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Research Paper

Evaluation of sensitivity to water erosion by climate indices in the oued valley of El arab-Algeria.

Aouachria Miloud [1,2], Bouziane Mohammed Toufik [1], Meradi Samira [2], Madi Mohammed [2].
[1]: Mohamed kheider Biskra-Algeria University
[2]: Scientific and technical research center on arid regions Biskra-Algeria
aouachriam@yahoo.com

Abstract: The predictability of soil degradation and the spatialization of water erosion, the subject of this work, is established with great precision. This study was conducted in the upstream part of the Oued El Arab valley, which presents one of the Aurès valleys in eastern Algeria. Due to its position, its physical components and the importance of socio-economic issues that are localized, this watershed is subject to significant erosive dynamics. The analysis and the treatment of the indices of erosivity of the rains give us an important information about the phenomenon of water erosion, whose index of erosivity of wischmeier varies between: 36.42 t / km^2; 58.27 t / km^2 and 73.44 t / km^2 respectively for Babar, Kais and Elhamma. The prediction of soil loss due to aggressive rains in this area exceeds 117 t / km^2 / year. The result is a document that is a decision support tool in terms of management and protection of natural resources.

Keywords: Erosivity of rainfall, soil, vulnerability, Oued El-Arab valley.

Introduction

The climate in North Africa is characterized by irregular and fluctuating rainfall both geographically and seasonally. These rains cause significant water erosion within the watersheds and contribute to the siltation of dam reservoirs (Touahir et el .., 2018). In the southern Mediterranean basin, the semi-arid climate is a major factor in the severity of the phenomenon of water erosion (Tadrist, et el.., 2016). Water erosion is a complex phenomenon due to its irregular, random nature and its spatio-temporal discontinuity (Achite, 2005). The erosivity of rains is of major importance, whose raindrops can break up aggregates and disperse their constituent particles. These particles occur on the soil surface when the runoff force becomes greater than the resistance to soil detachment (Maamar, et el..., 2016). Water erosion develops when rainwater, which can no longer infiltrate the soil, trickles down onto the plot, removing soil particles. This refusal of the soil to absorb excess water appears either when the intensity of the rains is greater than the infiltrability of the soil surface (Hortonian runoff), or when the rain arrives on a surface partially or totally saturated by a water table (saturation runoff). These two types of runoff generally appear in very different environments, although a combination of the two is sometimes observed (Le Bissonnais, 2002). In arid zones, mountain ranges are the most exposed to erosion, which is manifested by soil degradation. This phenomenon is characteristic in the Maghreb region whose water and soil potentials are seriously threatened (Achite, et el…, 2006). The severity of water erosion resides both in the high levels of sediment transport in addition to the spatio-temporal variability of the phenomenon. Overall, there are large differences in the state and trend of soil erosion in different regions of the world where North Africa has poor or very bad erosion conditions and a tendency to deterioration (FAO, 2016). In our work, we have studied the erosivity of rain which is the appropriate factor for the prediction of soil losses (Wischmeier, et el… 1958). It is also defined as its capacity to cause erosion (Maamar-kouadri, k. et el…2016).We studied the erosivity of rain at the level of the upstream watershed of Oued el Arab through several indices which are: the Fournier IF index, the modified Fournier Arnoldus IFA index and the Wischmeier index. We established a risk erosion map as a function, on the one hand, of the existence of spatialized data describing these factors and, on the other hand, of the existence of operational models capable of describing the processes and assess the intensity of erosion from available data. The objectives of this study are: the description of the biophysical environment and its degradation, the assessment of the sensitivity of the watershed in terms of predisposition to erosion, the search for the causes of its degradation and the identification of priority areas requiring strengthening means to combat water erosion.

