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Comparing between ten regression equations to estimate rainfall erosivity using a long-term precipitation dataset in Tunisia

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Abstract

Water erosion is one of the major threats to soils in Tunisia, affecting 49% of the total area. Annually, the Tunisian water capacity storage decreases by 25 Mm³ due to dam siltation. The Universal Soil Loss Equation (USLE) is a powerful tool that is widely used by scientists in many countries to provide estimates of soil loss and sediment yields from specified land surface areas. Rainfall erosivity is one of the five factors considered in the USLE to quantify the climate effect on the soil loss rate. This paper analyses and compares rainfall erosivity values that were compiled with ten different regression equations using the annual precipitation and the Modified Fournier Index (MFI). Those equations were applied on 55 stations in Tunisia and using 115 years of data. The results showed that the equations developed by Bolinne et al., overestimate the rainfall erosivity. In contrary, the Renard&Freimun and the Yu &Rossewell equations underestimate the rainfall erosivity. In the other hand the Apaydinthe Irvem and Belaid equations can be highly dependent on the rainfall amount and the Modified Fournier Index (MFI) values. The Roose and Arnoldus SI and Ferro equations provide statistically equivalent erosivity values to those that were computed using I30. On average, the difference in the erosivity estimates using those equations are 22% and 18% and 15% respectively. The Rango& Arnoldus SI equation provides the closer erosivity values to those computed using Wischmeier equation with a 2% difference on average. The Arnoldus SI equation provides the most statistically equivalent values for all the sites with a linear regression and an R²of 0.98. Based on those results, the Arnlodus SI equation was adapted and used to construct rainfall erosivity map In Tunisia using GIS. Finally, the rainfall erosivity values may vary significantly depending on the equations used due to the original condition in which they were developed. It is crucial to select a proper equation that can be adapted to local conditions, especially based on climatic regions. On the other hand, the spatial distribution of rainfall erosivity can be highly dependent on the number and the distribution of stations.

Key Words: rainfall erosivity, regression equation, spatialdistribution, Tunisia, erosivity map

Comparaison entre dix équations de régression pour estimer l'érosivité des précipitations à l'aide d'un ensemble de données sur les précipitations à long terme en Tunisie

Résumé

L'érosion hydrique est un phénomène complexe très répandu en Tunisie et menace 49% du pays. 25 Mm³ de sédiments annuellement stockés derrière les grands barrages et 877 lacs collinaires. L'équation universelle de la perte de sol (USLE) est un modèle puissant qui est très utilisé dans de nombreux pays pour estimer la perte en sol. L'érosivité des pluies est l'un des cinq facteurs pris en compte dans l'USLE pour quantifier l'effet du climat sur le taux de perte de sol. Cet article analyse et compare l'érosivité des pluies estimé en utilisant dix différentes équation de régression qui se basent sur la pluviométrie annuelle et l'Indice de Fournier Modifié (IFM). Ces équations ont été appliqué en utilisant les enregistrements 55 stations pluviométriques et pluviographiques réparties en Tunisie sur une période de 115 ans. Les résultats obtenus montrent que l'équation de Bolinne surestime l'érosion en revanche celles de Renard & Freimun et de Yu & Rossewell sous-estime les pertes en sol. Cependant les équations de Apaydinthe, Irvem et Belaid sont fortement dépendantes des valeurs des pluies annuelles et de l'indice de Founier Modifié. Les équations de Roose, Arnoldus SI et Ferro SI donnent des valeurs proches comparées à celles calculées à partir de l'équation de Wischemier (I30). En moyenne, les différences d'estimation pour les équations citées précédemment sont respectivement de l'ordre de 22%, 18% et 15%. L'équation de Rango & Arnoldus SI fournit les valeurs d'érosivité les plus proches de celles calculées en utilisant l'équation de Wischmeier avec une différence moyenne de l'ordre de 2%.Cependant, l'équation d'Arnoldus SI fournit les valeurs statistiquement les plus équivalentes pour toutes les stations. En effet, cette équation présente une régression linéaire avec un coefficient de corrélation R2de l'ordre de 0,98. Sur la base de ces résultats, l'équation d'Arnlodus SI a été adaptée et utilisée pour élaborer une carte d'érosivité des pluies en Tunisie en utilisant le SIG. Finalement, les valeurs d'érosivité des pluies peuvent varier considérablement selon les équations utilisées en raison des conditions d'origine dans lequel elles ont été développées. Il est crucial de sélectionner une équation appropriée qui peut être adaptée aux conditions locales, en particulier en fonction des régions climatiques. D'autre part, la distribution spatiale de l'érosivité des pluies peut être fortement dépendante du nombre et de la distribution spatiale des stations.

