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Spatial and temporal trends of rainfall seasonality in continental climate zone of Tadla perimeter's in Morocco by principal component analysis (PCA)

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Abstract: The spatial and temporal study of periodic rainfall (month, quarter, semester and agricultural year) at the Tadla perimeter, a semi-arid climate zone in central Morocco, was based on data from 27 rainfall stations at 1958-2018 period, using Mann-Kendall test coupled with Sen's test and completed by Principal Component Analysis (PCA) method. The keys results of the study are that monthly rainfall varies in wide range from 4 to 44 mm/month, with a significant trend in nine out of twelve months of the agricultural year: The agricultural year ends in July and August with a stable monthly rainfall; impacting other periodicities given the significant downward trend in rainfall in the last three quarters of the agricultural year that are: December-January-February follow-up with March-April-May and June-July-August; in both wet semester (September-February) and dry (March-August) semester and also in the annual period.PCA method identifies seven variables of periodicity intra-annual with significant rainfall trends, distributed between two homogeneous geographical delimitations, defined by a grouping at the 13 sites of rainfall stations for variables following: monthly in December and April, quarterly in March-April-May and both semesters wet and dry and by versus other grouping at the 14 sites of stations for monthly variables months at September and at June.

***Index Terms* -Tadla perimeter, rainfall, seasonality, PCA, climate changes**

I. INTRODUCTION

The characterization study of rainfall trend in a semi-arid climate zone, starting from the initial observation of a gradual decrease in the annual rainfall accumulation, with respect to climate change, observed over large areas of the Western Mediterranean and non-Sahelian West Africa, related to the G.I.E.C. report (2013), prompted by such circumstances in a more restricted space on the territory of the Oum Er Rbia hydraulic basin to which our study area belongs (Jouilili et al, 2013), also on the large territory of Northern Morocco (Sebbar et al, 2011) and also in the neighboring country of Algeria exactly in its North-Western zone (Taibi et al, 2013).

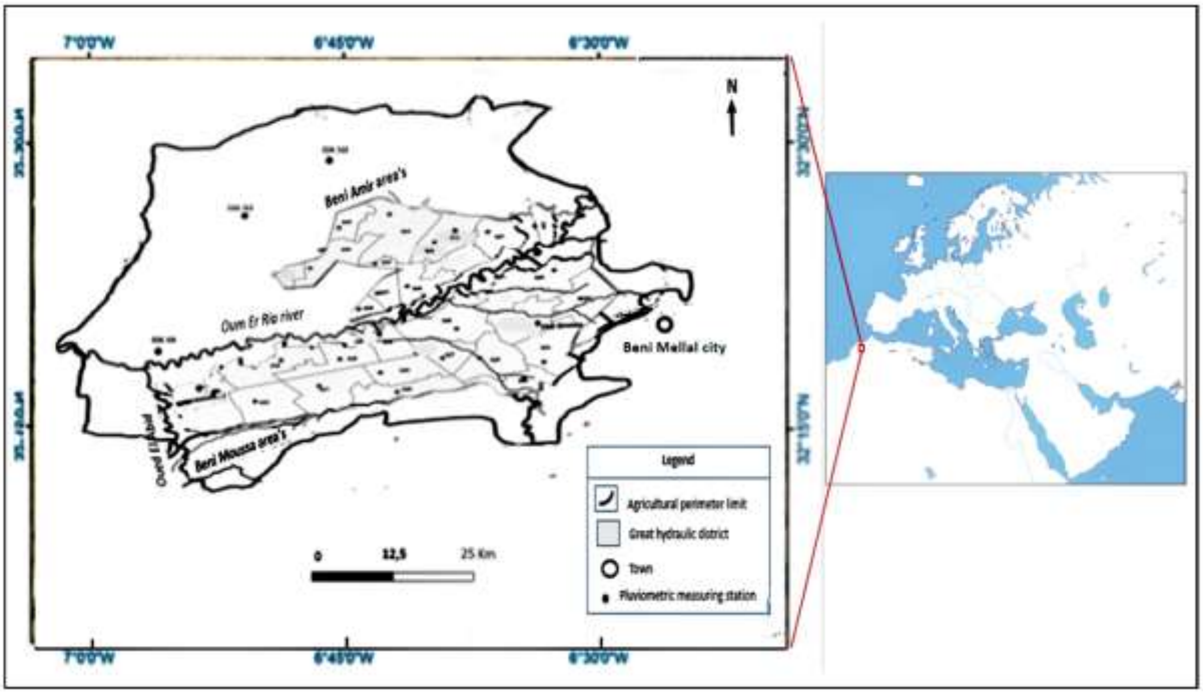
So we are led to deepen analyses to identify any possible change in the rainfall regime with reasoning by more restricted periodicities within the annual period, notably : month, quarter and semester; with using of appropriate methods of trending rainfall relayed by the Principal Component Analysis (PCA) method., recommended by various authors in similar works, notably in : extended areas of the Moroccan territory by Driouech, (2010), Sebbar et al (2011) and Hanchane (2013); on the northern Mediterranean shore in the south of France by Norrant and Douguédroit (2004) and in the north of Algeria by Touhami (2017). The present research work firstly an event-driven diagnosis of rainfall trends over several decades, on data from the large network of meteorological stations in intra-annual periodicities, by Mann-Kendall trend tests associate with Sen's regression tests (Tramblay et al, 2005), including intermediate results which are processed by PCA method (Wigley et al, 1984) with the aim of spatial and temporal configuration of the current rainfall regime according to seasonal subdivisions of the year.

II. PRESENTATION OF STUDY AREA

2.1 Geographical location

Study area refers to the perimeter of the Tadla, between longitudes West 6° 18' 08 " and 7° 04' 39" and latitudes North 32° 10' 16 " to 32° 40' 10", accounting for most of the Tadla plain, in the central continental situation of Morocco at a distance of 200 km from its economic capital Casablanca; area perimeter's 3600 km² and altitudes of about 400 m (O.R.M.V.A. du Tadla, 2020) and subdivided by river Oum Er Bia into two distinct areas: the "Beni Moussa" area on the left bank and the "Beni Amir" area on the right bank (Figure 1).

Figure 1 Geographical location of the study area and indications of the location points of the rainfall measuring stations in Tadla perimeter's study area.



2.2 Climate framework

Continental climate zone, specifically in semi-arid zone climate related to the Mediterranean basin, with air temperature between extremes of 40 °C in August to 3.5 °C in January, evaporation of 1800 mm per year and rainfall of 300 mm per year (O.R.M.V.A. du Tadla, 2020).

2.3 Hydro-agricultural infrastructures, irrigation water saving policy and potential for agricultural development in the Tadla perimeter (study area)

The irrigated perimeter of Tadla can be identified as a study area, with a useful agricultural area of 243,000 ha (68% of the total area); half of which is cultivated with diversified irrigated crops and half with rainfed crops dominated by wheat. A large surface area is equipped with large hydraulic infrastructures (98,300 ha) including 69,600 ha in the Béni Moussa area and 28,700 ha in the Béni Amir area; in addition to 22,000 ha of irrigable land in a pivot system, pumping of underground water and small-scale hydraulics. Considering the declining trend in mobiliszable water resources, under the effects of climate change (Sebbar et al, 2011; Jouilili et al, 2013; Hanchane, 2013 ; Krimissa, 2017), a regional resilience policy aims at replacing the predominant gravity irrigation system by a rational system of drip irrigation, with a target of 89,000 ha (74% of the irrigable surface area of the perimeter), 49,000 ha of which is currently being implemented, in the form of collective reconversion on agricultural plots, with no or low energy use; by total financing from the Moroccan State within the framework of the National Irrigation Water Saving Programme (PNEEI) (Ministère marocain de l'agriculture, 2020 ; O.R.M.V.A. du Tadla, 2020).

