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SEDIMENT TRANSPORT AND RAINFALL EROSIVITY EVOLUTION IN TWELVE BASINS IN CENTRAL AND WESTERN ALGERIA

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Abstract: Soil erosion by rain and surface runoff is an important problem in the Mediterranean countries. The study of the relationship between erosion and sediment transport with hydrological and climatic factors have been conducted in many countries around the world. The aim of this work is to show rainfall impact on the variability of spatial and temporal concentration in twelve drainage basins in the west of Algeria. We will also seek to find a representative parameter of rainfall erosive potential on a Time and spatial scale. When studying sediment transport in twelve drainage basins of the Centre and the west of Algeria, we have found that the modified Fournier index Which explains much of the specific degradation compared to the Fournier index. The study of the temporal variability of the annual rainfall series, modified Fournier index and concentration of the precipitation in the year for a series from 1930 to 2007 showed a negative trend of the two variables. The annual rainfall and modified Fournier index have declined by more than 20%. This decline is more significant in inland areas.

Keywords: Sediment transport; annual rainfall; monthly rainfall; basins; western Algeria

INTRODUCTION

Soil erosion by rain and surface runoff is an important problem in the Mediterranean countries. The energy produced by rain and surface runoff added to physical factors such as climate, vegetation cover, topography and soil characteristics play a prevail role in the erosive process. This phenomenon is becoming more widespread because of the land vulnerability and the negative impact of human activities. Soil erosion becomes increasingly worrisome, causing a significant loss of arable lands and the dams siltation in the Mediterranean region (Hudson, 1991). These losses vary from one country to another: 500 to 600 million tons /year in Turkey (Celik *et al.*, 1996), 40% and 45 % of the area in Morocco and Tunisia repectevly are menaced (Chevalier *et al.*, 1995). In Lebanon, according to the FAO (1989), land loss is of the order around 50 to 70 $t.ha^{-1}.yr^{-1}$ in the Anti Lebanon Mountains. The following works (Heush *et al.*, 1970; Demmak, 1982; Meddi, 1992; Morsli, 1996; Morsli, 2012; Touaibia *et al.*, 2000; Laouina *et al.*, 2000; Roose *et al.*, 1993) have shown that erosion is very active in the Maghreb countries, which has caused large losses of soil and water resources. In Algeria, according to Gay (1995), 45% of agricultural lands has been damaged by erosion and 6 million hectares are exposed to very active erosion (Heddadj, 1997). The specific erosion varies between 2000 and 4000 $t.km^{-1}yr^{-1}$ (Demmak, 1982).

Many authors talk about the impact of rainfall on soil erosion. It is the raindrop energy that causes particle detachment. This phenomenon has been demonstrated by Wischmeier (1960) in the United States. Roose (1980) has found that rainfall energy in West Africa is 256 times more important than that of the surface runoff. According to Heush (1970), the surface runoff energy is more important than rainfall energy in the erosion phenomenon in Mediterranean and semi-arid regions. However, Meddi (1992), Meddi *et al.* (1998), Touabia *et al.* (2000) and Meddi *et al.* (2001) have shown that rainfall energy explains the erosion phenomenon better than runoff energy, in the drainage basin of wed Mina and Beni Chougrane Mountains.

The study of the relationship between erosion and sediment transport with hydrological and climatic factors have been conducted in many countries in the world such as: Zhang *et al.* (2004) in PRC, Ray *et al.* (2011) and Essien *et al.* (2011) in Nigeria, Si Ahmed *et al.* (2011) in Canada.

To show the importance of rainfall factor in the assessment of erosion, many authors have proposed various climatic erosivity indexes. In the bibliography, we refer to rainfall erosivity, such as: Arnoldus index (1977), Fournier index (1960), Martin index (1990) and Wischmeier index (1959).