Mots Clés : érosivité des pluies, équation, distribution spatiale, Tunisie, carte d'érosivité

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INTRODUCTION

Runoff is caused by excess rainfall that can no longer infiltrate, thus sweeping away soil particles. This behavior of the soil to stop excess water appears either when the intensity of the rainall intensity is greater than the infiltrability of the soil surface, or when the rainfall occurs on a partially or fully saturated surface. Once the runoff has started on the plot, erosion can take different forms, which combine in time and space: sheet erosion, rill erosion and linear or concentrated erosion in talweg.

Erosive processes depend on a multiplicity of interacting factors, hence the complexity to model. The factors of erosion that must be considered to study erosive phenomena are now the subject of a consensus and include the soil, land use, topography and climate.

The possibility of a risk erosion mapping is therefore a function of the existence of spatialized data describing these factors on the one hand, and of the existence of operational models capable of describing the processes and of the erosion intensity from the available data. Dynamic mapping is an essential point of our method and makes it largely original, since it must make it possible to draw up predictive maps of the erosion hazard by regularly updating the data, the variability of which falls within a short time scale.

Thus, to characterize the influence of the climate, the cumulative kinetic energy of the rainfall would probably be the most relevant parameter, but it is not available anywhere, and we will therefore retain in this work the cumulative rainfall, weighted by information on precipitation intensity.

The objective of this work is to propose an estimation approach for the evaluation of climatic hazard and specially to assess the impact of the aggressiveness of rainfall on the erosive phenomenon. We first present a comparison of multiple linear regressions to estimate the erosivity of the rain, then, a mapping of the rain erosivity index (R) in the form of isoerodent maps.

MATERIAL AND METHODS

Rainfall erosivity equations

The rainfall and runoff factor or rainfall erosivity factor (R) represents the effect that rainfall has on soil erosion and was included after observing sediment deposits after an intense storm (Benavidez et al.,2018) The R factor is the average annual sum of individual storm erosion index values, EI30, where E is the total kinetic energy for a storm per unit of area, and I_{30} is the storm's maximum 30-minute intensity (Yu & Rosewell,1996). Mathematically, R is

$$\boldsymbol{R_a} = \frac{\mathbf{1}}{\boldsymbol{n}}\sum_{\boldsymbol{j=1}}^{\boldsymbol{n}}\sum_{\boldsymbol{i=1}}^{\boldsymbol{m_j}}(\boldsymbol{EI_{30}})_{\boldsymbol{i}} \quad \text{(eq 1)}$$

Where Ra is the average annual rainfall erosivity, n is the number of years of records, m is the number of erosive storm events of a given year j and EI_{30} is the rainfall erosivity index (storm erosion index) of a single storm event i (Schonbrodt-stitt et al., 2013)

The equation for computing storm energy when rainfall is given by a continuous function is (Foster et al., 1981)

$$\boldsymbol{E} = \int_0^{\boldsymbol{D}} \boldsymbol{e_{si}dt} \qquad \text{(eq 2)}$$

Where e is the rainfall energy per unit of rainfall, (si) is the rainfall intensity for the time differential dt, t is time, and D is duration of rainfall for the storm. In most applications, equation 2 is written in discrete form as (Foster et al., 1981)

$$\boldsymbol{E} = \sum_{\boldsymbol{k=1}}^{\boldsymbol{p}} \boldsymbol{e_k \Delta V_k} \qquad \text{(eq 3)}$$

Where $\boldsymbol{e_k}$ is the rainfall energy per unit rainfall and $\boldsymbol{\Delta V_k}$ is the depth of rainfall for the kth increment of the storm hyetograph divided into p part.

