Modeling and mapping erosion under the S.I.G. Case of the urban townships of Tsiroanomandidy city and case of the rural townships of Tsiroanomandidy Fihaonana

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Abstract

Grace to the existence of a binding relationship: the annual climatic erosivity index (R); erodibility index of worked bare soil (K); the topographic index (LS); the vegetation cover factor (C); the anti-erosion factor (P); We can predict soil erosion.
The present study aims to predict soil erosion in the two municipalities of Madagascar (urban townships of Tsiroanomandidy city, rural townships of TsiroanomandidyFihaonana) by applying the Revised Universal Soil Loss Equation of WISCHMEIER and SMITH in 1975 (RUSLE) under the GIS. It involves various factors: climatic factor; soil factor; morphological factor; topographic factor; land occupation factor.
The results obtained are the actual erosion map of the two communes.

Keywords: *USLE, RUSLE, erosion, GIS, Tsiroanomandidy, Madagascar*

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1 Introduction

Currently, erosion is one of the worrying problems in Madagascar. Climate change and human activity amplify this phenomenon in this country. Faced with this worrying problem the Graduate School of Earth Science and Evolution at the Faculty of Sciences of the University of Antananarivo, under the aegis of Professor Raymond RAKOTONDRAZAFY, did not minimize this scourge. He has directed various researches in this direction, in the determination of the various factors of erosion. For all these reasons, we conducted a study in the Urban townships of Tsiroanomandidy City and in the Rural townships of Tsiroanomandidy Fihaonana in order to estimate, measure the degree of erosion in the sector.

The objective of this study is to develop a set of thematic maps presenting the result's analysis of the different factors involved in the phenomenon of erosion in order to model and map this phenomenon in the studied sector.

2. Presentation of the sector

The sector is in the Middle West of Madagascar. It is part of the central highlands and is located in the Bongolova region. When in the district, it is part of Tsiroanomandidy district (Fig 1).
Following the RN1 bis National Road, the studied sector is located 210 km from the capital Antananarivo.
Geographically, the area between the following coordinates is:
Xmin = 314, 42 km; Ymin = 800, 22 km
X max = 384, 29 km; Ymax = 850, 59 km
The sector covers an area of 1233.37 km². It is constituted up of two townships: the townships of Tsiroanomandidy City and the townships of TsiroanomandidyFihaonana.

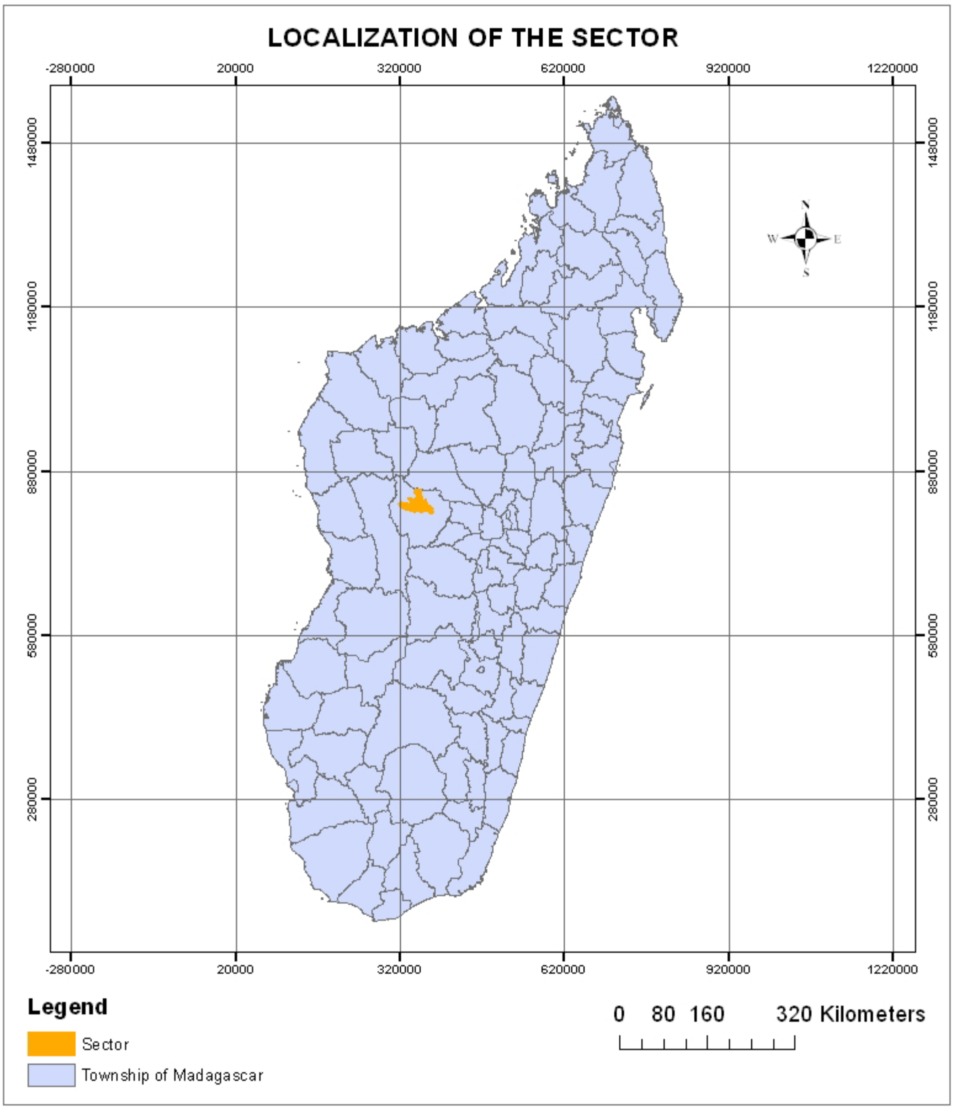

Fig.1: localization map

Identification of land use in the sector is important to determine the agronomic factor (C) and the anti-erosion factor (P). These two factors will be integrated into the RUSLE model for the spatialization of real erosion.
For soil typology, it is necessary for the production of the spatial model for erosion prediction. It enters into the determination of the parameter's erodibility (K). The typological identification of soils in the sector is based on the morphological and physico-chemical characteristics studied. The classification used is that presented in 1967 under the aegis of INRA by the Commission of Pedology and Mapping of Floors **[4],** and the classification of FOFIFA.

Finally, the slope map is used to determine the topographic index LS of the studied area. The topography influences primarily runoff and secondly erosion and ultimately sediment deposition. Figure 2 shows the slopes of the reliefs in the study area.

