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Analysis of trend rainfall: Case of North-Eastern Algeria

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Abstract

The climatic change is a reality largely recognized today in the scientific community. Nevertheless, its impact on precipitation, especially on annual, monthly and seasonally rainfall in arid and semi-arid regions is not yet certain. Indeed, very few studies have dealt with this matter in Algeria.

In this context to examine spatial distribution of annual and seasonal rainfall an attempt has been made using the inverse distance weighting (IDW) method. Trends and magnitude estimate of change in rainfall series were detected by Mann–Kendall tests and Sen's test slope, has been applied to the data registered of 35 stations in the watershed Constantinois Seybouse Mellegue (CSM) North-Eastern Algeria over a period of 43 years (1969–2012).

Results from spatial plot of annual rainfall showed that the rainfall increases with altitude, but is higher for the stations exposed to moist winds. It also increases from east to west and conversely decreases as one moves away from the coast to the south. From statistical method showed that there are increase trends at 95% confidence at annual scale in some rainfall stations with high altitude and coastal stations during winter season.

Key words: *climate change, Mann–Kendall test, North-Eastern Algeria, rainfall, trend*

INTRODUCTION

Water is used for transportation, is a source of power, and serves many other useful purposes for domestic consumption, industry in general and in the sector of agriculture in particular, which consumes approximately 70% of annually mobilized water. The amount or availability of water for various purposes is very much depending upon the amount of precipitation in that particular area. Excess or extended absence of rainfall will cause flooding and drought, respectively.

ADLER *et al.* [2000] stated that precipitation information is essential for understanding the hydrologic balance on a global scale and for understanding the complex interactions among the components within the hydrologic cycle.

Rainfall is one of the climatic factors that can indicate climate change [OBOT, ONYEUKWU 2010]. Global averaged rainfall is projected to increase, but both increases and decreases are expected at the regional and continental scales [IPCC 2013].

Thus, the climate variability can be regarded as the variability (extremes and differences of monthly, seasonal and annual values from the climatically expected value) inherent in the stationary process approximating the climate on a scale of a few decades. The inter-annual hydro climate can fluctuate considerably, resulting in the difficulty of detecting a statistically significant.

The interest in this topics has increased and major efforts have been spent in learning about precipitation variability and trends due to adverse effects of climate change [JAGADEESH, ANUPAMA 2014; JAYAWARDENE *et al.* 2005; KHOMSI *et al.* 2015; KUMAR *et al.* 2010; OBOT, ONYEUKWU 2010; PARTA, KAHYA 2006; SOLTANI *et al.* 2012]. Numerous studies have been carried out to analyze the trends in precipitation throughout the world and more especially in Mediterranean basin [GUIJARRO *et al*. 2006; LONGOBARDI, VILLANI, 2010; MEHTA, YANG 2008; PHILANDRAS *et al.* 2011] and in North of Africa region [KHOMSI *et al.* 2015; NOUACEUR, MURĂRESCU 2016].

BUFFONI *et al.* [1999] studied series of annual and seasonal precipitation from 32 stations located in northeastern of Italy for the period 1833–1996. They observed some decreasing trends in the annual series, which were statistically significant only for spring in the central south and for autumn in the North of Italy. COLOIERO *et al.* [2011] performed a statistical analysis of annual and seasonal precipitations over 109 rainfall series with more than 50 years of data observed in southern Italy (Calabria).

The employed rainfall data were first processed using a pre-whitening technique in order to reduce the autocorrelation of rainfall series. This study showed a decreasing trend for annual and winter-autumn and an increasing trend for summer precipitation. Moreover, high percentages of rainfall series showed breaks during the decade 1960–1970.

CHAKRABORTY *et al.* [2013] applied Mann–Kendall (MK) and Spearman's rho test (parametric) to detect the trend. The Sen's slope test was used to detect trend magnitude. The cumulative sum test CUSUM and cumulative deviations test were applied to detect change points to analyze the rainfall at Seonath sub basin in Chhattisgarh State (India) for 49 years (1960–2008). The result according to both tests was a decreasing trend in annual and seasonal rainfall series for the whole river basin.

FARHANGI *et al.* [2016] used the Mann–Kendall trend test method to study average monthly and annual rainfall time series of 40 stations in the west part of Iran. The study showed that the most rainy months in the country (November to May), in November 68% of the stations have upward trend, while in March 92% of the stations have downward trend. Analysis of mentioned time series of control stations reveals that 51% of time series have decreasing trends, while 49% experience increasing trends.

The objective of this paper is to analyse the trends and variability of long term time series of seasonally and annual precipitation based on different statistical methods for the implications of changes at the both scale are particularly significant for water resource management processes related to rainfall cycles.

In order to study trends in rainfall we used different statistic methods. Mann–Kendall (MK) (non-parametric) and Sen's slope were used to detect trend magnitude.

In the present paper, 43 years (1969–2012) of rainfall data from 35 rain-gauges situated in different parts of Constantinois Seybouse Mellegue (CSM) in North East of Algeria were used to study the trend of rainfall in the area. This study consists of four sections; first section introduces the paper and explains motives of this work. The second section describes the study area, the data employed and the statistical techniques applied for trend and step change detection. The third section discusses the results while the fourth one outlines the major findings.

STUDY AREA

Algeria is located in the northwest of the African continent; it forms with Morocco and Tunisia the southern edge of the Mediterranean. It is a very wide country, its country predominantly located in a semi-arid and arid zone, this is leading to the different general atmospheric circulation, the great geographical assemblages of the country and the latitude. The ridge of high pressure, common throughout Morocco-Spain in autumn and spring, prevents the occurrence of rain [TABET 2008].