The hyetograph is divided so that a constant rainfall intensity over an increment can be assumed. This intensity ik is (Foster et al., 1981)

$$\boldsymbol{i_k} = \frac{\boldsymbol{\Delta V_k}}{\boldsymbol{\Delta t_k}} \qquad \text{(eq 4)}$$

Where $\boldsymbol{\Delta t_k}$ is the duration of the increment over which the intensity is considered constant. The energy unit $\boldsymbol{e_k}$ is function of intensity. It is computed in U.S customary units with (Foster et al., 1981)

$$\boldsymbol{e_k} = \mathbf{916 + 311} * \boldsymbol{logi} \qquad i \le 3 \text{ in/hr} \qquad \text{(eq 5)}$$

and

$$\boldsymbol{e_k} = \mathbf{1074} \qquad i > 3 \text{ in/hr} \quad \text{(eq 6)}$$

Where $\boldsymbol{e_k}$ has units of ft-tonf/acre per inch of rain and intensity i has units of inch/hour

In U.S customary units R has units of Hundreds of feet.tonf.inch/acre.hour.year where the division by 100 is made for convenience of expressing the units, and it is computed with (Renard & Freimund, 1994)

$$\boldsymbol{R_a} = \frac{\mathbf{1}}{\boldsymbol{n}}\sum_{j}^{n}\sum_{\boldsymbol{i=1}}^{m_j}(\boldsymbol{EI_{30}} * 10^{-2})_{\boldsymbol{i}} \qquad \text{(eq 7)}$$

In agricultural Handbook N°537, Wischmeier and Smith (1978) presented a conversion from U.S customary units to metric or English units where the rainfall energy $\boldsymbol{e_k}$ is expressed in metric ton-metric per hectare per centimeters of rain (m.t-m/ha), the intensityi in centimeter per hour (cm/h) and R factor in ton-metric centimeter per hectare per hour per year (t-m.cm/ha.h.year). The conversion factor is 1.735 (Wischmeier and Smith, 1978). The corresponding metric unit version of the equations are:

$$\boldsymbol{e_k} = \mathbf{210 + 89} * \boldsymbol{log i}\ \mathrm{i} \leq \mathbf{7.6\ cm/h} \text{(eq 8)}$$

and

$$\boldsymbol{e_k} = \mathbf{289 i > 7.6\ cm/h} \text{(eq 9)}$$

The R factor metric units presented in Agriculture Handbook N°537 (t-m.cm/ha.h.year) were corrected to units of Mj cm / ha.h.year in the supplement to Agriculture Handbook N°537 (Wischmeier and Smith, 1981). In the initial release of Agriculture Handbook N°537 (1978), the US customary unit for force (tonf) was mistakenly converted to metric units of metric ton (a mass unit) rather than the SI units for force (Newton) (Foster et al., 1981) (Renard & Freimund, 1994).

With this correction in the supplement to Agriculture Handbook N°537, the rainfall energy $\boldsymbol{e_k}$ is expressed in Megajoule per hectare per mm of rain (MJ/ha) and the intensity i in millimeter per hour (mm/h) and the maximum 30-minute intensity I30 in centimeter per hour (cm/h) R factor in Mj cm / ha.h.year. The conversion factor is 1.702.(Wischmeier and Smith, 1981). The corresponding SI unit version of the equations are:

$$\boldsymbol{e_k} = \mathbf{0.119 + 0.0873} * \boldsymbol{log i} \qquad i \leq 76 \text{ mm/h} \qquad \text{(eq 10)}$$

and

$$\boldsymbol{e_k} = \mathbf{0.289} \qquad i > 76 \text{ mm/h} \qquad \text{(eq 11)}$$

Foster et al., (1981) proposed an easy and convenient conversion from US customary units to SI units to avoid the confusing between the values of the two systems. The R factor metric units presented are Mj.mm/ha.h.year with the only difference in the I30 units which is expressed in millimeter per hour (mm/h) and the conversion factor became 17.02(Foster et al., 1981).

For many regions worldwide rainfall data are not available in an enough and adequate spatial and temporal resolution. To overcome this restriction, several studies have aimed at the assessment rainfall erosivity using regression function and expressed R-factor as a function of those erosivity indexes. This paper analyses and compares rainfall erosivity values that were compiled with ten different regression equations using the annual precipitation and the Modified Fournier Index (MFI). The regression equations used are proposed by Roose (1976), Arnoldus (1977 and 1980), Bolinne et al., (1980), Rango&Arnlodus (1987), Renard & Freimund (1994), Yu and Rossewell, (1996), Ferro et al., (1999), Apaydin et al., (2006), Irvem et al., (2007) and Belaid (2015).