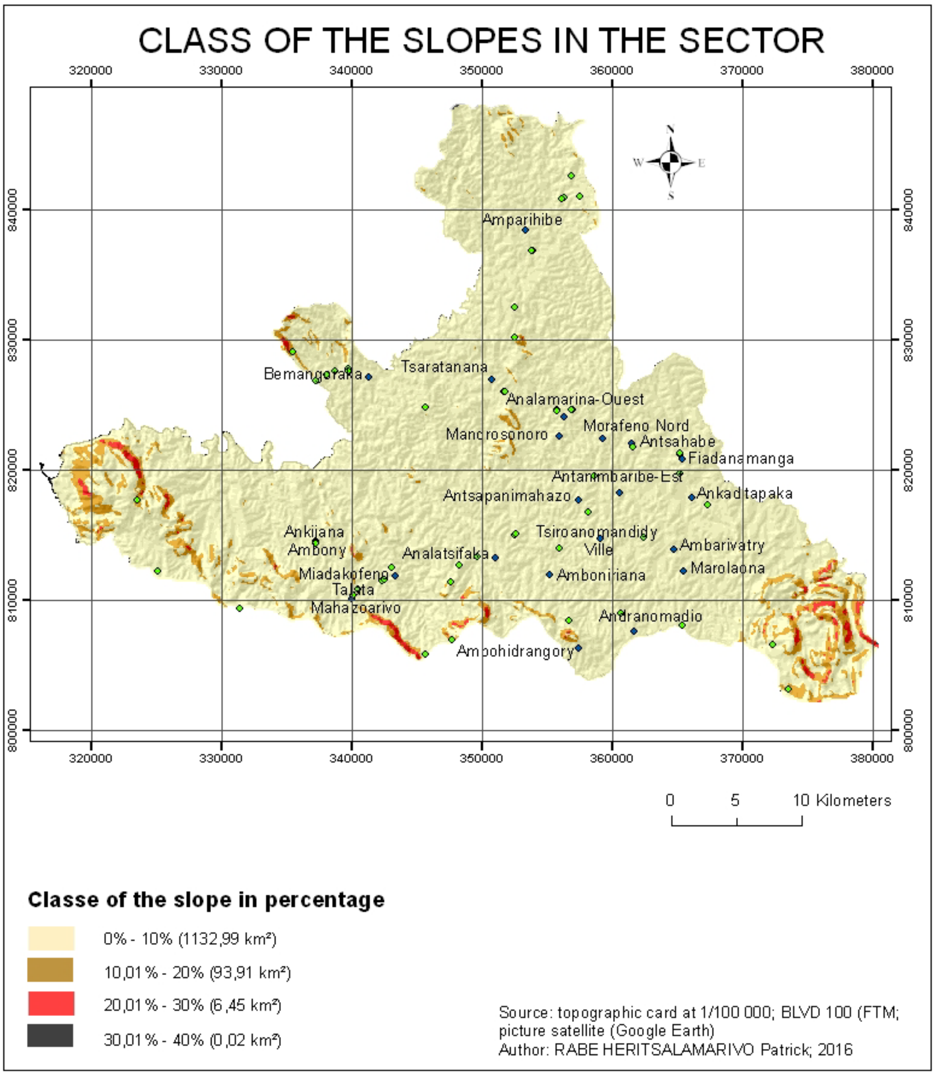

Fig.2: slopes map in the sector

3. Modeling of earth loss

The loss of soil or erosion in our area was determined by the USLE model Revised Universal Soil Loss Equation: (E = R x C x LS x K x P) developed by WISCHMEIER ET SMITH **[15].** We adapted to our site this Equation Universal. This equation, which is well adapted to GIS, has been used by several researchers to evaluate erosion or soil loss currently.

The Universal Equation WISCHMEIER model **[17]**: the Revised Universal Soil Loss Equation (RUSLE)

1) **E = K * R * L * S * C * P** (Equation 1)

E (t / ha / yr): measured or predictable erosion or soil loss in t / ha / year,

R (MJ x mm x ha-1 x h-1) is called rainfall factor or rainfall factor. It has been defined as the product of rain energy by its maximum intensity in 30 minutes. It can also be considered as the average annual index of erosion by rain.

Calculation of the erosivity of rains R

Rain is one of the main factors of soil erosion, this occurs when rainwater can no longer infiltrate the soil and pull particles out of the soil with particles **[16].** Thus, the role of the R factor is to characterize the erosive force of precipitation on the ground. The erosivity of rain is defined by the equation:

2) R = E * I30 (Equation 2)

Where E = the kinetic energy of the rains (MJ / ha)

I_{30} = the maximum rainfall intensity in 30 minutes expressed in mm / hour.

The kinetic energy of the rains is given by the following formula:

3) E = 210 + 89 log10 * I (Equation 3)

Where I = the intensity of rain.

These formulas (Equation n ° 2 and equation n ° 3) proposed by WISCHMEIER ET SMITH **[16]** as an indicator of erosivity remains difficult to apply for the study area since many of the data are missing, in addition, there is only one rain station in this area. There is very little information about the rainfall pattern in the sector. For this reason, I chose the erosion index of RENARD and FREIMUND **[10]** to determine the R factor.

4) $R = 0.0483P^{(1.610)}$;

Where P = Average annual rainfall in mm **[8]**. P is calculated from monthly average precipitation data from the Antananarivo meteorological service. It is integrated in the equation to produce a raster map of the factor R.

K (t x h x MJ-1 x mm-1) is called the soil factor and characterizes the soil erodibility factor. It can be defined as the susceptibility of the soil to erosion. It is evaluated taking into account: the texture; organic matter content; the structure; soil permeability regardless of vegetation cover and cultural practices. To calculate it, we used the charts provided for this purpose.

Physical soil analyzes were done in the laboratory to determine this erodibility factor. Once the physical analysis is done, the K factor is determined using WISCHMEIER's normographer **[18]** (Fig 3).

