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Article

The Innovative Trend Analysis Applied to Annual and Seasonal Rainfall in the Tafna Watershed (Algeria)

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Abstract

This study analyzes the temporal variability of seasonal and annual rainfall in the Tafna watershed (Northwest Algeria), using a homogeneous monthly rainfall database from 17 stations of 46 years of observation (1970-2015). Possible trends in seasonal and annual variations in rainfall were detected using the innovative trend analysis (ITA), which identifies trends in the low, medium and high values of a series. The results obtained indicate that seasonal rainfall showed a decreasing trend in winter and spring, while increasing trend is detected in summer and autumn. Low and high values categories are the most affected by the decrease in winter, while for spring it is the medium and high values, which are affected. In addition, spring showed the greatest decrease in arithmetic average and standard deviation. On the other hand, summer and autumn, present a growing trend affecting the low and high values, while in autumn, these are the medium and high values. Summer recorded the maximum increase in arithmetic average and standard deviation, and may present a flooding risk in future. Annually, a decreasing trend dominate. Most stations are marked by a decrease in their annual arithmetic means and standard deviation.

Keywords: rainfall, trend, ITA, Tafna, Algeria.

A Análise Inovadora de Tendências Aplicada a Chuva Anual E Sazonal na Bacia Hidrográfica de Tafna (Argélia)

Resumo

Este estudo analisa a variabilidade temporal da precipitação sazonal e anual na bacia hidrográfica de Tafna (Noroeste da Argélia), utilizando uma base de dados homogénea de chuva mensal de 17 estações de 46 anos de observação (1970-2015). Foram detectadas possíveis tendências nas variações sazonais e anuais da precipitação utilizando a análise de tendências inovadora (ITA), que identifica tendências nos valores baixos, médios e altos de uma série. Os resultados obtidos indicam que a pluviosidade sazonal mostrou uma tendência decrescente no Inverno e na Primavera, enquanto que a tendência crescente é detectada no Verão e no Outono. As categorias de valores baixos e altos são as mais afectadas pela diminuição no Inverno, enquanto que para a Primavera são os valores médios e altos, que são afectados. Além disso, a Primavera mostrou a maior diminuição na média aritmética e no desvio padrão. Por outro lado, o Verão e o Outono, apresentam uma tendência crescente que afecta os valores baixos e altos, enquanto que no Outono, estes são os valores médios e altos. O Verão registou o aumento máximo da média aritmética e do desvio-padrão, e pode apresentar um risco de inundação no futuro. Anualmente, predomina uma tendência decrescente. A maioria das estações é marcada por uma diminuição das suas médias aritméticas anuais e do desvio padrão.

Palavras-chave: chuva, tendência, ITA, Tafna, Argélia.

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1. Introduction

Precipitation, one of the fundamental components of the water cycle, is the main source of water supply. Their needs will increase in the future due to population growth and the socioeconomic development of communities. The variability of precipitation directly involves the two extremes, droughts and floods. These two meteorological hazards can both threaten water supply, irrigation and industry, and alter country strategies by causing catastrophic damage, both human and material (Wang *et al.*, 2020; Benzater *et al.*, 2019; Kreibich *et al.*, 2017; Ghenim *et al.*, 2016; Labban, 2016; Milly *et al.*, 2008).

The biggest challenge for these water resources is climate change. These changes are caused either directly (internal variability) or indirectly (external variability or climate change, due to anthropogenic activities) (Mohorji *et al.*, 2017; IPCC, 2013; 2007).

One assessment finds that the study of precipitation trends has become an increasingly active research topic for effective regional management of water resources and associated risks (Sun *et al.*, 2018; Fatichi *et al.*, 2012; Milly *et al.*, 2008).

Algeria is one of the countries hard hit by these climatic hazards affecting the entire territory (Elouissi, 2016; Elouissi *et al.*, 2016; Taibi *et al.*, 2013).

