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Applying revised universal loss equation model to forest lands in Central Plateau of Morocco

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RESUMEN

Este trabajo aporta los resultados de los datos recogidos relativos a la erosión del agua en el Plateau Central de Marruecos. Se intenta probar la eficiencia del modelo RUSLE para predecir la erosión en los terrenos forestales mediterráneos. El experimento fue realizado en las estaciones forestales de Lalla Regraga y Aïn Guernouch, situadas a una distancia de 50 y 100 km de Rabat. El modelo RUSLE considera la erosión como producto de la acción de la lluvia, la topografía y la vegetación. El modelo fue desarrollado en origen para tierras cultivadas y no ha sido aplicado a áreas forestales de Marruecos. Para verificar la precisión del modelo RUSLE en esta nueva situación, se consideraron dos conjuntos de 5 y 6 puntos de medida y la instalación de una estación climática en cada una de las estaciones consideradas. Estos lugares están caracterizados por un clima semi-árido de inviernos moderados, litología granítica y suelos arenosos en Aïn Guernouch y suelos arcillosos en Lalla Regraga. Ambas regiones muestran una cubierta forestal. Con la finalidad de introducir información procedente de teledetección, hemos analizado la profundidad térmica sobre todo el territorio, utilizando imágenes de temperatura de superficie procedentes del sensor MSG-SEVIRI, para caracterizar el suelo y aportar comparaciones entre otras regiones de Marruecos y España.

PALABRAS CLAVE: plateau central, Marruecos, profundidad térmica, lluvia, erosión por agua, RUSLE.

ABSTRACT

This paper reports the results of data compilation on water erosion in Central Plateau of Morocco. It tries to test the efficiency of the Revised Universal Soil Loss Equation (RUSLE) to predict erosion in Mediterranean forest situations. The experiment was conducted at forest stations of Lalla Regraga and Aïn Guernouch about 50 and 100 km respectively from Rabat, the capital of Morocco. RUSLE model translates erosion as a product of rain erosivity, soil erodibility, topography, vegetation and practices. It was mainly developed for cultivated lands, it was rarely applied to forest areas and never to forests in Morocco. To verify the accuracy of using RUSLE in these situations, two sets of 5 and 6 experimental Wischmeier type plots and a climatic station were installed at the above sited stations. The two experimental sites are characterized by a local semi arid with moderate winter climate, a hydrographic network represented mainly by first order gullies, a lithology showing granite lands with sandy soils at Aïn Guernouch site and schist land with clayey soils in Lalla Regraga site, a deciduous forest in the first site, and a coniferous one in the second site. In order to introduce information coming from remote sensing, we have analyzed the thermal depth over all territory, using MSG thermal images, to characterize the soil and obtain comparison with other regions in Morocco and Spain

KEY WORDS: central plateau, Morocco, MSG-SEVIRI, thermal depth, rain, runoff, water erosion, RUSLE.

INTRODUCTION

Erosion is among natural phenomena with the most concern regarding hydraulic policy that Morocco undertakes to promote the social and economic development. At a landscape scale erosion causes loss of nutrients and a decline of productivity. Several methods have been developed to study this phenomenon and to reduce its extent. Mathematical models remain however the most used method and the most adequate to quantify erosion.

In parallel to watershed study and management strategy, the High Commissariat of Waters and Forests and Combating desertification has anticipated to develop and to strengthen research concerning struggle against erosion. In an agronomy optic, aiming to compare soil loss and runoff according to different land uses, this institution concluded, with UNDP and FAO, the Project MOR/93/010 to adapt the Revised Universal Soil Loss Equation “RUSLE” (Renard K.G., Foster G.R., Weesies G.A., Mc COOL D.K. and Yoder D.C., 1997) to

Moroccan conditions. This model integrates all factors that govern erosion phenomenon. It translates it as a function of rain and runoff erosivity (R); soil erodibility (K); land topography (LS); vegetation factor (C) and operations factor (P).

Adaptation of the model goes through several steps: A first step is to convert in the software English units to SI units, as well as, translate English screens to French. The second step is related to the development of three databases proper to Morocco conditions. The last step consists of validating the model by comparing simulated soil loss with direct measurements of erosion from more than 100 experimental plots located in five Moroccan regions.

The present paper shows some results undertaken in the region of Rabat, on forestland, during the years 1997 to 2001.