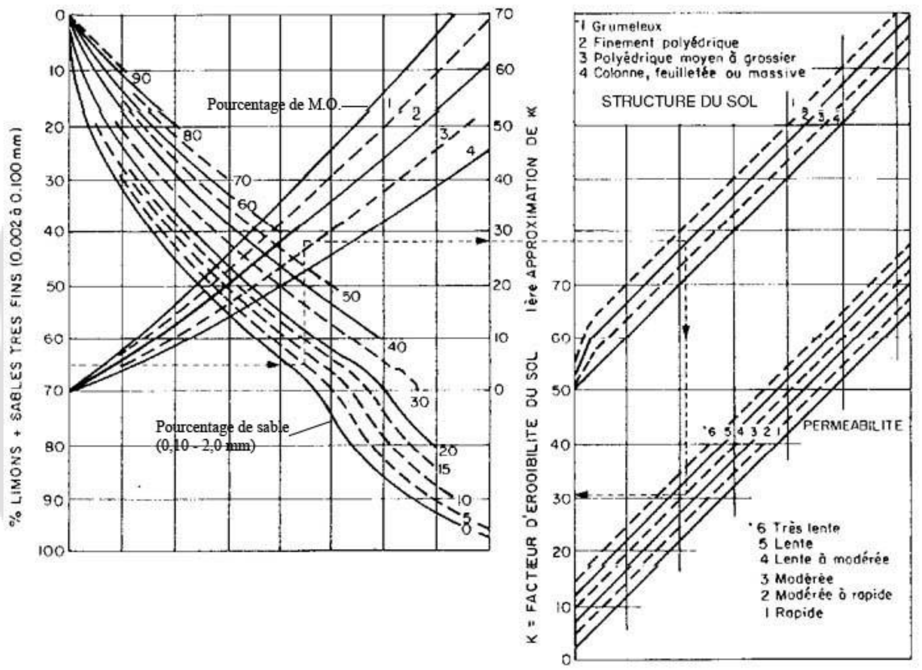

Fig.3: WISCHMEIER's normographer

S * L (dimensionless): the slope and slope factor takes into account both the length of the slope (L) and its slope (S). In practice, the two slope factors, L and S, are combined into a single topographic factor that makes it possible to globally evaluate the influence of the slope on the rate of erosion. Formulas, tables, and charts (Fig 4) make it possible to quantify the values of the topographic factor. In our study, for the determination of the LS factor, we used the WISCHMEIER chart in Figure 4.

C (dimensionless): The vegetation cover factor is defined in the USLE as the ratio of the soil loss of a plot grown under defined conditions to the corresponding soil loss of a continuous bare fallow plot. The value of the factor C is conditioned by several variables and their interaction requires information on: the green vault; vegetation cover; soil biomass; tillage. Each variable is treated as a sub factor and C. The difficulty of computing C led WISCHMEIER and ROOSE to calculate the C values from their experiences in North Africa and West Africa. These experiments on several plant coverings served as a reference for field applications.

And in Madagascar, the researchers used the values of vegetation cover determined from data obtained from work carried out by the Ministry of Agriculture, Livestock and Fisheries in 2004 **[2].** Table 1 provides the C factor values for the main crops and rotations practiced in Madagascar **[8].**

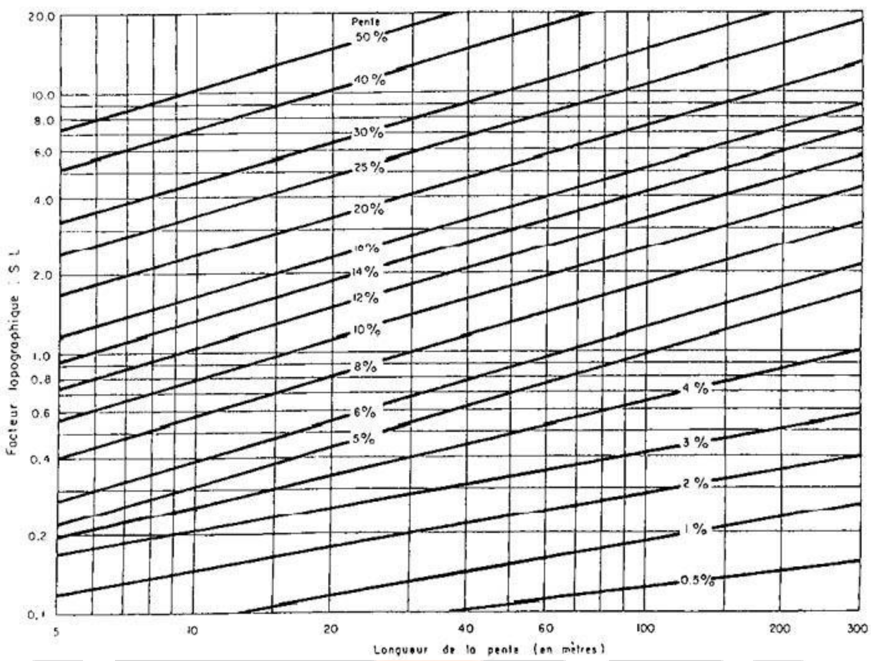

Fig.4: WISCHMEIER chart

Table 1: vegetation cover factor (Source: Payet et al. 2011)

Type of soil	C
Water plan	0
Dense forests	0,001
Rice field	0.15
Afforested zone	0,18
Surface built	0,2
Mangrove swamp	0,28
Savanna raised and shrubby	0.3
Mosaic of culture	0.5
Grassy savanna degraded	0.6
Forest degaded	0,7
Naked soil	1

P (dimensionless): the Support Practices Factor (or erosion control practices) is a measure of the effects of practices intended to change the profile, slope or direction of surface runoff flow and thereby reduce 'erosion. It includes cross-slope cultivation, contour cultivation, alternating strip cultivation, terracing and the development of grassed waterways. It varies between 1 on bare ground without any erosion control at 1 / 10th when on a weak slope, where ridging is practiced.
Table 2 shows the P-factor values as a function of conservation practice according to STONE and HILBORN in 2000 **[13].**
In the absence of anti-erosion measures, a single value of 1 is considered for this factor. Few erosion control techniques are practiced in Madagascar with the exception of paddy fields where the P factor has been adjusted to 0.1 and the agroforestry zones to 0.3 **[2].**

Table 2: Support Practices Factor (Source: Stone and Hilborn 2000)

Convenient of conservation	P factor
Culture in the sense of the slope	1
Culture to counter slope	0,75
Culture according to the curves of level	0,5
Culture in strips, to counter slope	0,37
Culture in strips, following the curves of level	0,25

4. Development of the RUSLE parameter maps and land loss calculation

4.1 Development of the RUSLE parameter maps

For the maps of the factors R, K, C, LS, and, P, it suffices to enter the values obtained in the attributes of the tables. Once entered in these attributes, the map of each factor is drawn up. Then we convert the maps to raster formats, because the Map Algebra calculator knows only rasters formats **[9].** It is in the latter that we made the land loss calculation.

4.2 Calculating and mapping land losses with the Raster Calculator module

Raster calculator is a calculator in "Map Algebra". It is used to spatialize the loss of land by a combination of different factors **[9].** After combination, the earth loss values are obtained. When on the map, it comes from the raster calculations of the various parameters (R, K, C, LS, and, P) in the Map Algebra spreadsheet.

5. Validation of the model

For the model to be reliable, it should be validated. The validation procedure of our model is based on the comparison of the RUSLE model with that of the Fournier model. The latter model is based on an empirical formula using only rainfall data **[9]** if one refers to the following formula:

5) **If $Ce = p^2 / P$** is the Fournier index whose **small p** is the highest monthly rainfall height and **large P** is the average annual rainfall height, the soil loss:

6) **DS in t / km² / year = 52.49Ce - 513.21 [9]**.

