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Study of Sediment Transport in Ten Basins in the West of Algeria

Mohamed Meddi
LGEE – Ecole Nationale Supérieure d’Hydraulique – Algérie,

Capacity of some Algerians dams in the year 2010 by Remini.B, in 2000

Dams	Initial Capacity (10^6 m^3)	Amount of silt in 2010 (10^6 m^3)
Fergoug	18	31
Zardezas	31	37
Oued El Fodda	228	82
Ghrib	280	227
K'sob	11.6	11.1
Foum El Gherza	47	39.5

Simulation of the silting of the Oued EBDA Dam with the model of ORTH

- ✓ In the case where the dam was carried out in 1970, the siltation rate would be 79% in 2015
- ✓ In the case where the dam was carried out in 1980, the siltation rate would be 60% in 2015
- ✓ In the case where the dam was carried out in 2000, the siltation rate would be 28% in 2015

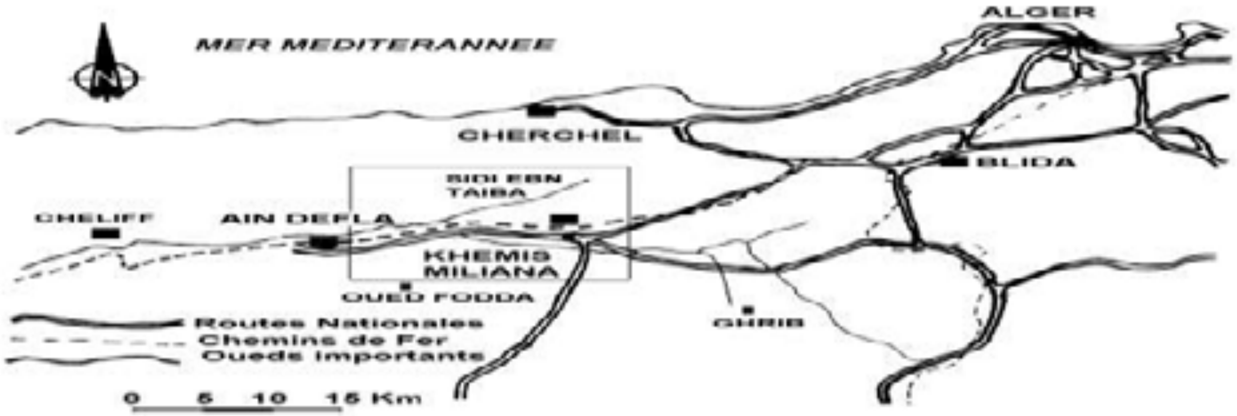
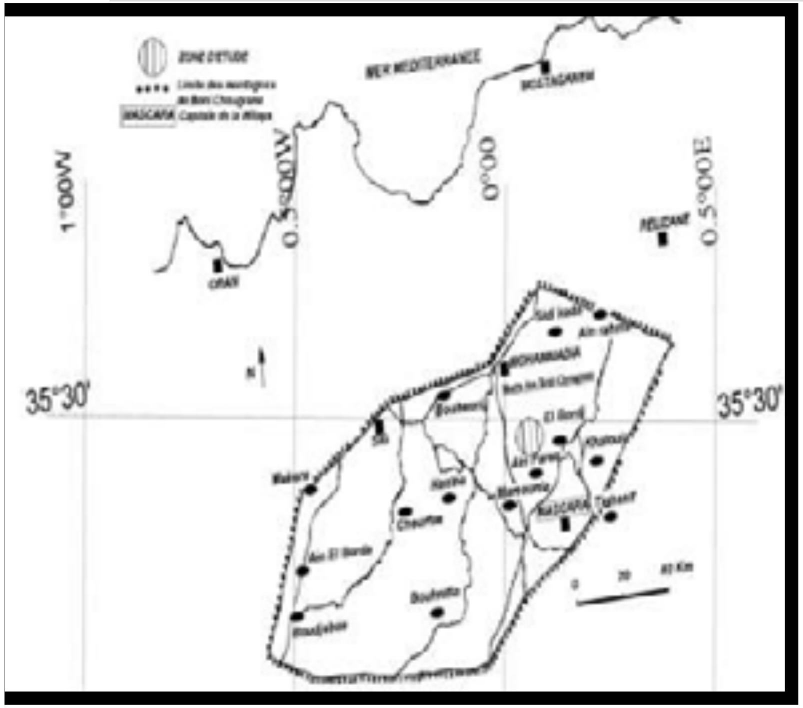


