J. Mater. Environ. Sci. 2 (S1) (2011) 433-438 *EL Aroussi et al.*
ISSN : 2028-2508
CODEN : JMESCN

Colloque International « Journées des Géosciences de l'Environnement »
Oujda, 21, 22 et 23 Juin 2011 « Environnement et développement durable ».

Methodological approach for assessing the potential risk of soil erosion using remote sensing and GIS in the Oued El Malleh watershed (Pre-Rif, Morocco).

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Abstract

This paper presents the results of our study on mapping the spatial evolution of the land from the modeling process of erosion. Indeed, this contribution aims determining rapid changes in land cover and land use and modeling of soil erosion in the study area where we have little data and that soil losses are mainly water. 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).The loss of soil have been estimated by the RUSLE module integrated into the GIS Idrisi. The results allow the identification of sectors across the basin where interventions are needed to limit the process of land degradation.

Keywords: Erosion, GIS, Idrisi, Oued El Mellah, Fez Morocco

1. Introduction

Soil erosion is a growing problem in the north of Morocco, particularly in the Pre-Rif domain. Soil erosion not only decreases agricultural productivity, but also reduces the water availability. In the current study, an effort to predict potential annual soil losses has been conducted, for the prediction; the Revised Universal Soil Loss Equation (RUSLE) has been adopted in a Geographical Information System (GIS). Evaluation studies of erosion and quantification of soil losses were limited to the Rif (Heusch et al. 1970, Benmoussa et al. 1993,,....) and other). Where the model used for this evaluation was the universal equation of soil loss by USLE Wischmier. However the application of this model raises many question marks about the effectiveness of it in the **R**if region (mountainous region where very steep slopes prevail and where there is development of gullies and even badlands) knowing that the model can only apply to sheet erosion, with reliefs of the plain or low hill slope and less than 20%.

So we decided to apply this model to the Oued El Mell**a**h watershed where conditions are most suitable (agricultural land, slopes do not exceed 20%).

2. The objectives of this study are:

-Mapping the spatial and temporal evolution of land use from remote sensing data (Landsat images) over a period of 24 years (1987-2011).
-Estimation of net soil loss using RUSLE and Sedimentation modules integrated into the GIS Idrisi Andes.
-Identification of areas for the basin where interventions are needed in order to limit the process of land degradation.

3. Physical setting of the study area

The Oued El Malleh catchment (Figure. 1) is located at the North of Fez city, it has an area of approximately 34 km². It is bordered in the East and North by Oued Sebou valley, in the West by Oued Mekkes catchment and in the South by the Saiss plain's, with altitudes between 250 m and 900 m (Jbel Zalagh). (Figure.1).

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 of resolution. This map shows a very abrupt relief with slopes exceeding 80% along Jabal Zalagh.

Several geological formations occur throughout the watershed, we observe different deposition of different ages: gypsiferous Triassic clays in the northwest of the basin, calcareous sandstone of the Lias (Jbel Tghat and Jbel Zalagh), the Miocene marls sandstones, the Pliocene conglomerates the and the travertine Quaternary (Essahlaoui et al. 2001).