Martial mad Methods

Characteristics of the study area

The study basin is a sub-basin of the upstream part of Oued El-Arab, it is bounded to the North West by the Aurès mountains, the main ones of which are (Dj - Chenntgomma, Dj- Aidel). East and South - East by Djebel Tadelist, Djebel Bouzendag. North and North - East by the Khenchela plain. It lies between the meridians of longitudes 6 ° 55 'and 7 °

13' East and the parallels of latitude 35 ° 10 'and 35 ° 22' North. The Oued El-Arab watershed at the Babar dam site covers an area of 567 km² approximately 40 km south of the city of Khenchela and is located north of the large hydrographic basin of Chr Melrhir (figure 1). Most of the hydrographic network drains Cretaceous and Quaternary soils (figure 1). It is a very rugged watershed, with altitudes varying between 900 and 1215 m (figure 2) decreasing from upstream to downstream (from north to south). The mountainous relief of the northern part and the extreme south - east, northeast defines very steep slopes exceeding 25%. The gentler slopes, which drop to 3%, occupy more than 66% of the area of the basin in the center and near the dam reservoir (figure3). The hydrographic hair practically follows the major tectonic accidents, underlined by coarse alluviums which are essentially conglomerate, from sands to pebbles. The importance of the drainage is mainly due to the semi-permeable nature of the formations which constitute the basin but also to the strong slope of the slopes and the occurrence of irregular and violent rains. In general, the geological formations of the Oued El Arab watershed is made up of more than 80% of more or less detrital genesis, represented by alluvial deposits formed of silt, clays, gravels, pebbles, and eluvials occupy the center of the basin.

Average precipitation decreases from upstream to downstream, from 456.57mm in the north of the basin to 300mm in the dam sector to the south.