CHARACTERISATION OF THERMAL DEPTH THROUGH REMOTE-SENSING

The studies on the erosion of the ground are evidently associated to the study of the vegetation covers existing on the surface. The characterisation of such covers at a global level, which characterise large regions such as is the case of Morocco, turns out to be difficult due to several reasons: the database are not updated, effective errors are made when transforming the spatial resolution of the data, the influence of the phenological state of such covers, which depends on the time of analysis, etc. On the other hand, remote-sensing on the thermal spectrum and at a low resolution has not been included in geological studies of analysis of the erosion.

Considering all these factors, we have tried to carry out a previous analysis of the conditions existing on the global territory of Morocco which comprises the areas analysed in this work, by using high-time resolution thermal images in order to characterise the thermal evolution of the surface and establish the ground depth which the thermal oscillation of the surface is sensitive to. This magnitude is an indicator of the surface state since a high value in the depth of the ground reveals a high thermal oscillation on the surface and is associated to conditions of little or no vegetation. The opposite case, with effective vegetation covers, results in lower daily thermal oscillation values and, consequently, lower values of ground depth sensitive to thermal variations.

Description of the method

We have based the physical process on the analysis of the loss of heat happening on the ground surface due to the thermal conduction that takes place inwards, up to a concrete depth, introducing also the time factor, which is the one establishing the temperature variation cycle. Thus, the relation existing between the temporal variation of the temperature and the conduction of the temperature in the surface thickness is given by:

$$\frac{\partial T}{\partial t} = \frac{k}{\rho_b\, C} \cdot \frac{\partial^2 T}{\partial z^2}$$

where T is the temperature, t, the time, z, the thickness of the ground's depth through which the heat conduction takes place, C, the specific heat of the ground ($J \cdot kg^{-1} \cdot K^{-1}$), k the ground's thermal conductivity ($W \cdot m^{-1} \cdot K^{-1}$) and, finally, ρ_b , is the density of the ground ($kg \cdot m^{-3}$). This relation has a high interest in agrometheorology and geology, since only the temperature, time and depth magnitudes intervene, parameters which are easier to measure in the ground than the fluxes of energy. Thus, the factor $\frac{k}{\rho_b\, C}$ is called thermal diffusivity and it expresses the velocity at which the temperature inside a body can change.

On the other hand, the temperature variations, as much in surface as in depth follow approximately a sinusoidal function, so that the resolution of the former differential equation results relatively easy in an harmonic model which will have a diurnal periodicity in our case. That is, there is a period of 86400 seconds. Thus, the expression used in our model to describe the temperature variations at a generic depth level will be:

$$(\Delta T)_Z = (\Delta T)_0 \cdot e^{-Z\sqrt{\frac{\omega}{2 \cdot a}}}$$

where ΔT_z is the maximum-minimum temperature oscillation at a level of z centimetres of ground depth, ΔT_0 is the thermal oscillation in the surface, w is the angular frequency in the sinusoidal variation considered for a day and a is the thermal diffusivity of the ground, where an averaged, standard value of 0.005 $cm^2 \cdot s^{-1}$ has been taken.

Methodology

In order to establish the depth of thermal oscillation, images from the MSG-SEVIRI sensor, whose time frequency is 15 minutes, have been used, although it has a spatial resolution of 3km in the nadir. In order to analyse the territory of Morocco in conditions of maximum thermal oscillations, summer scenes with clear skies have been taken. The earth surface temperature has been established from the bands of 11 and 12 μm. Next, the thermal oscillation for all the territory comprised in this study has been calculated. The number of images analysed per day is 96, corresponding to the 96 15-minute periods available from the MSG. In this way, the establishment of the thermal oscillation will be the most accurate possible. 1K is the oscillation threshold value that has been agreed on to establish the maximum depth of thermal sensitivity. Values lower than this one will be considered as not having thermal sensitivity.

Results

Results are summarised in a graphic way in the Figure 1. Results from the Iberian Peninsula have also been included so that they can be compared with more known zones by the reader. As can be seen in the image, the depth thickness of what we have called thermal sensibility is arranged in an interval between 30 and 50 centimetres. The different behaviour between the North of Morocco, with lower thickness, and the interior zones, can be observed. Thus, the plots analysed in this work, near Rabat, have a thermal behaviour similar to the one occurring in the Castilian plateau, with depth values of around 40 cm. In the figure, regions of Ain Guernouch and Lalla Regrega, near of Atlantic Ocean and Rabat, are shown. The Moroccan zones near the desert covered by bare land can also be distinguished with higher values of thermal depth.