Rainfall erosivity represents the interaction between the kinetic energy of rain and soil surface (Wischmeir & Smith, 1978). R factor (erosive rainfall) reflects the climatic influence in the soil erosion phenomenon (Lal, 1990, Hashim *et al.*, 2001). It has been shown that the R factor is highly related to soil loss around the world (Wischmeier & Smith, 1978; Lo *et al.*, 1985; Renard & Freimund, 1994). To estimate soil loss in a given region, the Universal Soil Loss Equation (USLE) is the most widely used (Wischmeir, 1959; Wischmeir & Smith, 1978; Renard *et al.*, 1997). The R factor of the universal equation represents the average value of annual accumulated EI30 index. The EI30 index is calculated for each rainfall event, as the product of the kinetic energy of rain (E) and the maximum intensity recorded during 30 minutes. The estimation of this index requires long series of short-term rain gauge measures (Wischmeir & Smith, 1978). The absence of this kind of data has led many researchers to develop relationships for the estimation of this factor through annual or monthly rainfall. Many relationships have been established to calculate the R factor according to annual and monthly rainfall (annual rainfall, Fournier index, modified Fournier index) around the world (Roose, 1977; Renard & Freimund, 1994; Touabia, 1999; De Luis *et al.*, 2010; Diodato *et al.*, 2007; Torri *et al.*, 2006); Yang *et al.*, 2003; Loureiro *et al.*, 2001; Ufoegbune *et al.*, 2011; USDA-ARS, 2008). Yu *et al.*(1996) and Renard *et al.* (1994) have shown that in Australia and the United States respectively, the annual rainfall is highly correlated with the R factor. In Algeria, Touabia *et al.* (2009) found a good correlation between monthly rainfall and the R factor. However, in Morrocco, Kalman (1970) has associated the maximum daily rainfall to annual rainfall to develop a relationship calculating the R factor like the Med REM model in Italy (Diodato, 2004 et 2005). The close relationships between Fournier index (1960) or the modified Fournier index of Arrnoldus (1977) and the R factor (rainfall erosivity) of the universal equation (USLE) has been found in many studies (Renard & Freimund, 1994; Diodato *et al.*, 2007; Rowntree, 2002; Morgan, 1986; Meddi, 1992; Coutinho & Tomas, 1994; Cohen *et al.*, 2005; Oduro-Afriyie, 1996; Silva, 2004). To introduce the seasonal effect of rainfall, Natalia (2005), in Colombian Andes, has developed two distinct models, one for the wet season and the other for the dry season. In the Mediterranean countries, this approach has been used to develop a representative formulation of rainfall aggressivity instead of the R factor of the universal equation (Coutinho & Tomas, 1994 in southern Portugal; Touabia, 1999 in Algeria; Kalman (1970) in Morocco; De Luis *et al.*, 2010 in Spain; Diodato, 2004 and 2005 in Italy, Torri *et al.* (2006) in Italy).

When studying the erosion phenomenon in a micro drainage basin in a semi-arid area, Laadjali *et al.* (1990) have found that WISCHMEIER climatic aggressivity index, total rainfall and surface runoff influence the erosion phenomenon. But this index comes in second place in terms of efficiency in the explication of erosion, after the total rainfall. When studying the erosion in the Marne Massif (France) on a monthly scale, Martin (1990) has found a small connection between soil losses and WESCHMEIR index. The total rainfall does not explain erosion at all, given the scale of rainfall irregularity in the year and its high variability in space. We should therefore view the seasonal rainfall variability involving an index which takes into account the monthly rainfall concentration as well as the daily precipitation frequencies at a given threshold. The aim of this work is to show rainfall impact on the variability of specific degradation in twelve drainage basins of center and west Algeria (**Fig. 1** and **Table 1**). We will also seek to find a parameter representative of rainfall erosive potential, among the annual rainfall, monthly rainfall of the wettest month, Fournier index and the modified Fournier index, on a temporal scale (for every basin).

In a second step, we will study the temporal and spatial evolution of the factors representing the rainfall aggressivity and the monthly concentration of rainfall CPI (Oliver, 1980).

MATERIALS AND METHODS

Presentation of the study area

The studied area has an extension of about 133.500 km^2, is located between 34°18′54″ and 36°48′12″ North latitude and 2°10′10″ and 3°10′11″ East longitude and covers three of the North West Algeria larger basins, the Algeries Coastal, Cheliff and the Oranie basins (**Fig. 1**). This region corresponds to the center of what geographers call the Maghreb. The studied area is characterized by a large physiographic and climatic variability: it is bounded from the Saharan Atlas in the southern part and, moving through the high plains, the Tellian relief, the Mtidja, Cheliff and Oran valleys and the coastal mountain ranges, comes to the northern boundary, the Mediterranean Sea.

Relief

The physical setting of the study area is characterized by the heterogeneity of the large natural units. The Tellian Atlas in the west is more divided and less imposing than that of the east. The High Plains in West Algeria are more arid than those in the East. The region can be subdivided in five different orographic groups: coastal relief; inland plains and basins, mountains and plateaus, the Tellian Plateaus and the high plains (**Fig. 1**). The hills of Oran which extend from Ain-Temouchent to Arzew Mountains, crossing the Djebel Murdjadjo form the coastal relief, where the altitude ranges from 300 to 650 m with a south-west to north-east orientation.

The massif that extends from Traras to the Ouarsenis (350 to 800 m) is an obstacle to maritime influences, their distance from the Mediterranean Sea ranges from 20 to 70 Km. the inland plains, i.e., Maghnia Plain (400 m), Sidi Bel-Abbes Plain (470 m) and Ghriss plain (between 400 and 600 metres) are located in the piedmont of the Tellian Plateaus. We can also distinguish the Mohammadia Plain and the Cheliff Plain in the east (between 60 and 150 m of altitude) with a length of about 190 km. The Tellian Plateaus are expanded between the Mina high basin and the Moroccan border, at a distance of 300 km. These plateaus (with heights ranging from 900 to 1600 m) dominate the inland basins and slope to the High Steppes (Medjrab, 2005).