DS: Disappearance of Soil

6. Organization chart of the methodology

An organization chart has been designed in Figure 5 to synthesize the methodology of erosion modeling in the study area

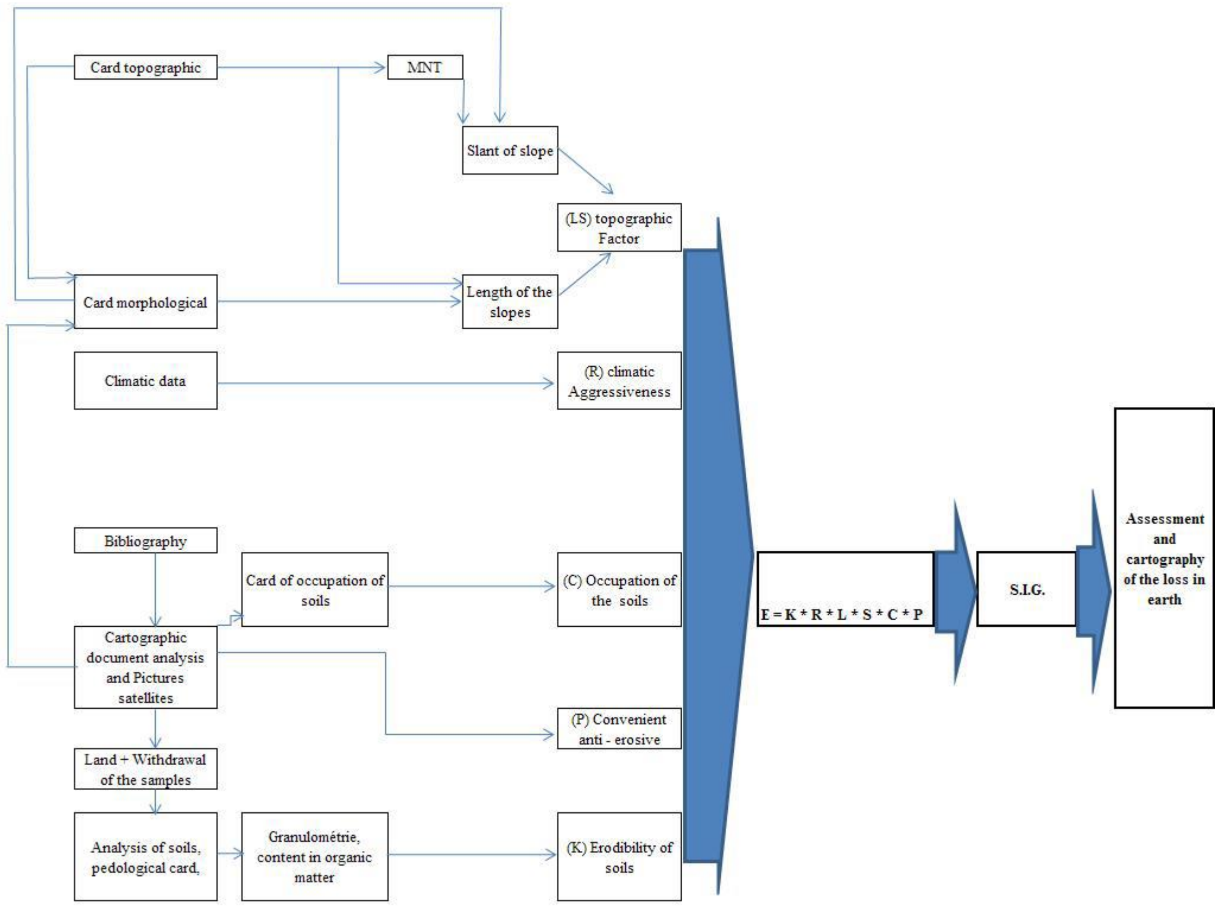

Fig.5: organization chart (source: author)

7. Results and interpretation

7.1 Erosivity parameter (R)

Given the data we have, the value we attributed to the R-factor is unique in the sector under study. By the application of the formula of RENARD and FREIMUND **[10]** the index of erosivity R of the sector is 50 MJ.mm/ha.h.yr for the average of the year 2011 to 2013, it is 129 MJ.mm/ha.h.yr for the average of the 60s and it is 109 MJ.mm/ha.h.year for the average of the 70s.

ZANTE et al in 2003 **[19]** categorizes the erodibility index R in three categories according to the year (dry year, median year and wet year):

• Dry year: 25 MJ.mm/ha.h.year;

• R median year: 64 MJ.mm/ha.h.year;

• R wet year: 93 MJ.mm/ha.h.year.

The value of R for the average of the year 2011 to 2013 in the sector is considered as R median year.

7.2 Erodibility parameter (K)

The spatialization of the K parameter is feasible through soil typology analysis and identification. Figure 6 shows the spatial redistribution of the K factor.

ROOSE and SARRAILH in 1990 **[12]** classified soils according to values of erodibility factor K into five classes. This classification was taken over by:

- K <0.10: soils highly resistant to erosion;
- 0.10 <K <0.25: soils resistant enough to erosion;
- 0.25 <K <0.35: soils moderately susceptible to erosion;
- 0.35 <K <0.45: soils susceptible to erosion;
- K> 0.45: soils very sensitive to erosion.

The soils of the sector are considered as less erosion-sensitive soils with respect to the average of their erodibility index K with an average value of 0.16 t.ha.h / ha.MJ. mm.

The results obtained for the K factor at the sector scale ranged from 0.1 t.h./MJ.mm for the most resistant soils to 0.21 t.h./MJ.mm for the most erodible soils (Fig.6).