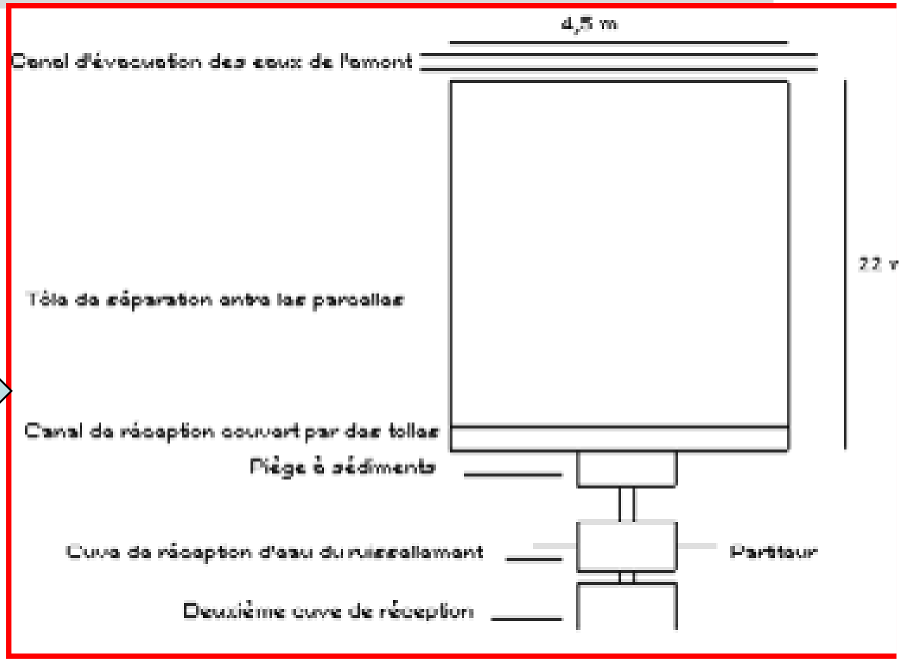
Table 2 Expressions retenues donnant la dégradation spécifique (t km^{-2} an^{-1}) en fonction du débit liquide (m^3 s^{-1}) et de la superficie (km^2) à l'échelle annuelle.

Données retenues	Expressions	Coefficient de corrélation	Erreurs*
Algérie = barrages (18) +stations hydrométriques (50) Maroc = barrages (16) Tunisie = barrages (11) $N = 95$	$Ds = 3286.24\ Ql^{-0.234}\ S^{-0.197}$	0.82	37.5% < 5% 62.5% < 10% 100% < 20%
Algérie = barrages (18) Maroc = barrages (16) Tunisie = barrages (11) $N = 45$	$Ds = 3754.09\ Ql^{-0.34}\ S^{-0.142}$	0.89	35.48% < 5% 74.19% < 10% 100% < 20%
Algérie = barrages (18) +stations hydrométriques (50) $N = 86$	$Ds = 9313.31\ Ql^{0.079}\ S^{-0.548}$	0.77	26.67% < 5% 53.33% < 10% 90% < 20%
Maroc = barrages (16) Tunisie = barrages (11) $N = 27$	$Ds = 31697.72\ Ql^{0.204}\ S^{-0.527}$	0.84	44% < 5% 68% < 10% 100% < 20%
Algérie = barrages (18) Maroc = barrages (16) $N = 34$	$Ds = 9802.57\ Ql^{-0.469}\ S^{-0.212}$	0.84	38.46% < 5% 65.38% < 10% 96.15% < 20%
Algérie = barrages (18) Tunisie = barrages (11) $N = 29$	$Ds = 31697.72\ Ql^{-0.26}\ S^{-0.242}$	0.82	24% < 5% 44 % < 10% 92% < 20%

* 37.5% des résidu ont une valeur < 5%,
62.5% des résidu ont une valeur < 10%,
100% des résidu ont une valeur < 20%.

EXPERIMENTAL PLOTS IN THE MOUNTAINS OF BENI – CHOUGRANE (WEST OF ALGERIA)





**** Sol brun calcaire sur grès (limoneux)***

Lr = 0,09 P +0,03 IPA – 0,52 avec N = 69 R^2 = 0,68 et R =0,83

Es = 27,64 P – 10,59 IPA + 44,19 avec N = 49 R^2 = 0,37 et R = 0,61

Es = 219,59 Lr – 14,13 IPA + 225,87avec N = 39 R^2 = 0,33 et R = 0,57

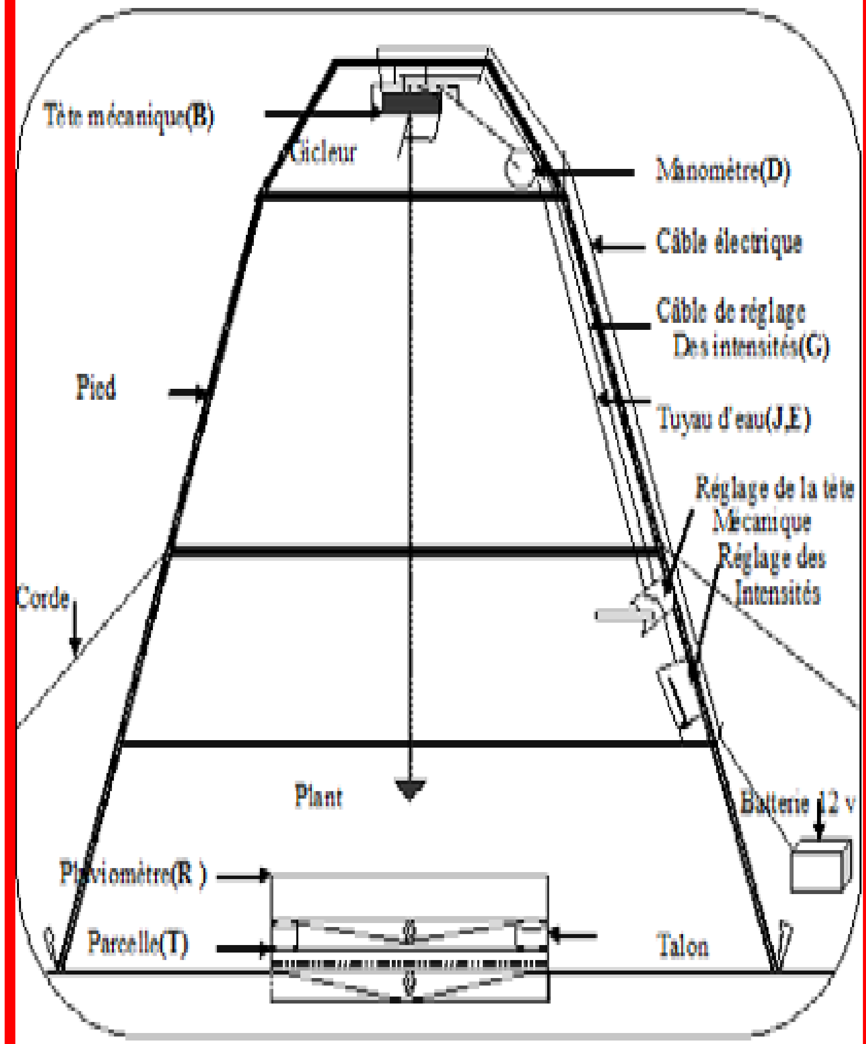
**** Sol brun vertique sur marne (argileux)***