Climate and rainfall variability

The northern part of Algeria is characterized by a Mediterranean climate with a relatively cold and rainy winter and a hot and dry summer. The annual rainfall reaches 400 mm in the west, 700 mm in the centre and 1000 mm in the east for the coast. This type of climate is also found in the Tellian Atlas chains where we record totals ranging from 800 to 1600 mm in the eastern summits, while the values are lowered in the centre (700 to 1000 mm) and in the west (600 mm). In the plains of the Tellian Atlas, rainfall varies between 500 mm in the west, 450 mm in the centre and 700 mm in the east. The climate of the Saharan Atlas is very hot and dry in summer and mild in winter with lower rainfall compared to the north, owing to its distance from the sea (Meddi, 2001; Meddi & Meddi, 2002). These rainfall averages were calculated on the basis of 218 stations with observation periods from 1968 to 1998. A comparative study (Meddi, 2001) with the map of the National Agency of Water Resources made by Laborde (1993) shows a drop of 13% in the

Table 1. Characteristics of the studied drainage basins

Drainage basins	Stations	Surface (km^2)	Altitude max (m)	Altitude min (m)	Annual Rainfall (mm)
Taht	Kef Mahboula	680	1250	475	333.3
Haddad	S.A. Djilali	470	1160	225	263.2
Chouly	Chouly RN7	170	1616	720	453.4
Isser	Bensekrane	1230	1616	247	392.8
Isser	Remchi	1930	1616	85	624.3
Tikazale	Tikazale	588	1650	100	323.7
Sikkak	Ain Youcef	218	1400	200	384.8
El Harrach	Baraki	970	1629	20	653.8
Mazafran	Fer à Cheval	1900	1629	10	457.5
Bouroumi	Attatba	680	1530	40	504.3
Belah	Pont RN11	55	736	25	585.0
Allalah	Sidi Akacha	295	996	80	503.0

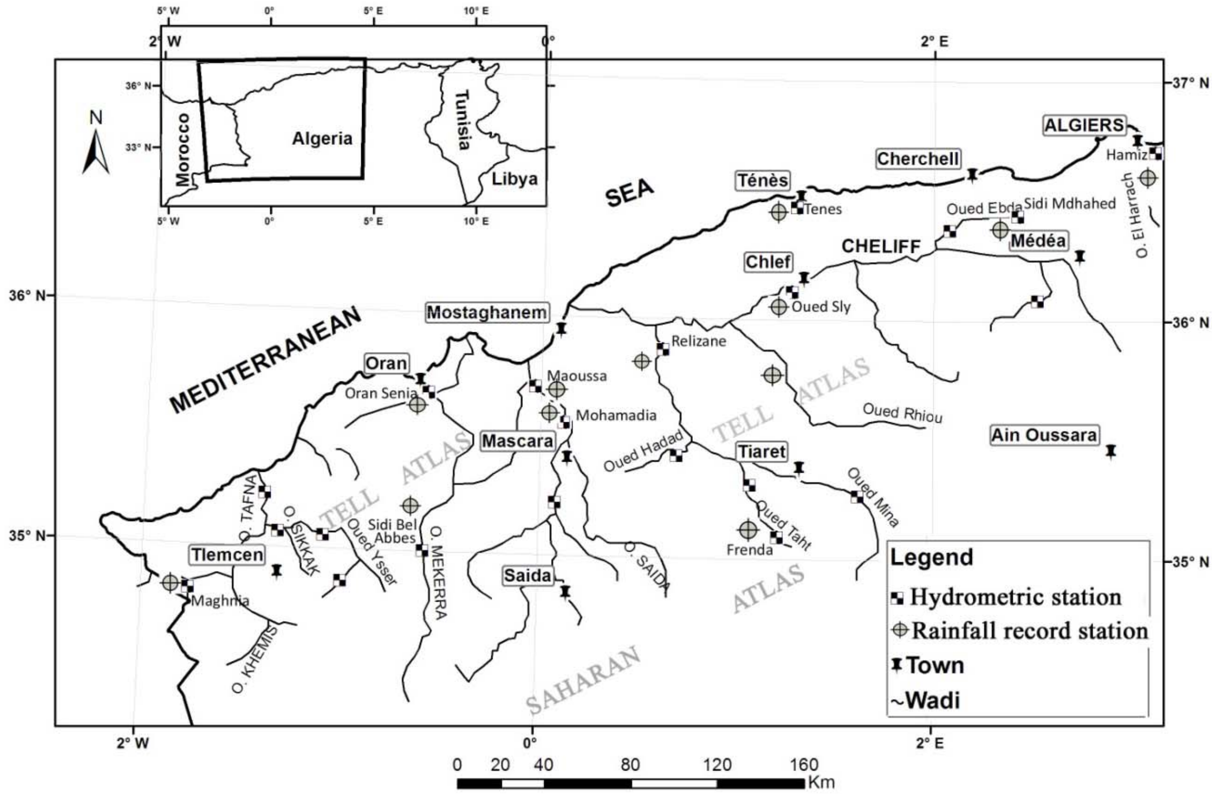

Fig. 1 Studied zone.

annual average rainfall after 1975 in the centre and the west of Algeria. The annual average of the totals precipitated ranges between 311 mm in the station of Bouhanifia dam (west) and 755 mm in the station of Medea (centre).