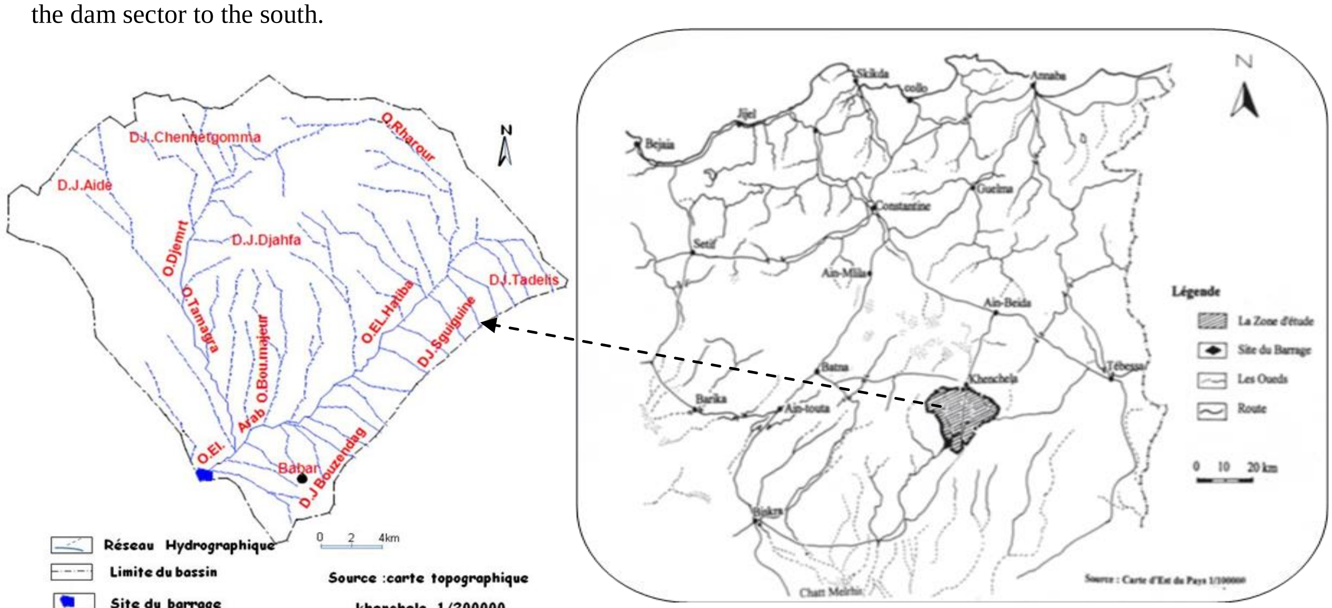

Figure 1. Location of the study area

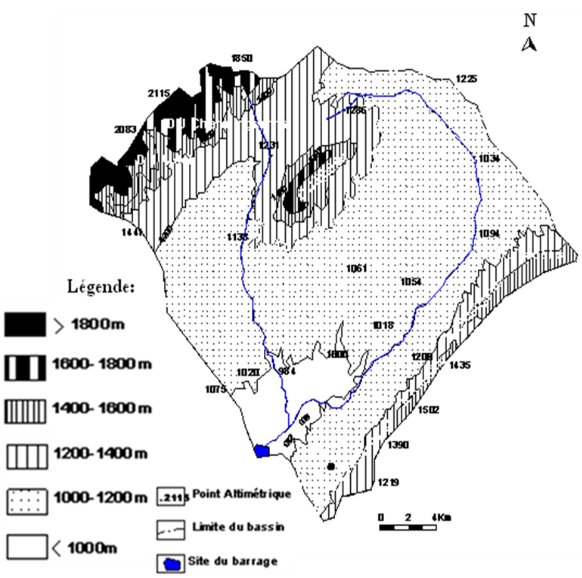

Figure 2. Oued watershed. El-arab; the altitudes

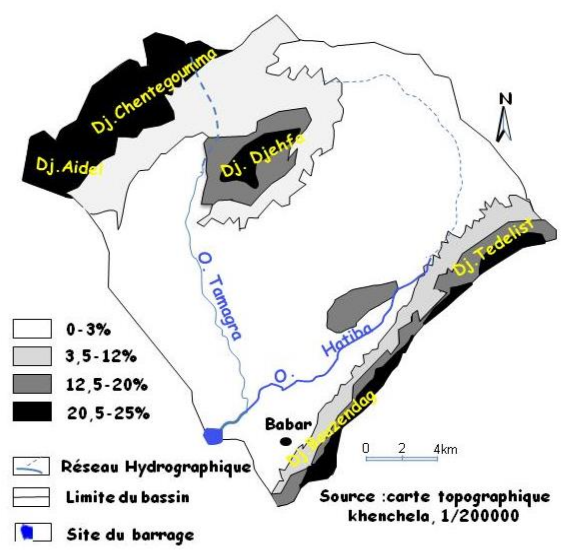

Figure 3. Oued.El-arab watershed; the slopes

Figure 1. Location of the study area

Calculation of rainfall erosion indices

a- Erosion index of furnier ' IF'

It is given by the following relation:

$$IF = {P_i}^2 \Big/ \overline{P_{an}}$$

With:

p_i^2 : The most rainy month's rainfall in mm.

$\bar{P}_{an}$: Average annual rainfall height mm / year.

b- Arnoldus erosion index 'IFA'

He just changed the furnace index by changing of the p_i^2 wettest month by the sum of the monthly averages for the 12 months of the year such as:

$$IFA = \sum_{i=1}^{n=12} {P_i}^2 \Big/ \overline{P_{an}}$$

With:

p_i^2 : Monthly rain of each month of the year (mm).

$\overline{P_{an}}$: Average annual rain (mm).

c- Calcul de l'érodibilité 'E' de fournier 1960

It is given by the following relation

$$E = \frac{1}{36} \times C^{2,65} \times \left(\frac{h^2}{S}\right)^{0,46}$$

With:

E: soil degradation (t / km^2 / year).

$C = IF = \frac{P^2}{\bar{P}_{an}}$, furnace index (mm.)

$\frac{h^2}{S}$: Orographic coefficient.

d- Wischmeier's index ' R '

It is given by the following relation (Haoues, 2008 et Sahraoui, et el...2005) ; $R = KC^n$

With: $C = h_1 \times h_{24} \times \bar{H}$

However

h_1 Maximum height of rain fell in 1 hour with a return period of 2 years.

h_{24} Maximum rainfall in 24 hours with a return period of 2 years.

$\bar{H}$ Average annual rainfall.

$K, n,$ Climate-related coefficients (in a semi-arid climate: $K = 0{,}751, n = 0{,}80$

For the estimation of the rains fell during miseries of different periods (t) and of frequent frequencies, we apply the Montanari relation (Haoues, 2008, et Rerboudj, 2005) below:

$$P_t = P_{max}\left(\frac{t}{24}\right)^b$$

P_t Rain of short duration in hour of given frequency.

b Climate exhibitor (b = 0,28).

P_{max} Maximum daily rain at given frequency.

$$P_{t(\%)} = \bar{P}_{j(\%)} \times \left(t/_{24}\right)^b$$

With:

$P_{t(\%)}$ Rainfall Frequency and Duration

$\bar{P}_{j(\%)}$ Average annual maximum daily rainfall.

t Concentration time.

b Climate exhibitor from each station.