Rainfall erosivity estimators

Working in the USA and West-Africa, Arnoldus (1977,1980) attempted a correlation between Fournier's index F and know values of the R-factor for 164 stations in the USA and 14 in the West-Africa.

$$\boldsymbol{F} = \frac{\boldsymbol{P_m^2}}{\boldsymbol{p}} \qquad \text{(eq 12)}$$

Where Pm is the average rainfall of the month with the highest precipitation and P is the average annual precipitation.
Arnoldus (1977) determined that Fournier's index cannot be used to approximate the R-factor of the USLE. To overcome this restriction, a modification of Fournier's Index proved to be successful; this new index is Mofidited Fournier Index (MFI) as follow: (Arnoldus, 1977)

$$\boldsymbol{MFI} = \sum_{\boldsymbol{i=1}}^{\mathbf{12}} \frac{\boldsymbol{P_i^2}}{\boldsymbol{p}} \qquad \text{(eq 13)}$$

Where Pi is monthly precipitation and P is annual precipitation.
In Morocco, based on monthly precipitation data for 112 stations, Arnoldus (1980), slightly modified the log-log relationship founded in West-Africa, and created the erosivity Map for Morocco in metric units (Arnoldus, 1977).Following the work in Sebou watershed in Morocco, Rango& Arnoldus (1987) suggested a new relation to approximate the R-factor using MFI index using 200 stations data.

Arnoldus didn't specify the precipitation units used, he just identified the R factor units as metric units and mentioned that the conversion factor of 1.735 from US customary units to metric units is given for Morocco (Arnoldus, 1977) and a rounded 1.74 is given for Africa and the Middle East (Arnoldus, 1980). In both cases, the conversion factor is different from the 17.02 presented by Foster et al. (1981). (Renard &Freimund, 1994) and 1.702 presented by Wischmeier and smith (1981) in the supplement of the Agricultural handbook N°537. According to Renard & Freimund, (1994) the units presumably used are the units of t-m.cm/ha.h.year for the R factor presented in Agricultural Handbook No. 537 (Wischmeier and Smith, 1978).

Based on the conversion factors from US customary units to metric units presented by Arnoldus (1977,1980) and Foster et al., (1981), a new conversion factor for the two different metric units used (t-m.cm/ha.h.year and Mj.mm/ha.h.year) can be identified and it is around 9.8 (the Foster's conversion factor divided by the Arnoldus's conversion factor 17.02/1.735 =9.8).Renard & Freimund, (1994), mentioned that the precipitation used to calculate MFI is in millimeters, on the other hand, Chehlafi et al., (2019 et 2014) and Hniad et al., (2018), working in Morocco, defined the precipitation unit used in equation 15 is inch.

Table1. show the ten different regression equations using the annual precipitation and the Modified Fournier Index (MFI) that will be used to compute the rainfall erosivity.

Table 1 –the ten regression equations that were used to compute rainfall erosivity in this study

Study area	Equation	Authors	Units
West Africa	$R = P * (0.5 \pm 0.05)$	Roose	R:100 of foottonf.inch/acre.h.year/P : Inch
Morocco	$R = 1.735 * 10^{(1.5*logMFI-0.8188)}$ $R = 0.264\ (MFI)^{1.5}$	Arnoldus,	R : t-m.cm/ha.h.year
Belgium	$R = 3.27 * \mathrm{MFI} - 168.42$	Bolinne et al	R : 10-2 tm.cm/ha.h/ P:mm
Sebou - Morocco	$logR = 1.74 * logMFI + 1.29$	Rango& Arnoldus	R: t-m.cm/ha.h.year
the continental United States	$R = 0.0483 * P^{1.610}$ P≤ 850 mm $R = 587.8 - 1.219 * P + 0.004105 * P^2$	Renard & Freimund,	R : MJ.mm/ha.h.year P : mm
Australia	$R = 0.0438 * P^{1.61}$	Yu &Rosewell	
Spain	$R = 21.56 * MFI^{0.927}$	Apaydin et al.,	
Turkey	$R = 0.1215 * MFI^{2.2421}$	Irvem et al	
Australie	$R = 21.56 * MFI^{0.927}$	Ferro	
Tunisia	$R_{m-30} = 16.66 * MFI_m^{00.82}$	Belaid	