Highlighting the precipitation evolution and its impacts is a key tool for planning, adaptation, mitigation to these meteorological hazards and decision-making (Yevjevich *et al.*, 1984). The trends detection, spatial and temporal, is an important step for the analysis of this evolution (Sayemuzzaman *et al.*, 2013). To better understand this evolution, several works have been carried out in the Mediterranean and in Algeria, in particular in the catchment area of Tafna (Northwest Algeria). The work of (Ghenim *et al.*, 2011) on precipitation in the Meffrouche and Beni Bahdel dams during the period 1946-2009, detected moderate sequences of drought and humidity, but with a slight dry tendency, although some years have been very wet or extremely dry. Taibi *et al.* (2013) studied precipitation in northern Algeria over a period of seven decades (1936-2009) and found that the decade 1980-1990 was the most deficient. Again, Elouissi *et al.*, 2016 found a decrease in rainfall in the Macta, the underlying catchment area of the Tafna, during the period 1970-2011. The most brutal and significant fluctuation in the far west of Algeria is observed around the 1980s during which there was a fairly significant decrease in annual precipitation. This period of deficit has been characterized since then by its intensity and duration (Meddi *et al.*, 2009). The interannual variability of annual precipitation is marked by a significant decrease of more than 20% in the Tafna catchment area. This decline was observed in the second half of the 1970s (Meddi *et al.*, 2010). The average precipitation deficit, detected after 1970, is 26%; it is mainly observed during the winter and spring season (Ghenim *et al.*, 2014; 2010). Since 1970, this decrease in precipitation has had a significant impact on the reduction of approximately 62% of runoff (Meddi *et al.*, 2013).

In recent decades, several methods have been developed to analyze trends in precipitation time series such as the Bravais-Pearson coefficient (r), the Tau (τ) of the Mann-Kendall test and the Rho (ρ) of the Spearman test. Recently, an innovative method of trend analysis (ITA), proposed by Sen (2012), was applied to identify trends in precipitation, water quality, solar radiation and evaporation in different regions of the world (Ahmad *et al.*, 2018; Caloiero *et al.*, 2018; Zhou *et al.*, 2018; Dabanli *et al.*, 2016; Kisi, 2015). This method allows the graphical evaluation of trends in low, medium and high values in the time series.

The aim of this article is to identify the spatio-temporal trends of seasonal and annual rainfall in the Tafna watershed (Northwest Algeria), by applying the Innovative Trend Analysis (ITA) on 17 stations during a period of 46 years (1970-2015).

2. Study Area and Data

The Tafna watershed, located at the extreme west of Algeria. It is bounded by 1° and 2° west longitude and 34°5' at 35°3' north latitude. Covers an area of 7245 km^2, less than one third of its surface area is located on Moroccan territory. However, 5340 km^2 is on the Algerian territory (Aboura, 2006; ABH, 2006). The basin is delimited by Tlemcen Mountains, mainly composed of mountains in the south (800 to 1400 m of altitude). This orographic structure, which is dominated to the north by the Taras Mountains (1081 m) of narrow width, constitutes an important barrier against precipitation (Meddi *et al.*, 2013). The hydrographic network of the Tafna River is composed of two main wadis, the East Isser and the Tafna. It takes its source in the mountains of Tlemcen.

The soils of the Tafna basin consist of four major groups:

- The alluvial soil covering the low terraces and floodplains of the wadis;
- The stony land in the foothills of the mounts of Tlemcen and of Traras;
- The red soils crust, localized in the plains of Maghnia and Ouled Riah;
- Marly lands, covering much of the region of Tlemcen (Bouanani, 2005).

Vegetation is a key factor in rapid surface runoff, evaporation rate and retention basin. The presence of vegetation will therefore act as a regulator in the flow regime (Bouchelkia *et al.*, 2013).

The climate of the Tafna Basin is comparable to that of the entire Mediterranean region of North Africa (Meddi *et al.*, 2013). The general rainfall pattern is comparable to that of the semi-arid Mediterranean regions of northern

Algeria (Meddi *et al.*, 2010), with two principal seasons: a long dry warm summer-autumn and a winter-spring with frequent heavy precipitations. The average annual temperature varies from 11°C in winter to 28 °C in summer (Zettam *et al.*, 2017; Taleb *et al.*, 2008). This system is marked by winter rainfall with peaks in December, January and February, and a long period of dryness from June to September. Annual rainfall varies between 240 and 688 mm. year-1· This system is also marked by high spatial and temporal variability in total rainfall (Meddi *et al.*, 2010).