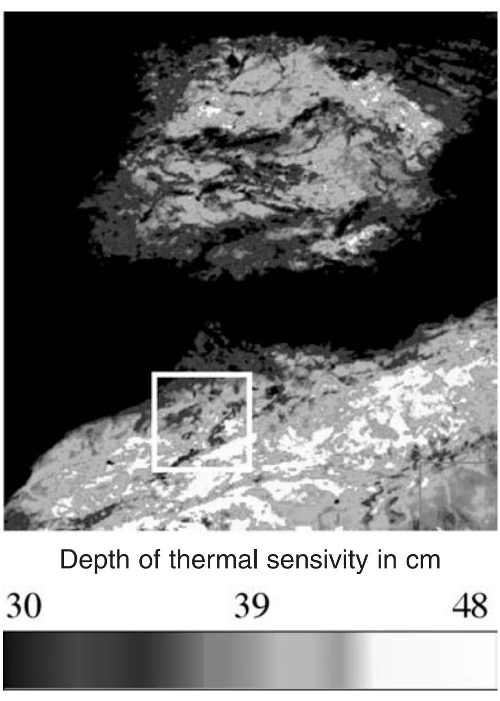

***Figure 1.** Depth of thermal sensivity in cm, obtained for Morocco. Regions of Ain Guernouch and Lalla Regrega are shown.

MATERIAL AND METHODS

The experiment is conducted at the forest stations of Lalla Regraga and Aïn Guernouch, which are respectively 50 and 100 km south east of Rabat (Fig. 2). The two sites are located in a Mediterranean semi arid bioclimatic, characterized by a cool and rainy winter and hot and dry summer

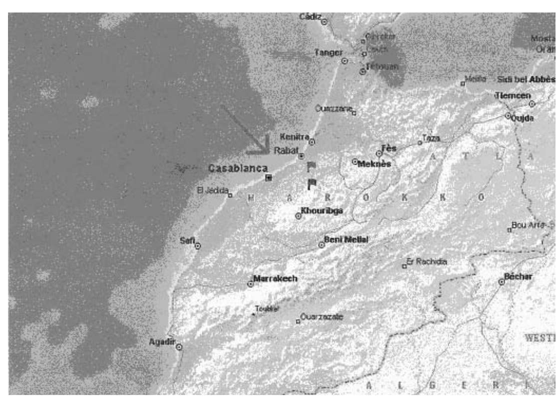

Figure 2. Topographical map of northern Morocco showing Lalla regraga (red flag) and Aïn Guernouch (blue flag).

Although relatively expensive, the method using erosion plots remains the most used and the most reliable. It consists of a rectangular land area of 22.1 m along the slope and 3 to 5 m wide, limited on all sides by a galvanized metal frame (Fig. 3 and Fig.4).

After studying environmental conditions and demarcation of physiographic units on the landscape, two juxtaposed witness plots and a climatic

Todas las figuras precedidas de asterisco se incluyen en el cuadernillo anexo de color

Figure 3. Witness plots at Lalla Regraga site.

Figure 4. Witness plots and Aïn Guernouch site.

station (min and max thermometer, evaporometer, automated tipping-bucket rainlogger and Hellman rain gauge) are installed to check the rain erosivity at the specific experimental zone and the soil erodibility of that physiographic unit. Other plots are installed on different natural vegetation types within the same unit to know the effect of vegetation cover on soil loss. Plots are installed on linear slopes. A full description of the plots is given in Tables 1 ad 2. Plots 4013 and 4014 have had their slope length cut in half to cover a uniform patch of *Chamaerops humilis.*

After each storm the water collected in reservoirs is measured and samples of one liter are taken and their concentration of solid material determined. Vegetation cover and soil roughness are measured with a profilometer during each season and the permeability code for calculation of K is defined after measuring infiltration with a double ring. Data used in this article were collected from 1997 to 2001.

Plot n°	4011	4012	4013	4014	4015	4016
Length	22.1 m	22.1 m	11.05 m	11.05 m	22.1 m	22.1 m
Width	3 m	3.9 m	2.75 m	3.25 m	3.2 m	11 m
Area	66.3 m^2	86.19 m^2	30.39 m^2	35.91 m^2	70.72 m^2	243.1 m^2
Altitude	320 m	320 m	320 m	320 m	310 m	290 m
Exposition	WNW	WNW	NNW	NNW	NNW	N
Slope	31%	31%	39.5%	39.5%	37%	38%
Vegetation	*Asphodelus microcarpa* *Tapsia gargarica*	*Asphodelus microcarpa* *Tapsia gargarica*	*Chamaerops humilis* *Asphodelus microcarpa*	*Chamaerops humilis* *Asphodelus microcarpa*	*Arisarum vulgare* *Arislochia betica* *Tapsia gargarica* *Pistacia lentiscus*	*Tetraclinis articulata*

Table 1. Description of erosion plots installed at forest station of Lalla Regraga.

