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

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Absract

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 on two sets of 5 and 6 Wishmeier type plots at forest stations of Lalla Regraga and Ain Guernouch about 50 and 100 km respectively from Rabat. The two experimental sites are characterized by a local semi arid with moderate winter climate, 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. Analysis of data collected shows that effective erosion measurements varied from 50 to 840 kg/ha/yr, wheras estimated erosion by RUSLE varied from 10 to 200 kg/ha/yr.

Résumé

Cet article présente le résultat de la compilation de données sur l'érosion hydrique au Plateau Central du Maroc. Il essaie de tester l'efficience de l'équation universelle de perte en terre révisée (RUSLE) à prédire l'érosion en situation forestière méditerranéenne. L'expérience a été menée sur deux ensembles de 5 et 6 parcelles de type Wishmeier aux stations forestières de Lalla Regraga et Aïn Guernouch, situées à 50 et 100 km respectivement de Rabat. Les deux sites expérimentaux sont caractérisés par un climat local semi aride à hiver modéré, une lithologie granitique avec des sols sableux à Ain Guernouch et schisteuse à sols vertiques à Lalla Regraga, une forêt caducifoliée au premier site et conifère au second. L'analyse des données collectées montre que les mesures effectives de l'érosion varient de 50 à 840 kg/ha/an, alors que l'érosion estimée par RUSLE varie de 10 à 200 kg/ha/an.

Introduction

In parallel to watershed study and management strategy, the "Haut Commissariat aux Eaux et Forêts et à la Lutte Contre la Désertification" has anticipated to develop and to strengthen research concerning struggle against water 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.

Materials and methods

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. After studying environmental conditions and demarcation of physiographic units on the landscape, two juxtaposed witness plots and a climatic station are installed to know the rain erosivity in 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 (Figure 1).

Figure 1. Exaple of experimental plots at Aïn Guernouch (left) and Lalla Regraga (right)

Results and discussion

- ✓ **Rainfall-Runoff Erosivity**

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. Application of this formula to data taken at the two sites of study is given in tables 1; 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.

Table 1. Erosivity factor at Lalla Regraga and Ain Guernouch forest stations

Site	Period	Number of showers	Total rainfall (mm)	total R MJmm/hahyr	Mean rainfall per shower (mm)	Mean R per rain shower (MJmm/hahyr)
Lalla Regraga	1997-2001	36.6	289.3	24.74	8	0.71
Aïn Guernouch	1997-2001	41	292	29	7.2	0.4

- ✓ **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 remains the most used method. 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 2 s 5 and 6. The plot 4024 shows the least erodibility because of its low content in coarse silt and very fine sand, the most easily transported fraction of a soil (Yassin M. and L. Cihacek. 1992).

Table 2. Soil erodibility at Lalla Regraga and Aïn Guernouch plots

Plot n°	4011 4012	40134014	4015	4016	4021 4022	4023	4024	4025
K (t×ha×h/ha×MJ×mm)	0.026	0.022	0.01	0.015	0.012	0.012	0.009	0.013

- ✓ **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

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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.

Table 3. Values of topographic factor (LS) for Lalla Regraga plots.

Plot n°	4011	4012	4013	4014	4015	4016	4021	4022	4023	4024	4025
LS factor	4.40	4.40	3.30	3.30	5.84	5.84	2.84	2.84	2.18	4.40	2.18

- ✓ **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 subfactors 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. 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.

Canopy

The effect of canopy cover is calculated by the formula: $CC = 1\text{-}F_c\text{*}\exp(-0.1\text{*}H)$

where:
- CC is the canopy cover subfactor 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 $F_c(A)$, $F_c(a)$ and $F_c(b)$ and fall height x(A), y(a) and z(b) are calculated. Percent surface covered by trees (A) shrub (a) and herbs (b) is shown on table 4.

Table 4. Percent surface covered by trees (A) shrub (a) and herbs (b)

PLOT N°	4011	4012	4013	4014	4015	4016	4021	4022	4023	4024	4025
H(m)	0.15	0.10	0.16	0.20	1.24	3.08	0.03	0.03	3.55	0.27	0.14

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 figure 10 of 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 subfactor is pondered for percent soil covered by trees shrub and herbaceous vegetation (Table 5).

Table 5. Root mass at Lalla Regraga and Ain Guernouch plots

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

Surface roughness

Increasing the surface roughness decreases the transport capacity and runoff detachment by reducing the flow velocity. Plots 4013 and 4014 have the highest standard deviation because tufts of dwarf palm tree constitute bumps over the soil.

Cover management factor values were generated by RUSLE model.

Support practice factor

At natural forest lands where soil is not disturbed by any support practice its value is 1.

- ✓ **Effective quantification of soil loss**

Graphic representation of the annual erosion rate (Figure 2) at the different plots does not show a logical pattern. It does not vary according to precipitation abundance nor does it vary according to runoff occurrence. However, when the values are accumulated on a seasonal basis, the analyses give better correlation factors between these parameters at all plots

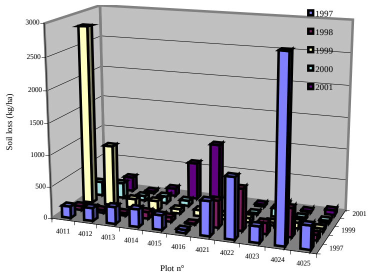

Figure 2. Annual soil loss at each plot

- ✓ **Model validation**

For each land use soil loss is estimated by using RUSLE software and correlated to soil loss measured directly on established plots (Figure3).

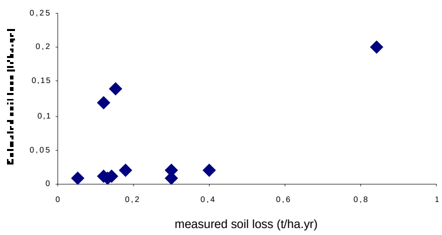

Figure 3. Correlation graphic of soil loss
calculated by RUSLE and measured on the field

Conclusion

Estimations of soil loss are generally best for high rates of erosion. In our case the experiment coincidently met with a dry cycle that generated little runoff and small erosion amounts. To have a good estimate of average annual soil loss, it is preferred to have a series of data over a 10 years period. Reliable data collection during all this period is still ahead before we can validate RUSLE model for forestlands in Morocco.

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