III. DATA AND METHODS

3.1 Rainfall series data

Rainfall records over 60 agricultural years from 1958-1959 to 2017-2019, with the agricultural year (or agricultural campaign) beginning on September 1 and ending on August 31; on a network of 27 rainfall stations in the study area; under the responsibility of the Tadla Regional Office for Agricultural Development, an organism under the supervision of the Moroccan Ministry of Agriculture; rainfall stations locations on the map in Figure 1and their references in Table 1.

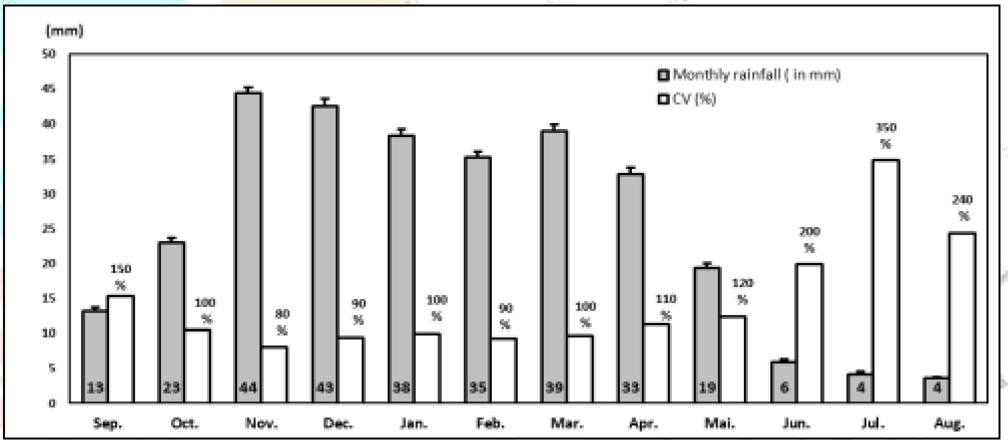
Table 1: Characterization of rainfall measurement stations, data sources for the study perimeter 1958-1959 / 2017-2018 observation period.

Rainfall station	Latitude (decimal degree)	Longitude (decimal degree)	Altitude (m)	Annual rainfall Mean (mm)	Rainfall station	Latitude (decimal degree)	Longitude (decimal degree)	Altitude (m)	Annual rainfall Mean (mm)
501(S1)	32,44904	-6,52868	439	311	526(S26)	32,26538	-6,58727	438	305
503(S3)	32,49110	-6,61800	445	295	527(S27)	32,29153	-6,58631	430	307
504(S4)	32,4843	-6,68850	436	292	528(S28)	32,34263	-6,65059	415	290
505(S5)	32,50961	-6,75735	440	293	529(S29)	32,24111	-6,65533	444	309
507(S7)	32,69192	-6,69192	415	283	530(S30)	32,25353	-6,69301	434	297
508(S8)	32,44800	-6,77486	416	290	531(S31)	32,25321	-6,74462	417	292
510(S10)	32,57349	-6,84426	465	293	532(S32)	32,20524	-6,80568	439	285
511(S11)	32,51589	-6,53523	464	298	533(S33)	32,23287	-6,94245	386	279
512(S12)	32,45697	-6,93983	409	277	534(S34)	32,30551	-6,90118	376	280
Ahl Souss (SAH)	32,46843	-6,59654	441	292	535(S35)	32,28971	-6,69201	412	306
520(S20)	32,41407	-6,49830	445	314	536(S36)	32,30287	-6,76874	399	299
521(S21)	32,36804	-6,45427	462	331	538(S38)	32,30088	-7,02236	353	274
523(S23)	32,28061	-6,46358	476	336	Ouled Gnaou (SOG)	32,30616	-6,50465	449	351
525(S25)	32,21005	-6,53183	474	334					

Annual cumulative rainfall per station is an average of 274 to 336 mm/year with a station coefficient of variation (CV in %) of 31 % to 44 %; total annual rainfall of 293 to 310 mm; rainfall distribution per month is of contrasted repartition illustrated in Figure 2.

Monthly rainfall varies over a wide range from 4 to 44 mm/month, with very high CVs ranging from 80 % to 350 %, reflecting large fluctuations between months.

Figure 2*:* Monthly rainfall distribution with margins of error and coefficients of variation (CV %) at the Tadla perimeter (Period to 1958-1959 at 2017-2018).



In this case, present study envisages further analysis of rainfall trends by focusing on periodic components of year, both temporally and spatially approach's.

3.2 Methods

In order to characterize the periodic trends of intra-annual precipitation, the usual temporal subdivisions taken into account are: month, quarter and semester, in relation to the annual period. For this purpose, in a first phase, Mann-Kendall trend tests are carried out, relayed by Sen regression tests; in a second phase, use is made of Principal Component Analysis (PCA) method (Wigley et al, 1984) in order to complete in spatial and temporal configuration seasonal trends of precipitation regimes with reference to similar works (Norrant and Douguédroit, 2004; Sebbar et al, 2011; Hanchane, 2013 and Touhami, 2017); the attributes of these methods are described below. It should be noted that numerical statistical processing was done using SPSS, R and Excel software.

3.2.1 Trend statistical methods applied on rainfall time series

a. Mann-Kendall test

A non-parametric test of correlation between time and time series variable, its meaning is sign of the multivariate standard normal of distribution (Kendall and Stuart, 1976).

b. Sen's test

A non-parametric test of correlation between time and temporal serie variable, its meaning is sign of the multivariate standard normal of distribution (Kendall and Stuart, 1976).

3.2.2 Principal Component Analysis (PCA) method:

PCA is a multivariate statistical interdependence method for condensing a set of distribution variables into new restricted composite dimensions (Yergeau and Poirier, 2013) with validation by minimum correlations between variables in 50% of cases, with sampling adequacy by "Kaiser-Meyer-Olkin" (KMO) index, on the quality of inter-variable correlations in the range 0 to 1 and its interpretation grid is : Excellent (>0.8), good (0.7 to 0.8), medeum range (0.6 to 0.7), low range (0.5 to 0.6) and unacceptable (< 0.5); its accoupled with verifying independence between variables by Bartlett's sphericity test .

IV. RESULTS AND DISCUSSION

4.1 Trends in periodic precipitation

4.1.1 Trend evaluations by Mann-Kendall test and Sens's test

a. Calculations results statistical of trend tests

The collections of results of trend tests conducted are presented in Tables 2 and 3; their analyses are reported below.

b-Monthly precipitation trend

* By Mann-Kendall test: 9 out of 12 months of the agricultural year in cumulative rainfall with a significant trend, in September to way of increase affiliated to the opposite direction of decrease for eight months (November, December, January, February, March, April, May and June); in October, July and August, the situation stil stationary. Just level significance test is the beginning between September and January (p-value < 5%) and continued from February to June at a very significant level (p-value < 1%).