Plot n°	4021	4022	4023	4024	4025
Length	22.1 m	22.1 m	22.1 m	22.1 m	22.1 m
Width	3 m	3 m	9.4 m	2.9 m	2.9 m
Area	66.3 m^2	66.3 m^2	207.74 m^2	64.09 m^2	64.09 m^2
Altitude	600 m	600 m	600 m	600 m	600 m
Exposition	NW	NW	WNW	SW	N
Slope	19%	19%	17.16%	29.5%	15%
Vegetation	*Asphodelus microcarpa* *Chamaerops humilis* *Rumex bucephalophorus* *Arisarum vulgare* *Tapsia gargarica* *Diplotaxis catolyca* *Ormenis mixta*	*Asphodelus microcarpa* *Chamaerops humilis* *Rumex bucephalophorus* *Arisarum vulgare* *Tapsia gargarica* *Diplotaxis catolyca* *Ormenis mixta*	*Quercus suber*	*Rumex-bucephalophorus* *Lavandula stoechas* *Cistus monspeliensis* *Urginia sp.* *Asphodelus microcarpa* *Montisallca salmontica* *Bellis silvestris*	*Asphodelus microcarpa* *Cistus monspeliensis* *Lavandula stoechas* *Bellis silvestris* *Tapsia gargarica* *Arisarum vulgare* *Chamaerops humilis*

Table 2. Description of erosion plots installed at forest station of Aïn Guernouch.

RESULTS AND DISCUSSION

Rainfall-Runoff Erositvity

R is the rainfall-runoff erosivity factor. It is the average annual summation (EI) values in a normal year's rain. The erosion-index is a measure of the erosion force of specific rainfall. When other factors are constant, storm losses from rainfall are directly proportional to the product of the total kinetic energy of the storm (E) times its maximum 30-minute intensity (I). R factors represent the average storm EI values over a 22-year record. R is an indication of the two most important characteristics of a storm determining its erosivity: amount of rainfall and peak intensity sustained over an extended period.

At each experimentation site a recording raingage is installed and the energy of each storm is calculated from the charts. Each rain shower is divided into uniform intensity intervals and an equation of energy-intensity is used for each interval (Brown and Foster 1987).

$$e = 0.29\ [1-0.72 \exp(-0.05i)]$$

with (e) having units of MJ/ha•mm of rain and (i) has units of mm/h. Calculations are made for each storm then added to find the annual value using the formula:

$$R = \frac{1}{n} \sum_{j=1}^{n} \left[\sum_{k=1}^{m} (E)(I_{30})\ k \right] j$$

with:

E: total storm kinetic energy
I_{30}: Maximum 30 mn rainfall intensity
J: indication of number of years used to produce average
K: index of number of storms in each year
N: number of years used to obtain average R
M: number of storms in each year
R: average annual rainfall erosivity

Application of this formula to data taken at the two sites of study is given in Table 3. At Lalla Regraga forest station, the mean rain energy factor for the five years record is 24.74 MJ.mm/ha•h.yr, while it is 29 MJ.mm/ha•h.yr at Aïn Guernouch forest station site. Although data recorded are not long enough the values look representative of the area involved.

Site	Year	Number of showers	Total rainfall (mm)	total R MJmm/hahyr	Mean rainfall per shower (mm)	Mean R per rain shower (MJmm/hahyr)
Lalla Regraga	1997	46	404.3	21.21	8.8	0.5
	1998	34	221.4	25.38	6.5	0.75
	1999	45	394.8	28.24	8.76	0.63
	2000	29	194	23.64	6.7	0.8
	2001	29	232	25.24	8.8	0.87
	Mean	36.6	289.3	24.74	8	0.71
Aïn Guernouch	1997	41	308.7	32.04	7.53	0.8
	1998	36	246.5	34	6.85	0.2
	1999	53	327.5	32.5	6.18	0.2
	2000	42	309.4	16.02	7.37	0.4
	2001	33	266	28.9	8.06	0.24
	Mean	41	292	29	7.2	0.4

Table 3. Erosivity factor at Lalla Regraga and Ain Guernouch forest stations.