Lr = 0,09 P +0,02 IPA -0.34 avec N = 69 R^2 = 0,61 et R = 0,78

Es = 23,12 P – 9,78 IPA + 77,64 avec N = 43 R^2 = 0,39 et R = 0,62

Es = 187,73 Lr – 11,13 IPA + 209,79avec N = 43 R^2 = 0,34 et R = 0,59

Rainfall Simulator



Parcelles	Intensités	Pentes	Etats d'humidités		
			Sec	Humide	T. humide
1	30	12.5		28 %	34 %
2	50			30 %	32 %
3	80			29 %	34 %
4	30	25.0		30 %	35 %
5	50			29 %	33 %
6	80			28 %	34 %

- To check the representativeness of the selected period in terms of daily rainfall exceeding a threshold, we have considered two rainfall stations with series from 1940 to 2007. The figures show a reduction in the number of rainy days for the three thresholds from the mid-1970s,. These results are consistent with those of the annual rainfall in the west of Algeria that showed a significant reduction from that date. we note that the selected period is not significantly different from the whole period or the period that comes after 1990. 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. Therefore, we believe that the chosen study period is representative of the hydrological and climatic regime of the region.

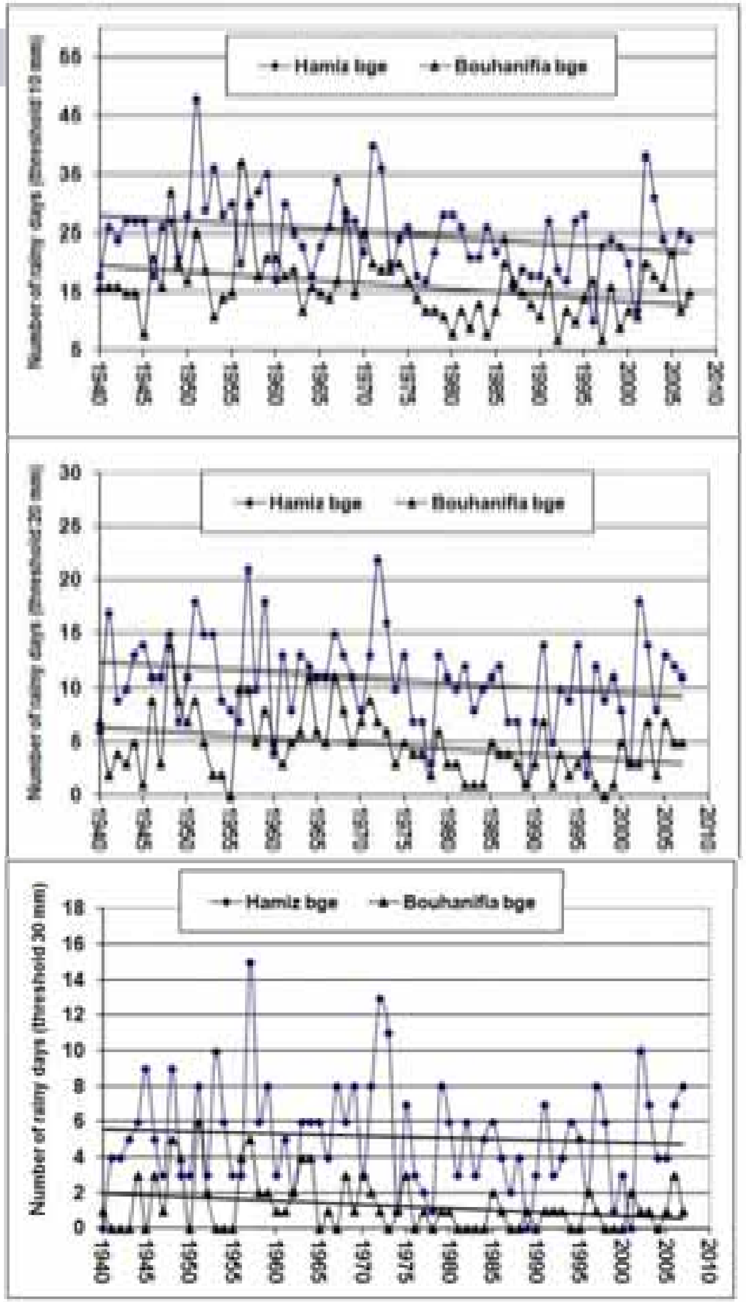
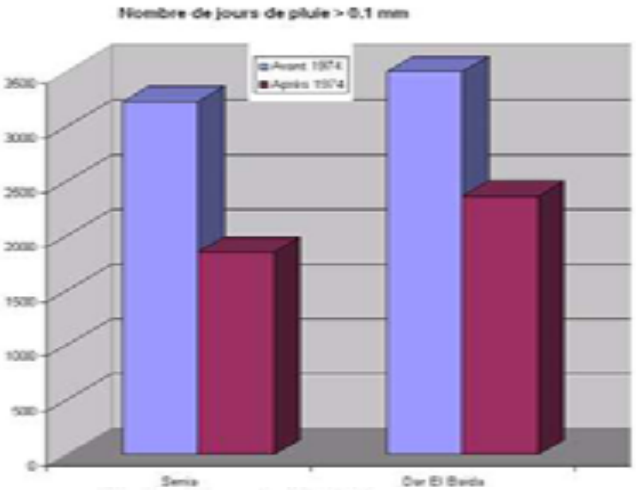
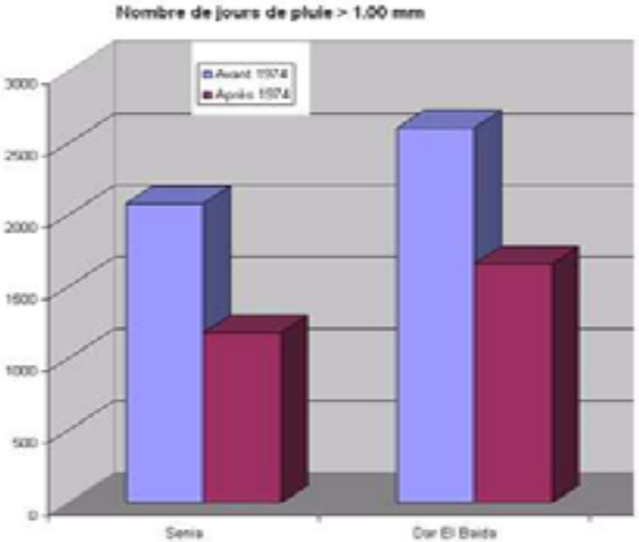
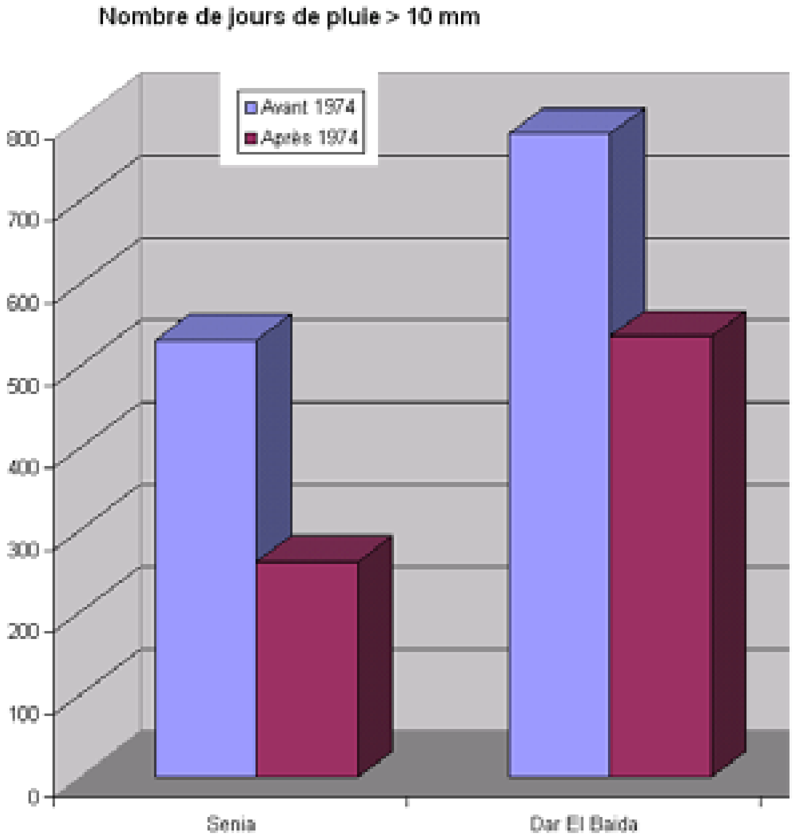


Figure 2. Number of rainy days at the thresholds of 10, 20 and 30 mm

Evolution of the number of days of rainfall superior to a threshold







Aim

Search a parameter representative of rainfall to improve the expression for estimate the specific degradation

1. Climate indicators

Rainfall: mean annual rainfall

- **Aggressiveness of rainfall**

The aggressiveness of the rain can be measured using two indices:

- Fournier Index

$$IF = p_j^2 / P$$

The climate index is the ratio of the square of rainfall Pj (mm) of the wettest months to the annual rainfall P (mm).