Monthly rainfall data are collected from ANRH (National Agency for Water Resources). Stations with more 10% of gaps were removed. Therefore, 17 stations are selected (Fig. 1). Outlier detection and filling gaps are made using Hydrolab software (Hydrolab, 2010) was developed by J.P. Laborde, professor at the University of Sofia Antipolis, in October 1998. Integrated in Excel, it allows a simple use of hydrological tools. These steps are essential and allowed to build a database with continuous records period from September 1970 to December 2015 (Meddi *et al.*, 2010; Elmeddahi, 2016; Elouissi *et al.*, 2017). The first step is to form groups of neighboring stations for each month by considering matrices, which are classified into columns of monthly values. Each pair of these matrices is subject to outlier detection. The accumulated residuals method is applied. Missing data were estimated using Hydrolab Excel Macro (Hydrolab, 2010). These macros use PCA (Principal Component Analysis) to estimate missing data. Seven to eight iterations are necessary to stabilize the process According to Laborde (2013). This criterion allowed the selection of 17 stations with a continuous recording period from 1970 to 2015.

3. Methodology

The ITA methodology has been proposed by Sen (2012), this method does not require restrictive assumptions such as those commonly used in the Mann Kendall trend test and Spearman's rho test. In addition, low, medium and high values of a parameter can be evaluated graphically by this method (Kisi *et al.*, 2014). The concept is based on the fact that if two time series are identical, so their scatter points will fall almost along the line 1:1 (45°). The hydrometeorological time series is first divided into two equal parts and arranged separately in ascending order. The first half is placed on X-axis, while the second on Y-axis to obtain a scatter plot. The 1:1 (45°) straight line divides the diagram into two equal triangular sections, where the higher (lower) triangular area is for the increa-