Soil erodibility

The soil erodibility factor (K) is the average long-term soil and soil-profile response to the erosive power of rainstorms. Calculating this factor by using the nomograph (Wischmeier and al. 1971) remains the most used method. Its algebraic form is given by:

$$K = [2.1*10^{-4}(12-MO)M^{1.14}+3.25(s-2)+2.5(p-3)]/100$$

with:

K: soil erodibility expressed in t•ha•h/ha•MJ•mm
MO: % organic matter
M: (% fine sand + % silt)
s: the class of structure
p: the code of permeability

All physical and chemical data collected on soil characteristics are introduced in the RUSLE software, corrections are made for the presence of coarse material at the soil surface. The program output is the K factor expressed in ton•acre•hour/hundreds of acres•foot•ton•inch. To convert this value to SI units (t.ha.h/ha.MJ.mm) values were multiplied by 0.1317. Results are shown in Table 4. The plot 4024

Plot n°		4011 4012	4013 4014	4015	4016	4021 4022	4023	4024	4025
Clay (%)		38.86	39.63	44.4	39.5	15.73	16.73	20.33	12.86
Silt (%)	Fine	18.2	20.2	26.2	28.3	4.03	4.96	2.6	1.56
	Coarse	14.13	10.3	8.1	10.6	5.6	6.26	4.8	6.76
Sand (%)	Fine	15.14	15.26	6.9	6.3	16.2	15.36	15.4	13.6
	Coarse	15.6	15	14.3	15.3	58.4	56.66	56.8	55.2
OM (%)		1.76	2.63	5.29	4.3	1.25	1.66	1.02	1.06
C (%)		1.02	1.53	3	2.52	0.72	0.97	0.59	0.6
Hydraulic onductivity		0.81	2	6.92	2.24	2.9	7	6.15	1.28
Permeability class		2	2	1	2	1	1	1	2
Structure code		3	3	2	2	2	2	2	2
K (t·ha·h/ha·MJ·mm)		0.026	0.022	0.01	0.015	0.012	0.012	0.009	0.013

Table 4. Soil erodibility at Lalla Regraga and Aïn Guernouch plots.

shows the least erodibility because of its low content in soil OM and in silt and very fine sand, the most easily transported fraction.

Slope length and steepness

The slope length (L) and steepness (S) are the factors characterizing the plot topography. For experimentation reasons, plots used to determine factors L and S have linear slope. Simulation of this factor by RUSLE program necessitates the choice of LS value from tables in 703 handbook, depending on soil conditions and its reaction to erosion. For Lalla Regraga and Aïn Guernouch sites Table [4-1] of RUSLE handbook was used. Values of this factor are given in the Table 5. We notice that, in Lalla Regraga, despite plots 4013 and 4014 have the largest slope steepness, their factor LS is the smallest because they have smaller lengths. At Aïn Guernouch plot 4024 has the highest LS factor because of its steepness.

Plot n°	4011	4012	4013	4014	4015	4016	4021	4022	4023	4024	4025
Length (m)	22.1	22.1	11.05	11.05	22.1	22.1	22.1	22.1	22.1	22.1	22.1
Gradient (%)	31	31	39.5	39.5	37	38	19	19	17.16	29.5	15
LS factor	4.40	4.40	3.30	3.30	5.84	5.84	2.84	2.84	2.18	4.40	2.18

Table 5. Values of topographic factor (LS) for Lalla Regraga and Aïn Guernouch plots.

Cover management

In forest land logging, fire, grazing, mechanical site preparation, wildlife and other activities disturb and destroy cover, exposing soil to the erosive forces of rainfall and runoff. Despite variation due to the effect of each of these activities, C factor can give an appreciation of these conditions.

Not all sub factors applying to Moroccan forest environments are integrated in the model. Nevertheless, we tried to adapt major ones. They are: (1) amount of bare soil, or conversely, ground cover, (2) canopy, (3) soil reconsolidation, (4) high organic content, (5) fine roots and (6) soil roughness.

Bare soil

Erosion is a function of the percent exposed soil. In forestland, bare soil tends to be in patches randomly distributed over the area. For Lalla Regraga and Aïn Guernouch sites, measures were taken seasonally from 1997 to 2001 a mean value of autumn winter and spring measurements are presented in Tables 6, 7 and 8. Notice that plot 4012 has the highest bare soil percentage during autumn because the main cover in this plot is herbaceous vegetation that declines during summer, where as during spring it's plot 4016 that shows the highest numbers.

Plot n°	4011	4012	4013	4014	4015	4016	4021	4022	4023	4024	4025
Rock	5.9	7.1	4	0	6.7	2	0.2	0	0	0	0.2
Gravel	7.6	6.7	15	4.2	16.1	9.2	25.2	27.1	5.7	36	16.8
Litter	39.2	33.1	7.16	74.5	52.3	73.2	56.5	61	95.7	36.1	54.1
Base	0	4.2	0	0.3	1.8	0	0.3	0	0	0	0.2
Bare soil	30.4	26.2	19.3	15.2	23	12.4	16.3	12.4	10.7	26.1	21.3
Tree	0	0	0	0	58.7	70.4	0	0	70.4	0	0
Shrub	0	4.5	40.4	46.5	0	0	0	0	2.5	5.4	30.1
Herbaceous	0	0	0	0	0	0	0	0	0.7	15.3	0

Table 6. Percent land cover at Lalla Regraga and Aïn Guernouch plots during autumn.