The Tellian Atlas range dominates the coastline and receives much more humid flows from the North than the West. Schematically, precipitation over the whole of our study area is quite diverse; on the one hand by their causes, and on the other hand by the quantities collected, they decrease from the coastal region to interior region with a strong latitudinal gradient, altered nevertheless by the orographic effect of the Saharan Atlas where rains are decreasing.

Our study of area concerns the northeastern part of Algeria (Fig. 1). It is limited by the parallel meridians 4°50' E and 8°40' E and parallel 37°50' N and 34°16' N. The total area of this zone is approximately 89,630 km^2. This geographic extends over a length of about 1000 km and is covers the watersheds of coastal Constantine (03), Constantine High Plateaus basin (07), Kebir Rhumel (10), Medjerda (12) and Seybouse (14). Mean annual temperatures (1997–2006) are relatively warm on the coast various between 18°C to the 20°C due to the influence of the sea, as a factor in winter and refreshing in midsummer. They reduce inward on the Tell south from 15°C to 17.6°C due to the continental [ONM 2006]. Thermal minima are generally achieved in January while the maxima are reached in July and August. TABET [2008] shows that the coastal stations are characterized by maximum between 25 and 30°C reached in July. The minima are recorded in January. They are below 10°C. Autumns are warmer than springs.

DATA COLLECTION

In order to more accurately describe the variability of the climate and also to reconstitute the missing data in homogeneous regions, all stations with less than 10 years of observations were excluded. We have taken into account the rainfall network available in the basin of Constantinois Seybouse Mellegue (CSM), i.e. a total of 35 stations over a period of 44 years (1969–2012).

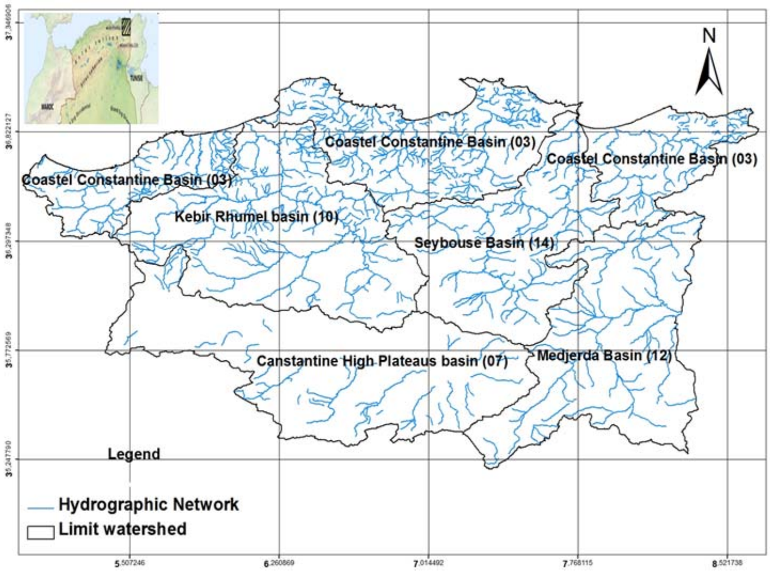

Fig. 1. Basins and rainfall station of CSM zone; source: own elaboration

The stations integrated in this study are selected according to their latitudinal position, the distance with respect to the sea, completeness and the length of the series one chose. Before the data can be used, and even though they are in an adequate format, it is important to check the reliability and accuracy of the data series. The control makes it possible to validate the data before their organization within a data bank for their making available for operational purposes. The double mass method and the objective Student's *t* test were applied to the data time series of each station. Student's *t* test assesses homogeneity by determining whether or not various samples are derived from the same population [PANOFSKY, BRIER 1968]. In a homogeneous series, variations are caused only by the variation in weather and climate [CONRAD, POLLAK 1950]. Thus, modified series obtained through the subtraction of the reference series from the original series of each station should be more capable of detecting any homogeneity resulting from non-climatic factors [SU *et al.* 2006]. The results reveal that there is no statistically significant variation or break point existing in the rainfall time series at the 95% level of confidence.

The results of Table 1 show summary statistics of annual rainfall in 35 stations for the time period 1969–2012 including the description intrinsic of observations and we compute the parameters of skewness and kurtosis.

The skewness is a measure of symmetry for a normal distribution. Negative values for the skewness indicate data that are skewed left and positive values for the skewness indicate data that are skewed right. Kurtosis is a measure of whether the data are heavy-tailed or light-tailed relative to a normal distribution. Datasets with low kurtosis tend to have a flat top near the mean rather than a sharp peak. The standard normal distribution has a kurtosis of zero. Positive kurtosis indicates a peaked distribution and negative kurtosis indicates a flat distribution.

Many studies characterize heavy rainfall by 75th, 90th and 99th percentile [LUPIKASZA 2008; MARTINEZ *et al.* 2007; KHOMSI *et al.* 2011]. The values of annual percentiles are higher in the stations situated in the east and southeast of our region.

The Figure 1 shows the location of various measurement stations established in this work.

METHODS AND MATERIALS

Trend tests are tests which allow the identification or estimation by certain methods of the existence or absence of a trend in hydrological time series data with level of significance given.

MANN–KENDALL TEST

In order to detect trends in the time series of precipitation amounts, it was used the Excel template MAKESENS (Mann–Kendall test for trend and Sen's slope estimates), developed by the researchers of the Finnish Meteorological Institute [SALMI *et al.* 2002].

The non-parametric Mann–Kendall test, which is commonly used for hydrologic data analysis, can be used to detect trends that are monotonic but not necessarily linear. The null hypothesis in the Mann–Kendall test is independent and randomly ordered data. The Mann–Kendall test does not require assuming normality, and only indicates the direction but not the magnitude of significant trends [MANN 1945; KENDALL 1975].