- Modified Fournier index proposed by ARNOLDUS (1978)

$$IF = \sum_{i=1}^{12} p_i^2 / P$$

Class index Fournier

<25 very low rainfall along the rainy season
25-40 low rainfall abundant along the rainy season
40-60 moderately abundant rainfall along the rainy season
> 60 rainfall abundant along the rainy season

1. Climate indicators

- Index of concentration of rainfall

$$ICP(\%) = \frac{P_M}{P}$$

PM: monthly average wettest month of the year in mm
P: total annual rainfall in mm

This index provides information on the magnitude rainfall concentration of in relation to the wettest month.

rainfall Concentration (by CNEA Tunisia)

<15% Low monthly rainfall concentration
15 - 20% monthly concentration of moderate rain
> 20% Concentration monthly rainfall very important

Figure 1. Studied zone.

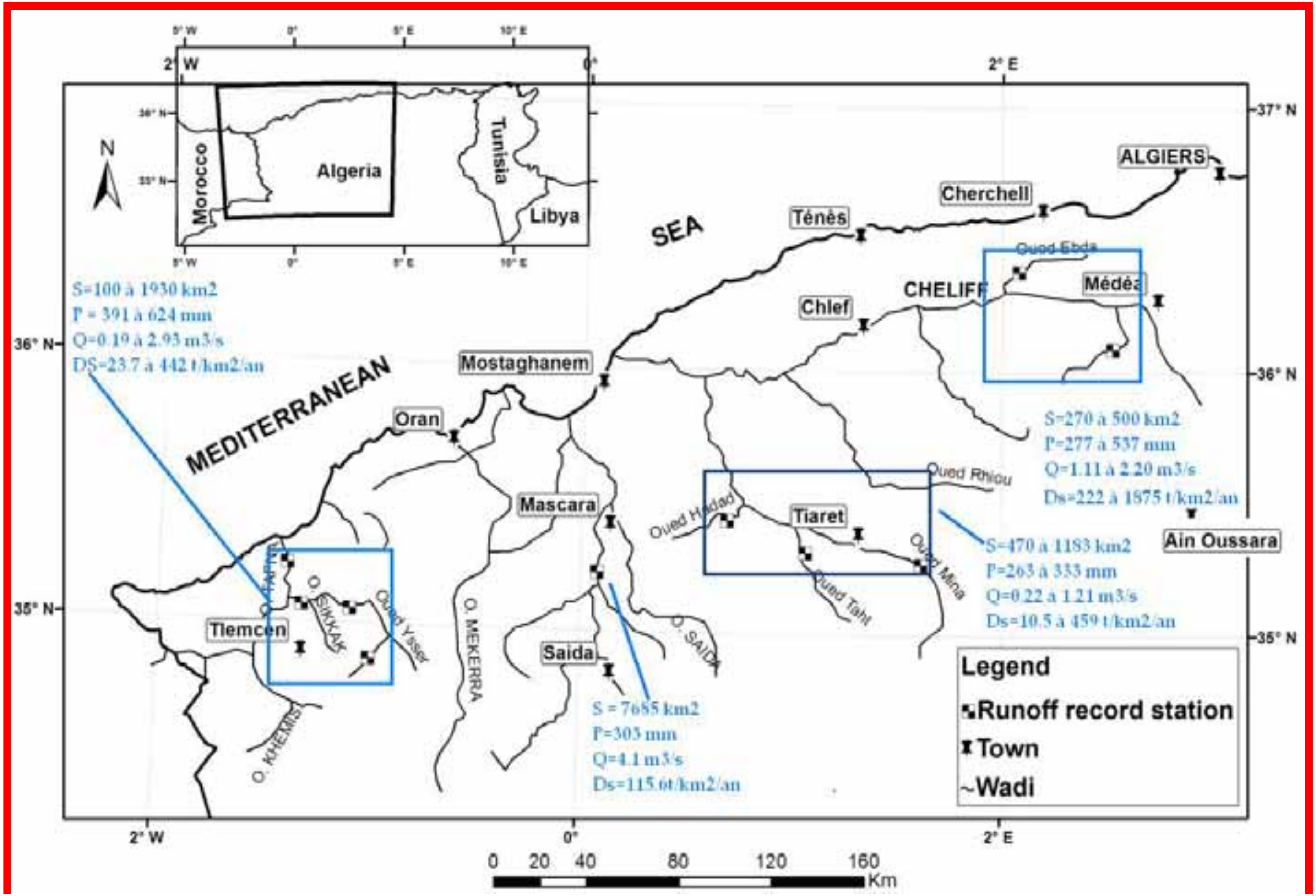


Table 1. Characteristics of the studied drainage basins.