Rainfall Regime of the Studied Region

The annual rainfall in the study area varies from 263 to 654 mm. It is concentrated during the cold season (November to April). January is the wettest month of the hydrological year. Rainfall amounts are extremely variable from one year to the next. Interannual rainfall variability was very high in 1969, the annual rainfall was 771.4 mm, while in 1983, we have recorded just 129 mm in Mascara station. The monthly precipitation is also very irregular and generally concentrated in a few days of the wettest months, resulting in drought periods during the rainy season. About half of the annual rainfall takes place in 25 to 30 days during the months of November, December and January (Benchetrit, 1972). This rainfall never lasts more than a few hours and represents therefore almost all the torrential rains, whose intensity exceeds 30 mm in two hours or 20 mm in two concentrated hours (Benchetrit, 1972). In 70 torrential rains observed in Mascara from 1913 to 1938, 53 occurred in winter (Seltzer, 1946). Precipitation of the end of summer and autumn represents the most dangerous rain for soil preservation; this rain is brought by storms from a northerly and north-westerly direction (Meddi, 1992).

MATERIAL, METHODS AND DATA

The data used come from the two organizations responsible of rainfall network, i.e., the National Agency of Water Resources (N.A.W.R) and the National Meteorological Office (NMO).

The available pluviometric data are very heterogeneous in terms of measurement reliability and observation series duration (Laborde, 1993).

In this series of weather data, errors may occur for many reasons (floppy read error, posting error, equipment derating, etc. The lack of information is mainly concentrated during the period 1961-1968.

During the data processing, some values appear to be singular compared to the rest of the time series. The existence of outliers can lead the climatologist to misinterpretations.

We have tried to identify a maximum of measuring stations satisfying the following conditions:

- Information covering the last six decades
- Not more than five consecutive years of gaps
- Less than 10% of gaps in the whole series on the monthly scale

Measurements of sediment transport in Algeria are systematic taking of water samples using a bottle with a capacity of 500 cl. These samples are taken at a single point on the edge or in the middle of the river. The samples are more numerous during floods, while, in low water level or when the flow is constant during the day, one sample is taken. The difficulty of the measurement is the non-uniformity of the concentration of sediment in the measurement section.

This measurement technique allows a study of temporal variation of the sediment transport, as well as the influence of climatic and morphometric factors, and the establishment of graphs or mathematical models to estimate the annual sediment.

In the first part of the work, we took the specific degradation (ton ha^{-1} yr^{-1} as dependent variable. The explanatory factors are: The annual rainfall (Pan) in mm, Fournier index and the Modified Fournier index to choose the best factor, characterizing the aggressivity of the rainfall, could explain the variability of sediment transport.

We have tried to take the longest possible observation series of the parameters studied. The gaps observed in the hydrometric series and sediment transport after 1990 has forced us to work on the period prior to that date. Therefore, the selected period is from 1966/67 to 1989/90 (24 years).

In the second part of the work, which consists in the temporal monitoring of rainfall aggressivity, twelve rainfall stations representing studied basins were selected with a long observation period from 1930 to 2007.

The statistical analysis of annual and monthly precipitation series and all the researches have been done on rainfall amounts of the year that begins on September 1^{st} of the year K and ends on August 31^{st} of the year K+1. To check the representativeness of the selected period in terms of daily rainfall exceeding a threshold, Fournier (1960) defined a rainfall distribution index (FI), as the ratio between rainfall for the wettest month of the year (pm) and the annual precipitation (Pan) using Eq. 1 (see also **Table 2**):

$$FI = \frac{p_m^2}{P} \quad (1)$$

Arnoldus (1980) showed that the correlation between Fournier index (FI) and EI30 is poorly. Based on this result, he proposed the modified Fournier index (MFI) taking into account precipitation of all months of the year (**Eq. 2**, see also **Table 3**). The modified Fournier index (MFI) is defined as:

$$MFI = \frac{\sum_{i=1}^{12} p_i^2}{Pan} \quad (2)$$

Table 2. Conceptual scale for assessing the Fournier index (Oduro-Afriyie, 1996)

Class	Soil Loss (t/ha/yr)	Fournier Index	Erosion risk
1	< 5	< 20	Very Low
2	5 – 12	21 – 40	Low
3	12 – 50	41 – 60	Moderate
4	50 – 100	61 – 80	Severe
5	100 – 200	81 – 100	Very Severe
6	> 200	> 100	Extremely Severe

According to Arnoldus (1980) the MFI index is a good approximation of rainfall arosivity factor (R) to wich it is linearly correlated. The classes of this index proposed in CEC (1992) are summarized in the **Table 3**.

Precipitation concentration index (PCI), proposed by Oliver in 1980 expresses the seasonal and annual variability of precipitation in %. The low values of PCI indicate a uniform distribution of precipitation during the year. However, the high values represent either high concentration of monthly rainfall or seasonality. It is written as follows:

$$PCI = \frac{\sum_{i=1}^{12} P_i^2}{\left(\sum_{i=1}^{12} P_i\right)^2} \quad (3)$$

The theoretical limits of the PCI are (Lobo & Gabriels, 2005): (a) when precipitation of each month of the year are the same, this index is equal to 8.3, and (b) when all the precipitation of the year occurs in a single month, the PCI is equal to 100.