The Mann–Kendall test statistic S is calculated using the formula that follows:

$$S = \sum_{j=1}^{N=1} \sum_{j=1}^{N} \operatorname{sign}(X_i - X_j) \qquad (1)$$

Where: $\operatorname{sign}(X) = \begin{cases} 1 & \text{if } X > 0 \\ 0 & \text{if } X = 0 \\ -1 & \text{if } X < 0 \end{cases}$

Table 1. Statistical summary of annual rainfall data of coastal zone

Basin	No	Station	Elevation Z m	Mean mm	Coefficient of variation	Skewness	Kurtosis	Percentile		
								75	90	99
03	01	Boukhlifa	160	902.6	24.9	0.02	–0.23	1 055.6	1 144.0	1 359.6
	02	Aokas	19	595.0	20.9	–0.23	–0.47	689.0	748.7	850.9
	03	Ain Roua	1 100	595.0	20.9	–0.23	–0.47	689.0	748.7	850.9
	04	Jijel	5	919.9	23.8	–0.03	0.00	1 061.7	1 210.0	1 416.7
	05	Taher	56	936.4	20.7	0.20	0.14	1 059.5	1 167.8	1 410.9
	06	Ramdan Djamel	50	583.8	23.9	0.92	1.19	671.1	725.3	1 028.0
07	07	Ain Djassar	865	280.0	30.2	–0.03	–0.83	355.7	368.7	481.2
	08	Ain Yagout	870	327.0	28.2	0.07	–1.17	406.7	460.7	491.1
	09	Seguene	1 400	440.5	32.5	0.28	–0.35	538.9	614.2	785.0
	10	Timgad	1 000	306.1	44.9	1.29	3.12	371.8	468.3	819.5
	11	Toufana	1 040	289.1	41.1	0.89	1.05	366.9	420.9	651.4
	12	Ain Beida	1 004	411.0	25.4	0.53	0.19	463.2	589.2	687.0
10	13	Beni Aziz	770	696.7	35.3	0.27	0.40	845.0	1 011.9	1 386.9
	14	Tadjenanet	845	332.5	28.5	0.54	0.60	378.7	439.0	597.0
	15	Boumalek	900	545.2	42.7	2.10	7.36	607.5	815.8	1 557.3
	16	Oueled Naceur	839	334.0	45.1	0.92	0.43	429.4	567.8	780.8
	17	Ain Fakroun	920	402.0	38.8	0.69	0.03	471.6	636.2	795.3
	18	Hama Bouziane	740	532.1	21.9	0.58	2.59	594.0	666.9	942.8
	19	El Milia	830	894.7	25.2	0.80	0.54	1 012.4	1 220.8	1 557.7
12	20	Souk Ahras	590	582.5	30.1	0.03	0.13	697.5	805.4	991.3
	21	Taoura	850	565.1	40.9	0.58	0.35	711.3	844.3	1 165.2
	22	Ain Sadjra	1 010	314.0	43.6	1.19	3.13	382.0	443.1	763.2
	23	Tébessa	890	367.0	32.9	0.48	–0.49	432.5	584.5	624.0
	24	Boukhadra	900	353.5	41.0	0.65	0.05	434.0	542.4	761.5
	25	Hammamet	460	331.1	33.4	0.79	1.39	388.9	469.9	676.6
	26	Ouenza	520	280.5	31.0	0.39	–0.37	343.3	407.1	498.7
	27	M'Dahourouche	870	348.9	34.9	0.52	0.49	416.4	505.8	700.0
14	28	Berriche	800	320.7	45.3	1.43	1.67	371.2	555.2	722.8
	29	Foum Khenga	100	309.8	35.6	1.03	0.80	362.0	448.7	628.3
	30	Bordj Sabath	525	542.6	24.9	0.97	0.89	595.5	730.5	928.5
	31	Heliopolice	875	598.4	26.6	–0.05	–0.67	715.4	812.8	904.7
	32	Machroha	750	1 130.7	43.0	0.42	–0.71	1 572.9	1 811.3	2 170.5
	33	Bouchegouf	480	548.3	26.9	0.33	–0.39	641.4	745.8	884.0
	34	Ain Berda	40	630.0	23.8	0.21	–0.53	734.8	842.9	973.0
	35	Pont Bouchet	800	613.4	22.5	0.53	–0.17	697.5	824.6	933.6

Source: own study.

When S is high and positive it implies that the trend is increasing, and a very low negative value indicates a decreasing trend. The variance of S, for the situation where there may be ties (that is, equal values) in the x values is given by:

$$\mathrm{Var}(S) = \frac{1}{18}\left[N(N-1)(2N+5) - \sum_{i=1}^{m}(t_i-1)(2t_i+5)\right] \quad (2)$$

Where m is the number of tied groups in the data set and t_i is the number of data points in the i^{th} tied group. For n larger than 10, Z_{MK} approximates the standard normal distribution [YENIGUN *et al.* 2008].

$$Z_{MK} = \begin{cases} \dfrac{S-1}{\sqrt{\mathrm{Var}(S)}} & \text{if } S>0 \\ 0 & \text{if } S=0 \\ \dfrac{S+1}{\sqrt{\mathrm{Var}(S)}} & \text{if } S<0 \end{cases} \quad (3)$$

The presence of a statistically significant trend is evaluated using the Z_{MK} value, the positive value of Z_{MK} indicates an upward trend and its negative value a downward trend. The statistic Z_{MK} has a normal distribution. To test for either an upward or downward monotone trend at α level of significance, H_0 is rejected if the absolute value of Z_{MK} is greater than Z (1 – α/2), where Z (1 – α/2) is obtained from the standard normal cumulative distribution tables.