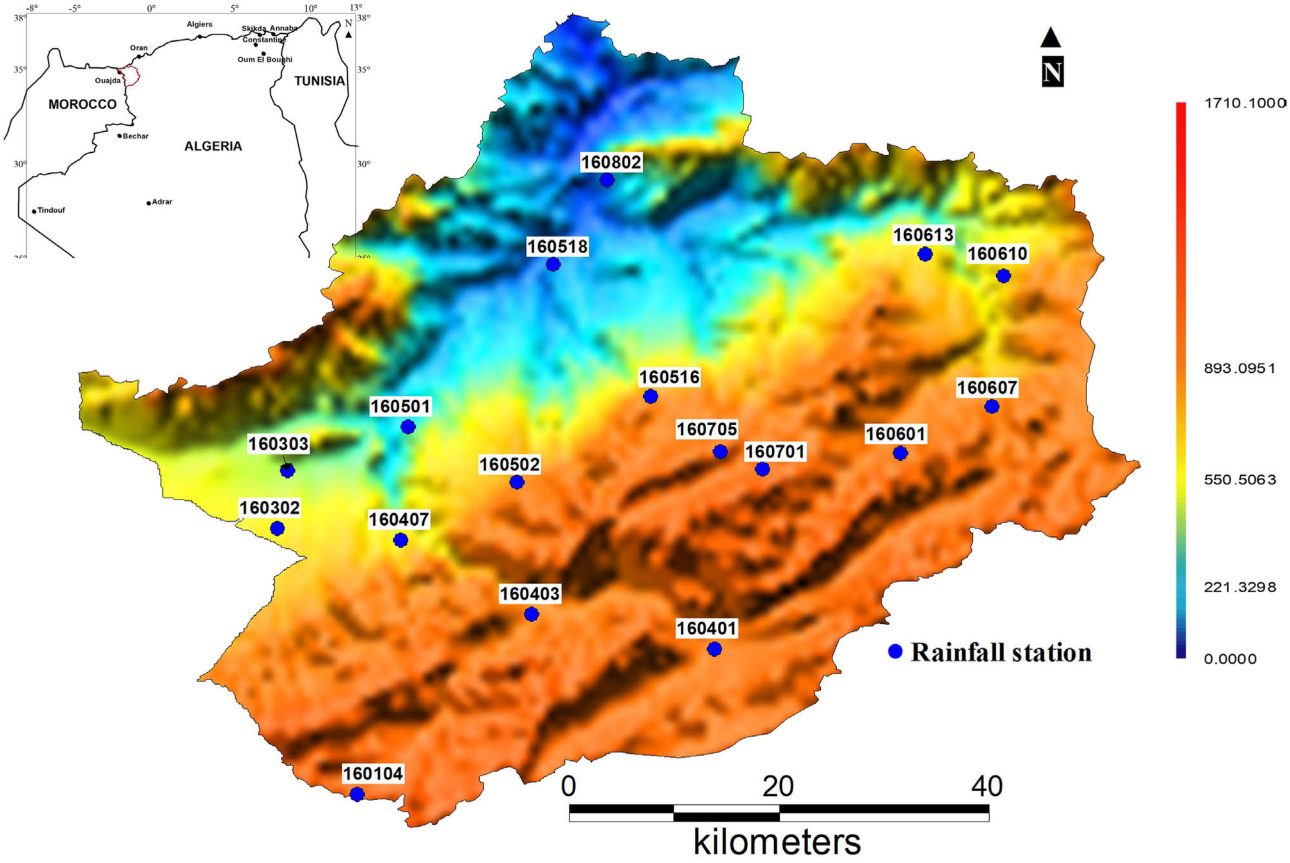

Figure 1 - Tafna watershed and stations locations.

sing (decreasing) trend element. If the scattering points appear on or near the 1:1 (45°) straight line, this means that there is no significant trend in the hydrometeorological recordings. Else, if the points are above (below) the 1:1 straight line (45°), it is possible to confirm an increasing (decreasing) trend in the time series (Dabanli *et al.*, 2016; Sen 2012, 2014). The plot can show possible partial trends for "low", "medium" and "high" precipitation data (Öztopal and Sen, 2016) (Fig. 2).

As the dispersion of the points is non-parametric, the serial correlation coefficient does not become effective in this trend study.

As supplementary information, the arithmetic means *(m_1 and m_2), standard deviations (s_1 and s_2) of the half-series (1970-1992 and 1993-2015) and the trend slope (S)* are represented in ITA template (Fig. 2). The latter is calculated using Eq. (1) (Elouissi *et al.*, 2016; Sen, 2014):

$$S = \frac{(m_2 - m_1)}{\left(\frac{n}{2}\right)} \qquad (1)$$

where n is data number.

In addition, tables offer linguistic interpretation where a trend is assigned to each section (low, medium and high). Three symbols are used (+, -, 0) indicating respectively increasing, decreasing and no trend existence. (Elouissi *et al.*, 2016). In addition, the comparison between the arithmetic means (standard deviation) of the two halves is presented on the tables as a percentage of variation.

4. Results and Discussion

To detect trends in seasonal and annual precipitation, the ITA method was applied to the 17 rainfall stations in the Tafna watershed during the period (1970-2015). The trend calculations are achieved through an R Package and the results are shown in Figs. 3 to 7.

By examining Figs. 3 to 7, Tables 1 to 5 are created. These summarize ITA parameters (m_1, s_1, m_2, s_2 and S). In addition, it presents the precipitation trends for each station (last column) and for each rainfall category (low, medium and high).

The trend frequencies for each rain category are presented in Table 6.

4.1 Seasonal Trends

The rainfall trends in each season detected by the ITA are summarized in Tables 1 to 4. Winter rainfall (Table 1) is dominated by negative trends. Only two stations 160104 (South of basin) and 160518 (North of basin) exhibits significant increasing trend (12%). The low and