Drainage basins	Stations	Surface Km^2	H max m	H min m	Annual rainfall mm	Average annual discharge. m^3/s
Ebda	Arib Ebda	270	1417	275	536.8	2.20
Taht	Kef Mahboula	680	1250	475	333.3	0.27
Haddad	S.A. Djilali	470	1160	225	263.2	0.22
Chouly	Chouly RN7	170	1616	720	453.4	0.404
Isser	Bensekrane	1230	1616	247	392.8	1.44
Isser	Remchi	1930	1616	85	624.3	2.93
Tlata	Ghazaouet	100	1113	65	391.3	0.19
Deurdeur	Sidi Mokorfi	500	1313	190	277.3	1.11
Oued El hammam	Trois Rivières	7685	1457	295	302.6	4.06
Oued Mina	S. A. Ben Amar	1183	1283	600	307.4	1.21

2. Pluviometric regime of the studied region

- The annual rainfall in the study area varies from 287 to 624 mm.

- It is concentrated during the cold season (November to April).

- 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,

- About half of the annual rainfall takes place in 25 to 30 days during the months of November, December and January.

- 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.

3. Parameters used in the Study

We took the specific degradation (t/km2/year), rain and the climatic indexes as dependent variables. The explanatory factors are:

- **Specific degradation (Ds) in t/km2/year.**
- Annual rainfall (P) in mm.
- **Rainfall of the wettest month of the year (p) in mm.**
- Maximum monthly rainfall of the cold season (psfd) in mm.
- **Maximum monthly rainfall of the warm season (pscd) in mm.**
- Monthly rainfall amount of the cold season (spsfd) in mm.
- **Monthly rainfall amount of the warm season (spscd) in mm.**
- Maximum daily rainfall recorded during the year (pjm) in mm.
- **Maximum daily rainfall amount of every month recorded during the year (spjm) in mm.**

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 have forced us to work on the period prior to that date. Therefore, the selected period is from 1966/67 to 1989/90 (24 years).

Table 2. Statistical Characteristics of Variables

Stations		Ds	P	p	p^2/P	pjm^2/P	$spjm^2/P$	Pschd	Psfrd	$Pscd^2/P$	$Psfd^2/P$	$spsfd^2/P$	$spscd^2/P$
Bouskrane	Mean	441,9	392,8	117,8	36,9	4,22	9,39	78,1	314,7	19,7	256,4	64,3	9,94
	C.V	0,97	0,21	0,26	0,41	0,53	0,31	0,59	0,26	1,01	0,35	0,31	0,87
Sidi Abd El Kader	Mean	139,8	263,2	71,38	19,8	2,45	6,65	73,6	189,6	25,9	141,9	33,5	11,7
	C.V	0,90	0,21	0,20	0,28	0,40	0,26	0,59	0,29	1,22	0,40	0,40	0,95
Sidi Mokrfi	Mean	221,7	277,3	75,49	21,9	1,33	4,26	76,9	200,4	26,8	150,3	39,6	12,9
	C.V	0,72	0,31	0,36	0,55	0,52	0,39	0,36	0,43	0,75	0,53	0,51	0,60
Remchi	Mean	35,63	624,3	173,8	50,9	5,85	17,2	127	497,8	28,7	400,1	97,5	13,1
	C.V	1,63	0,35	0,46	0,64	0,47	0,32	0,39	0,40	0,59	0,47	0,52	0,58
Chouly R.N. 7	Mean	23,72	453,4	123,9	35,4	4,98	11,4	108	345,4	27,9	265,3	65,9	12,5
	C.V	1,33	0,24	0,32	0,48	0,65	0,39	0,30	0,30	0,44	0,38	0,37	0,47
Kef Mahboula	Mean	10,50	333,3	90,72	25,2	2,71	6,88	76,9	256,4	19,3	198,8	47,9	8,97
	C.V	1,38	0,25	0,30	0,39	0,44	0,30	0,36	0,28	0,51	0,34	0,31	0,48
Aribs Ebda	Mean	2028	536,8	141,2	38,3	5,22	11,4	121	416,4	133	1271	75,2	15,3
	C.V	0,61	0,25	0,29	0,39	0,59	0,35	0,57	0,26	1,00	0,33	0,34	0,98
Sidi Ali Ben Amar	Mean	459,2	307,4	76,33	19,6	2,96	8,13	90,3	217,1	29,4	156,2	36,8	11,4
	C.V	0,83	0,23	0,21	0,31	0,44	0,15	0,47	0,25	0,89	0,33	0,28	0,59
Ghazaouet	Mean	126,8	391,3	126,6	42,6	8,62	15,9	93,9	297,4	25,7	229,2	63,8	16,6
	C.V	1,66	0,30	0,34	0,46	0,43	0,34	0,34	0,38	0,56	0,48	0,51	0,69
Trois Rivières	Mean	115,6	302,6	93,8	31,4	5,8	10,4	88,0	214,6	29,8	156,4	44,4	14,4
	C.V	0,72	0,23	0,42	0,73	1,06	0,58	0,37	0,34	0,71	0,47	0,58	0,57

4. Relation between Solid Transport and Pluviometry

4.1. Annual Scale:

The average annual rainfall, rainfall of the wettest month and rainfall of the cold season (from November to April) give the best correlation coefficients (with the specific degradation) for all the studied basins. Rainfall of the cold season represents the main annual rainfall for the ten basins (70 % and more).

Rainfall of the wettest month explains **44%, 47%, 78% and 51%** of the specific degradation variance in the basins of the **extreme west (Bensekrane, Chouly RN. 7, Remchi, Ghazaouet and Sidi Ali Ben Amar)** respectively. These drainage basins are characterized by variability of the annual rainfall which is concentrated during only a few months. 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.