* By Sen's test: Into group of 9 variables mentioned above, consequently the variable month of November is excluded.

c. Trend periodic precipitation in multiplicities of months

c1. Quarterly precipitation

* By Mann-Kendall test: Over four quarters, the three show significant negative trend in December-January-February (DJF), March-April-May (MAM) and June-July-August (JJA), at very significant respective levels in first two cases and just significant in last case; as for autumn quarter September-October-November (SON), its continues over time with a constant rainfall.

*By Sen's test: Retained by previous test the three quarters DJF, MAM, JJA, after so we eliminate the last quarter, its judged to be non-compliant.

c2. Semester rainfall trend

In the Mann-Kendall test, for wet semester (September to February) and dry semester (March to August), there is a significant downward trend in rainfall; with half of rainfall stations in the first half of the year at a very significant level and the second half of the year with a trend that hardly exceeds the right significant level. In Sen's test, two semesters conformed and were retained.

c3. Annual rainfall trend

In very significant trends and are also globally favorable by regressive Sens's test.

Table 2: Mann-Kendall test and Sens's test on trend rainfall for monthly variables from September to May by measuring stations at the Tadla perimeter (1958-2018 period).

Month	Statistics / Satations	SOG	SAH	S1	S3	S4	S5	S7	S8	S10	S11	S12	S20	S21	S23	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S38
September	Kendall tau-B (KTB)	,178*	0,173	,222*	,252**	,238**	,300**	,215*	0,173	,259**	,211*	,221*	,231*	,272**	,189*	,189*	0,159	0,165	0,184	0,098	0,166	,218*	0,171	0,142	0,143	,210*	,208*	,194*
	Significance level (KTB)	S	NS	S	TS	TS	TS	S	NS	TS	S	S	S	TS	S	S	NS	NS	NS	NS	NS	S	NS	NS	NS	S	S	S
	Ho: Absent trend (Mann-Kendall)	No	Yes	No	No	No	No	No	Yes	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	No
	Sense of trend (MK)	H	ND	H	H	H	H	H	ND	H	H	H	H	H	H	H	ND	ND	ND	ND	ND	H	ND	ND	ND	H	H	H
	Lower terminal. CI coef. SEN's	0,136		0,202	0,224	0,231	0,282	0,209		0,236	0,205	0,223	0,205	0,279	0,124	0,124						0,195				0,095	0,134	0,065
	Average value coef. SEN's	0,354		0,373	0,406	0,414	0,497	0,445		0,423	0,372	0,475	0,414	0,477	0,315	0,315						0,406				0,269	0,325	0,446
	Upper terminal CI coef. SEN's	0,572		0,543	0,588	0,596	0,712	0,682		0,610	0,539	0,727	0,622	0,674	0,507	0,507						0,617				0,442	0,515	0,828
October	Kendall tau-B (KTB)	-0,008	0,033	-0,006	-0,020	-0,018	-0,016	-0,031	0,033	0,033	-0,011	-0,026	0,040	0,088	0,100	0,100	-0,028	0,005	-0,009	0,037	-0,005	0,055	0,047	0,059	0,070	0,085	0,058	-0,038
	Significance level (KTB)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Ho: Absent trend (Mann-Kendall)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Sense of trend (MK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Lower terminal. CI coef. SEN's																											
	Average value coef. SEN's																											
	Upper terminal CI coef. SEN's																											
November	Kendall tau-B (KTB)	-0,091	-0,087	-0,152	-0,127	-0,107	-0,104	-0,138	-0,087	-0,068	-0,113	-0,086	-0,109	-0,073	-0,079	-0,079	-0,129	-0,107	-0,122	-0,057	-0,053	-0,117	-0,115	-0,074	-,175*	-0,078	-0,096	-0,154
	Significance level (KTB)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	NS	NS	NS
	Ho: Absent trend (Mann-Kendall)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
	Sense of trend (MK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	B	ND	ND	ND
	Lower terminal. CI coef. SEN's																								~~-0,235~~			
	Average value coef. SEN's																								~~-0,112~~			
	Upper terminal CI coef. SEN's																								~~0,012~~			
December	Kendall tau-B (KTB)	-0,057	-0,154	-0,088	-0,109	-0,066	-0,092	-0,155	-0,154	-0,136	-0,134	-0,137	-0,109	-0,105	0,014	0,014	-0,097	-0,090	-0,048	-0,080	-0,084	-,182*	-,197*	-,178*	-,187*	-0,106	-0,103	-,175*
	Significance level (KTB)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S	S	NS	NS	S
	Ho: Absent trend (Mann-Kendall)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	No
	Sense of trend (MK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	B	B	B	B	ND	ND	B
	Lower terminal. CI coef. SEN's																					-0,257	-0,266	-0,256	-0,261			-0,205
	Average value coef. SEN's																					-0,144	-0,153	-0,146	-0,151			-0,108
	Upper terminal CI coef. SEN's																					-0,031	-0,040	-0,036	-0,041			-0,010
January	Kendall tau-B (KTB)	-0,133	-0,007	-0,097	-0,089	-0,047	-0,083	-0,099	-0,007	-0,121	-0,100	-0,163	-0,164	-0,136	-0,151	-0,151	-0,110	-0,131	-0,136	-0,152	-0,119	-0,174	-0,175	-,182*	-,186*	-,177*	-0,149	-0,143
	Significance level (KTB)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	S	NS	NS
	Ho: Absent trend (Mann-Kendall)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	Yes	Yes