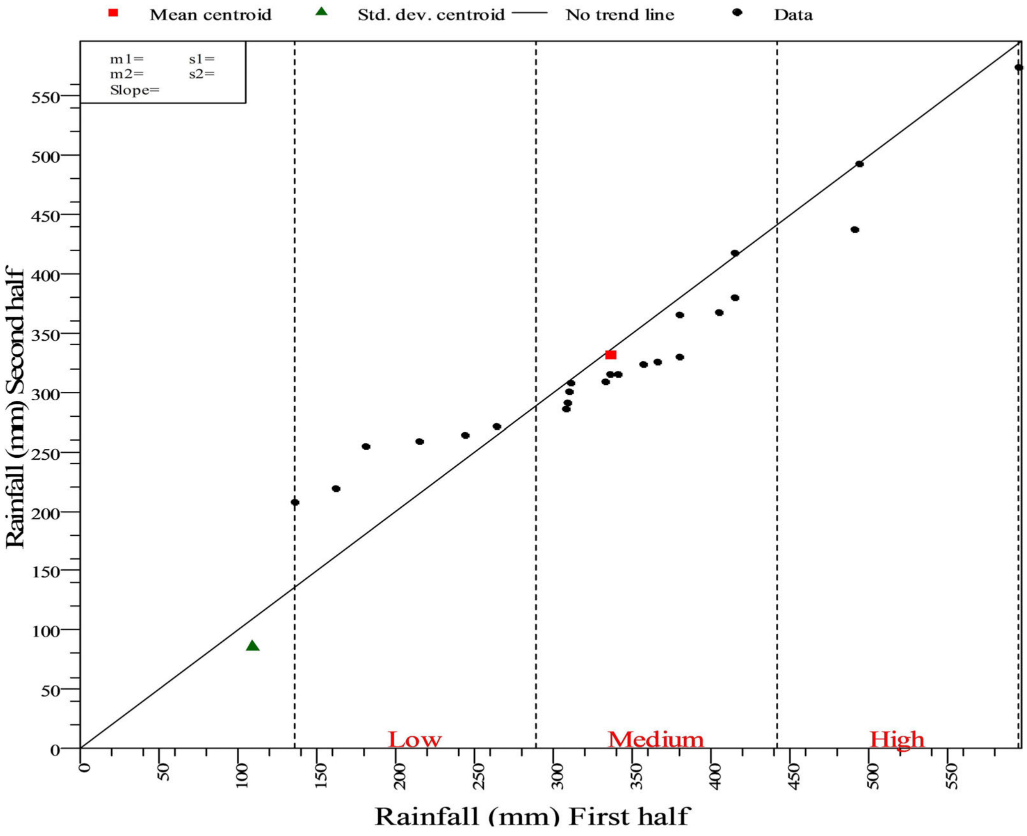

Figure 2 - Innovative trend template.