The maximum daily rains of a given frequency are determined by the Galton relation which makes it possible to determine the maximum daily rains

$$P_{jmax} = \frac{\bar{P}_j}{\sqrt{C_v^2 + 1}} \times e^{u\sqrt{\ln(C_v^2 + 1)}}$$

$$P_{j(\%)} = \frac{\bar{P}_j}{\sqrt{Cv^2 + 1}} \times e^{u \times \sqrt{Ln(Cv^2 + 1)}}$$

For short rains (showers) of different frequencies the relationship will be as follows:

$$P_{j(\%)} = \frac{\bar{p}_j}{\sqrt{Cv^2 + 1}}$$

However:

$P_{j(\%)}$ Average daily rains estimated from the linear regression made with annual rains.

In Algeria, three relations have been adopted for that cited IN Sarvary, 1985 deduced graphically by Body in 1981 (Rerboudj, 2005).

$\bar{P}_j = 0{,}0525 \times \bar{P}_{an} + 18{,}6. \rightarrow$ relation (a)

$\bar{P}_j = 0{,}088 \times \bar{P}_{an} + 9{,}2 \rightarrow$ relation (b)

$P_j = 0{,}233 \times P_{an} + 6{,}1 \rightarrow$ relation (c)

With:

$\bar{P}_{an}$ average annual rainfall.

In our case, we take the relation (a) used in the Algerian East according to Sarvary in Sary, 1985 (Haoues, 2008, et Rerboudj, 2005).

$$\bar{P}_j = 0{,}0525 \times \bar{P}_{an} + 18{,}6.$$

For the Babar Station

$$\bar{P}_j = 0{,}0525 \times 300{,}02 + 18{,}6 = 20{,}175mm$$

Cartography

The mapping of water erosion in the Oued El-Arab watershed aims to spatialize the empirical equations of the Fournier IF index, the modified Fournier Arnoldus IFA index and the Wischmeier index. we have established erosion risk maps to determine the sensitivity of land to erosion under the influence of weather agents and to allow the location and classification of the degrees of erodibility of soils in the same physical unit.

Results

The results of calculating the erosivity indices' IF, IFA, E and R 'are shown in the following tables:

Table 1. The erosivity index 'IF, IFA, E'

Station	IF (mm)	IFA (mm)	E (t/km^2an)
Babar	06,20	29,69	32,28
El-Hamma	05,28	40,96	21,46
Kais	10,89	37,12	146,25

Table 2. Wischmeier index 'R'.

Station	Babar	Kais	El-Hamma
Altitude (m)	945	960	1125
Cv	0,38	0,29	0,19
b	0,28	0,28	0,30
$\bar{P}_{an}$ (mm)	300,02	399,91	456,57
h_1 (mm)	13,19	16,11	15,38
h_{24} (mm)	18,85	19,87	20,6
$P_{j(\%)}$ (mm)	34,35	42,56	40,59
$\bar{P}_j$ (mm)	32,11	41,81	37,34
R (t/km^2)	36,42	58,27	73,44

Table 3.Values obtained from rainfall erosivity 'IF, IFA, E, R' index

Station	R (t/km^2)	IF (mm)	IFA (mm)	E(t/km^2)
Babar	36,42	06,20	29,69	32,28
El-Hamma	73,44	05,28	40,69	21,46
Kais	58,27	10,89	37,80	146,25

The results from the calculation of the different indices suggest a variation in each station taken in isolation (Table 3), this is certainly due to the spatial variation of the elements of the climate. Indeed the basin in its configuration and its extent shows a variation according to an altitudinal and latitudinal gradient which strongly influence on the water balance. Note that the values of the IFA index are larger than those of I F; this is explained by the fact that the Fournier index (IF) only takes into account the rainfall of the wettest month. On the other hand, the Fournier Amoldus index (IFA) takes into account the monthly rainfall of all the months of the year, which makes its values a little high. On the other hand, the values of the three calculated indices, is well illustrated on the isoerosivity maps: are practically the same with very close values; on the other hand, the iso-erosivity map (figure 4) (R) presents values of the Wischmeier erosivity index totally different from the other maps. This is due to the rain on the one hand and the intercalation of more vulnerable continental formations.