	Sense of trend (MK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	B	B	B	ND	ND
	Lower terminal. CI coef. SEN's																							-0,256	-0,261	~~-0,194~~		
	Average value coef. SEN's																							-0,146	-0,151	~~-0,081~~		
	Upper terminal CI coef. SEN's																							-0,036	-0,041	~~0,032~~		
February	Kendall tau-B (KTB)	-,205*	-,189*	-,221*	-,200*	-,182*	-,185*	-,204*	-,189*	-,206*	-,240**	-,300**	-,274**	-,274**	-0,174	-0,174	-,211*	-,237**	-,254**	-,235**	-,188*	-,285**	-,260**	-,249**	-,274**	-,234**	-,270**	-,252**
	Significance level (KTB)	S	S	S	S	S	S	S	S	S	TS	TS	TS	TS	NS	NS	S	TS	TS	TS	S	TS	TS	TS	TS	TS	TS	TS
	Ho: Absent trend (Mann-Kendall)	No	No	No	No	No	No	No	No	No	No	No	No	No	Yes	Yes	No	No	No	No	No	No	No	No	No	No	No	No
	Sense of trend (MK)	B	B	B	B	B	B	B	B	B	B	B	B	B	ND	ND	B	B	B	B	B	B	B	B	B	B	B	B
	Lower terminal. CI coef. SEN's	-0,307	-0,276	-0,284	-0,267	-0,244	-0,270	-0,276	-0,276	-0,275	-0,290	-0,321	-0,281	-0,292			-0,329	-0,357	-0,328	-0,345	-0,322	-0,371	-0,371	-0,319	-0,332	-0,337	-0,361	-0,311
	Average value coef. SEN's	-0,172	-0,146	-0,160	-0,141	-0,122	-0,139	-0,146	-0,146	-0,147	-0,167	-0,194	-0,163	-0,178			-0,185	-0,209	-0,197	-0,201	-0,172	-0,229	-0,225	-0,191	-0,205	-0,200	-0,229	-0,182
	Upper terminal CI coef. SEN's	-0,037	-0,017	-0,036	-0,015	0,000	-0,008	-0,017	-0,017	-0,018	-0,043	-0,066	-0,045	-0,063			-0,040	-0,062	-0,065	-0,057	-0,023	-0,086	-0,080	-0,063	-0,078	-0,063	-0,098	-0,053
Mars	Kendall tau-B (KTB)	-,411**	-,281**	-,316**	-,344**	-,349**	-,348**	-,350**	-,281**	-,362**	-,326**	-,404**	-,371**	-,418**	-,413**	-,413**	-,419**	-,414**	-,424**	-,444**	-,399**	-,418**	-,435**	-,456**	-,456**	-,431**	-,438**	-,397**
	Significance level (KTB)	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS
	Ho: Absent trend (Mann-Kendall)	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
	Sense of trend (MK)	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	Lower terminal. CI coef. SEN's	-0,301	-0,333	-0,320	-0,367	-0,399	-0,313	-0,311	-0,333	-0,299	-0,336	-0,337	-0,313	-0,334	-0,309	-0,309	-0,324	-0,280	-0,355	-0,328	-0,326	-0,345	-0,354	-0,327	-0,341	-0,359	-0,341	-0,330
	Average value coef. SEN's	-0,208	-0,206	-0,205	-0,241	-0,268	-0,202	-0,201	-0,206	-0,189	-0,216	-0,227	-0,207	-0,233	-0,211	-0,211	-0,224	-0,190	-0,249	-0,229	-0,224	-0,243	-0,252	-0,226	-0,239	-0,253	-0,238	-0,223
	Upper terminal CI coef. SEN's	-0,114	-0,079	-0,089	-0,115	-0,137	-0,091	-0,091	-0,079	-0,079	-0,095	-0,117	-0,101	-0,132	-0,112	-0,112	-0,125	-0,100	-0,143	-0,131	-0,122	-0,141	-0,150	-0,125	-0,137	-0,146	-0,135	-0,116
April	Kendall tau-B (KTB)	-,392**	-,288**	-,399**	-,390**	-,396**	-,351**	-,339**	-,288**	-,357**	-,403**	-,388**	-,394**	-,363**	-,387**	-,387**	-,435**	-,431**	-,388**	-,426**	-,438**	-,425**	-,442**	-,469**	-,448**	-,405**	-,432**	-,415**
	Significance level (KTB)	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS
	Ho: Absent trend (Mann-Kendall)	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
	Sense of trend (MK)	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	Lower terminal. CI coef. SEN's	-0,306	-0,287	-0,310	-0,331	-0,321	-0,304	-0,321	-0,287	-0,317	-0,323	-0,372	-0,288	-0,276	-0,299	-0,299	-0,322	-0,287	-0,326	-0,306	-0,318	-0,326	-0,325	-0,353	-0,384	-0,312	-0,340	-0,356
	Average value coef. SEN's	-0,202	-0,163	-0,202	-0,213	-0,205	-0,185	-0,198	-0,163	-0,197	-0,212	-0,245	-0,187	-0,175	-0,191	-0,191	-0,216	-0,189	-0,213	-0,203	-0,212	-0,219	-0,221	-0,237	-0,267	-0,202	-0,229	-0,235
	Upper terminal CI coef. SEN's	-0,098	-0,039	-0,094	-0,095	-0,089	-0,065	-0,076	-0,039	-0,077	-0,101	-0,118	-0,085	-0,074	-0,084	-0,084	-0,111	-0,090	-0,100	-0,100	-0,106	-0,111	-0,116	-0,120	-0,149	-0,092	-0,119	-0,114
May	Kendall tau-B (KTB)	-,254**	-,291**	-,330**	-,308**	-,319**	-,279**	-,324**	-,291**	-,270**	-,311**	-,288**	-,323**	-,282**	-,307**	-,307**	-,297**	-,230*	-,271**	-,319**	-,286**	-,356**	-,397**	-,289**	-,264**	-,230*	-,320**	-,315**
	Significance level (KTB)	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	S	TS	TS
	Ho: Absent trend (Mann-Kendall)	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
	Sense of trend (MK)	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	Lower terminal. CI coef. SEN's	-0,412	-0,424	-0,453	-0,413	-0,511	-0,431	-0,452	-0,424	-0,456	-0,489	-0,340	-0,424	-0,451	-0,371	-0,371	-0,447	-0,378	-0,399	-0,441	-0,454	-0,439	-0,474	-0,413	-0,493	-0,429	-0,461	-0,501
	Average value coef. SEN's	-0,237	-0,245	-0,280	-0,240	-0,328	-0,246	-0,272	-0,245	-0,267	-0,311	-0,171	-0,261	-0,270	-0,212	-0,212	-0,268	-0,189	-0,219	-0,265	-0,277	-0,270	-0,306	-0,222	-0,289	-0,234	-0,275	-0,310
	Upper terminal CI coef. SEN's	-0,062	-0,066	-0,107	-0,067	-0,145	-0,061	-0,092	-0,066	-0,078	-0,132	-0,002	-0,099	-0,088	-0,053	-0,053	-0,089	0,000	-0,039	-0,089	-0,099	-0,101	-0,137	-0,031	-0,086	-0,038	-0,088	-0,118