Plot n°	4011	4012	4013	4014	4015	4016	4021	4022	4023	4024	4025
Rock	5.2	5.2	0	0	2.7	0	0.2	0.3	0.1	0	0.2
Gravel	4.7	4	0.7	3.5	3.2	9.1	37.6	43.7	13.9	21	26.2
Litter	33.1	32	64.7	74.5	83.7	51.1	41.5	38.5	62.7	48.6	58.2
Base	8.9	9	1.1	0.7	0	0.4	0	0	4.8	0.3	4
Bare soil	25.3	35	17.8	13.2	6.4	21.7	14.1	12.1	15.7	17.1	6.7
Tree	0	0	0	0	40.7	54.6	0	0	66.5	0	0
Shrub	1.7	2	8.7	3.9	0	0	0	0	1.9	22.2	26.9
Herbaceous	2.4	3	4.4	4.2	1.7	16	0	0	8.3	0.7	4

Table 7. Percent land cover at Lalla Regraga and Aïn Guernouch plots during winter.

Plot n°	4011	4012	4013	4014	4015	4016	4021	4022	4023	4024	4025
Rock	3.2	4.3	0.35	0.15	1.75	0.35	0	0	0	2.35	0
Gravel	10.2	15.7	1.8	0.65	16.4	6.15	7.3	6.95	2.05	7.8	6.35
Litter	3.05	1.6	10	6.15	21.7	27.4	66	67.6	83.1	63.9	70.1
Base	4.7	3.45	0.85	0.95	1.1	0.95	3.35	1.25	0.65	0	2
Bare soil	12.2	14.2	5.25	4.85	10.3	22.7	11.4	3.95	5.15	15.5	2.6
Tree	0	0	0	0	70.8	64.5	0	0	77.3	0	0
Shrub	30.7	15.2	42.2	55.4	0	0.25	0	0	15.5	15.8	18.5
Herbaceous	46.9	52.5	60	46.4	72.6	54.1	61.2	56.9	36	4.3	31.8

Table 8. Percent land cover at Lalla Regraga and Aïn Guernouch plots during spring.

Canopy

Vegetation canopy intercepts the rain and retains water on its foliage, drops of water form thereafter and fall to the ground. Drops falling from the canopy may be larger than the original raindrops. One part of the intercepted rain never arrives to the ground because it is evaporated during and after rainstorm, another part reaches the ground in the form of stemflow and can contribute to total runoff.

Values of percent land occupied by different type covers for Lalla Regraga and Aïn Guernouch sites are indicated in the Tables 6, 7 et 8.

The effect of canopy cover is calculated by the formula:

$$CC = 1\text{-}F_c{*}\exp(-0.1{*}H)$$

where:

CC is the canopy cover sub factor ranging from 0 to 1,
F_c is the fraction of land covered by canopy; and
H is distance that raindrops fall after striking the canopy.

The fall height is expressed in (m) it depends of the canopy shape. Within natural forests three vegetation types are distinguished: trees (A); shrubs (a); and herbs (b). For each category, the fraction of land cover Fc(A), Fc(a) and Fc(b) and fall height x(A), y(a) and z(b) are calculated. Fall height for each plot is calculated by (Glen A. Weesies, personal contact):

$$H(m) = F_c(A)x + F_c(a)y + F_c(b)z$$

With:

$$F_c(A) = \%(A) / [(A)\% + (a)\% + (b)\%]$$
$$F_c(a) = \%(a) / [(A)\% + (a)\% + (b)\%]$$
$$F_c(b) = \%(b) / [(A)\% + (a)\% + (b)\%]$$

Percent surface covered by trees (A) shrub (a) and herbs (b) is shown in Table 9.

Plot n°	4011	4012	4013	4014	4015	4016	4021	4022	4023	4024	4025
A	0	0	0	0	0.49	0.54	0	0	0.60	0	0
A	0.40	0.22	0.41	0.54	0.00	0.00	0.00	0.00	0.12	0.79	0.37
B	0.60	0.78	0.59	0.46	0.51	0.46	1.00	1.00	0.28	0.21	0.63
Ax	0	0	0	0	1.23	3.06	0	0	3.5		
Ay	0.13	0.07	0.14	0.18	0.00	0.00	0.00	0.00	0.04	0.26	0.12
Bz	0.02	0.03	0.02	0.02	0.02	0.02	0.03	0.03	0.01	0.01	0.02
H(m)	0.15	0.10	0.16	0.20	1.24	3.08	0.03	0.03	3.55	0.27	0.14

Table 9. Percent surface covered by trees (A) shrub (a) and herbs (b).