SEN'S ESTIMATOR OF SLOPE

Sen's method proceeds by calculating the slope as a change in measurement per change in time, as shown here in equation bellow:

$$Q = \frac{X_i - X_j}{i - j} \quad (4)$$

Where: Q = slope between data points X_i and X_j; X_i = data measurement at time j; X_j = data measurement at time k; i = time after time j, X_i and X_j constitute the pairs of observations identified by place in the series.

RESULTS

VARIABILITY OF MEAN ANNUAL RAINFALL

The region of coastal Constantine basin characterize by the high elevation so that can receive up to 1800 mm per year this importance depends to the mountains of Kabylie Eastern with tops to intensify 1000 m, the chains numidic (Sidi Dris 1364 m), the mounts of Constantine (Djebel Ouahche 1281 m). Also, a precipitation is in close relationship to their position compared to the rainy currents but the contrary in other stations for example Jijel located at an altitude of 6 m receives on average a rainfall of 920 mm, whereas Ain Roua situated at 1100 m altitude doesn't exceed 595 mm as shown in Figure 2, so it can be deduced that the average rainfall of the stations does not depend solely on altitude but there are other factors that influence the spatial distribution of precipitation in the region.

The climatic conditions of Kebir Rhumel are those of the Mediterranean climate. Annual rainfall presented in Figure 2 varies from 332 in Tadjenanet station to El Milia 894 mm in the northern part of the basin with elevations of this part between 740 to 920 m. This area is subjected to the double influence of a Mediterranean mode giving a climate moderated to North and a less degree with a subtropical mode in the South. The distance of the sea, the presence in the North of high reliefs of the Numidic chain, cause a progressive drying of the masses of air coming from North. Nevertheless precipitations of cyclonic origin remain most abundant. Medjerda basin shows that annual rainfall can reach 280 to 582 mm in the North of the area on the mountains which constitute the border with El Taref and which is covered with large forests. The high variability is mainly due to the heavy rains received by the summits of the Souk-Ahras region, where the winds blowing from North and Northwest upload their rains before they arrive to the southern part of the basin which is characterized by low rainfall is 280 mm. The High Plains receive moisture winds that arrive to cross the mountains of the Tell Atlas. These winds are much drier and especially as one moves away to the south. Region of the Constantine High Plateaus is characterize by a high altitude than the zone Tellian but it showed a major reduction in annual rainfall less than 450 mm for the station Seguene to 280 mm for Ain Djassar. The Tell-west is less watered because it is in the shelter position relative to the south of Atlas ranges. These result were found relevant with climate variability and the decline in rainfall that has affected Africa. In Algeria, the work of MEDDI and MEDDI [2009] shows a decrease in annual precipitation that exceeds 36% in the Mascara region and in the extreme west. The study by KINGUMBI *et al.* [2000] showed that there was a significant decline of annual rainfall in central Tunisia between 1976 and 1989.

VARIABILITY OF MEAN SEASONAL RAINFALL

The study of seasonal variability is essential to see if the decline or increase in rainfall is peculiar to a particular season or to several seasons, it allows to better visualize the chronology of the means seasonal rainfall over time. We evaluated the variability of seasonal precipitation as a percentage for a period extending from 1969 to 2012 in the stations available.

To estimate the variability of spatial for the season rainfall (autumn, winter, spring and summer) precipitation, the inverse distance weight (IDW) method, one of the simplest interpolation techniques [LONGOBARDI, VILLANI 2010] have been selected to obtain the map illustrated in Figure 3.