NB : Abbreviations or marks : NS : Trend insignificant ; "S" or (*) : Significant trend with p< 0,05; "TS" or (**): Highly significant trend with p< 0,01.
"B" : Trend direction down ; "H" : Upward trend direction.
~~-0,194~~ No-conforming confidence interval terminal for Sens's test
CI coef. SEN's :Confidence interval of Sen's test coefficient

Table 3: Mann-Kendall test and Sens's test on trend rainfall for monthly variables from June to August, quarterly, half-yearly and annual by measuring stations in Tadla perimeter (1958-2018 period).

	Statistiques / Satations	SOG	SAH	S1	S3	S4	S5	S7	S8	S10	S11	S12	S20	S21	S23	S25	S26	S27	S28	S29	S30	S31	S32	S33	S34	S35	S36	S38
June	Kendall tau-B (KTB)	-,281**	-0,145	-,258**	-0,140	-0,108	-0,103	-0,185	-0,145	-0,141	-0,180	-0,172	-,231*	-,306**	-,315**	-,315**	-0,161	-0,086	0,018	-,213*	-0,098	-0,078	-0,041	-0,139	-0,091	0,021	-0,012	-,214*
	Significance level (KTB)	TS	NS	TS	NS	NS	NS	NS	NS	NS	NS	NS	S	TS	TS	TS	NS	NS	NS	S	NS	NS	NS	NS	NS	NS	NS	S
	Ho: Absent trend (Mann-Kendall)	No	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
	Sense of trend (MK)	B	ND	B	ND	ND	ND	ND	ND	ND	ND	ND	B	B	B	B	ND	ND	ND	B	ND	ND	ND	ND	ND	ND	ND	B
	Lower terminal. CI coef. SEN's	-0,686		-0,999									-0,725	-0,876	-0,497	-0,497				-0,486								-0,733
	Average value coef. SEN's	-0,297		-0,518									-0,297	-0,457	-0,214	-0,214				-0,164								-0,333
	Upper terminal CI coef. SEN's	0,091		-0,037									0,131	-0,039	0,069	0,069				0,158								0,066
July	Kendall tau-B (KTB)	0,085	0,011	0,114	0,077	0,133	0,111	0,032	0,011	0,096	0,117	0,078	0,113	0,016	0,024	0,024	0,057	0,075	0,119	0,055	0,110	0,136	0,146	0,080	0,072	0,123	0,099	0,075
	Significance level (KTB)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Ho: Absent trend (Mann-Kendall)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Sense of trend (MK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Lower terminal. CI coef. SEN's																											
	Average value coef. SEN's																											
	Upper terminal CI coef. SEN's																											
August	Kendall tau-B (KTB)	0,127	0,019	0,104	0,084	0,136	0,171	0,066	0,019	0,120	0,094	0,091	0,082	0,029	-0,001	-0,001	-0,097	-0,053	0,032	-0,084	-0,125	0,014	-0,059	-0,094	-0,059	0,024	-0,023	0,086
	Significance level (KTB)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Ho: Absent trend (Mann-Kendall)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Sense of trend (MK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Lower terminal. CI coef. SEN's																											
	Average value coef. SEN's																											
	Upper terminal CI coef. SEN's																											
SON	Kendall tau-B (KTB)	0,012	0,017	0,012	0,015	0,028	0,045	-0,027	0,017	0,067	0,041	0,015	0,023	0,093	0,071	0,071	-0,027	-0,007	0,000	0,017	0,027	0,002	-0,020	0,018	-0,044	0,062	0,037	-0,111
	Significance level (KTB)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Ho: Absent trend (Mann-Kendall)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Sense of trend (MK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Lower terminal. CI coef. SEN's																											
	Average value coef. SEN's																											
	Upper terminal CI coef. SEN's																											
DJF	Kendall tau-B (KTB)	-,267**	-,204*	-,237**	-,249**	-,186*	-,259**	-,292**	-,204*	-,275**	-,267**	-,332**	-,307**	-,315**	-,176*	-,176*	-,275**	-,300**	-,262**	-,270**	-,250**	-,330**	-,367**	-,358**	-,376**	-,292**	-,331**	-,352**
	Significance level (KTB)	TS	S	TS	TS	S	TS	TS	S	TS	TS	TS	TS	TS	S	S	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS
	Ho: Absent trend (Mann-Kendall)	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
	Sense of trend (MK)	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	Lower terminal. CI coef. SEN's	-0,154	-0,141	-0,152	-0,142	-0,119	-0,144	-0,140	-0,141	-0,148	-0,157	-0,186	-0,158	-0,174	-0,134	-0,134	-0,157	-0,165	-0,152	-0,174	-0,151	-0,182	-0,197	-0,198	-0,205	-0,176	-0,193	-0,172
	Average value coef. SEN's	-0,090	-0,077	-0,089	-0,080	-0,057	-0,082	-0,082	-0,077	-0,088	-0,095	-0,125	-0,099	-0,115	-0,067	-0,067	-0,093	-0,102	-0,090	-0,108	-0,086	-0,123	-0,136	-0,137	-0,145	-0,113	-0,129	-0,113
	Upper terminal CI coef. SEN's	-0,027	-0,013	-0,026	-0,017	0,005	-0,019	-0,024	-0,013	-0,028	-0,033	-0,064	-0,039	-0,056	-0,001	-0,001	-0,030	-0,039	-0,029	-0,043	-0,020	-0,064	-0,076	-0,077	-0,085	-0,051	-0,065	-0,054
MAM	Kendall tau-B (KTB)	-,471**	-,376**	-,463**	-,441**	-,465**	-,416**	-,450**	-,376**	-,428**	-,464**	-,455**	-,485**	-,458**	-,468**	-,468**	-,489**	-,477**	-,470**	-,489**	-,514**	-,493**	-,510**	-,472**	-,508**	-,439**	-,489**	-,486**
	Significance level (KTB)	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS
	Ho: Absent trend (Mann-Kendall)	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
	Sense of trend (MK)	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	Lower terminal. CI coef. SEN's	-0,189	-0,195	-0,213	-0,205	-0,212	-0,191	-0,202	-0,195	-0,198	-0,210	-0,206	-0,188	-0,184	-0,199	-0,199	-0,204	-0,197	-0,203	-0,202	-0,206	-0,202	-0,206	-0,213	-0,216	-0,198	-0,210	-0,213
	Average value coef. SEN's	-0,142	-0,134	-0,159	-0,148	-0,157	-0,135	-0,146	-0,134	-0,142	-0,156	-0,151	-0,139	-0,136	-0,150	-0,150	-0,156	-0,148	-0,150	-0,155	-0,157	-0,154	-0,160	-0,161	-0,165	-0,147	-0,160	-0,160
	Upper terminal CI coef. SEN's	-0,095	-0,073	-0,106	-0,092	-0,101	-0,079	-0,091	-0,073	-0,085	-0,101	-0,095	-0,090	-0,088	-0,100	-0,100	-0,108	-0,100	-0,100	-0,107	-0,108	-0,107	-0,114	-0,108	-0,114	-0,095	-0,111	-0,107
JJA	Kendall tau-B (KTB)	-0,013	-0,124	-0,108	-0,057	-0,009	0,022	-0,067	-0,124	-0,037	-0,062	-0,090	-0,116	-0,165	-,186*	-,186*	-0,062	-0,008	0,089	-0,146	-0,068	-0,053	0,002	-0,092	-0,042	0,055	0,031	-0,115
	Significance level (KTB)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	S	S	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	Ho: Absent trend (Mann-Kendall)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Sense of trend (MK)	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	B	B	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	Lower terminal. CI coef. SEN's														-0,056	-0,056												
	Average value coef. SEN's														0,097	0,097												
	Upper terminal CI coef. SEN's														0,250	0,250												
Sh	Kendall tau-B (KTB)	-0,154	-0,140	-0,162	-0,145	-0,111	-0,152	-,205*	-0,140	-0,130	-0,162	-,273**	-,207*	-0,169	-0,073	-0,073	-,236**	-,222*	-,199*	-,199*	-0,155	-,236**	-,246**	-,221*	-,270**	-0,161	-,212*	-,326**
	Significance level (KTB)	NS	NS	NS	NS	NS	NS	S	NS	NS	NS	TS	S	NS	NS	NS	TS	S	S	S	NS	TS	TS	S	TS	NS	S	TS
	Ho: Absent trend (Mann-Kendall)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	No	Yes	Yes	Yes	No	No	No	No	Yes	No	No	No	No	Yes	No	No
	Sense of trend (MK)	ND	ND	ND	ND	ND	ND	B	ND	ND	ND	B	B	ND	ND	ND	B	B	B	B	ND	B	B	B	B	ND	B	B
	Lower terminal. CI coef. SEN's							-0,121				-0,137	-0,109				-0,134	-0,121	-0,117	-0,108		-0,134	-0,137	-0,127	-0,131		-0,126	-0,146
	Average value coef. SEN's							-0,069				-0,085	-0,059				-0,079	-0,071	-0,065	-0,057		-0,082	-0,086	-0,077	-0,081		-0,072	-0,098
	Upper terminal CI coef. SEN's							-0,018				-0,032	-0,010				-0,024	-0,020	-0,014	-0,006		-0,029	-0,034	-0,026	-0,031		-0,018	-0,050
Ss	Kendall tau-B (KTB)	-,374**	-,348**	-,373**	-,367**	-,369**	-,316**	-,415**	-,348**	-,355**	-,355**	-,410**	-,384**	-,391**	-,376**	-,376**	-,427**	-,417**	-,409**	-,391**	-,423**	-,441**	-,450**	-,420**	-,413**	-,364**	-,412**	-,470**
	Significance level (KTB)	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS
	Ho: Absent trend (Mann-Kendall)	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
	Sense of trend (MK)	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	Lower terminal. CI coef. SEN's	-0,172	-0,189	-0,193	-0,182	-0,186	-0,164	-0,197	-0,189	-0,181	-0,182	-0,186	-0,169	-0,165	-0,177	-0,177	-0,188	-0,185	-0,196	-0,177	-0,189	-0,188	-0,192	-0,196	-0,206	-0,187	-0,197	-0,202
	Average value coef. SEN's	-0,122	-0,129	-0,138	-0,123	-0,127	-0,106	-0,141	-0,129	-0,124	-0,126	-0,131	-0,119	-0,116	-0,126	-0,126	-0,138	-0,135	-0,142	-0,127	-0,138	-0,138	-0,143	-0,143	-0,151	-0,131	-0,144	-0,151
	Upper terminal CI coef. SEN's	-0,071	-0,069	-0,083	-0,065	-0,069	-0,047	-0,086	-0,069	-0,067	-0,070	-0,075	-0,068	-0,068	-0,074	-0,074	-0,089	-0,085	-0,088	-0,078	-0,087	-0,089	-0,095	-0,089	-0,097	-0,075	-0,091	-0,099
year	Kendall tau-B (KTB)	-,404**	-,327**	-,373**	-,325**	-,284**	-,323**	-,424**	-,327**	-,318**	-,354**	-,419**	-,398**	-,392**	-,307**	-,307**	-,457**	-,421**	-,396**	-,427**	-,385**	-,447**	-,479**	-,421**	-,421**	-,348**	-,419**	-,493**
	Significance level (KTB)	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS	TS
	Ho: Absent trend (Mann-Kendall)	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No	No
	Sense of trend (MK)	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B	B
	Lower terminal. CI coef. SEN's	-0,105	-0,118	-0,120	-0,112	-0,110	-0,114	-0,126	-0,120	-0,111	-0,118	-0,112	-0,129	-0,117	-0,116	-0,115	-0,128	-0,121	-0,120	-0,115	-0,122	-0,121	-0,122	-0,117	-0,115	-0,112	-0,126	-0,126
	Average value coef. SEN's	-0,067	-0,081	-0,087	-0,077	-0,074	-0,079	-0,094	-0,084	-0,077	-0,084	-0,081	-0,098	-0,087	-0,082	-0,078	-0,098	-0,091	-0,088	-0,084	-0,089	-0,093	-0,094	-0,087	-0,086	-0,079	-0,095	-0,095
	Upper terminal CI coef. SEN's	-0,028	-0,044	-0,053	-0,042	-0,037	-0,043	-0,062	-0,048	-0,042	-0,050	-0,050	-0,066	-0,057	-0,048	-0,041	-0,067	-0,061	-0,056	-0,052	-0,057	-0,066	-0,066	-0,057	-0,057	-0,046	-0,063	-0,063