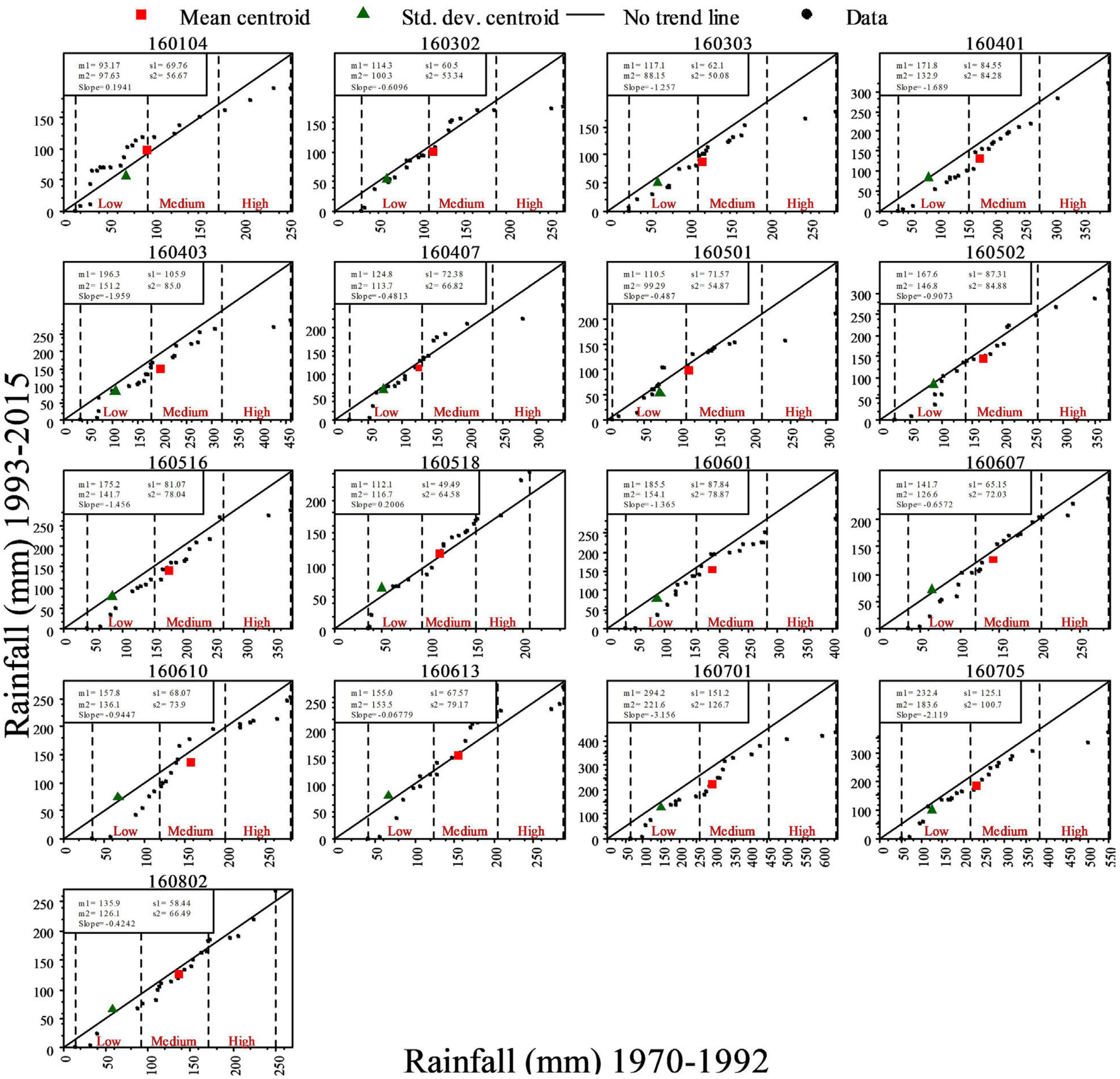

Figure 3 - Winter rainfall trend.