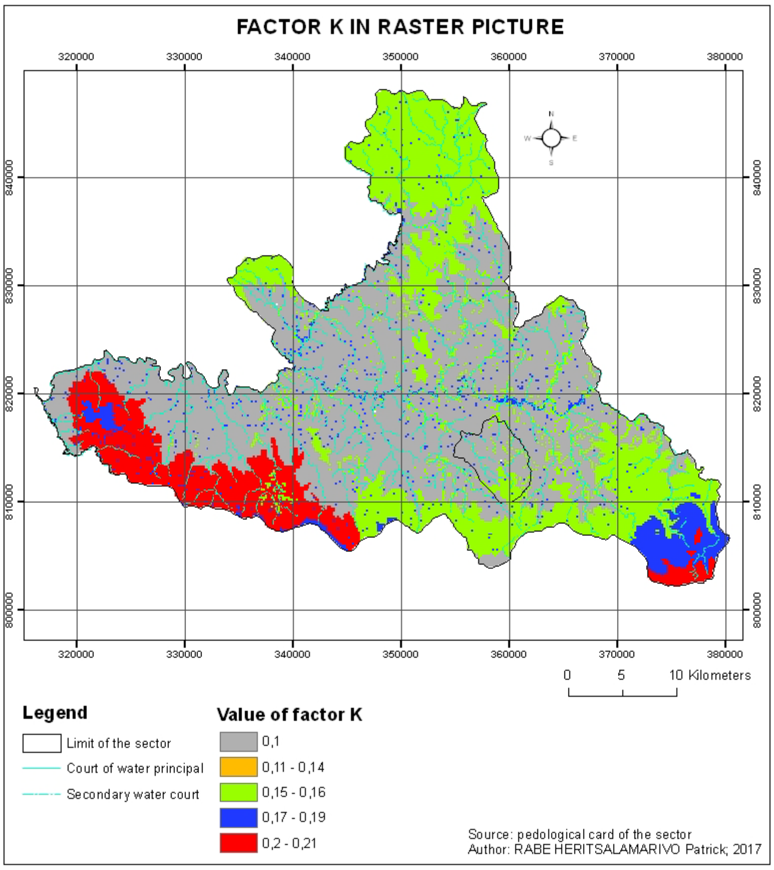

Fig.6: factor K card in the sector (source: author)

7.3 The topographic factor (LS)

The spatialization of the topographic factor LS is done grace to: the topographic map; to the morphological map and the map of the slopes. Figure 7 shows the spatial redistribution of the LS factor.

The combination of length and slope angle in the abacus made it possible to establish the thematic map of LS. The values obtained for the LS factor have been grouped into five classes of values: they are between the range of 0.5 and 11 (Fig. 7). These values depend on the accumulation of the flow. The main drainage axes have important values, while the whole has low values **[8].**

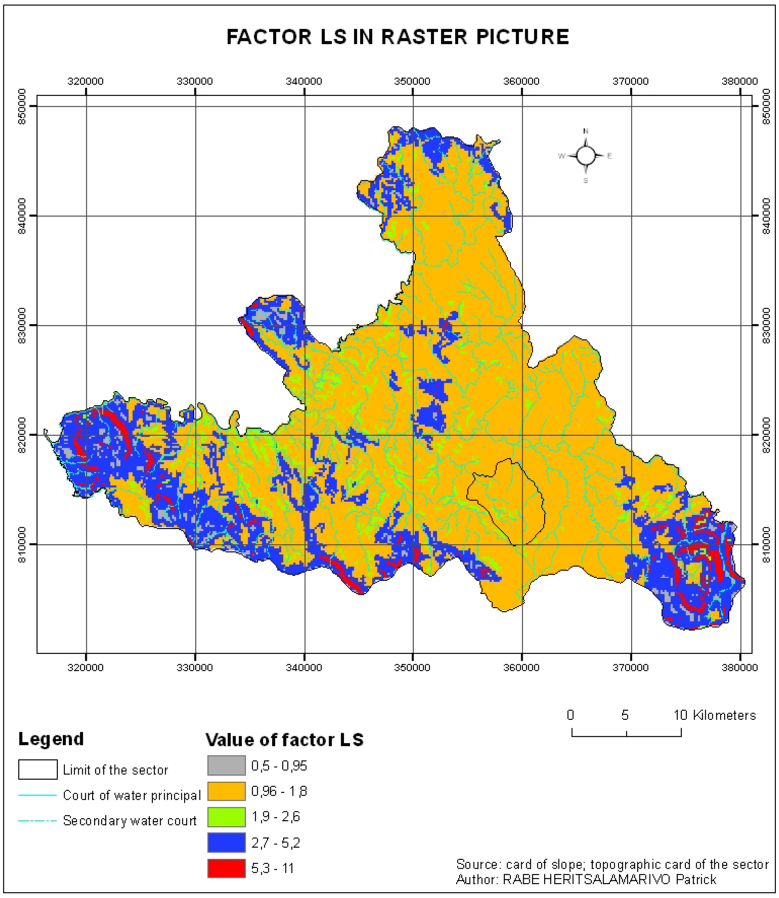

Fig.7: factor LS card in the sector (source: author)

7.4 The agronomic factor (C)

A map of the vegetation cover index was developed at the sector level using the land cover map. Figure 8 expose the spatialization of factor C.

According to Figure 8, four types of major occupations occupy almost the entire sector: the lowest value (C<0.3) remains in the residential area, in the wooded area and in the wooded savannah and shrub; the mean value (0.31<C <0.7) remains in degraded grass savannah and areas covered by degraded forests; the highest coefficients (C= 1) correspond to bare floors.

With regard to erosion processes, the spatial distribution map shows that the area’s most vulnerable to erosion are attributed to the type of bare land occupation (Fig 8).

7.5 The anti-erosion factor (P)

It is the ratio of soil loss with specific support on agricultural land to the corresponding loss with parallel slope plowing **[17].**

The factor P takes into account the anti-erosive effectiveness of support practices.

The spatialization of the factor P is feasible thanks to the exploitation the map of occupation’s grounds. Figure 9 shows the spatialization of the factor P.

Anti-erosion practices in the study sector are rare. Only the rice fields have a value of P equal to 0, 1 and the remains have a value of P equal to 1 (Fig. 9).

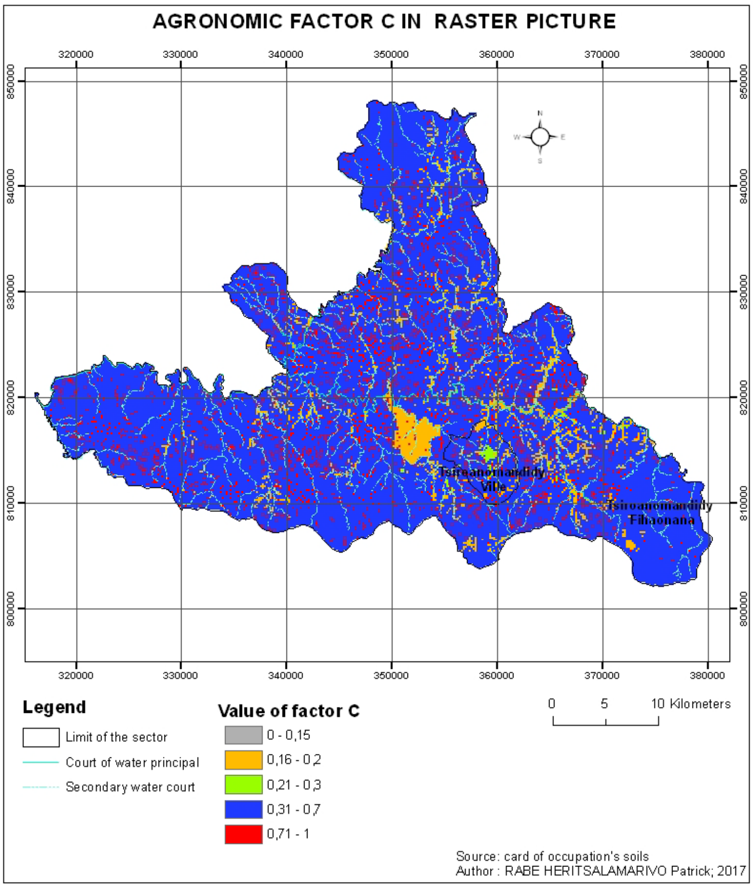

Fig.8: agronomic factor C card in the sector (source: author)