Study area

Pluviographic and pluviometry records were used to compute rainfall erosivity values at 55 stations that are shown in fig.3 which are distributed climate all over Tunisia. The is divided in to five bio-climatic class: humid and sub-humid in the North of the country, arid and semi-arid in the center and Saharan in the south and the rainfall is ranged between 1600 mm in the North(Ain drahem) and 50 mm in the South.

The amount of data per station ranged from 12 to 115 years, depending on the station the rainfall data were recorded between 1962 and 2015. Monthly and annual data were missing at same stations. The 65 stations are part of two national rainfallgauge networks that are managed by the Water Recourse General Direction (WRGD) (25) and National Institute of Meteorology (NIM) (30). The first ones (25) were equipped by pluviographs and the second ones (30) were equipped by pluviometers.

RÉSULTATS ET DISCUSSION

First, we managed to convert the Arnoldus and Rango&Arnlodus equation from the original metric units (t-m.cm/ha. h. year) to the SI metric units (Mj.mm/ha.h.year). Those modified equations are given as following: Arnoldus SI equation:

$$R = 17 * 10^{(1.5*logMFI-2.92)} \qquad \text{(eq 14)}$$

and Rango&Arnlodus SI equation

$$R = 10 * 10^{(1.74*logMFI-1.15)} \qquad \text{(eq 15)}$$

The SI version of the Wischmeier and Smith equation was used to compile the rainfall erosivity factor for each storm at 25 stations. Then, we have managed to compute the mean annual rainfall erosivity value at each station.

Ten (10) different regression equations using the annual precipitation and the Modified Fournier Index (MFI) were used to compile rainfall erosivity factor for the 65 stations.

The regression equations used are proposed by Roose (1977), Arnoldus (1977 and 1980), Bolinne et al., (1980), Rango&Arnlodus (1987), Renard & Freimund (1994), Yu and Rossewell, (1996), Ferro et al., (1999), Apaydin et al., (2006), Irvem et al., (2007) and Belaid (2015). Then, the mean annual rainfall erosivity values was calculate for each station. The rainfall erosivity compiled using I_{30} were compared among those estimated by the ten regression equations for every station which equipped by pluviograph.

Based on the result of the comparison, we manage to identify the equation that provide the most statistically equivalent erosivity values. This equation was used to calculate average annual erosivity for each station. At final we manage to elaborate rainfall erosivity map of Tunisia.

The table 2 shows the rainfall erosivity (Mj.mm/ha.h.year) that was computed for the 25 stations of the WRDG.

Table 2–Rainfall erosivities computed using I_{30} and the ten regression equations

	Using I30	Using Annual precipitation			Using MFI						
Stations	Wischmeier	Roose	Renard & Freimund	Yu &Rossewell	Arnoldus SI	Ronga, Arnoldus, SI	Bolinne et al., SI	Ferro et al.,	Apaydin et al.,	Irvem et al.,	Belaid,
Abida Cassis	560	842	353	320	856	779	1981	818	900	1001	452
Aïn Jaffel	3183	1370	774	702	2334	2436	2780	1993	1651	4340	773
Aïn Saboun	666	652	234	213	466	376	1754	463	610	392	321
Aïn Taga	2948	1525	920	834	2178	1861	3071	1615	1431	3069	681
Lebna dam	1846	1393	795	721	1711	1686	2821	1495	1357	2703	650
BirAyed	660	886	374	348	778	697	2037	750	848	868	429
Bou Arada	373	605	208	188	486	404	1702	490	634	430	332
El Hamma	152	197	34	31	208	147	1309	222	370	117	206
Gabes	79	161	25	22	215	153	1280	229	378	123	210
Gabès DRE	759	452	130	118	758	676	1542	732	834	833	423
Haffouz	512	555	180	164	463	373	1647	460	608	388	319
Haïdra	328	467	137	124	414	335	1558	423	574	337	304
MatmataAnc	381	383	100	90	517	434	1476	517	658	471	373
Mellegue	466	668	244	221	400	315	1772	403	555	312	295
Oued El Abid	443	753	295	267	635	564	1870	635	758	660	388
Oued El Kheïrat	481	489	148	134	509	426	1580	510	652	460	340
Oued Mgaiez	1365	1388	790	717	1388	1364	2812	1267	1213	2058	588
Oued Tine cassis	432	728	280	254	781	700	1842	752	850	872	430
Sarrat	560	608	209	190	386	278	1705	366	520	266	278
Sejnène	9153	3972	4295	3895	9122	11748	14762	6818	3818	3898	1623
Sidi Boubaker	803	1114	555	503	931	859	2359	882	948	1134	473
SilianaLaouej	506	766	304	275	627	543	1887	616	742	628	381
TuburboMajus	817	1068	518	470	912	839	2290	866	936	1100	468
Zriba Aïn Sfaya	526	544	175	158	597	513	1636	589	720	584	371
Izid dam	187	421	116	105	231	170	1512	249	400	141	221