Reconsolidation

Soil reconsolidates and becomes less erodible over time after land is retired from tillage. At Lalla Regraga and Aïn Guernouch sites only plots 4021 and 4022 have been plowed a few years ago (before 1994) all the others are natural forestlands. According to Dissmeyer and Foster (1984), the value of this factor for plots 4021 and 4022 is 0.6, for the other plots it is 0.45.

Organic matter content

Under permanent forest, topsoil accumulates a large quantity of organic matter content not accounted for in the USLE soil erodibility nomograph which only goes as high as 4 % organic matter. Wishmeier and Smith (1960) recommended multiplying by a coefficient of 0.7 to account for the high organic matter content of permanent forest soils. In our situation, grazing, low vegetation cover and climate (drought and heat) do not allow formation of thick humus, which avoids us all adjustment.

Fine roots

A dense mat of fine roots is usually present in the top 5 cm of forest soils. This sub factor is pondered for percent soil covered by trees shrub and herbaceous vegetation. Fine root masse values are shown in Table 10.

Plot n°	4011	4012	4013	4014	4015	4016	4021	4022	4023	4024	4025
Root Mass (Kg/ha)	10	10	20	20	40	23	108	108	45	20	100

Table 10. Root mass at Lalla Regraga and Aïn Guernouch plots.

Surface roughness

Surface roughness has been shown to directly affect soil erosion. (Cogo et al. 1984), and to indirectly affect it through the impact on residue effectiveness. Increasing the surface roughness decreases the transport capacity and runoff detachment by reducing the flow velocity. Values of surface roughness, are shown in table 11. We can notice that plots 4013 and 4014 have the highest standard deviation because tufts of dwarf palm tree constitute bumps over the soil.

Year\Plot n°	4011	4012	4013	4014	4015	4016	4021	4022	4023	4024	4025
1997	2,75	1,98	3,4	5,15	2,63	3,22	1,21	1,53	1,79	5	1,75
1998	2,06	1,09	2,33	3,66	1,94	2,12	1,92	1,57	1,27	1,66	1,53
1999	1,85	1,22	3,1	2,81	1,96	4,87	2,24	1,46	2,09	1,06	1,71
2000	1,23	1,16	2,61	2,58	1,87	2,55	1,01	1,41	2,92	1,48	1,96
2001	2,75	2,01	3,2	5	2,84	3,1	1,21	1,63	1,74	4,8	1,67

Table 11. Standard deviation of soil roughness (cm) at Lalla Regraga anad Aïn GUernouch plot.

Cover management factor values as generated by RUSLE model are presented in Tabla 12.

Year\Plot n°	4011	4012	4013	4014	4015	4016	4021	4022	4023	4024	4025
1997	0.04	0.03	0.01	0.01	0.01	0.01	0.03	0.03	0.01	0.01	0.01
1998	0.02	0.05	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.01
1999	0.04	0.06	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.03	0,02
2000	0.06	0.06	0.01	0.01	0.01	0.01	0.03	0.02	0.04	0.03	0,01
2001	0,02	0,05	0,01	0,01	0,01	0,01	0,01	0,01	0.01	0,02	0,01

Table 12. Cover management factor values in erosion plots of Lalla Regraga and Aïn Guernouch.

Support practice factor (P)

By definition, the support practice factor (P) in RUSLE is the ratio of soil loss with a specific support practice to the corresponding loss with upslope and downslope tillage. These practices principally affect erosion by modifying the flow pattern, grade, or direction of surface runoff and by reducing the amount and rate of runoff (Renard and Foster 1983).

At natural forestlands where soil is not disturbed by any support practice, the value of this factor is 1.

EFFECTIVE QUANTIFICATION OF SOIL LOSS

After each storm, soil loss has been measured for each plot. Their graphic representation (Fig. 5) shows that the general tendency of erosion is the same but the rate varies from a plot to an other. A decreasing classification of soil loss from all the plots show that plot 4024 gives the highest erosion rate followed respectively by plots 4022, 4021, 4013, 4014, 4023, 4012, 4011, 4025, 4015 and 4016. A detailed statistical analysis will be presented on an other paper.