Study Site

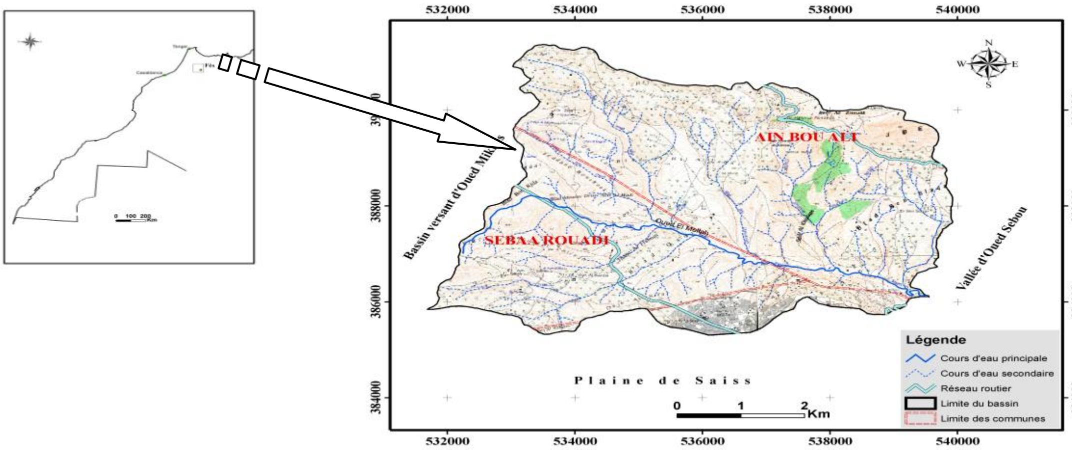

Figure 1: Localisation and Digital Elevation Model of the El Malleh catchment

3.1 Soils

Four different types of textures are observed:

- Sandy texture for aerated soil, with an high nutrient content – 10, 4 and 234 units;
- Silty texture, for a fairly solid ground, rich oozes, and poor physical properties - 316, 15, 16 and 17 units;
- Clay texture, for a soil rich in clay, poorly ventilated, impervious and difficult to cultivate 16 unit;
- Balanced texture corresponding to the optimal texture, with all the qualities of the previous - 3 and 19 units.

Other analyses were made on these soils:

- Equivalent humidity is very high for the undeveloped soil (5-11%) the lowest values are saved for soil calcimagnesitic soils (from 2% to 4%).
- pH is moderately basic (between 8.30 and 8.88).
- $CaCO_3$ levels vary between 19.23% and 68.21% for the undeveloped soil and 62.47% for calcimagnesitic soils.
- Organic matter content is very high for the Regosolic soil (8.71%), and minimum values are observed for the modal soils (between 3.2%).

These tests are released at the center CEBAS (Murcia, Spain)

4. Methodology and measurements

4.1 Land use mapping

Analysis of satellite data(Landsat image for the period of 24 years) has identified six main types of land use, land strongly degraded "badlands", plow land, mixed of plow land and olive trees, reforestation, **irrigated** crops, and urban area) .(Figure.2).

The diachronic study of land use shows a modification of the natural landscape with extension of the area occupied by the soil heavily eroded (badlands) (+54, 75%), in benefit of the reforestation area (-42, 17%), and there is an extension of the area occupied by irrigated crops (15.91%), while the area occupied by the cereal olive, and urban area did not undergo significant change (7.41%, 8.81%, and 4.34%) , (Table.1).