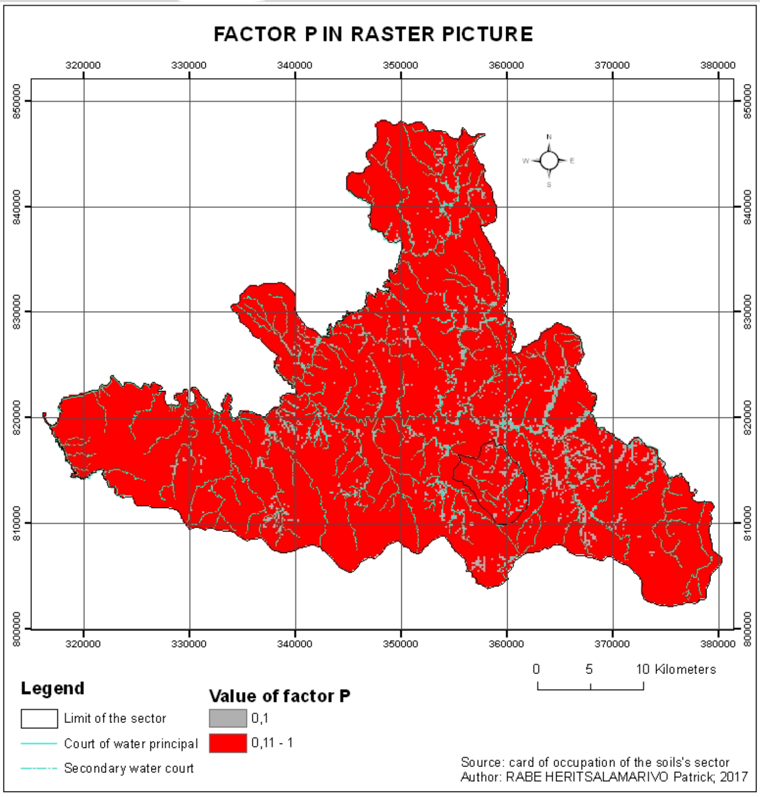

Fig.9: factor P map in the sector (source: author)

7.6 Results of land loss

The mapping of the main factors (K, LS, R, C, and P) involved in soil water erosion resulted in the actual or current erosion map **(Fig 10)** of the study area. . The data obtained (maps) was integrated into the calculator option of the Arc.GIS software **[3]** at the space analyst menu to measure, evaluate and produce the soil erosion risk maps of the sector .

Generally, if the value is large, it means that the erosion rate is high, if the value is small; it indicates a low erosion rate. WISCHMEIER in 1978 indicated the threshold of tolerance of the earth losses between the interval 1 T / Ha / Year and 15 T / Ha / Year at most.

Figure 10 expose the actual erosion in the study area.

The values of the real erosion (t/ha/an) obtained at the sector level were grouped into 5 value classes as follows (Fig 10):

- A first class grouping areas with actual erosion less than 5t / ha / year (Fig 10); it constitutes 58.4% of the surface area's studied sector and covers mainly the sectors which are on the plain of the quaternary glacis;
- A second class that groups areas with current erosion of between 5 and 10 t / ha / year. it constitutes 24.6% of the area's sector; it focuses mainly on the slopes of low hills and low rumps in the sector;
- A third class that groups together areas with actual erosion between 11 to 19 t / ha / year. it represents 13.5% of the area of the sector; it is particularly found on the slopes of the middle and middle hills;
- A fourth class grouping areas with current erosion of between 20 t / ha / year and 33 t / ha / year; it represents 2.8% of the area's sector; they are on the mountainous areas;
- The last class includes areas with actual erosion between 34 and 86 t / ha / year (Fig 10); it represents 0.7% of the area's sector and focuses on mountain areas.

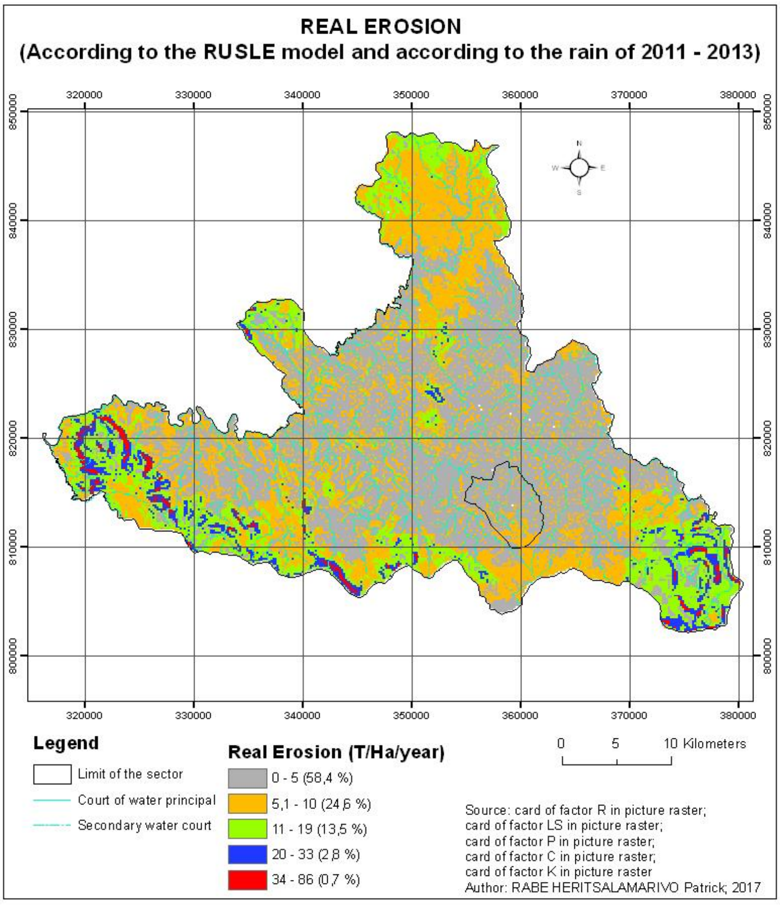

Fig.10: real erosion card in the sector (source: author)

The map resulting from actual or actual erosion (Fig. 10) shows that eroded surfaces have a heterogeneous spatial distribution in the area.