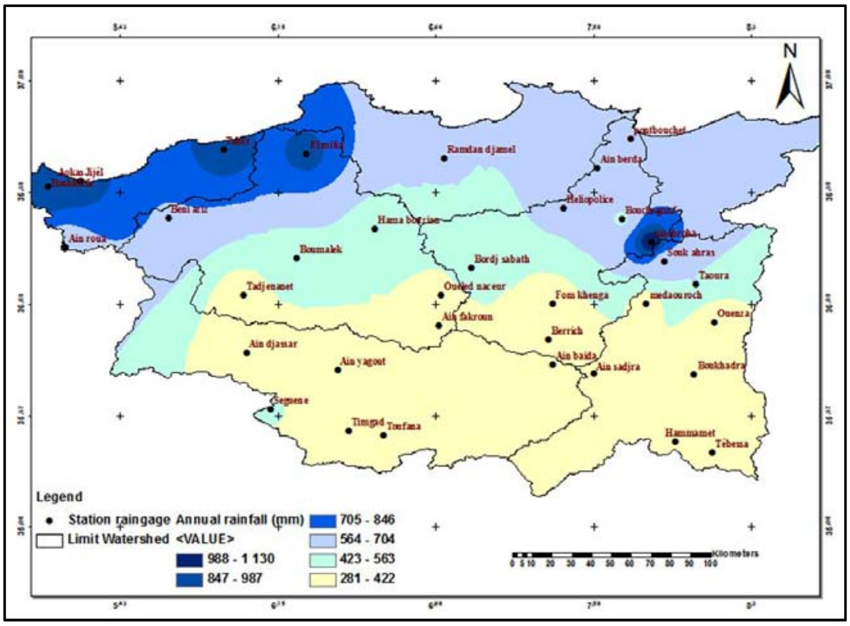

Fig. 2. Variability of mean annual rainfall time series; source: own elaboration

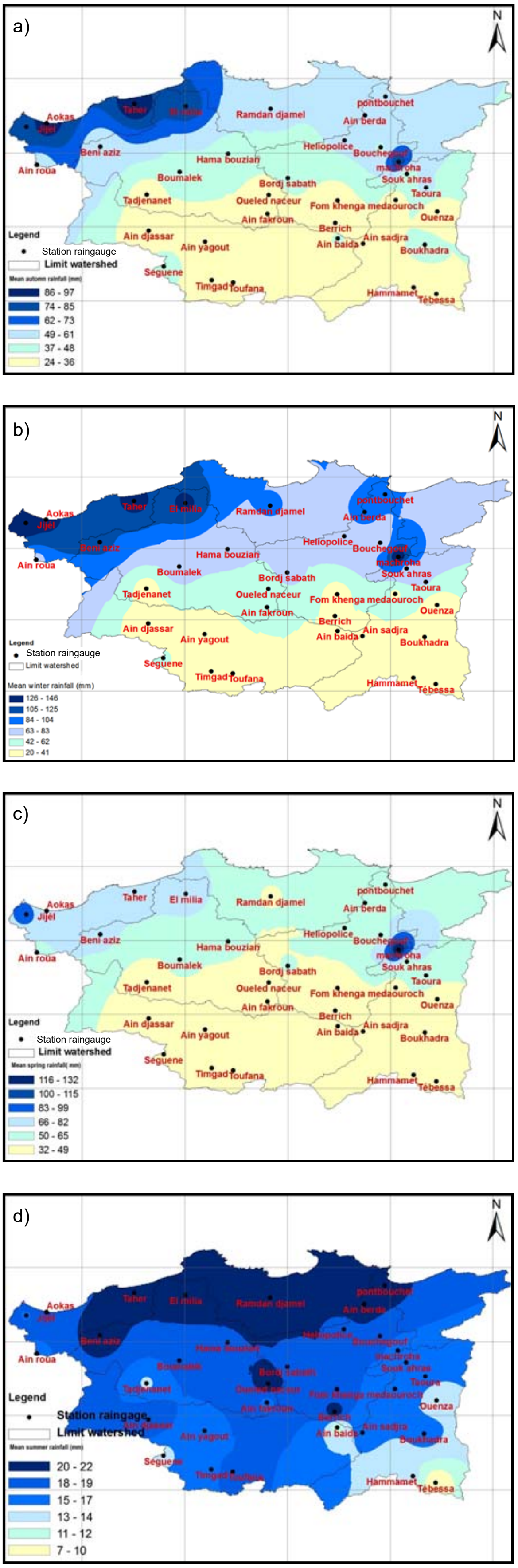

Fig. 3. Spatial distribution of mean rainfall in: a) autumn, b) winter, c) spring, d) summer; source: own study

Mean autumn variability

Figure 3a shows that the average autumns rainfall varied from 20 to 100 mm, or we noticed that more than 70% of the rain is concentrated in the western Constantine coastal regions and the north of the Medjerda. The rest of the region receives only low rainfall. This translates into a relative dispersion of autumn rains.

Mean winter variability

The mean variability of winter rainfall time series, over the whole dataset, is illustrated in Figure 3b. The map shows that rainfall is the highest relative to all stations and this related to the climate characterize the area.

Rainfall bands ranging from 105 to 150 mm cover 20% of the area including the stations of Jijel, Machroha, El Milia and Taher belongs to the bioclimatic stage humid with winter-soft, while stations Ain Berda and Ramdane Djamel belongs to the bioclimatic sub-humid with winter-hot. Going into interne area, the mean winter rainfall amount less than 80 mm including the resort of Souk-Ahras, Bouchegouf, Heliopolice, Boumalek and Hama Bouziane belongs to the wet zone with winter-fresh. The station of Ouled Naceur and Ain Fakroun belongs to the sub-humid stage with winter-soft. Rain bands ranging from 60 to 20 mm occupy 40% of the study area is suitable for the stations of Tébessa, Ouenza, Ain Yagout, Bukhadra and Timgad belong to the bioclimatic stage Semi-Arid with winter-fresh.

Mean spring variability

Results from mean spring rainfall (Fig. 3c) showed that the highest value of variability was observed at Jijel and Machroha. The others stations depicted the largest value both in Seybouse and Kebir Rhumel varies between 66 to 86 mm rainfall analysis; this proves that rainfall in Kilimanjaro is least reliable. However, this rains season plays an important role in the agricultural and socioeconomic activities of our region.

Mean summer variability

In the summer, we noticed that the precipitation is zero in the station of Ain Yagout, Seguen, and Timgad which mean that this season is dry and the maximum value does not exceed 46 mm (Fig. 3d).

Finally, we note that maritime influences facilitate the formation of rain in winter mainly in the littoral regions. Rainfall is important in winter, average in autumn and spring and minimal in summer.

TREND ANNUAL RAINFALL

The tests of Mann–Kendall applied to the series of annual pluviometric data of the 35 stations chosen over one period of 1969–2012, detected a trend significant on different level. For 35 stations only 24 series did not know any significant tendency. This result thus does not translate a specific regional behaviour. The stations with positive trends have their own specificities. Some are located between the mountains or the others are located at low altitude near the sea. The magnitudes of positive trends in annual rainfall were recorded at Jijel station (5.915 mm), Ouled Naceur (3.445 mm), Ain Fakroune (5.705 mm) Helio Police (22.951 mm), Machroha (2.181 mm) and Ain Berda (2.707 mm) districts (Tab. 2) while the negative trends were recorded in the districts Taoura –5.657 mm in Ain Sedjra –2.946 mm and Foum el Khanga –2.500 mm at level 0.90 to –3.126 mm in Boukhadra districts at level 0.99.