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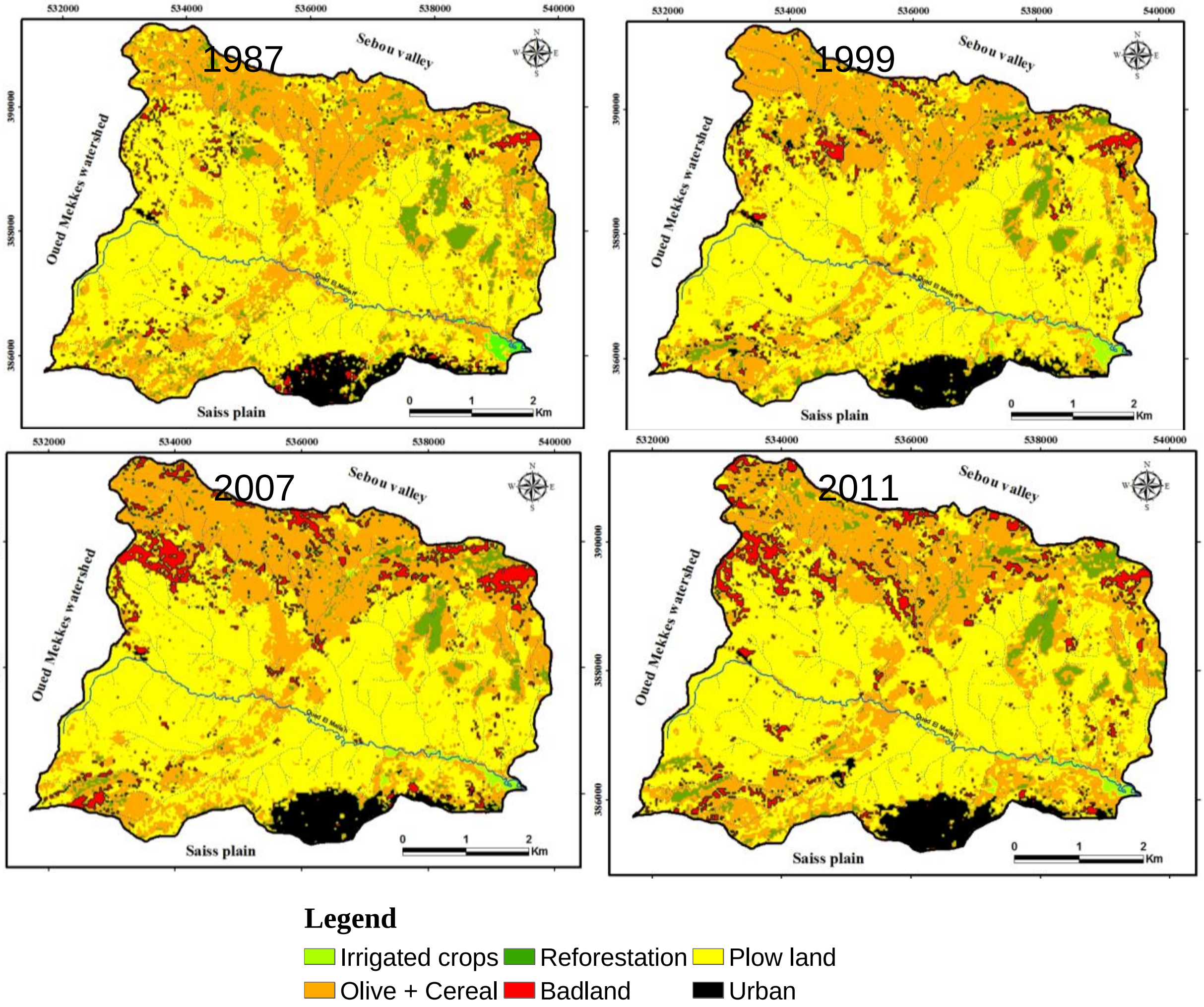

Figure 2: Evolution of land use in the Oued El Malleh watershed between 1987 and 2011

Tableau 1: Land use change for the period (1987 to 2011)

Land use	1987	1999	2007	2011	% Change
Badlands	3,58	4,74	7,85	7,90	54,75
Urban	3,56	4,58	3,58	3,73	4,34
Reforestation	6,75	3,65	3,18	4,75	-42,17
Olive + Cereal	26,84	30,02	31,31	28,99	7,41
Plow land	58,65	56,06	53,31	53,90	-8,81
Irregated crops	0,62	0,95	0,77	0,74	15,91

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4.2. RUSLE model

The RUSLE module was integrated into the GIS Idrisi. 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). Such static assessments of soil losses were then used as inputs into an algorithm of deposition (sedimentation) that models the movement of sediment to the outlet. The model combines empirical RUSLE factors affecting the extent of erosion and is as follows: 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.