We compared the result of each regression equation with the Wischmeier's rainfall erosivity for all the stations.

The Bolinne equation provide significantly different erosivity values when compared to the erosivity computed using I30. The erosivity values ranged between 14762 Mj.mm/ha.h.year at Sejnen station and 1280 Mj.mm/ha.h.year at Gabes Station. This equation overestimates the erosivity with an average of 296% for all the stations.

At low rainfall amounts (P<400mm, MFI<70mm), the Apaydin equation overestimate the erosivity compared to those computed using Wischemeier equation. However, at higher rainfall amounts, the difference decreases, and the equation underestimates the erosivity. On average, a 44% difference was observed. This equation provides erosivity values ranged between 3818 Mj.mm/ha.h.year at Sejnen station and 370 Mj.mm/ha.h.year at El Hamma Station

At low MFI value (MFI<40mm), the Irvem equation underestimates the erosivity compared to those computed using Wischemeier equation. However, at medium MFI value(40mm<MFI<150mm), the difference increases, and the equation overestimates the erosivity. At higher MFI value (MFI>150mm), the difference decreases to the value of 57% at Sejnen station (MFI= 266, R=3898 Mj.mm/ha.h.year). On average, the difference observed was around 14%. This equation provides erosivity values ranged between 4340 Mj.mm/ha.h.year at Ain Jaffel station and 170 Mj.mm/ha.h.year at El Hamma Station

The Renard&Freimun and the Yu &Rossewell equations predict significantly smaller rainfall erosivity with an average difference around 55% and 59% respectively for all stations. The Renard&Freimun equation provides erosivity values ranged between 4295 Mj.mm/ha.h.year at Sejnen station and 25 Mj.mm/ha.h.year at Gabes Station. The Yu &Rossewell equation provides erosivity values ranged between 3895 Mj.mm/ha.h.year at Sejnen station and 22 Mj.mm/ha.h.year at Gabes Station.

The Belaid relationship provides significantly different erosivity values specially at high rainfall amounts. On average, the difference in the erosivity estimates is 25%. This relationship gives erosivity ranged between 1623 Mj.mm/ha.h.year at Sejnen station and 206 Mj.mm/ha.h.year at El Hamma Station.

The Roose and Arnoldus SI and Ferro equations provide statistically equivalent erosivity values to those that were computed using I30. On average, the difference in the erosivity estimation using The Roose and Arnoldus SI and Ferro equations are 22% and 18% and 15% respectively. In fact, The Roose equation provides erosivity values ranged between ranged between 3972 Mj.mm/ha.h.year at Sejnen station and 161 Mj.mm/ha.h.year at Gabes Station. However, the Ferro equation provides erosivity values ranged between 6818 Mj.mm/ha.h.year at Sejnen station and 222 Mj.mm/ha.h.year at El Hamma Station. The Arnoldus SI equation provides the closer erosivity values for all stations which ranged between 9122 Mj.mm/ha.h.year at Sejnen station and 208 Mj.mm/ha.h.year at Gabes Station.