TREND SEASONAL RAINFALL

The application of statistics *Z*, and *Q* on the series of totals of autumn precipitation show a near zero tendency in all studied stations, and a tendency to high in the two following stations: Ouled Naceur and Ain Fakroun. The stations viz. Jijel, Taher and Ain Fakroune shows decreasing trend in winter rain fall with Sen's slope 1.273; 1.086 and 0.714 mm respectively, whereas Seguene shows negative trends with Sen's slope –0.418 mm. The Mann–Kendall test statistic on the trend of spring totals shows a significant upward trend for the stations of Ain Djessar (0.358 mm) and Machroha (2.115 mm), as well as significant downward trends for the Aokas stations (–0.431 mm); El Milia (–2.340 mm); Ain Sadjra (–0.431 mm); Hammamet (–0.7444 mm) and Berriche (–0.592 mm). For the summer totals, this test shows a significant upward trend for the following stations: Taher (0.134 mm): Ain Djassar (0.214 mm); Ain Beida (0.237 mm); Tedjenanat (0.211 mm); Souk-Ahras (0.207 mm); Berriche (0.272 mm) and Machroha (0.460 mm). That the other stations do not represent any significant trend.

Table 2. Result of test Z_{MK}, statistical significances (*SS*) and Sen's slope estimate (*Q*) for annual and season rainfall

Station number	Annual			Autumn			Winter			Spring			Summer		
	test Z_{MK}	*SS*	*Q*	test Z_{MK}	*SS*	*Q*	test Z_{MK}	*SS*	*Q*	test Z_{MK}	*SS*	*Q*	test Z_{MK}	*SS*	*Q*
S1	–0.88		–2.402	0.52		0.282	1.50		0.851	–0.58		–0.279	–1.27		–0.129
S2	–1.06		–1.927	–0.19		–0.077	0.15		0.069	–1.97	*	–0.791	–0.01		0.000
S3	–1.06		–1.927	0.09		0.013	–0.26		–0.072	–1.57		–0.426	–0.47		–0.040
S4	2.17	*	5.915	0.90		0.396	2.09	*	1.273	–0.05		–0.033	0.52		0.040
S5	1.63		3.536	0.13		0.136	1.99	*	1.086	–0.48		–0.171	2.03	*	0.134
S6	0.23		0.416	0.00		0.000	1.06		0.387	–0.76		–0.137	0.05		0.001
S7	1.40		1.224	1.14		0.213	0.49		0.072	1.99	*	0.358	2.34	*	0.214
S8	0.11		0.268	–0.40		–0.068	0.28		0.043	–0.27		–0.048	0.56		0.062
S9	–2.34	*	–3.858	–1.16		–0.295	–1.91	+	–0.418	–1.39		–0.428	0.67		0.070
S10	–0.92		–1.492	–0.07		–0.021	–0.48		–0.066	–0.86		–0.170	0.50		0.065
S11	0.05		0.111	0.82		0.167	–0.13		–0.011	–0.69		–0.225	–0.79		–0.090
S12	–0.21		–0.272	0.75		0.171	–0.54		–0.092	–0.90		–0.225	2.04	*	0.237
S13	–0.33		–1.078	–0.49		–0.134	–1.02		–0.525	–0.42		–0.203	–0.92		–0.048
S14	1.55		2.034	0.86		0.129	1.48		0.263	0.50		0.110	1.78	+	0.211
S15	–0.35		–1.079	0.19		0.059	–0.05		–0.030	–0.58		–0.153	0.84		0.085
S16	1.71	+	3.445	1.67	+	0.271	1.00		0.284	0.72		0.158	1.41		0.093
S17	3.23	**	5.705	1.98	*	0.425	3.03	**	0.714	1.49		0.380	0.38		0.041
S18	0.93		1.260	0.40		0.085	0.95		0.210	–0.97		–0.233	1.24		0.089
S19	0.35		0.638	0.19		0.043	1.10		0.686	–2.34	*	–0.938	–0.23		–0.012
S20	0.57		1.419	–0.28		–0.071	1.23		0.683	–0.57		–0.241	1.91	+	0.207
S21	–1.93	+	–5.657	–1.28		–0.420	–1.40		–0.576	–1.61		–0.590	1.02		0.116
S22	–1.93	+	–2.946	–0.64		–0.142	–1.87	+	–0.368	–2.11	*	–0.431	0.33		0.037
S23	0.19		0.328	1.00		0.254	–0.32		–0.060	0.02		0.007	0.35		0.085
S24	–2.72	**	–3.126	1.61		0.417	0.84		0.171	0.48		0.107	1.09		0.076
S25	0.31		0.539	–0.53		–0.091	–1.40		–0.147	–2.73	**	–0.744	–0.23		–0.026
S26	0.84		1.419	0.52		0.282	–1.13		–0.129	–1.08		–0.243	0.50		0.073
S27	0.46		0.961	–0.19		–0.077	0.68		0.174	0.03		0.008	2.44	*	0.272
S28	–0.56		–0.445	0.09		0.013	–1.35		–0.270	–2.53	*	–0.592	0.34		0.026
S29	–1.81	+	–2.500	0.90		0.396	0.78		0.172	–1.49		–0.276	0.37		0.048
S30	0.09		0.332	0.13		0.136	2.17	*	0.765	0.31		0.084	0.07		0.002
S31	3.51	***	22.951	0.00		0.000	0.62		0.262	–0.15		–0.039	1.17		0.094
S32	1.73	+	2.181	1.14		0.213	2.46	*	1.952	2.90	**	2.115	3.35	***	0.460
S33	1.55		2.720	–0.40		–0.068	0.92		0.278	–0.52		–0.141	0.95		0.074
S34	1.77	+	2.707	–1.16		–0.295	2.11	*	0.792	–0.75		–0.153	0.75		0.051
S35	1.25		2.353	–0.07		–0.021	2.13	*	0.825	–0.23		–0.070	1.14		0.077

*** If trend at α = 0.001 level of significance, ** if trend at α = 0.01 level of significance, * if trend at α = 0.05 level of significance, + if trend at α = 0.1 level of significance.
Source: own study.