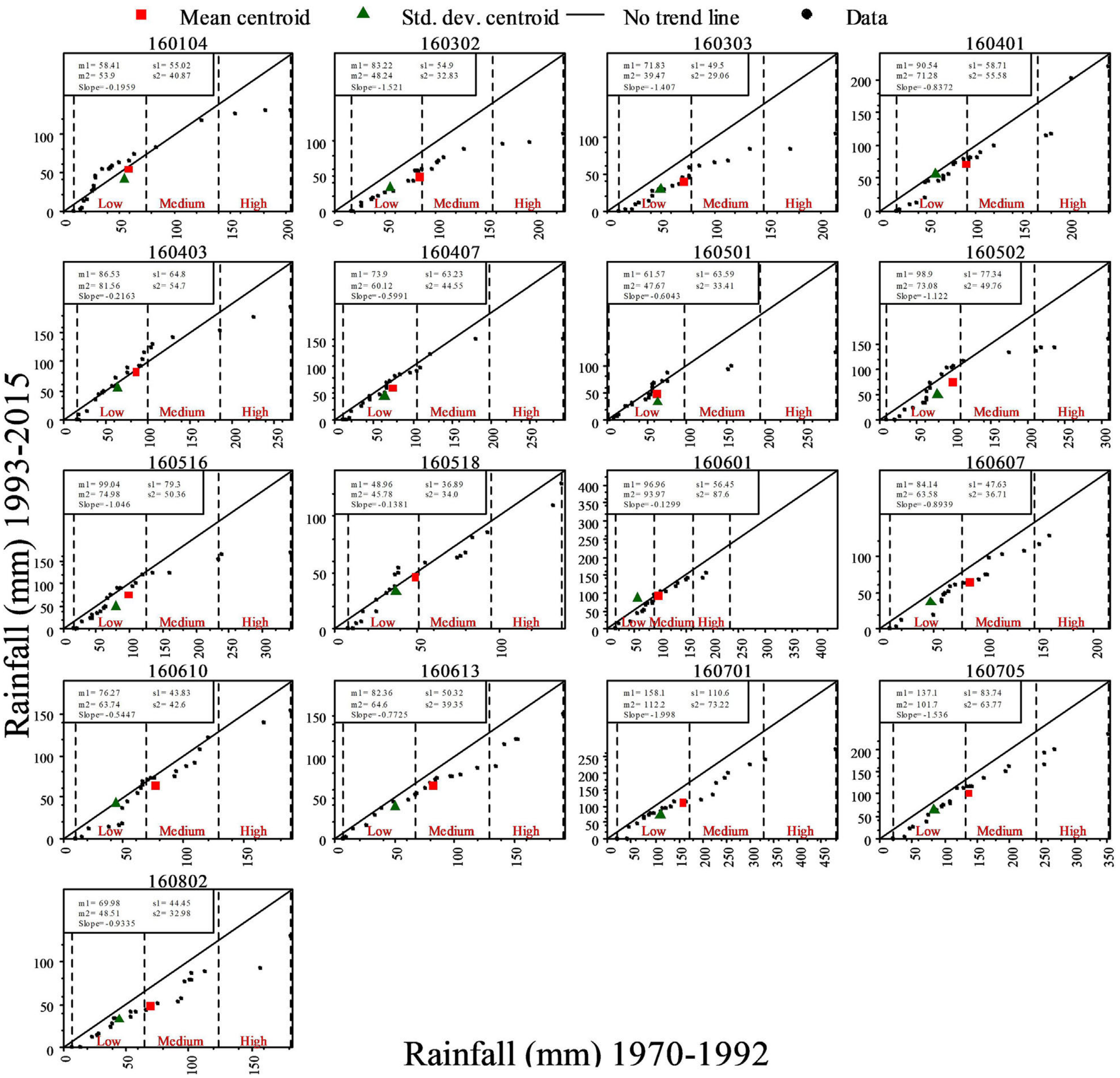

Figure 4 - Spring rainfall trend.

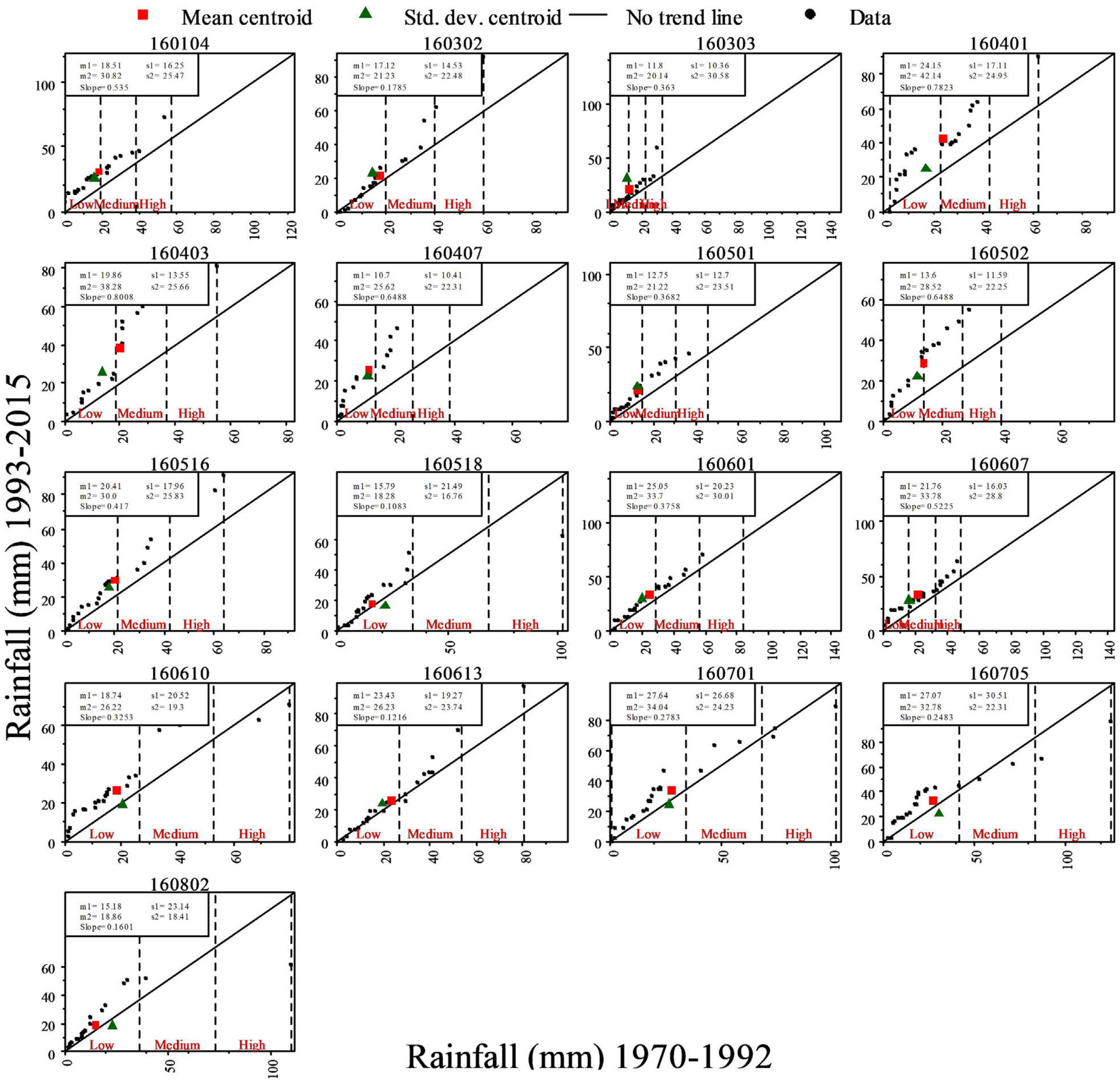

Figure 5 - Summer rainfall trend.