Oliver (1980) has compiled the following ranges to characterize the nature of the monthly rainfall distribution in the year (**Table 4**). Oliver (1980), Michiels (1992) and showed that the PCI was appropriate to evaluate and compare the concentration of rainfall between rainfall stations.

RESULTS AND DISCUSSION

Relation Between Solid Transport and Pluviometry

To show the relevance of using one of the two indices that characterizes rainfall aggressivity, twelve basins of central and western Algeria were selected. The correlation between the modified Fournier index and specific degradation, on an annual scale, is better Compared to the coefficient with the Fournier index for all studied basins (**Table 5**). The variance explained varies between 37% and 83%. This relationship is more pronounced in the extreme west.

Table 3. Classes of MFI (CEC, 1992)

Class	Description	MFI range
1	Very low	< 60
2	Low	60 – 90
3	Moderate	90 – 120
4	High	120 – 160
5	Very High	> 160

Table 4. Conceptual scale to evaluate the PCI index (Oliver (1980)

Class	PCI	Concept
1	0.8 –10	Uniform
2	11 – 15	Moderately seasonal
3	16 – 20	Seasonal
4	21 – 50	Highly seasonal
5	51 – 100	Irregular

Table 5. Correlation coefficient (specific degradation – explanatory variables)

Stations			FI	MFI	Stations			FI	MFI
Bensekrane	Extreme West	r	0.57	**0.65**	Tikazale	West	r	0.43	**0.70**
		r^2	0.33	**0.42**			r^2	0.19	**0.49**
Chouly	Extreme West	r	0.54	**0.84**	Pont RN11	Center	r	0.45	**0.71**
		r^2	0.29	**0.71**			r^2	0.20	**0.50**
Remchi	Extreme West	r	0.84	**0.91**	Sidi Akacha	Center	r	0.56	**0.61**
		r^2	0.71	**0.83**			r^2	0.32	**0.37**
Ain Youcef	Extreme West	r	0.33	**0.64**	Fer a Cheval	Center	r	0.69	**0.85**
		r^2	0.11	**0.41**			r^2	0.48	**0.72**
Sidi Aek Djilali	West	r	0.53	**0.70**	Attatba	Center	r	0.68	**0.80**
		r^2	0.28	**0.49**			r^2	0.46	**0.64**
Kef mahboula	West	r	0.13	**0.81**	Baraki	Center	r	0.39	**0.64**
		r^2	0.02	**0.66**			r^2	0.15	**0.41**

r = Correlation coefficient. r^2 = Coefficient of determination

Besides, it should be noted that rainfall cannot explain the specific degradation variability, it is therefore necessary to involve runoff and physical factors of the drainage basin: lithology, vegetation cover and morphometry.

Therefore, the rainfall aggressivity, represented by this index, explains a large part of the variance of the specific degradation in the western and center part represented by twelve basins (**Table 5**). Meddi (1992) when studying the phenomenon of sediment transport in the Wadi Mina watershed, found that the modified Fournier index significantly increases the multiple correlation coefficient of the variables explained, i.e., the turbidity and the specific degradation in this part of Algeria. Generally, the stormy rains of the autumn season are responsible for this phenomenon (Meddi, 1992). These results can be explained by the fact that this rainfall contributes to erosion and sediment transport. After a long dry season characterized by high temperatures, rainfall of the wettest month causes the destruction of soil aggregates. The surface runoff facilitates the transport of detached particles. These results are consistent with those found in Algeria (Meguenni & Remini 2008); Italy (Ferro *et al.*, 1999); Morocco (Sadiki *et al.*, 2004; Elbouqdaoui *et al.*, 2005; El Garouani *et al.*, 2008), Australia (Yu *et al.*, 1996), Chile (Olivares *et al.*, 2011) and Iran (Kiassari, 2012), where the modified Fournier index was used instead of the R factor that represents rainfall erosivity to explain the phenomena of erosion and sediment transport. Annual rainfall also plays an important role in explaining these two phenomena for the basins of the centre of the country.

In a second part, the temporal evolution of annual rainfall, modified Fournier index and precipitation concentration will be analyzed. For northern Algeria, rainfall deficit has started synchronously from 1975 (Meddi & Hubert, 2003; Meddi *et al.* 2010). We have distinguished two periods: a relatively wet period before 1975 and a dry period after this year. The interannual fluctuation of rainfall is characterized by a wet period from 1930 to 1975 followed by a deficit period from 1975 to 2007. We have noticed, for the period ranging from 1930-1975, that all stations had more than 50% of surplus years, while from 1976 to 2007 all stations had more than 70% of deficit years, these deficits vary from one station to another with different proportions.