DISCUSSION AND CONCLUSION

To detect the existence of a possible trend in the series of rainfall data, two approaches were used seasonal and annual rainfall variability over time.

The map of distribution of annual and seasonal rainfall for rain-gauge stations are given in Figure 2 and 3. The statistical analysis of rainfall data is presented in Table 1. From the table it can be seen that the North region received the highest mean annual and seasonal rainfall. The mean annual rainfall varies from 583 mm for Ramdan Djemel to 936.4 mm for Taher. This situation is characterized by a polar air down quite large in the middle and upper layers of the atmosphere. These disturbances, arriving in winter, cross Europe and keep their polar front character arriving in the North where they give heavy rains often accompanied by snowfall on the Atlas. Looking at the amount of rainfall in different seasons (Tab. 1), it is marked that all the stations receive the maximum rainfall in winter seasons and minimum rainfall in summer season.

The degree of variability is often measured by the coefficient of variation [Groupe Chadule 1974]. This coefficient is only the ratio of the standard deviation of a series to its mean. According to CAMBERLIN [1994], the use of this statistical concept requires considerable caution, especially in regions with low rainfall.

The results of coefficient of variation have represented higher varies between 20% (Taher) and 45% (Berriche) indicating that there is significant variation in the total amount of rainfall between the locations. The correlation coefficients between rainfall and time for all four stations are presented in Table 1.

To detect the annual and seasonal trends we use the non-parametric tests of Mann-Kendall, which allow to cross constraints imposed by other parametric methods and which have proved their effectiveness in this type of application. Generally, the Figure 2 shows a decreasing in rainfall from North to South. These results demonstrate the impacts of anthropogenic developments in the study area in agreement with the observations by HASSINI *et al.* [2011], MEDDI [2013], BALAH and AMARCHI [2016] and KOURAT and MEDJERAB [2016].

The results of the non-parametric Mann–Kendall test (Z_{MK}), statistical significances (*SS*) and Sen's slope estimate (Q) of rainfall at annual and seasonal (1969–2012) in different watershed of CSM area is shown in Table 2. Both negative and positive trend significant were found in annual and seasonal rainfall over the study area. The direction of annual rainfall trend was, in general, sliding and statically significant across the Coastal Constantine and Seybouse basin. In the humid zone only one of six stations showed increase trends with significance at 95%. For this station showed that Sen's slope estimates 5.915 mm in the arid zone shows decrease varies between –3.858 and –5.657 mm. However, the semi-arid zone showed an increase in the statistical significance from 95 to 99.90% through 99%. This is illustrated in Figure 4, where the majority of rainfall is strongly represented in wet region. It can thus be said that this trend follows well the limits of the basin which play the role of climatic screen. The positive trend for the two respective sub-basins the coastal plains, Atlas Tellian and the other basin is Constantine high plateaus.

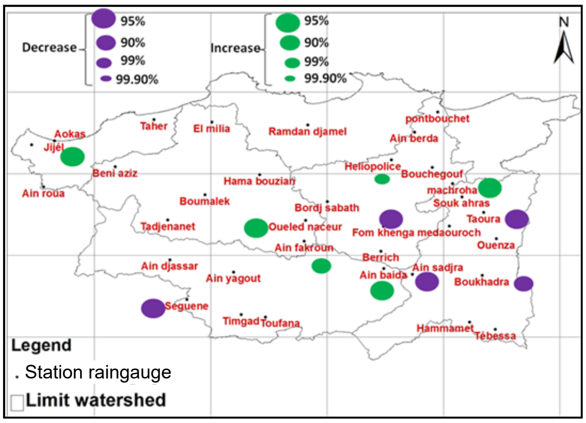

Fig. 4. Trend in annual rainfall CSM region from 1969–2012; source: own study

From the Sen's slope estimator revealed that the rate of increase in the autumnal rainfall was detected in Ouled Naceur at level 95% and in Ain Fakroun at 99% as was shown in Figure 5a, since its stations are located in the inner Tell.

For winter season (Fig. 5b), they are six stations are statistically significant at 95% for (Jijel, Taher, Bordj Sabath, Machroha, Ain Berda and Pont Bouchet) this is the latest stations are located in the two coastal parts and Atlas Tellian at high altitude and one stations at level 99% for Ain Fakroun. For stations with trend negative are Seguene and Ain Sedjra with significant 90%.

Figure 5c illustrates the trends in spring season is increasing in Ain Djassar at level 95% and Machroha at level 99% for negative trend statistically significant at a 95% level in four stations (Aokas, El Milia, Ain Sedjra and Berrich). Only Hammamet station a 99% level, it therefore corresponds to a uniform field which covers the entire basin. It seems to describe, in a rough manner, the general atmospheric circulation.

Figure 5d shows a trend in the summer season increase for the Taher, Ain Djasser, Ain Baida and M'Daourouche stations at a level of 95% and two stations (Tadjenanet and Souk-Ahras) at level 90% and a Machroha station has a level of 99.99%. This confirms that these stations are linked to the continental regime fueled by storms during the summer season.

The seasonal precipitation amounts enable us to highlight a more detailed assessment of the precipitation patterns in the region. Thus, even if the highest amounts correspond to winter, in the Northern part, there are reduced differences between seasons, especially between summer and spring.