NB : Abbreviations or marks : NS : Trend insignificant ; "S" or (*) : Significant trend with p< 0,05; "TS" or (**): Highly significant trend with p< 0,01.
"B" : Trend direction down ; "H" : Upward trend direction.
-0,194 No-conforming confidence interval terminal for Sens's test
CI coef. SEN's :Confidence interval of Sen's test coefficient
Abreviations of periodics precipitations trend variables: MAM: Quarter "March-April-June "; SemH: Wet semester ; SemS: Dry semester

4.2 Principal component analysis (PCA) on precipitation trends

On 13 variables of periodicity of precipitation released by Sens's tests (Tables 2 and 3); PCA is applied in successive treatments, in fact 7 variables are finally retained for effective analysis, the results of which are given below.

4.2.1 PCA results on trends of precipitation periodicity variables

a. Matrix correlations between variables (Table 4)

Table 4: Matrix of correlations of periodic rainfall trend variables at the Tadla perimeter for the period 1958-2018.

	September	December	April	June	MAM	SemH	SemS
September	1,000						
Décember	0,232	1,000					
April	0,063	0,599	1,000				
June	-0,246	-0,133	-0,209	1,000			
MAM	0,232	0,521**	0,821***	-0,049	1,000		
SemH	0,237	0,585***	0,634***	-0,267	0,510**	1,000	
SemS	0,439*	0,583***	0,660***	-0,116	0,754***	0,682***	1,000

* Abreviations : MAM: Quarter "March-April-June "; SemH: Wet semester ; SemS: Dry semester

* Significance levels (unilateral) of the correlation coefficient : (*) : significant (p < 0,05) ; (**): highly significant (p < 0,01) et (***): very highly significant (p < 0,001).

Our PCA is justified by a matrix with 50% significant coefficients (Yergeau and Poirier, 2013).

b. PCA validity tests on analyzed variables

PCA is confirmed by appropriate tests with results in Table 5.

Table 5: PCA evaluation by KMO index and Bartlett test in periodic rainfall trend variables in Tadla perimeter (1958 to 2018 period).

KMO index and Bartlett test		
Kaiser-Meyer-Olkin Index (KMO) for measuring sampling quality.		0,723
Bartlett Sphericity Test	Chi-square approximate	91,916
	Degrees of freedom	21
	Significance	7,525E-11

The PCA is validated (see paragraph on PCA; part "Materials and methods") since the KMO index is in norms: between "good" (index 0.7) and "excellent" (index 0.8); Bartlett's sphericity test is very significant for variables analyzed independently of each other (Yergeau and Poirier, 2013).

c. Eigenvalues and PCA components on selected variables

The indicators of the CPA conducted are presented in Table 6.

Table 6: Eigenvalues and PCA components on periodic rainfall trends in Tadla perimeter (1958-2018 period).

Component	F1	F2	F3	F4	F5	F6	F7
Eigenvalue	3,714	1,141	0,868	0,556	0,418	0,197	0,106
Variance.percent (%)	53,052	16,294	12,406	7,942	5,978	2,818	1,511
Cumulative.variance.percent (%)	53,052	69,346	81,752	89,693	95,671	98,489	100,000

The first two component axis (F1 and F2) have a cumulative variance percent 69.34%, and are retained because explained its near to minimum standard of 70 % (Yergeau and Poirier, 2013).

d- Characteristic elements of PCA on analyzed variables

The main elements of the CPA are set out in Table 7.

Table 7: Component values, representation qualities and PCA contributions of periodic rainfall trend variables of the Tadla perimeter (1958-2018 period).