The Oued el Arab watershed appears to be the least watered compared to its neighboring basins (O. Reboa, O. Labiod). The results obtained from the calculation of the different indices suggest a variation in each station, however: The Wischmeier index varies in hierarchy from 36.42 t / km^2 to 73.44 t / km^2 respectively at the El-Hamma station located at 1125m above sea level. The Wischmeier index varies in hierarchy from 36.42 t / km^2 to 73.44 t / km^2 respectively at the Babar station and that of El Hamma located at 950 m and 1125m altitude, this variation is not considerable compared to that found in the neighboring reboâ basin 96.14 - 127.77 t / km^2 (Sahraoui, 2005).

The furnace index is very low; ranges from 05.28 mm at El Hamma station to 10.89 mm at Kais station; this difference is negligible compared to that found in the neighboring Reboa basin 29.53-46.38mm (Sahraoui, 2005).

The Fournier index - Arnoldus fluctuates between 29.69 mm at Babar station at 950m altitude and 40.49mm at El-Hamma station located at 1125m altitude. But remains weak compared always to that of the neighboring basin of Reboa which is between 92.53mm and 134.29mm according to (Sahraoui, 2005).

The calculated values of the two indices of 'Fournier and Arnoldus' are quite low in all stations, which indicates the small amount of rain received by the watershed.

The erosion index of 'Fournier', although these values are low, but it shows us a diversity in its spatial distribution.

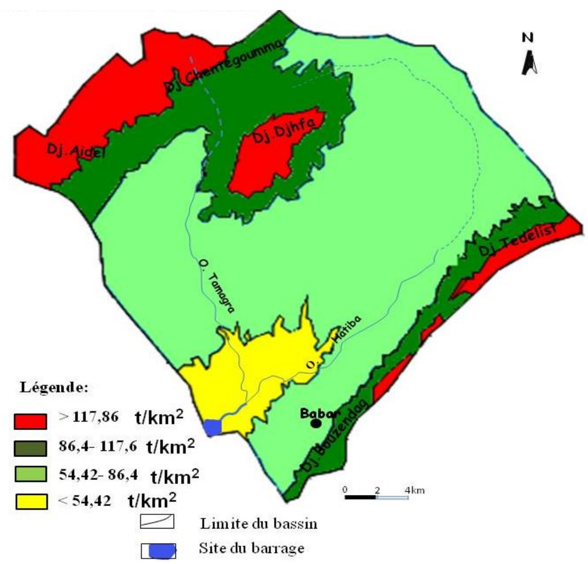

Figure 4. Erosivity index Wischmeier 'R' in the watershed of the Oued.El-arab.

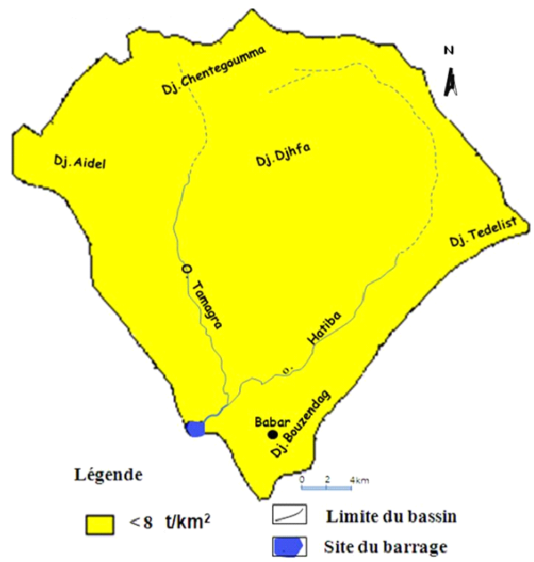

Figure 5. Erosion index 'E' in the Oued watershed. El-arab.