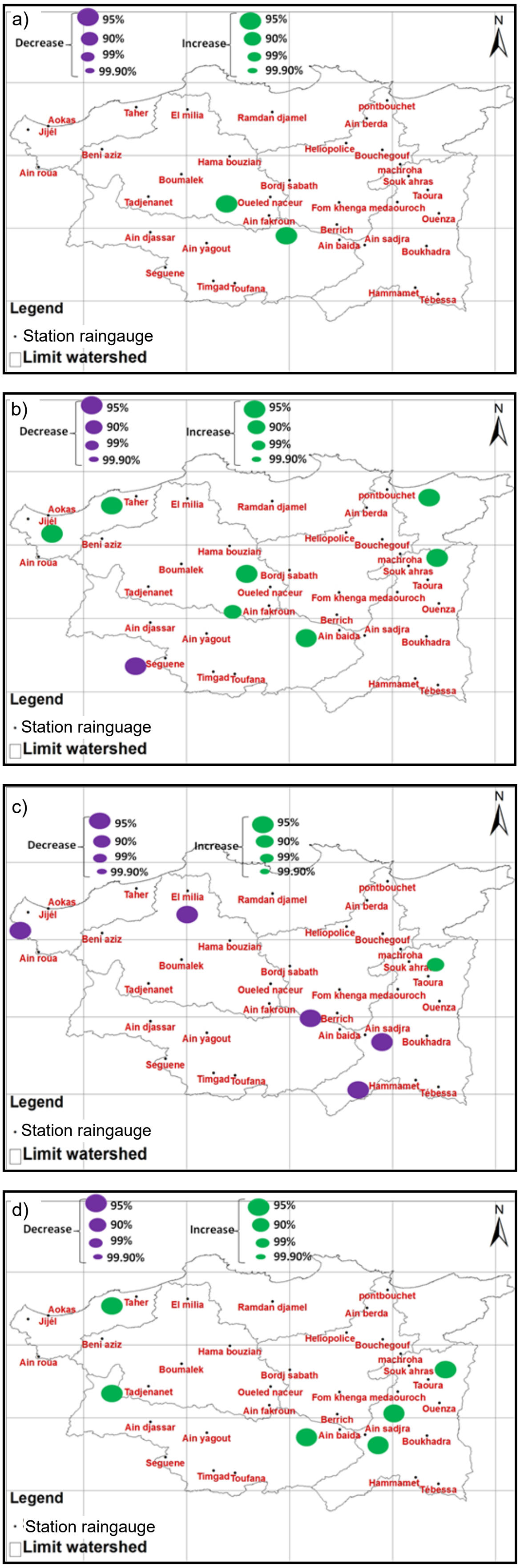

Fig. 5. Trend of rainfall in: a) autumn, b) winter, c) spring, d) summer; source: own study

Many studies have attempted to determine the trend in rainfall at different scales namely country, regional or district levels and the similar results have been reported by the several researchers for monthly, seasonal and annual series of rainfall. BENKHALED *et al.* [2008] studied trend in annual discharge annual precipitation over the 1965–1994 in the semiarid region of South-Eastern Algeria. The results indicate that no significant trend is detected for annual discharge and precipitation at major catchments up to 95% confidence level. The decreasing trend in Chott Melghir discharge is mainly attributed to the decrease of precipitation. Also, NOUACEUR [2010] reported an increase in frequencies from wet to very humid years recorded in fifteen Algerian stations (these stations stand out by long time series and cover fairly the whole territory).

Decreasing of at least 20% of total annual rainfall is also observed at all five stations in Macta region. As for the relationship between climate indices and variability of annual precipitation, canonical correlation analysis shows that, from 1950 to 2004, precipitation at the five stations are negatively correlated with NINO and, to a lesser degree, with NAO. Decreasing trend in the annual mean rainfall was observed by MEDDI *et al.* [2010] and TRAMBLEAY *et al.* [2013] show a strong tendency towards a decrease of precipitation totals and wet days together with an increase in the duration of dry periods, mainly for Morocco and western.

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Analiza tendencji opadów – przykład północno-wschodniej Algierii

STRESZCZENIE

Zmiana klimatu jest faktem powszechnie uznawanym obecnie przez społeczność naukową. Mimo to jej wpływ na opady, szczególnie na roczny, miesięczny i sezonowy opad na obszarach klimatu suchego i półsuchego, nie jest jeszcze dobrze rozpoznany. Do tej pory tylko kilka badań w Algierii dotyczyło tej kwestii.

W związku z tym podjęto próbę zbadania przestrzennego rozmieszczenia rocznych i sezonowych opadów za pomocą metody odwrotnej odległości (IDW – ang. inverse distance weighting). Trendy i wielkość oszacowanych zmian w seriach opadów analizowano testem Manna–Kendalla, a test nachylenia Sena użyto do danych zgromadzonych w 35 posterunkach opadowych w zlewni Constantinois Seybouse Mellegue (CSM) w północno-wschodniej Algierii w ciągu 43 lat (1969–2012).

Wyniki analiz przestrzennego rozkładu rocznych opadów wykazały, że opad rośnie wraz z wysokością nad poziomem morza i jest większy w stanowiskach eksponowanych na wilgotne wiatry. Opad rośnie ze wschodu na zachód, a maleje od wybrzeża w kierunku południowym. Metody statystyczne ujawniły rosnący (przedział ufności 95%) trend opadów w niektórych posterunkach na dużych wysokościach i w posterunkach przybrzeżnych w okresie zimy.

Słowa kluczowe: *opad, północno-wschodnia Algieria, test Manna–Kendalla, trend, zmiana klimatu*