Periodic Precipitation Trend Variables	Component		The quality of representation			Contributions (%)	
	F1	F2	Cos^2 (1)	Cos^2 (2)	Extraction	F1	F2
	(1)	(2)	(3)=$(1)^2$	(4)=$(2)^2$	(3) + (4)	(5)=[100*$(1)^2$/ (Eigenvalue F1=3,714)]	(6)=[100*$(2)^2$/ (Eigenvalue F2=1,141)]
September	0,397	-0,678	0,157	0,460	0,617	4,238	40,279
Décember	0,765	0,077	0,585	0,006	0,591	15,742	0,520
April	0,860	0,262	0,739	0,069	0,808	19,911	6,006
June	-0,273	0,730	0,074	0,533	0,608	2,002	46,757
MAM	0,845	0,265	0,714	0,070	0,784	19,223	6,168
SemH	0,810	-0,052	0,655	0,003	0,658	17,647	0,236
SemS	0,888	0,002	0,788	5E-06	0,788	21,227	5E-04

* Abreviations of periodics précipitations : "MAM": Quarter "March-April-June "; SemH: Wet semester ; SemS: Dry semester

Analysis of the results are as follows:

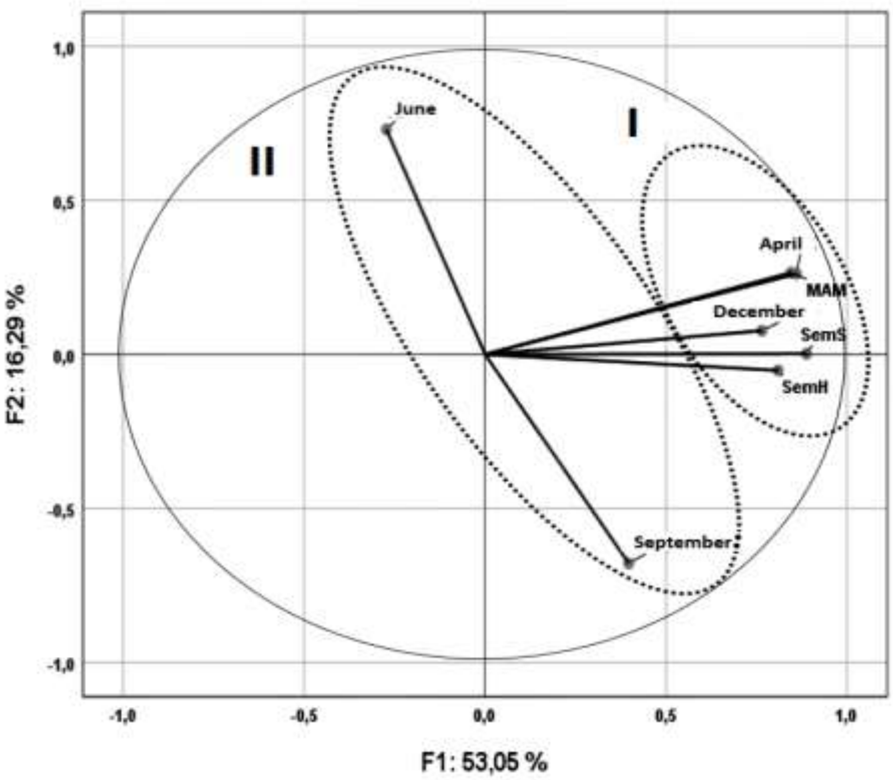
***First level:** Qualities of representations for variables*
Maximum information explained in total qualities of extraction of variables is from 0.59 to 0.81; of which on axis F1 is important for group I of five variables of monthly periodicities of December and April, quarterly of MAM and semesterly (wet and dry), compared to a very low value (minus 0.2) for group II of only two monthly variables of September and June; focus on axis F2, situation reversed by low value (minus 0.07) on variables in group 1versus high value (0.50) on variables in group 2.

***Two level:** Contributions of variables*
On F1 axis, information extraction contributions are high in group 1 variables (at 16 % to 21 %), but very low (< 4%) in group 2 variables; on opposite case of axis F2, it is minimal (< 6%) in group 1 coupled with increased level (> 40%) in group 2.

4.2.2 Graphical presentations on factorials axis's of the PCA

PCA achieved is shown by a circle of correlations in Figure 6.

Figure 6: PCA correlation circle for periodic precipitation trend variables at the Tadla Perimeter at 1958-2018 period

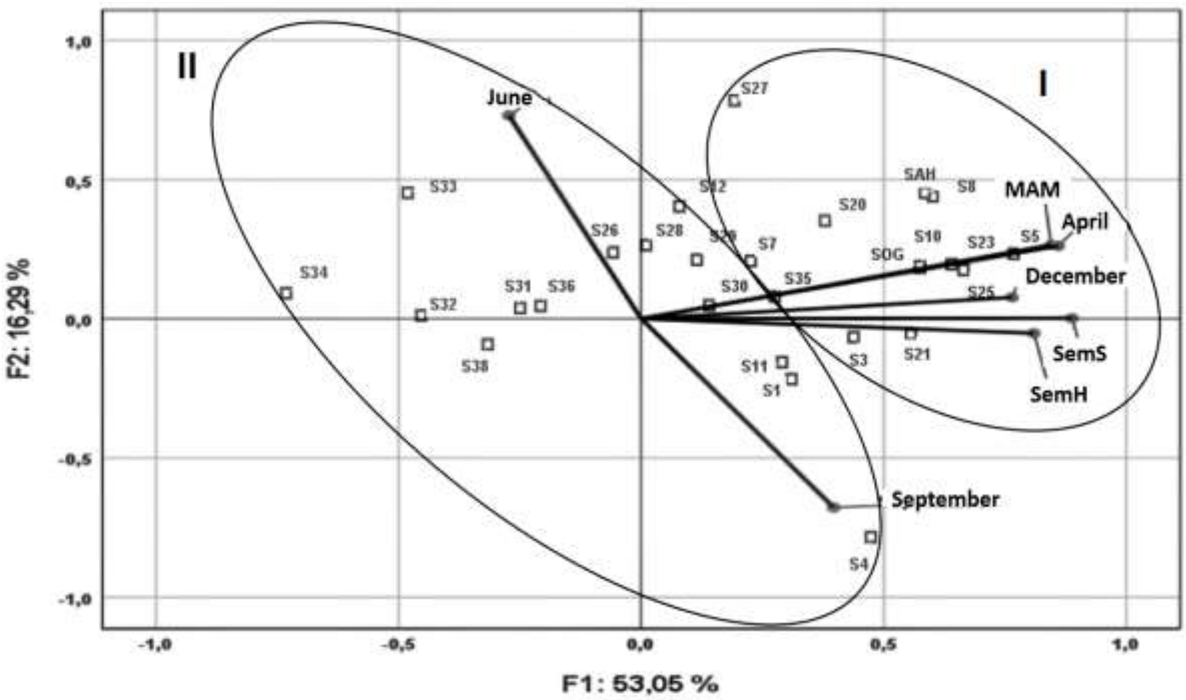


Graphical representations are important in monthly variables (September, April and June), quarterly (March-April-May = MAM) and semesterly (two both dry and wet), but witch reduced to the December month variable; groups 1 and 2 were identified, form so two homogeneous sets.