Regarding annual rainfall, a reduction is observed for all stations (**Table 6**, **Fig. 2**). This decrease exceeds 20%. It is higher than 30% for the interior stations in the west of the country, i.e., the plain of Ghriss (Maoussa station) and Sidi bel Abbes plain (station of Sidi bel Abbes). The question that arises is: did this lowering of annual rainfall influence the temporal evolution of indices representing the rainfall erosivity?

The rainfall of the stations representing the centre of the country have a moderate to high erosion potential for the entire period and before 1975, according to the modified Fournier index. After 1975, it is moderate. For the western region, this potential, according to the same index, is low and it turned to a very low after 1975 with a decrease in annual rainfall (**Table 6** and **Fig. 2**).

The reduction of this index after 1975 is in the same proportion as the annual rainfall. Based on the values taken by this index, which is considered as an indication of erosivity, the rainfall of the centre are more aggressive than those of the West (**Table 6** and **Fig. 2**).

This aggressivity also decreases with the reduction of total rainfall recorded after the change in the rainfall regime observed in Algeria and the Maghreb and Mediterranean countries (Meddi & Hubert, 2003; Meddi *et al.* 2010; Sebbar *et al.*, 2011; Yesilırmak *et al.* 2008; Costa *et al.* 2009; Caloiero *et al.* 2009). This rainfall trend in our region has been linked to global warming and changes in the pressure gradients between the Azores and Iceland (Houghton *et al.*, 2001) and ENSO phenomenon (Meddi *et al.*, 2010).

In contrast to these findings, in Spain, some increase (8.8%) of the modified Fournier index (MFI) was observed in the Central Pyrenees, the region of Valencia and Andalusia (De Luis *et al.*, 2010). However, our results are consistent with those found in the central basin of the Ebro (Angulo-Martınez & Begueria, 2012).

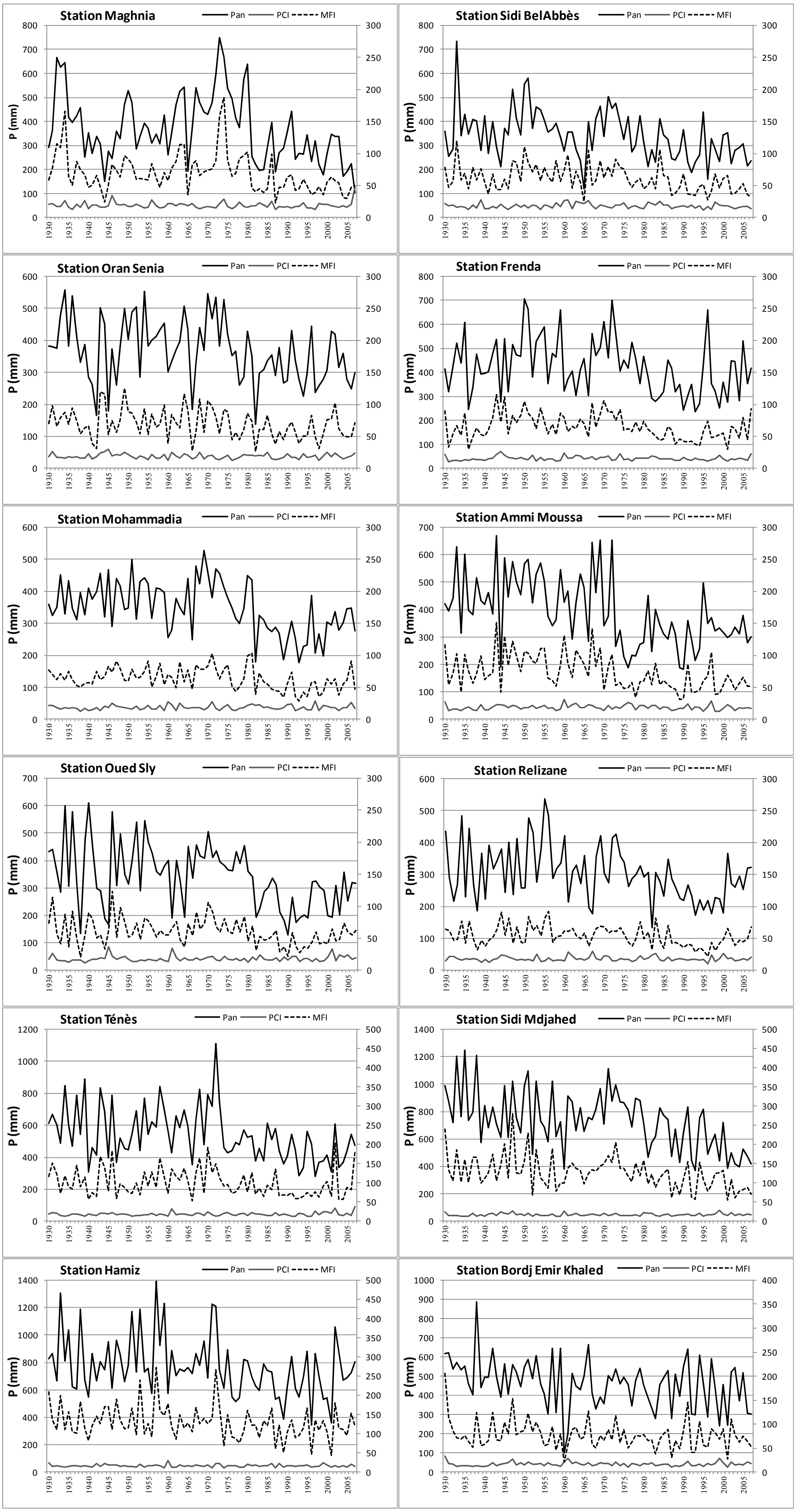

Fig. 2 Temporal evolution of the annual rainfall (Pan), MFI and PCI.