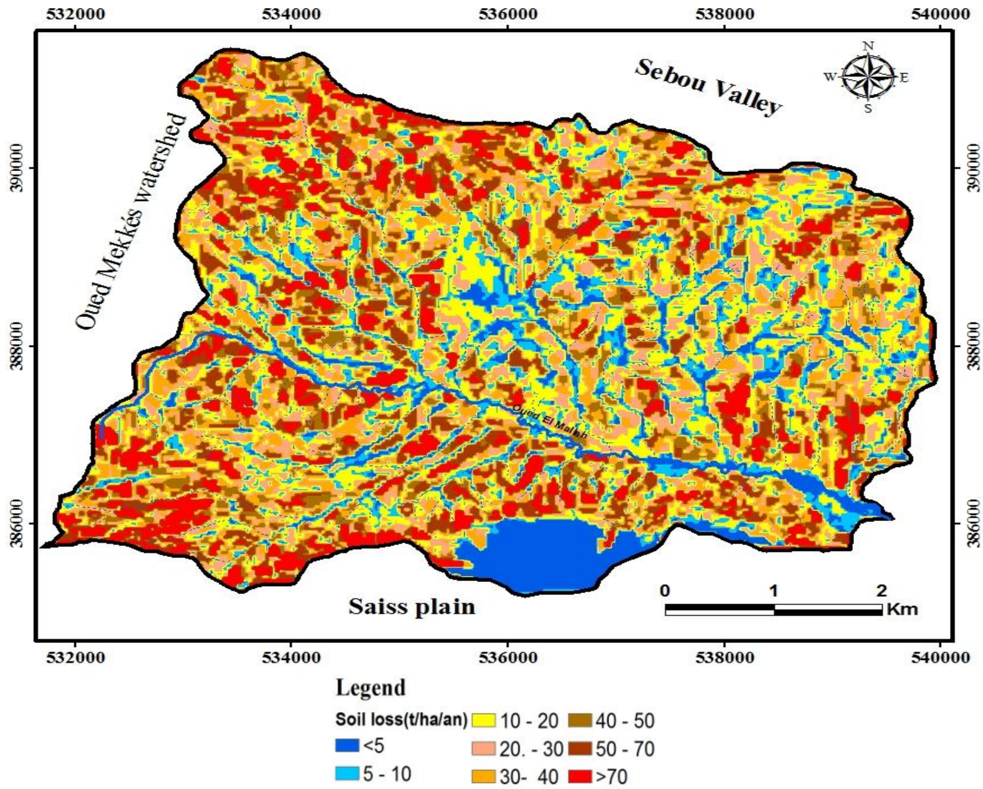

Figure 3:.Map of soil loss determined by the Rusle model

The RUSLE factors were calculated (in the form of raster layers) for our watershed in the basis of the soil and land use map. The R-factor was calculated from monthly and annual precipitation data. The K-factor was estimated using soil maps available from the report «Soil Study in 1 / 100000 for agricultural development in the Fez circles and Keria Tissa in Taounate province". 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. The P-factor in absence of data was set to 1.

4.2.1. Results

The average soil losses determined by RUSLE vary between 10.95 t / ha / yr as the minimum value measured in the Irrigated crops areas and 157.4 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 52.83 t / ha / year (Figure. 3).
The technique allows us to assess the potential erosion across the basin and to identify areas that require interventions against soil degradation.

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4.3 Sedimentation Model

Sedimentation model is based on the results of the RUSLE model to calculate the balance of erosion in each elementary plot considered homogeneous (Figure. 4). It uses homogeneous polygons resulting from the calculation of the RUSLE module to assess the net movement of soil (erosion or deposition) in plots or sub watersheds (Lewis et al., 2005).

These assessments static soil losses were then used in an algorithm deposition (sedimentation) that models the movement of soil loss to the outlet.