4.2.3 PCA spatialization of periodic precipitation trends

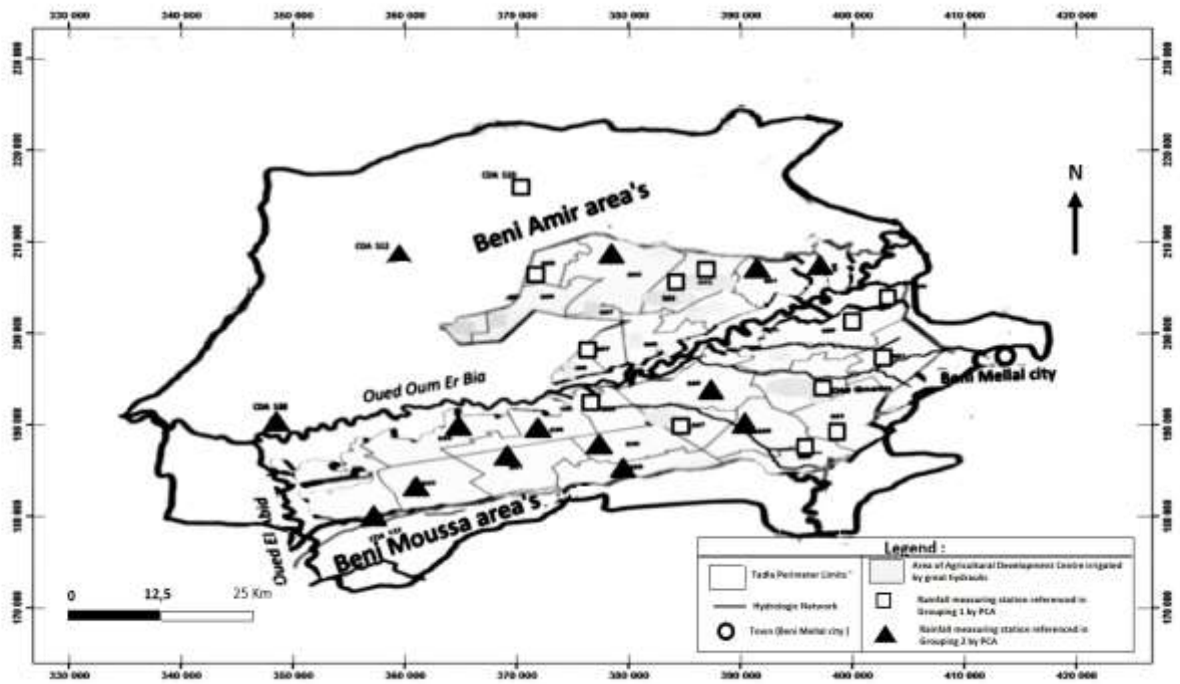
A bi-plot of the PCA spatializes trends in precipitations periodicities (the variables) with rainfall measuring stations (the individuals), is illustrating in Figure 7.

Figure 7: Bi-plot for PCA on periodic rainfall variables at Tadla perimeter of 1958-2018 period.



Regionalization of periodic rainfall trend in Tadla perimeter is defining by tow homogeneous spatial groupings (Figure 8): ***Group I***, witch identified by 13 sites measuring rainfall (stations in Beni Amir area: S3; S5; S7; S8; S10; SAH and stations in Beni Moussa area: S20; S21; S23; S25; S27; S35; SOG) for five variables (Tow monthly: December and April, one quarterly: March-April-May and tow semesterly: dry and wet). ***Group II***, its interest of 14 rainfall sites (at Beni Amir Stations: S1; S4; S11; S12; at Beni Moussa Stations: S26; S28; S29; S30; S31; S32; S33; S34; S36; S38) for 2 monthly trend precipitations variables (months: September and June).

Figure 8: Regionalization of periodic rainfall trends at the Tadla perimeter for the period 1958-2018.



In Tadla perimeter, geographical delimitations of grouping 1 and grouping 2 of periodic rainfall trend were found on respectively predominantly eastern and western positions.

4.3 Analysis of results compared to similar work's research

In monthly periods, rainfall reduction trends observed are confirmed in semi-arid continental Moroccan regions in March and June (Hanchane, 2013), in the Rhone River area in southern France in November and March (Norrant and Douguédroit, 2004) and in northern Algeria (Touhami, 2017); the observation of a significant positive trend in September, which is rarely reported in the literature on Moroccan territory, can be explained by our recent and extended rainfall series (1958-2018), marking a change in rainfall at the beginning of the agricultural year. During the quarter, our work identifying a significant drop in rainfall during the three quarters of the year is confirmed on Moroccan territory: In the extreme north (Tangier zone) and in the Sais plain (Meknes-Fez zone) (Driouech, 2010); conversely in the center, in winter, spring and autumn, with a small increase in rainfall (Sebbar et al, 2011); confirmed in the center, west-north and north Algeria over at least two seasons (Touhami, 2017). In half-yearly intervals, a downward trend in rainfall is affirmed in Morocco over extended winters

(October-March) (Driouech, 2010). In terms of annual rate, the regression of rain intensity observed in the study zone intersects with the work carried out in central Morocco (Sebbar et al, 2011), in semi-arid Moroccan continental zones (Hanchane, 2013) and in northern Algeria (Taibi et al, 2013).

Our regionalization of rainfall trends by the PCA, having identified two homogeneous geographical areas, is integrated, on an annual basis, into one of the five climatic zones of central Morocco with negative trends in winter and spring (Sebbar et al, 2011), which can be compared to northern Algeria with its six rainfall regions (Taibi et al, 2013) and to the three delimitations in the French south-eastern Mediterranean (Norrant and Douguédroit, 2004); on a semester basis: Our case is comparable to the gradual rainfall decrease from north to south of the semi-arid Algerian region of the Macta basin area (Chibane et al, 2015); at quarterly intervals: we refer to the five regions between central and west-north Algeria concerning the first three seasons of the agricultural year (Touhami, 2017); at monthly intervals: our observations of rainfall trend decrease in two homogeneous regional areas in autumn and spring months, are similar to the work carried out in West Africa such as the three rainfall sub-regions identified in the N'Zi basin area in central at Côte d'Ivoire country (Koudou, 2015).

V. CONCLUSION

The study of rainfall trends in our semi-arid climate zone, is reporting a structural circumstance of reduction over time of the annual volume of rainfall, which had prompted us to carry our analyses on restricted periodicities: in months, quarters and semesters, by appropriate methods; so is revealing that significant trends concern only 9 out of 12 months of the agricultural year, with the first month in September marked by a tendency of rainy increase; by shifting the month of October without change, relayed at continuous series of eight months (at November to June) with a tendency of rainy regression. In seasonal temporally, a significant reduction trend of rainfall is for last three quarters of the agricultural year, to know: December-January-February; March-April-May and June-July-August; in semesterly intervals, the both a wet semester (September to February) and a dry semester (March to August) are still tendency of rainfall decrease. These are supplemented by regionalization approach in our study area, of periodics rainfall trends by Principal Component Analysis (PCA) method, which has enabled us to identify two main homogeneous geographical areas. These pertinent results of trend analyses and regionalization of periodic rainfall in this semi-arid climate model area are of capital importance for possible exploitation in design of climate change impact resilience programs, focused on rational and efficient use of water resources scarcity in vulnerable environments.

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