Generally, daily rainfall of certain thresholds is responsible for the solid particles detachment. Demmak (1982) and Meddi (1992) have shown that rainfall of a threshold greater than 30 mm are responsible for soil loss in Algeria.

Many researchers have shown the danger of rainfall from certain thresholds such as Lavabre and Martin (1997) in the Maure Massif (France) where they have selected the daily rainfall exceeding 20 mm. To check the temporal evolution of the number of rainy days above three thresholds (10, 20 and 30 mm) in the study area, we have considered two rainfall stations with series from 1940 to 2007 (we chose these two stations for the availability of data on this scale). The figures n°3 shows a reduction in the number of rainy days for the three thresholds from the mid-1970s, especially for the station of Bouhanifia (west of Algeria). These results are consistent with those of the annual rainfall in the west of Algeria. We note that the selected period is not significantly different from the whole period or the period that comes after 1990 (Figure 3). The selected series include much of the years characterized by rainfall decrease and the number of rainy days exceeding the thresholds of 10, 20 and 30 mm. This change in rainfall regime has caused an acceleration of erosion in the Mediterranean basins (Joftic *et al*., 1992; Shabanet *et al*., 1998; Bou Kheir *et al*., 2001). Therefore, we believe that the chosen study period is representative of the hydrological and climatic regime of the region.

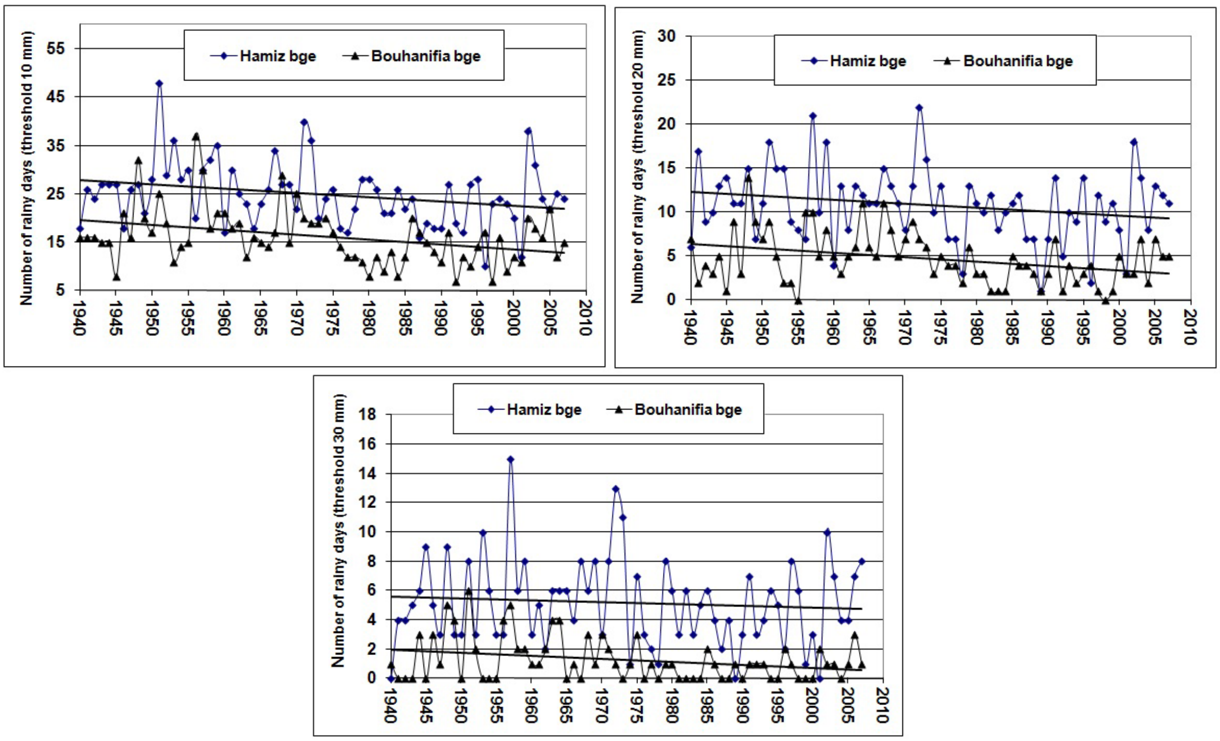

Fig. 3 Number of rainy days at the thresholds of 10, 20 and 30 mm in the stations of Hamiz dam (centre) and Bouhanifia dam (west).