Annual rainfall explains **57%, 23%, 22%, 45% and 24%** of the specific degradation variance in the **west central basins (Sidi Abd El Kader, Kef Mahboula, Sidi Mokrfi, Aribs Ebda and Trois Rivières)** respectively. At the level of these basins, the monthly rainfall of the cold season has a relatively homogenous distribution, which explains why the annual rainfall or that of the cold season (November to April) gives the best correlation coefficients with the specific degradation, Which means that the erosion by saturation is more significant in the west of Algeria. This observation was also made by LAHLOU A., 1990 in Morocco. Besides, it should be noted that rainfall can’t explain the specific degradation variability, it is therefore necessary to involve runoff and physical factors of the drainage basin namely: lithology, vegetation cover and morphometry.

4 - 2 SEASONAL SCALE:

Rainfall in the north of Algeria is characterized by a significant spatio-temporal variability. These observations led us to study this phenomenon on a seasonal scale in the drainage basin of wadi Ebda, where data are available. At this scale, we have taken the total rainfall of every season, rainfall of the wettest month and the maximum daily rainfall recorded.

- **Total rainfall (Ps) in mm at the seasonal scale (autumn, winter, spring and summer).**
- **Maximum monthly rainfall (p) in mm (rainfall of the wettest month of the year).**
- **Maximum monthly rainfall (ps) in mm (rainfall of the wettest month of the season)**
- **Maximum daily rainfall recorded during the year (Mjma) in mm.**
- **Maximum daily rainfall recorded during the season (Mjms) in mm.**

the total rainfall explains 58 % and 26 % of the warm season's concentration variance (autumn and summer). However, rainfall of the wettest month and Fournier index (adapted at this scale) explain only a small percentage of the turbidity variance. These results may be explained by the fact that rain of these seasons contributes in erosion and sediment transport phenomena. After a long dry season characterized by high temperatures, rainfall causes the destruction of soil aggregates. The surface runoff facilitates the transport of detached particles.

Table 5. Correlation coefficients (Turbidity – explanatory variables)

	P mm	P mm	p2/P
Autumn	**0.76**	**0.63**	0.35
Summer	**0.51**	**0.49**	0.46

In wet season (winter and spring), **rainfall of the wettest month explains 56 % and 51 % of the concentration variance**. However, total seasonal rainfall explains 45 % and 37 % respectively. Autumn rainfall contributes to the filling of soil stocks by infiltration. Winter and spring rainfall drip to a very large extent (low evaporation and a decrease of infiltration).This streaming represents the driving force for detached particles transport in Summer and Autumn, that is why rainfall of the wettest month explains better the sediment transport. During this month, there is a concentration of widespread floods. These floods are responsible for the largest part of the total volumes carried outside the drainage basin.

Table 5. Correlation coefficients (Turbidity – explanatory variables)

	Pmm	p mm	p2/P
Winter	**0.69**	**0.75**	0.65
Spring	**0.61**	**0.71**	0.74

5. Research of a Parameter Representative of Rainfall Erosion Potential on a Spatial Scale.

The study area is particularly affected by thermal and pluviometric variations that happen suddenly during certain periods of the year. Precipitation of the Algerian west is confronted, like rainfall of the arid and semiarid regions, to significant fluctuations in space and time. Erosion and sediment transport are closely linked to these pluviometric fluctuations. In the west of Algeria, autumn rainfall of northerly and northwesterly direction is responsible for a large part of sediment transport. In order to define the climatic factor which represents the climatic aggressivity at spatial scale, we have took the average values of the different factors defined above as the explanatory factors of specific degradation.

Table 6. Statistical characteristics of variables (1973/74 -1988/89)

	Ds	P	p	p^2/P	pjm^2/P	$spjm^2/P$	Pschd	Psfrd	$Pscd^4/P$	$Psfd^4/P$	$spsfd^4/P$	$spscd^4/P$
Mean	360,2	388,2	109,1	32,19	4,41	10,2	93,3	295	36,6	322,6	56,90	12,69
S.D	576,2	112,7	31,65	10,00	2,02	3,83	18,1	96,4	32,4	324,9	19,12	2,23
C.V	1,60	0,29	0,29	0,31	0,46	0,38	0,19	0,33	0,88	1,01	0,34	0,18

- Table 7 shows that **the annual rainfall and rainfall of the cold season wettest month explain 12% (R = correlation coefficient = 0.35) and 11% (R = correlation coefficient = 0.33) of specific degradation variance.** This result confirms those obtained at temporal scale (at the level of each basin). However, we have found that Fournier index of the warm and cold seasons gives very encouraging results. **They explain 92% and 85% respectively of the specific degradation variance**. These values show that rainfall is generally concentrated in a few months of the year.