The Rango&ArnlodusSI equation provides the closer erosivity values to those computed using Wischmeier equation with a 2% difference on average. This equation provides erosivity values ranged between 11748 Mj.mm/ha.h.year at Sejnen station and 147 Mj.mm/ha.h.year at El Hamma Station.

Fig 1 compares the erosivity values that were computed using I30 for all sites and the three regressions equations that provided statistically equivalent erosivity values. A linear regression was used for every equation and site with forthe Rango&Arnlodus SI and Arnoldus SI and Ferro equations an R^2 of 0.95 and 0.96 and 0.98 respectively.

Those results show that computing the rainfall erosivity using the Arnoldus SI equation provide the most statistically equivalent values for all the sites. This equation was adapted and usedon the 65 stations to construct rainfall erosivity map In Tunisia using GIS as showed in fig 2.

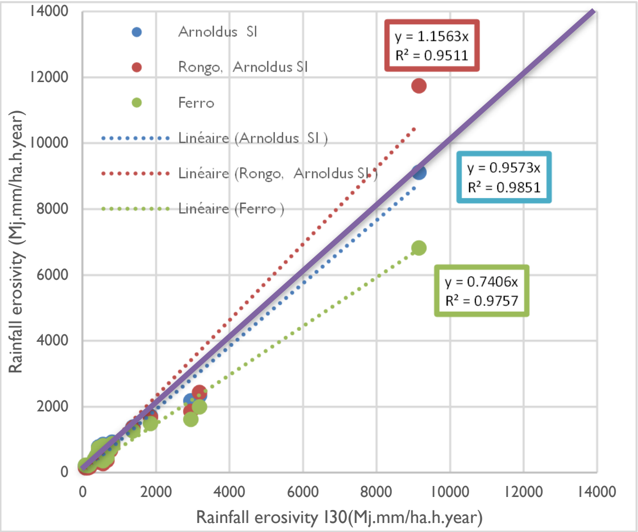

Fig. 1 – Comparaison between the R factors obtained using I30 and MFI

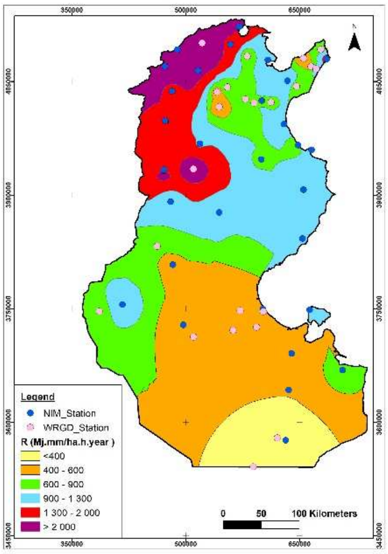

Fig. 2 – Spatial distribution of the Stations and Rainfall erosivity map

CONCLUSION

This study showed that the rainfall erosivity estimates using regression equations can be highly dependent on the rainfall amount and the Modified Fournier Index (MFI). The erosivity estimates that were obtained using the Apaydinand Irvem equations were significantly differents and highly sensitives to the rainfall amount and the Modified Fournier Index (MFI). Thus, those equations should be calibrated based on local precipitation data to generate reliable erosivity estimates. The Renard&Freimun and the Yu &Rossewell equations predicted significantly smaller rainfall erosivity. This difference can be explened by the original climatic conditons of those equations. The convertion of the Arnoldus and Rango&Arnlodus equation from the original metric units (t-m.cm/ha.h.year) to the SI metric units (Mj.mm/ha.h.year) provide statistically equivalent erosivity values to those that were computed using I30.

The results also showed that computing the erosivity using Roose, Arnoldus SI and The Rango&ArnlodusSI and Ferro equations provide statistically equivalent erosivity values to those that were computed using I_{30}. On average, the difference in the erosivity estimates using those equations and those using Wischmeier equation are 22% and 18% and 2% and15% respectively. This proves that the equations were developed in climatic condition similar to Tunisia's condictions provide statistically equivalent erosivity values to those that were computed using I_{30}.

A linear regression of the Arnoldus SI equation with an R^2 of 0.98 proves that this equation provides the most statistically equivalent values for all the sites. This equation was adapted and used on the 65 stations to construct rainfall erosivity map In Tunisia.