The nature of the monthly rainfall distribution in the year did not change after the break in the stationarity of annual rainfall series since 1975 (Table 6 and Figure 2). The distribution is seasonal for all stations where the PCI is between 16 and 20 for the three cases (entire period, period before 1975 and period after 1975). PCI values are comparable to those recorded in the South East of Spain (De Luis *et al*., 2010).

The impact of climate change on erosion can be expressed by the change in the erosive power of rainfall (Nearing, 2001) and the change in the plant biomass (Pruski & Nearing, 2002). The decrease of total precipitation and the indices representing rainfall aggressivity should not be interpreted as a decrease of erosion risk, because the process of soil erosion is closely linked to the dynamics of vegetation, soil surface state and watershed geomorphology. The western regions of Algeria have experienced a very significant drought since 1975. Therefore, the impact of reduced rainfall directly affects the vegetation cover. This is the phenomenon that occurred in western Algeria, where the poor vegetation cover accelerated the phenomena of erosion and sediment transport.

CONCLUSION

Rainfall erosivity, considering total rainfall or indices representing rainfall aggressivity, is an important parameter for soil erosion prediction under climate change. Despite its importance, rainfall erosivity is usually used in models when studying the relationship among rainfalls, as an explanatory factor of temporal or spatial variability of the specific degradation. In our study, twelve basins of central and western Algeria were used to determine the best parameters characteristics of rainfall to explain the variability of the specific degradation. Among the parameters Selected (the annual rainfall (Pan) in mm, Fournier index and the Modified Fournier index), we found that the modified Fournier index explains much of the total variance of this specific degradation for all the studied basins. On the basis of these results, the study of the temporal and spatial evolution of this factor in addition to the evolution of the precipitation concentration in the year was studied. The annual rainfall decreased after 1975, considered as the breaking date in the stationarity of annual rainfall series, by more than 20% for all stations of the centre and western of Algeria.

Table 6. Temporal variability of Annual Rainfall (Pan) in mm, FI, MFI and PCI

Stations		Pan	MFI	PCI
Tenès	Total 1930-2007	542,6	99,7	18,5
	Before 1975	612,8	109,3	17,9
	After 1975	446,9	86,6	19,4
	Difference (%)	**-27,1**	**-20,8**	**8,6**
Hamiz	Total 1930-2007	770,3	129,8	16,9
	Before 1975	843,3	142,2	17,0
	After 1975	670,8	112,9	16,7
	Difference (%)	**-20,4**	**-20,6**	**-1,3**
Sidi Mdjahed	Total 1930-2007	732,8	126,1	17,3
	Before 1975	820,2	141,9	17,4
	After 1975	613,7	104,5	17,2
	Difference (%)	**-25,2**	**-26,3**	**-0,9**
Oued Sly	Total 1930-2007	342,4	60,0	18,0
	Before 1975	387,2	66,8	17,7
	After 1975	281,2	50,7	18,4
	Difference (%)	**-27,4**	**-24,2**	**3,7**
Relizane	Total 1930-2007	302,5	53,6	18,0
	Before 1975	333,4	59,0	18,2
	After 1975	260,3	46,2	17,8
	Difference (%)	**-21,9**	**-21,7**	**-2,1**
Frenda	Total 1930-2007	424,6	65,1	15,5
	Before 1975	462,4	72,8	16,0
	After 1975	373,1	54,7	14,9
	Difference (%)	**-19,3**	**-24,8**	**-6,9**
Maoussa	Total 1930-2007	393,4	73,3	18,7
	Before 1975	458,7	86,3	18,9
	After 1975	304,4	55,6	18,5
	Difference (%)	**-33,6**	**-35,6**	**-1,8**
Mohammadia	Total 1930-2007	347,2	63,7	18,5
	Before 1975	386,9	69,7	18,3
	After 1975	293,0	55,4	18,8
	Difference (%)	**-24,3**	**-20,5**	**2,8**
Oran Senia	Total 1930-2007	366,2	69,1	18,9
	Before 1975	400,3	76,0	19,0
	After 1975	319,6	59,6	18,7
	Difference (%)	**-20,2**	**-21,5**	**-1,9**
Sidi Bel Abbès	Total 1930-2007	341,6	60,7	18,0
	Before 1975	379,1	68,1	18,3
	After 1975	290,6	50,7	17,5
	Difference (%)	**-30,5**	**-34,3**	**-4,6**
Maghnia	Total 1930-2007	367,8	68,4	18,9
	Before 1975	411,2	78,2	19,1
	After 1975	308,7	55,0	18,7
	Difference (%)	**-24,9**	**-29,6**	**-2,2**

The Modified Fournier Index (MFI) has also decreased with proportion similar to the annual rainfall. The decrease of annual rainfall and the number of days superior to 10, 20 and 30 mm and the index representing the rainfall aggressivity should not be interpreted as a decrease of erosion risk because the process of soil erosion is closely linked to the dynamics of vegetation. The structure of the rainfall year did not change, after this date, and the decrease or increase was low.

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