Table 7. Correlation coefficient (Specific degradation- explanatory variables)

	P	p	P2/P	Pjm2 /P	Spjm 2/P	Psch d	Psfrd	Pscd 2/p	Psfd 2/p	Spsf d2/P	Spsc d2/P
R	**0.35**	0.24	0.11	0.06	0.02	0.16	**0.33**	**0.96**	**0.92**	0.23	0.32
R2	**0.12**	0.06	0.01	0.00	0.00	0.03	**0.11**	**0.92**	**0.85**	0.05	0.10

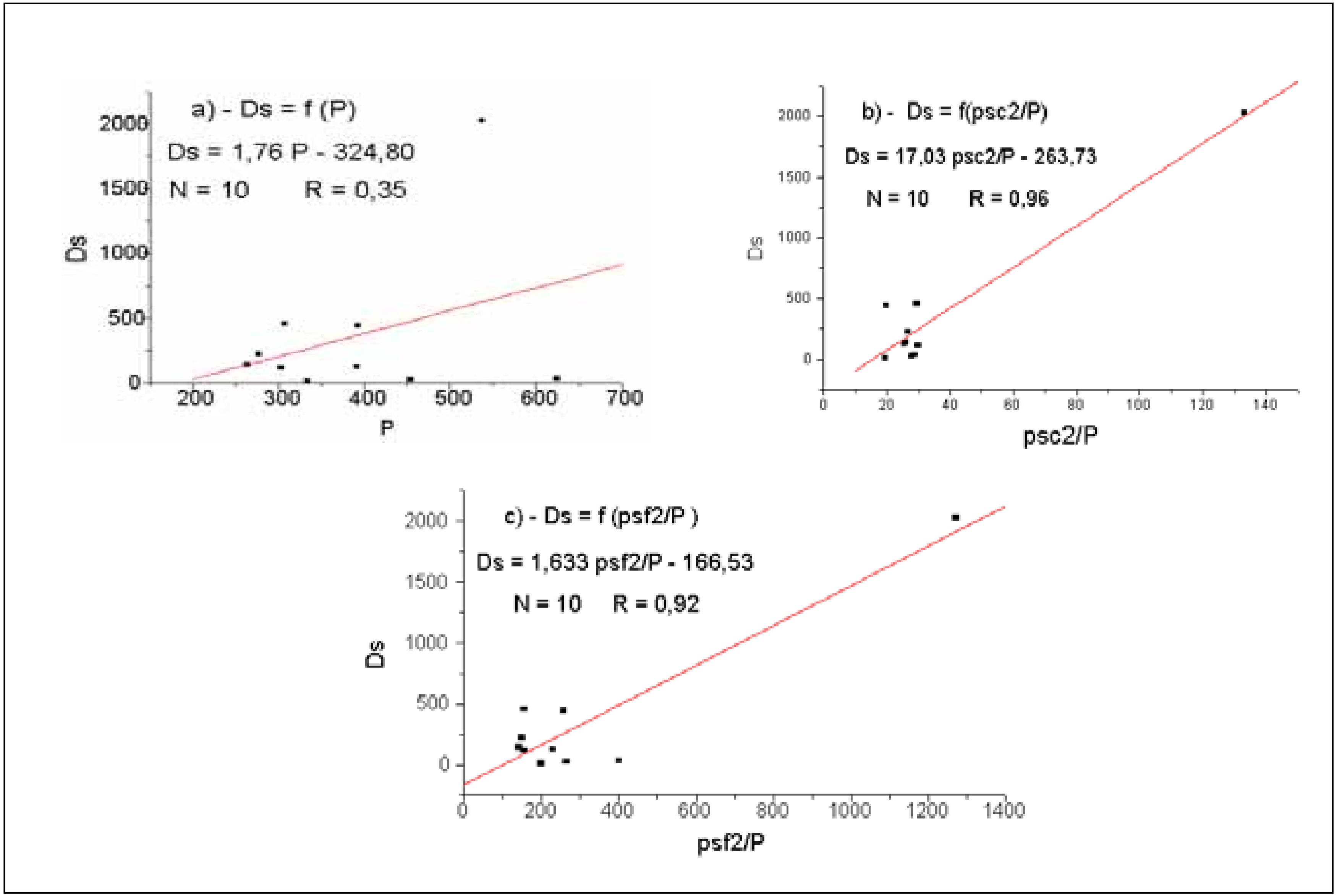


Figure 3. Relation between specific degradation and explanatory variables.

Conclusion

When studying sediment transport in ten drainage basins of the western Algeria and searching a factor representing rainfall aggressivity, we have found that:

- Rainfall of the wettest month explains 44%, 47%, 78% and 51% of specific degradation variance in the drainage basins of the extreme west, namely: Bensekrane, Chouly RN. 7, Remchi, Ghazaouet and Sidi Ali Ben Amar respectively.
- Annual rainfall explains 57%, 13%, 22%, 45% and 24% of specific degradation variance of the west central drainage basins ;i.e., Sidi Abd El Kader, Kef Mahboula, Sidi Mokrfi, Aribs Ebda et Trois Rivières respectively. At the level of these basins, monthly rainfall of the wet season has a relatively homogenous distribution.
- In warm season (summer and autumn), the total seasonal rainfall explains better the variability of the sediment concentration.
- In wet season (winter and spring), rainfall of the wettest month of the forecast period explains a large percentage of the turbidity variance.
- Fournier index of the warm and the wet season gives very encouraging results. They explain 92% and 85% respectively of the specific degradation variance. These values show that rainfall is generally concentrated in a few months of the year in the study area.


THANK YOU for YOUR ATTENTION!