potential erosion at the El Mellah catchment scal

Tab. 2 - Potential erosion for each land use unit

Land use	Area (ha)	% Area	Soil loss (t/ha/yr)
Urban	106,51	3,11	5.595
Reforestation	95,22	2,78	35.778
Olive + Cereal	743,57	21,68	43.845
Dump	10,54	0,31	14.191
Irrigated agriculture	32,34	0,94	19.571
Cereal	1882,47	54,89	41.62
Olive	529,48	15,44	49.189
Badland	29,31	0,85	150.677

4. Discussion

The study results confirm the fact that this model's application is significant. They show that the values recorded a high soil loss especially in the Pre- Rif region of Morocco. It ranges from 20 to over 50 t / ha / year (Tab, 3). This is much higher than tolerance levels of the soil losses in the United States, where losses of 6-11 t / ha / year. The results show therefore the seriousness of soil degradation due to the land use type and the local lithology that promotes soil erosion.

Tab. 2 - Soil loss in other watersheds

Watersheds	Area (Km^2)	Lithology	Slope Orientation	Average soil loss (T/ha/yr)
Oued Tlata (El Garouani, 2007)	123	Marls and sandy marls of Miocene	Nord-Sud	50
Oued Jemaa (El Garouani, 2003)	120	marly clay with outcrops of sandstone	Nord-Sud	28
Oued Nakhla	111,71	marls and flysch	Nord-Sud	38,7
Oued Boussouab (Sadiki A, 2004)	252,2	Dark pelites, marls clear, limestone marl	NE-SW	55,35

It is clear that several factors are simultaneously participating to soil erosion. They certainly vary in space and through time. Soil cultivation covers a wide range of agronomic practices and is varying seasonally and the rain also change under the cyclonic influences.

However, this technique allows us to assess the potential erosion across the basin and to identify areas that require interventions against soil degradation.

Conclusion

Soil loss is a major environmental risk in the area because the context globally favors erosion. The study results illustrate how it may be seriously constraining in the future. However, the phenomenon is varying following spatial and temporal changes that influence local factors activity.

For this purpose, soil erosion study needs to be linked to these changing factors such as crop yield, crop rotation cycles, managing techniques that are seasonally practiced for example. For these reasons, predicting soil loss is needed but its changing intensity and factors should receive more attention in soil erosion research.

References:

Ait Fora, (1995), *Modélisation spatiale de l'érosion hydrique dans un bassin versant du Rif marocain : validation de l'approche géomatique par la sédimentologie, les traceurs radioactifs et la susceptibilité magnétique des sédiments*. Thèse de PhD, Université de Sherbrooke, Québec, Canada.

Al Karkouri J. (2003), *Dégradation du milieu naturel dans le bassin de Beni Boufrah (Rif Central - Maroc) : analyse des facteurs et des processus, essai de quantification et modélisation spatiale*. Thèse doct. d'Etat, Université Mohamed V, Faculté des Lettres, 392 p.

Benmoussa M., Elyamani M. & Saidi A. (1993), *Application de l'équation universelle de perte en sol au bassin versant de l'oued Tasrafet*. GéoObserver, Rabat, 3, 59-70.

Chen H., El Garouani A., Lewis L.A. (2008), *Modelling soil erosion and deposition within a Mediterranean mountainous environment utilizing remote sensing and SIG- Wadi Tlata*. Morocco, *Geographica Helvetica*, 63, 36-47.

Daghmoumi R. (1994), *Apport de la géologie et du SIG à l'étude des bassins versants de l'Aoudour (Rif central)*. Thèse 3ème cycle, Univ. Mohammed V, Fac. Sci. Rabat, 162 p.