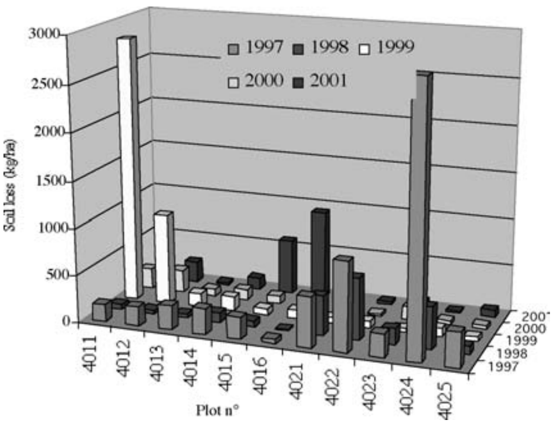

Figure 5. Annual soil loss at each plot

MODEL VALIDATION AND CONCLUSION

Validation procedure will be tested by using data collected by Forest and Watershed Management Services of Tetouan, Al Hoceima, Fes, Marrakech, Agadir and the National Center of Forest Research for the region of Rabat.

For each land use soil loss is estimated by using RUSLE software, and then correlated to soil loss measured directly on established plots. Values measured on the plots are reported on a graph with values estimated by RUSLE model (Fig. 6).

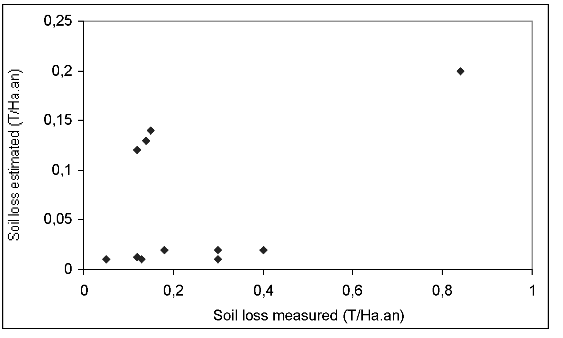

Figure 6. The correlation graphic of soil loss estimated and soil loss measured.

Erosion rates estimated using RUSLE are correlated to on field measurements of soil loss. The graphic representation of these values shows the lack of a significant correlation for small soil losses. Correlation becomes greater as soil loss gets bigger. The small values of securities measured on the land and appraised values by the RUSLE model are reported on the picture 6 and on a table 13, although dispersed, one can say that the securities present a positive tendency, and therefore a good correlative tendency of the measured erosion and the real erosion estimated by the model. One also notes according to the picture 5 that the model under esteem the rate of real erosion, this amplitude can be explained by the fact that during the follow-up, some imperfections would be susceptible to take place, the measures are numerous and the probability of the mistakes is not separated, one cannot pretend by consequence to a very big reliability and the outcome to very highly meaningful tests. Among these imperfections, one can citer: Of the mistakes in the measures and the withdrawals, essentially the measures that concern the states of surface as the expense ratio of the different constituent of surface, the roughness, the mass racinaire, and other parameters that enter directly in the development of the C factor, that is a very essential element in the determination of the erosion rate.

Direct use of some securities without can find those that reflect our local conditions.

The systematic drought that Morocco knew during the last years that coincides with the period of our survey was unfavorable worthy of the climatic aggressiveness and the parameters of growth of the plants in a regular manner.

Not to have followed all variations of the R factor because of a set of breakdown occurred in the pluviographes, we recommended the use of some averages of the unrecorded periods. Let's note that this factor knew a very big inter-seasonal worker variability and intra seasonal.

Data collected on the land concern the dripping, the precipitations, the specific deterioration are subject to several types of mistakes.

Data collected on the land concern our two sites and only take account of 5 successive years, to have a better evaluation of the casualty in earth yearly averages; it is preferable to have a set of regular data on at least a period of 10 years.

The evaluations are better for elevated rates of erosion whereas for the majority of the raised rates of erosion in our sites is weak to average.

The number of parcels interested by the survey is weak, this number must be multiplied to be able to have a larger databank and offering the possibility comfortably to have missing securities in a parcel, by really observed averages in another parcel.

Theoretically the RUSLE model is a multiplicative combination of 5 variables (factors) measured being able to each to generate a range of error.

The RUSLE model being he same derivative of empiric laws descended of hundreds of measures in experimental parcels, capable to generate some mistakes.

All these problems return the validation of the RUSLE model or all other model of the difficult erosion in one relatively short time.

To the light of these original results returned in this survey, that doesn't prove to be statistically very meaningful but earlier encouraging, he/it would be more discriminating to affirm than the absolute values of the losses in earth expressed in T/Ha/An and that constitute the product of exit of the RUSLE program, gotten in this work must be taken with warning and a prudent reading and in a relative sense that absolute, either for their interpretation and/or their generalization.

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