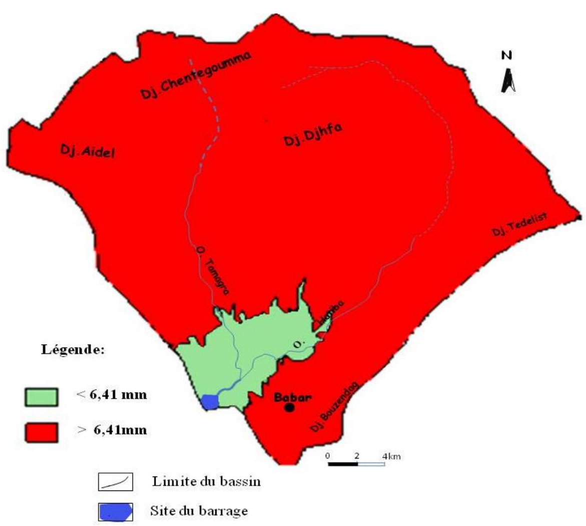

Figure 6. Fournier erosion index 'IFA' in the Oued watershed. El-arab

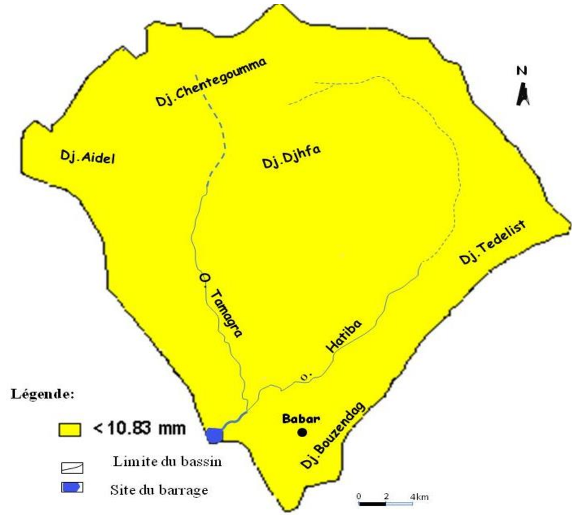

Figure 7. Arnoldus erosiveness index 'IF' in the Oued watershed. El-arab

Study of correlations

To generate and locate the spatial distribution of the erosivity indices, IF, IFA, R, E, we will be based on the simple correlation existing between these parameters such as:

$R = f(P_{an})$ et $R = f(H)$.

The results of these erosivity index correlation tests are shown in Table 4 and Figure 8 below.

Table 4. Correlation coefficient between the indices climatic, rain and altitudes

Indices	E	IF	IFA	R
P (mm)	0,078	0,046	0,994	0,998
r Altitude (m)	-0,5	-0,56	0,75	0,85

According to the correlation coefficient (r), the most acceptable relation is that of: $R, F, IFA = f(P_{an})$, but the easiest to use is the one related to altitudes. The distribution of these erosivity indices generally follows the distribution of precipitation, however the high erosivity values correspond to heavy precipitation.

Zoning of the erosivity classes was done according to altitudes, using the regression equations to estimate the value of these variables from anywhere in the study area such as: $R = 0{,}158 \times H - 104{,}18$

$IF = -0{,}0171 \times H + 24{,}68$

$IFA = 0{,}0431 \times H - 7{,}4535$

$E = 0{,}3512 \times H + 421{,}48$

Table 5. Zoning of the erosiveness classes of the indices: R, IFA.

Altitude classes	R	IFA
900 - 1000	38,56 - 54,42	31,33 - 35,64
1000 - 1200	54,42 - 86,14	35,64 - 44,26
1200 - 1400	86,14 - 117,86	44,26 - 60,34
≥ 1400	≥ 117,86	≥ 60,26

The area between 900 and 1000m responds to the risk of low erosion.
The area between 1000-1200m indicates the Djhfa plain and the piedmonts of the slopes with an average risk of erosion.
The 1200-1400m area of the piedmonts where the risk of erosion is high.
The area located on more than 1400m of the high slopes where the risk of erosion is very high over 117 t / km^2.

In 2011, the Ministry of Agriculture and Rural Development and Fisheries estimated that about 14 million hectares of mountain areas in the north of the country were degraded by water erosion. The various bathymetric surveys, carried out over the period 1986-2008 by the National Agency for Dams and Transfers on all 59 dams in operation, showed that the volume lost by siltation was 898 Mm³ or 13.4% of the total volume deductions (11_a). In general, specific erosion varies between 2000 and 4000 t / km^2 / year (3).