Finally, the spatial distribution of rainfall erosivity in this study isn't significant. In fact, the spatial distribution can be highly dependent on thenumber and the distribution of stations. Therefore, we manage to choose a largest number of stations with better distribution to creat a rainfall erosivity map.

Références

Apaydin, H., Ozturk, F., Merdun, H., Aziz, N.M., (2006). Determination of the drainage basin characteristics using vector GIS. Nordic Hydrology 37 (2), 129–142.

Arnoldus, H. M. J.: Methodology used to determine the maximum potential average annual soil loss due to sheet and rill erosion in Morocco, FAO Soils Bulletin, 34, 39–51, 1977.

Arnoldus, H. M. J.: An approximation of the rainfall factor in the Universal Soil Loss Equation, in: De Boodt, M. and Gabriels, D., Assessment of Erosion, 127–131, Chichester, UK, Wiley, 1980.

Belaid, H., (2015), Contribution à l'etude des processus de l'érosionhydrique en milieu semi-aride Tunisien (Cas du bassin versant Sbaihia, Zaghouan). Ths, pp 75-86

Benavidez et al., (2018) A review of the (Revised) Universal Soil Loss Equation ((R)USLE): with a view to increasing its global applicability and improving soil loss estimate, pp 2-10

Bolinne A, Lauant A, Rosseau P, Pauwels JM, Gabriels D, Aeltermann J (1980) Provisional rain erosivity map of Belgium. In: DeBoodt M, Gabriels D (eds) Assessment of erosion. Wiley, Chichester, pp 111–120

Chehlafi, A et al., (2014) Highway slopes protection throughmasonry or concretedarch, Journées Nationales de Géotechnique et de Géologie de l'Ingénieur JNGG2014, pp 4-6

Chehlafi, A et al., (2019) Highway cutting slopes with high rainfall erosion in Morocco: Evaluation of soil losses and erosion control using concrete arches, Engineering Geology, p3

Ferro, V., Porto,P. and Yu, B., (199)A comparative study of rainfall erosivity estimation for southern Italy and southeastern Australia, Hydrolog Sci Jpp 8-11

Ferro, V., Giordano, G., and Iovino, M.(1991): Isoerosivity and erosion risk map for Sicily, Hydrol. Sci. J., 36, 549–564, https://doi.org/10.1080/02626669109492543,.

Foster GR, McCool DK, Renard KG, Moldenhauer WC (1981) Conversion of the universal soil loss equation to SI metric units. J Soil Water Conserv 36:355–359

Hniad, O et al., (2018), Introduction of inclined open channels for the control of surface runoff of slopes in road structures, MATEC Web of Conferences 149, 02098 (2018), p3

İrvem, A., Topaloğlu, F., and Uygur, V.(2007): Estimating spatial distribution of soil loss over Seyhan River Basin in Turkey, J. Hydrol., 336, 30–37, https://doi.org/10.1016/j.jhydrol.2006.12.009.

Rango, A. and Arnoldus, H.(1987): Aménagement des bassins versants, Cahiers techniques de la FAO, Food and Agriculture Organization of the United Nations,.

Renard, K. and Freimund, J. R. (1994). : Using monthy precipitation data to estimate R-factor in the revised USLE, J. Hydrol., 157, 287–306,

Renard, K., Foster, G., Weesies, G., McCool, D., and Yoder, D.(1997): Predicting soil erosion by water: a guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE), Agricultural Handbook No. 703, 65–100, https://doi.org/10.1201/9780203739358-5,

Roose EJ (1976) Use of the universal soil loss equation to predict erosion in West Africa. Soil Conserv. Soc. Am, Ankeny, Iowa, pp 60–74

Schönbrodt-Stitt S & Bosch A & Behrens T & Hartmann H & Shi X & Scholten T. (2013) Approximation and spatial regionalization of rainfall erosivity based on sparse data in a mountainous catchment of the Yangtze River in Central China, Springer-Verlag Berlin Heidelberg, pp 2-17

Wischmeier, W. H. and Smith, D. D.(1978) : Predicting rainfall erosion losses, Agriculture Handbook No. 537, 537, 285-291, https://doi.org/10.1029/TR039i002p00285,

Yu B, Rosewell CJ (1996) An assessment of daily rainfall erosivity model for New South Wales. Aust J Soil Res 34:139–152