Daguin, F. (1927), *Contribution B 1' étude geologique de la région prérifaine (Maroc occidental)*. Notes et Mémoires Service Géologique, Maroc 1, 410p

De Waele J., F. Di Gregorio, M. El Wartiti, D. Fadli, R. Follesa, A. Marini and M.T. Melis (2004), *Geo-environmental risk in the upper valley of the Oued Sebou (Fes, Central Morocco): a preliminary approach*. Journal of African Earth Sciences 39) : 491–500

El Amrani Mohamed, Jean-Jacques Macaire, Hamid Zarki, Jean-Gabriel Bréhéret, Michel Fontugne (2008), *Contrasted morphosedimentary activity of the lower Kert River (northeastern Morocco) during the Late Pleistocene and the Holocene. Possible impact of bioclimatic variations and human action*. C. R. Geoscience 340; 533–542

Elbouqdaoui K., Ezzine H., Zahraoui M., Rouchdi M. et Badraoui M. (2006), *Évaluation du risque potentiel d'érosion dans le bassin-versant de l'oued Srou* (Moyen Atlas, Maroc). Sécheresse; 17 (3) : 425-31

El Garouani A., Chen. H, Lesewis L, Tribak A, Abahrour M, (2007), *Apport de la Télédétection et du SIG pour le suivi spatio-temporel de l'occupation du sol et de l'érosion nette dans le bassin de l'Oued Tlata (Maroc)*.

El Garouani A., Merzouk A., Jabrane R., Boussema M.R. (2003), *Cartographie de l'érosion des sols dans le bassin versant de l'Oued Jemâa* (Pré-rif, Maroc). Géomaghreb, 1 (1) : 39-46.

Essahlaoui et al. (2001), *Reconnaissance de la structure géologique du bassin de Sais occidental, Maroc, par sondages électriques*, Journal of African Earth Sciences. Vol. 32. No. 4, PP. 777-789.

Heusch B., Kalman R., Duhamel P.L. & Robert P. (1970), *Erosion, transport solide, sédimentation*. Ann. Rech. Forest. Maroc. n° sp. Etude sur l'érosion, 10, 390 p.

Rahhou M. (1999), *L'érosion dans le Prérif central, zone interfluviale Leben-Sebou-Ouergha, un prolongement de l'évolution naturel, une production sociale*. Thèse d'Etat, Univ. Mohammed V, Rabat.

Ruysschaert G., Poesena J., Verstraetena G. and G. Govers (2004), *Soil loss due to crop harvesting: significance and determining factors*. Progress in Physical Geography 28, 4: 467–501.

Sadiki A., Bouhlassa S., J., Auajjar J., Faleh A., Macaire J.J. (2004), *Utilisation d'un SIG pour l'évaluation et la cartographie des risques d'érosion par l'équation universelle des pertes en sol dans le Rif oriental (Maroc)* : cas du bassin versant de l'oued Boussouab, *Bulletin de l'Institut Scientifique,* Rabat, section Sciences de la Terre, 26, 69-79.

Siteri H., Aït Brahim L., Sossey A.F., Al Hamdouni I., El Hatimi N., Labraimi M., Ammar A., Baghdad B. & Tahri M. (2003), *Intégration du modèle USLE dans un SIG pour la détermination de la dégradation spécifique des sols dans le Rif Septentrional (cas du bassin versant de l'oued Nakhla)*. Trav. Inst. Sci. Rabat, sér. Géol. & Géogr. phys., 21, 241- 276.

Wall G.J., Coote D.R., Pringle E.A., Shelton I.J. (Eds) (2002). *RUSLE-CAN Équation universelle révisée des pertes de sol pour application au Canada*. Manuel pour l'évaluation des pertes de sol causées par l'érosion hydrique au Canada. Direction générale de la recherche, Agriculture et Agroalimentaire Canada, Contribution AAC2244F, 117p.

Wischmeier, W.H., Smith, D.D. (1978), *Predicting rainfall erosion losses – a guide for conservation planning*. U.S. Department of Agriculture, Agriculture Handbook, Washington, D.C.: 1-537.