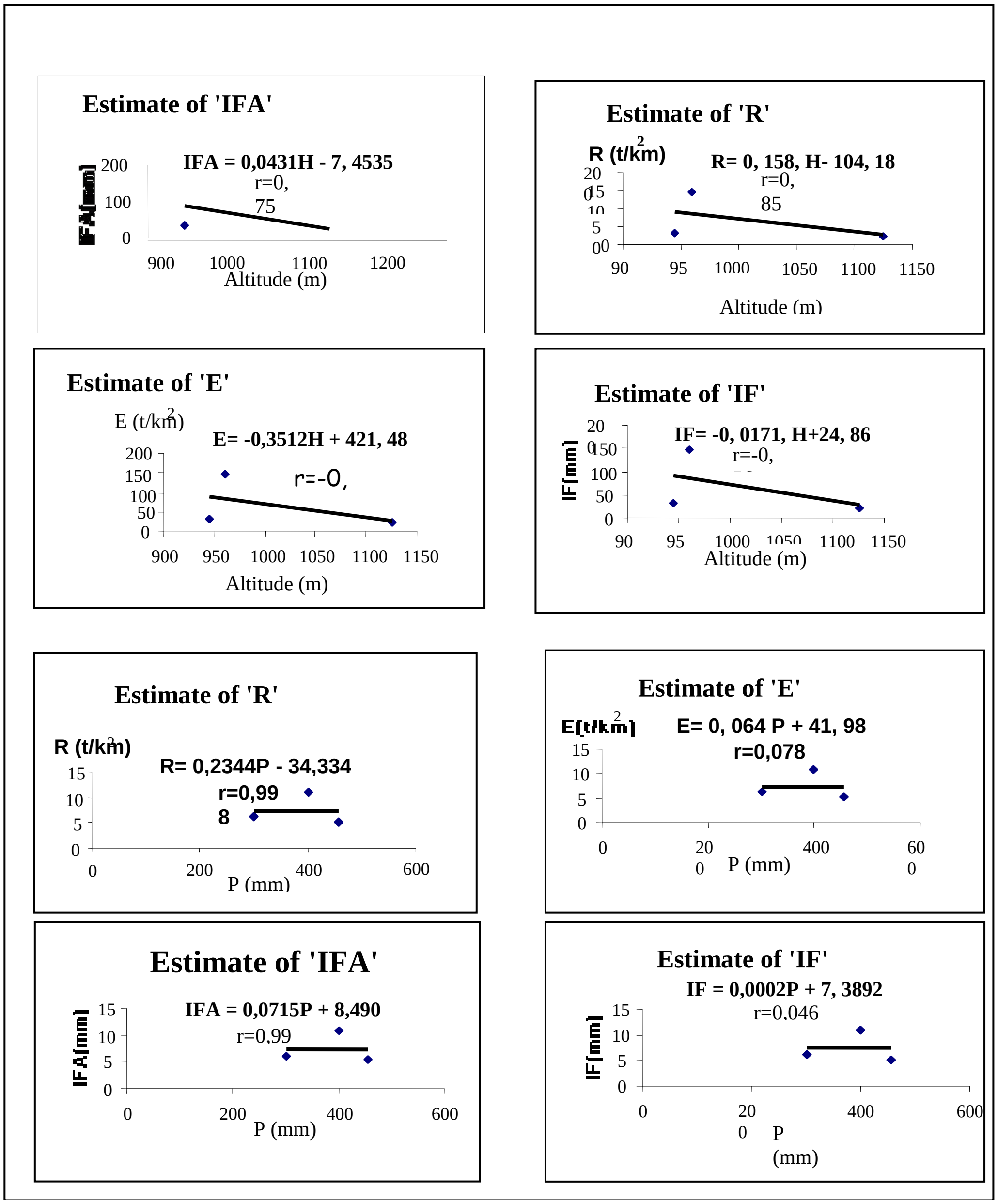

Figure 8. Estimation of rainfall erosion index

Conclusion

The use of rainfall erosion indices for the assessment and spatialization of the intensity of water erosion in the Oued El-Arab-Algeria valley allowed us to conclude:

The erosivity of the rains follows the rainfall fluctuations, and their orographic nature characterized by stormy rains, of which the watershed is distinguished by two zones: The first is the mountain sector (North-West, South –East and North -East), it is the most watered and the most affected by the aggressive effect of the rains, consequently the water erosion. The second is the central sector of the basin, which is a relatively less watered plain, which ensures that it is protected from the aggressiveness of the rains.

The increase in rainfall is considered to be a good estimator of the erosivity of rain.

The Wischmeier erosivity index appears to be the most satisfactory for predicting erosive risk across the extent of the study area. So from the sensitivity map, it is possible to obtain an estimate of the erosivity of rain on any point.

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