7.7 RUSLE model validation

Table 3 shows the comparison of soil loss values between the RUSLE model and the Fournier model

Table 3: Comparative Table of the RUSLE Model and the Fournier Model

Year	Precipitation (mm)	Model RUSLE (T / Ha / Yr)	Model Fournier (T / Ha / Yr)
1960 -1969	1608,8	79,16	45,29
1970 -1979	1452,0	66,00	46,43
2011- 2013	893,7	30,60	34,35

Both models have very different soil loss values for the years 1960-1969 and for 1970-1979 compared to 2011-2013 (Table 3). This disparity may be due to the use of current soil analysis results for the earlier erosion study (60-70 years). Note that at these times, there are no reliable soil analysis results available for this study. It is the rainfall data in these periods only that are available to study the earth losses.

Unlike the ones we saw in the 1960s and 1970's in terms of erosion, the soil loss results for 2011 - 2013 are quite similar (Table 3). The difference between these two models at this period is 3.75 T / Ha / year, with 30.60 T / Ha / year according to the RUSLE model, against 34.35 T / Ha / year for the FOURNIER model **[6]** (table 3) For this period, it can be said that the Fournier model can be used as validation in this erosion study. Indeed, both models can be working documents for decision-making in soil conservation and water conservation.

8. Discussion and recommendation

8.1 Determination of erosivity parameter R

Numerous equations are used to calculate R (Table 4) according to annual precipitation or the Fournier index **[10], [11] …**etc.

Table 4: Formulas used for R-factor estimation in Mediterranean countries

Method	Author	Variables
7) $\boldsymbol{R = 0.5Pax1.735}$	Roose (1975) for South Africa	
8) $\boldsymbol{R = P \times 0.5}$	Roose in Morgan and Davidson (1991) for West Africa	P: Annual precipitation (mm)
$(\mathbf{9})\ \boldsymbol{R = 0.0483P^{1.610}}$ **si P< 850 mm** $(\mathbf{10})\ \boldsymbol{R = 587.8 - 1.219P + 0.004105P^2}$ **si P> 850 mm**	Renard and Freimund (1994)	Annual precipitation (mm)

ROOSE has established the map of erosivity of rainfall over West Africa, which makes it possible to estimate R. on an African scale. This overall formula corresponds to an average of three other formulas previously developed in different regions of the world. But currently, thanks to the GIS or Geographic Information System, it is possible to determine the erosion of a given medium while varying the erosivity index R according to the authors listed in Table 4.

In this study we took the erosion index of RENARD and FREIMUND **[10],** because the soil loss is too excessive with the erosion index of ROOSE for South Africa (1975) and for the West Africa (1991). It is the index of RENARD and FREIMUND that gives us reliable results in the study area.

8.2 Determination of the erodibility parameter K

Several equations are now available for estimating the K factor. For example, this regression equation that has been established to estimate the value of K for Quebec soils **[14]:**

11) K = 2.8-7M 1.14 (12-M.O.) + 0.0043 (b-2) + 0.0033 (c-3)

Or

M = granulometric factor = (% silt +% very fine sand) (100 -% clay)
M.O = organic matter (%)
b = code of soil structure (very fine granular: 1, fine granular: 2, medium and coarse granular: 3, blok or massive: 4)
c = permeability class code (fast: 1, moderate to fast: 2, moderate: 3, slow to moderate: 4, slow: 5, very slow: 6).
This equation is valid for estimating the K factor of Quebec soils but not for the soils of the United States. Its difference may be due to the soil typology of both countries.
For WISCHMEIER, the K factor is determined using both methods:

i. 1st method: the WISCHMEIER and SMITH equation **[17]** used when the following data are available: the percentage of sand, very fine sand and clay; the percentage of organic matter; the structure of the soil; the permeability of the soil.

12) 100K = 2.1M 1.14 (10-4) (12-a) + 3.25 (b-2) + 2.5 (c-3)

Or:
M = (percentage of silt + very fine sand x (100 - percentage of clay)
a = percentage of organic matter
b = soil structure code used in soil classification
c = class of permeability of the profiles

ii. 2nd method: the normogram of WISCHMEIER and SMITH obtained from this formula above [18].

In our study, the WALL equation in 1997 **[14]** was not taken into account because it is not reliable in other countries, so we chose the best known Wischmeier and Smith normogram to determine the factor. K (Fig 3).

8.3 Determination of topographic factor LS

Several methods currently allow us to determine the topographic factor LS. There is the method that uses the mathematical formula; there is the method that uses the abacus.
Take the example of the WISCHMEIER mathematical formula, which has been calculated from the slope map and its length obtained from GIS treatments of the MNT:

13) LS = 1.6 * Pow ([flowacc] * resolution / 22.1,0.6) * Pow (Sin ([slope] * 0.01745) /0.09,1.3))

For the abacus, Wischmeier developed an abacus obtained for estimating the LS factor.
In this study, we chose the WISCHMEIER chart (Fig 4) for the determination of the topographic factor because it is the most used in the world of erosion modeling.

8.4 Determination of agronomic factor C

This factor is equal to the unit for plowed soil kept in fallow. To allow a more meaningful evaluation, WISCHMEIER [**15]** proposed dividing the growing season into five well-defined periods:

- **0.** Fallow: from plowing to soil preparation.
- **1.** Sowing: the preparation of the soil and 1 month after sowing.
- **2.** Establishment: the 2nd month after sowing.
- **3.** Growth and maturation: from the 3rd month after sowing until harvest.
- **4.** Thatch: from harvest period to plowing.

The numerous measurement sites in the United States (10,000 years - accumulated stations in 1976) have made it possible to draw up a table of the cultivation factors for different crops (including management and cultivation methods) and corresponding to the different stages of the growing season vegetation in the United States.
Another researcher uses the NDVI derived standard vegetation index from satellite imagery because it transforms vegetation reflectance as a percentage of vegetation cover **[1]** to estimate C-factor. However, one approach alternative was followed as a response to the lack of seasonal vegetation information; it is a question of replacing the C factor with the NDVI vegetation index **[7].**
In order to standardize our research and so that there was no confusion in our results, we took the C factor values of PAYET et al. These values are used by its authors in the modeling of water erosion of the South West Madagascar watershed (Table 1). Factor C varies between 1 for bare soil and less than 0.1 for dense forests **[8].**

8.5 Determination of the anti-erosion factor P

Several researchers [**13], [15]** attributed different values of the factor P according to conservation practice. But in our study, we have chosen the one used by ANTSANIAINA in 2015 **[2]**, which are values that are close to reality in the sector (Table 2).

8.6 Erosion study

The erosion study in the area using the RUSLE empirical model only applies to sheet erosion. It does not take into account other types of erosion: linear erosion; gully erosion or erosion in lavakas ... Now, in the sector studied there is different forms of erosion. The latter constitute a limit for this model.