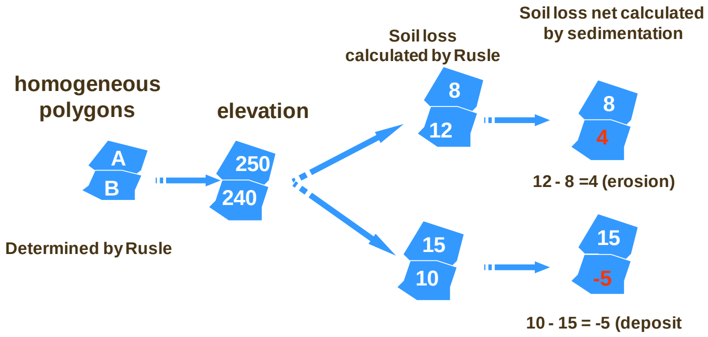

Figure 4: Principle model of deposition: Sedimentation (El Garouani A. 2007)

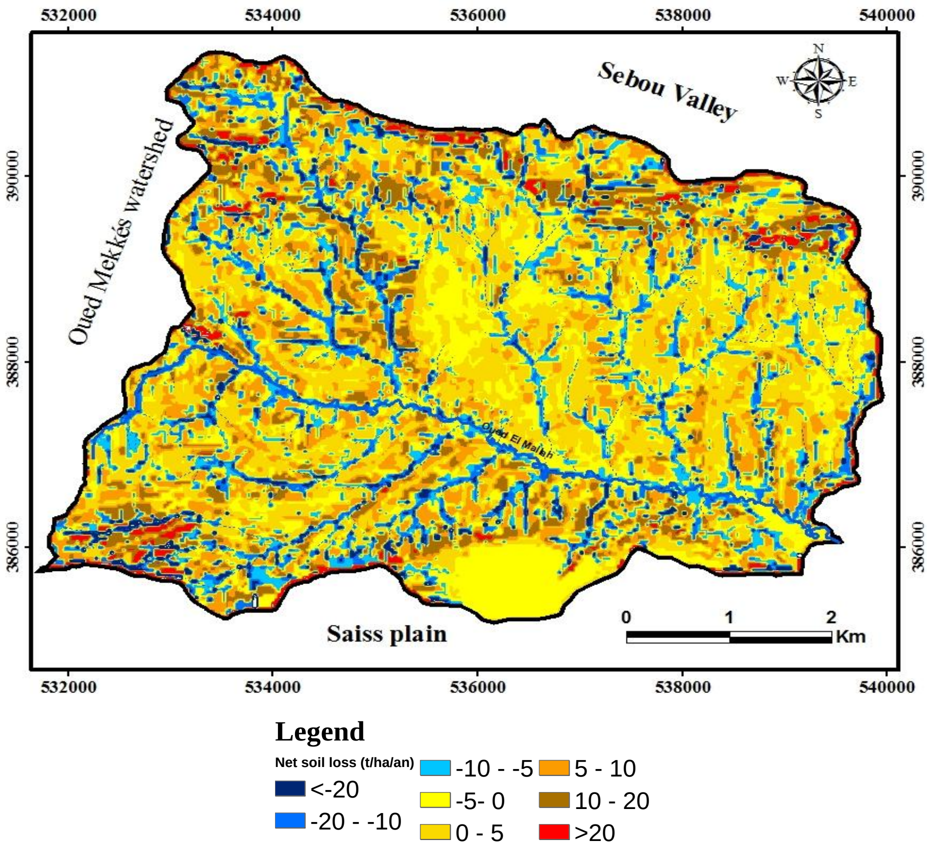

Figure 5:.Map of net soil loss determined by the sedimentation model.

Conclusion

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Taking into account the temporal variability of erosion and deposition at the same time led to lower values of soil erosion calculated by the RUSLE model (eg only 44.33 t / h / year as results for the model sedimentation in the badland). Despite this decline, there is always a problem of land degradation due to the type of land use and local lithology (Figure. 5).

At this stage of our research in the area, the specific annual erosion rate calculated by the models (RUSLE and sediment) should be considered as an indication and its importance lies in monitoring the temporal variation of the process. Indeed, the confidence intervals for the parameter values can't be defined by lack of measure on the plots and micro watersheds for calibration. A measurement campaign on the ground will be the next phase of our project.

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