9. Conclusion

The models that we presented in this survey will be destined to value the loss in land. However the verification of their validity, prove to be necessary to justify the model. This validity can be determined while comparing the results of the RUSLE model with those of the model FOURNIER. After validation, this model can be used to cartography the zones to risk of deterioration's soils in the sector. The cartography of soils in this part constitutes a tool of help's decision for prediction the erosion in the studied sector.

10. References

[1] AGAPIOU TO, HADJIMITSIS D.G. - Vegetation Indications and Field Spectroradiometric Measurements for Validation Buried of Architectural Remains: Verification under Area Surveyed with Geophysical Campaigns. Newspaper of Applied Remote Sensing, 5, Article ID,: 053554. [In line], 2011, [consulted November 20, 2017]. Available on:
http://dx.doi.org/10.1117/1.3645590

[2] ANTSANIANA (F.T.) - 2015 - Modelling and cartography of the zones to risk of erosion by combination of the factors in games: case of the basin pouring Lohazozoro - Andromba, memory of Master II in Geology to engineer's title, ESPA, 97p.

[3] BELASRI Asma, LAKHOUILI Abdellah - Evaluation of Soil Erosion Risk Using the Universal Soil Loss Equation (USLE) Geo - Information and Technology in Wadi El Makhazine Watershed, Morocco, Newspaper of Geographic Information System, [in line], 2016, [consulted October 12, 2017]. 10p. Available on:
https://www.researchgate.net /... /296335817_Estimation_of_Soil_E...

[4] C.P.C.S. - 1967 - Commission of Pédologie and Cartography of Soils. C.I.D.S.T.Antananarive, 87p.

[5] FATHIZAD Hassan, KARIMI Haji, ALIBAKHSHI Seyed Maryam - the evaluation of erosion and sediment by using the RUSLE model and RS and GIS techniques (case study: Arid and semi arid regions Doviraj of, Ilam province, Iran). International Newspaper of Agriculture and Crop Sciences (IJACS), [in line], 2014, [consulted October 12, 2017]. 12p. Available on:
https://pdfs.semanticscholar.org /... /db8a92e3ca8516704aa477e083...

[6] FOURNIER (F.) - 1960 - The relation between the erosion of soil by water and the atmospheric precipitations. PUF, Paris, 201 p.

[7] IOANNIS Z. GÎTAS - multi - temporal soil erosion risk assessment in. Chalkidiki using has modified USLE raster model. Pub. Rev. Sci EARSeL eProceedings, [in line], 2009, [consulted November 20, 2017], pp: 346. Available on:
https://www.researchgate.net /... /242519680_Multi-temporal_soil_e...

[8] PAYET Evelyne, DUMAS Pascal and PENNOBER Gwenaëlle - Modelling of the erosion hydrique of soils on a basin pouring the Southwest of Madagascar, the Fiherenana. [In line], 2011, [consulted October 12, 2017]. Available on: https://journals.openedition.org/vertigo/12591

[9] RAKOTOMAMONJY (T.E.) - 2016 - Modelling of the erosion hydrique of soils in the basin pouring Avaratrambolo, memory of Master II in Geology to engineer's title, ESPA, 82p.

[10] FOX Kenneth G., FREIMUND Jeremy R. - Using Monthly Precipitation Dated Estimate to the R factor in the Revised USLE. [In line], 1994, [consulted October 12, 2017], pp: 287-306. Available on:
www.scirp.org /... /reference/ReferencesPapers.aspx?ReferenceID...

[11] ROOSE Eric - Application of the equation forecasting's erosion of Wischmeier and Smith in West Africa, ORSTOM. [In line], 1975, [consulted October 09, 2015], 27p. Available on: horizon.documentation.ird.fr/exl-doc/pleins_textes/divers11-05/08469.pdf

[12] ROOSE Eric, SARRAILH Jean-Marie - Erodibilité of some soils tropical twenty years of measure in parcels of erosion under natural rains. Notebook. ORSTOM, set. Pédologie, flight. XXV, N° L-2. [In line], 1989 -1990, [consulted October 09, 2015], 24p. Available on: agritrop.cirad.fr/437263 /

[13] ROBERT P. Stone, HILBORN Don - universal Equation of the losses in earth (USLE), card technique, Soils, Farming Geniuses, Ministry agriculture, the food and the Business farming Ontario Canada. [In line], 2000, [consulted November 20, 2017], 8p. Available on:
www.omafra.gov.on.ca/french/engineer/facts/12-052.htm

[14] WALL G.J., COOTE D.R., PRINGLE E.A., SHELTON I.J. -RUSLE-CAN
Universal equation reviewed of the soil losses for application in Canada - Manual for the assessment of the soil losses caused by the erosion hydrique in Canada - final Document based on the temporary version of 1997, general Direction of research - Agriculture and Agroalimentary Canada - Ottawa (Ontario) - [in line], 1997, [consulted November 20, 2017], pp: 15 - 18. Available on:
sis.agr.gc.ca/siscan/publications/manuals/2002-92/rusle-can.pdf

[15] WISCHMEIER Walter H. - A rainfall erosion index for a universal soil loss equation. Soil Science Society of America Proceeding. 23. [In line], 1959, [consulted October 09, 2015], pp: 246-249. Available on:
https://www.sciencedirect.com/science/article/.../S20953119156109...

[16] WISCHMEIER Walter H., SMITH Dwight D. - Rainfall energy and its relation to soil loss. Trans. Am. Geophys. Union. Flight. 39. [In line], 1958, [consulted October 09, 2015], pp: 285-291. Available on:
https://www.sciencedirect.com/science/article/.../S20953119156109...

[17] WISCHMEIER Walter H., SMITH Dwight D. -Predicting rainfall erosion losses, U.S. Department of Agriculture has guide to conservation planning, Agriculture, Handbook No. 537. [In line], 1978, [consulted October 09, 2015], 67p. Available on:
https://naldc.nal.usda.gov/download/CAT79706928/PDF

[18] WISCHMEIER Walter H., JOHNSON C.B., CROSS-COUNTRY B.V. - *A* soil erodibility nomograph for farmland and construction sites. Newspaper Soil of and Water Conservation. 26. [In line], 1971, [consulted October 09, 2015], pp: 189 -193. Available on:
www.scirp.org /... /reference/ReferencesPapers.aspx?ReferenceID...

[19] ZANTE Patrick, COLLINET Jean, LECLERC Grégoire - 2003 - erosive risk Cartography on the basin pouring the restraint collinaire of Abdessadok (dorsal Tunisian), [in line], 2003, [consulted October 12, 2017]. Available on:
https://www.sciencedirect.com/science/article/.../S20953119156109...