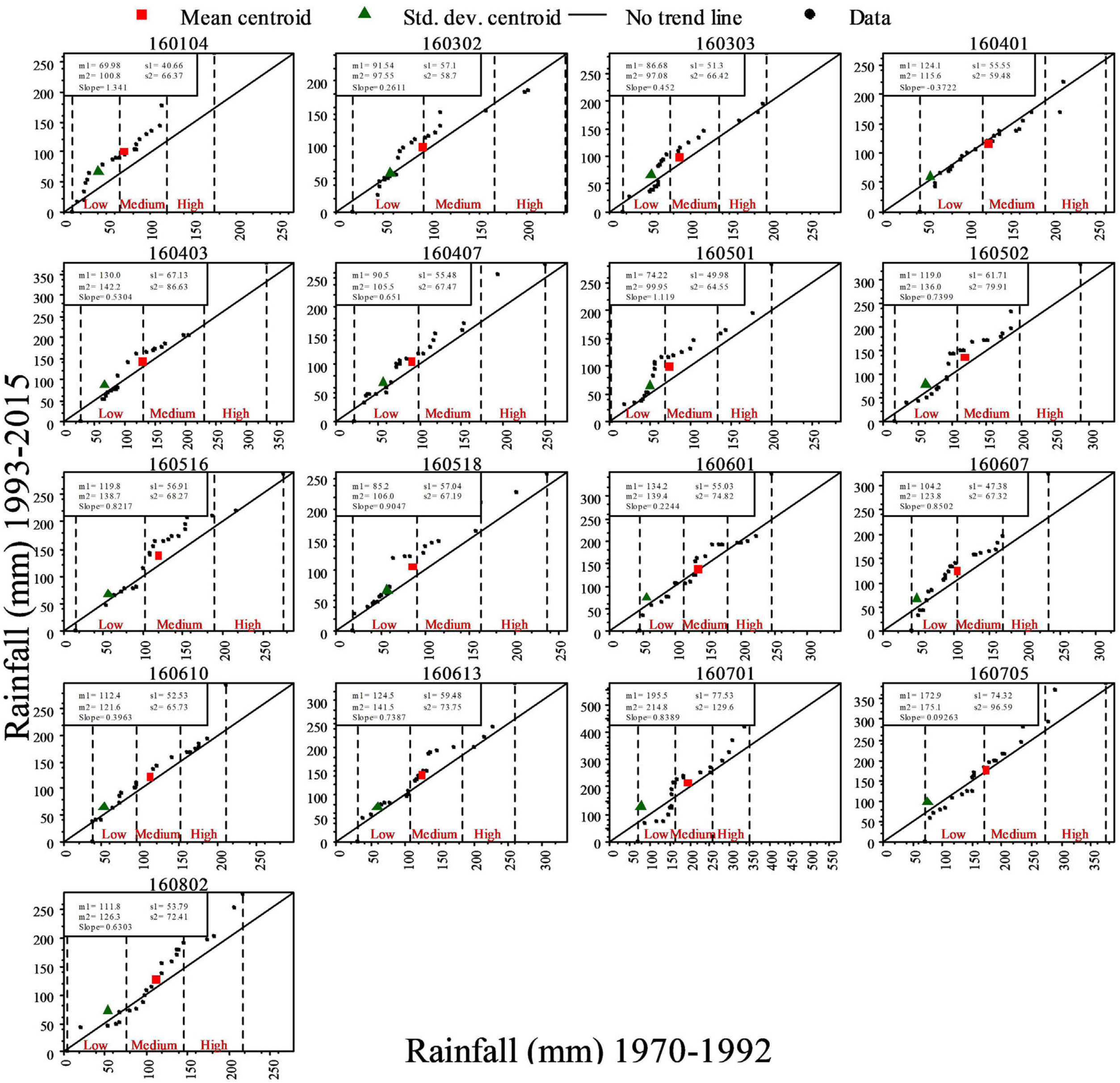

Figure 6 - Autumn rainfall trend.

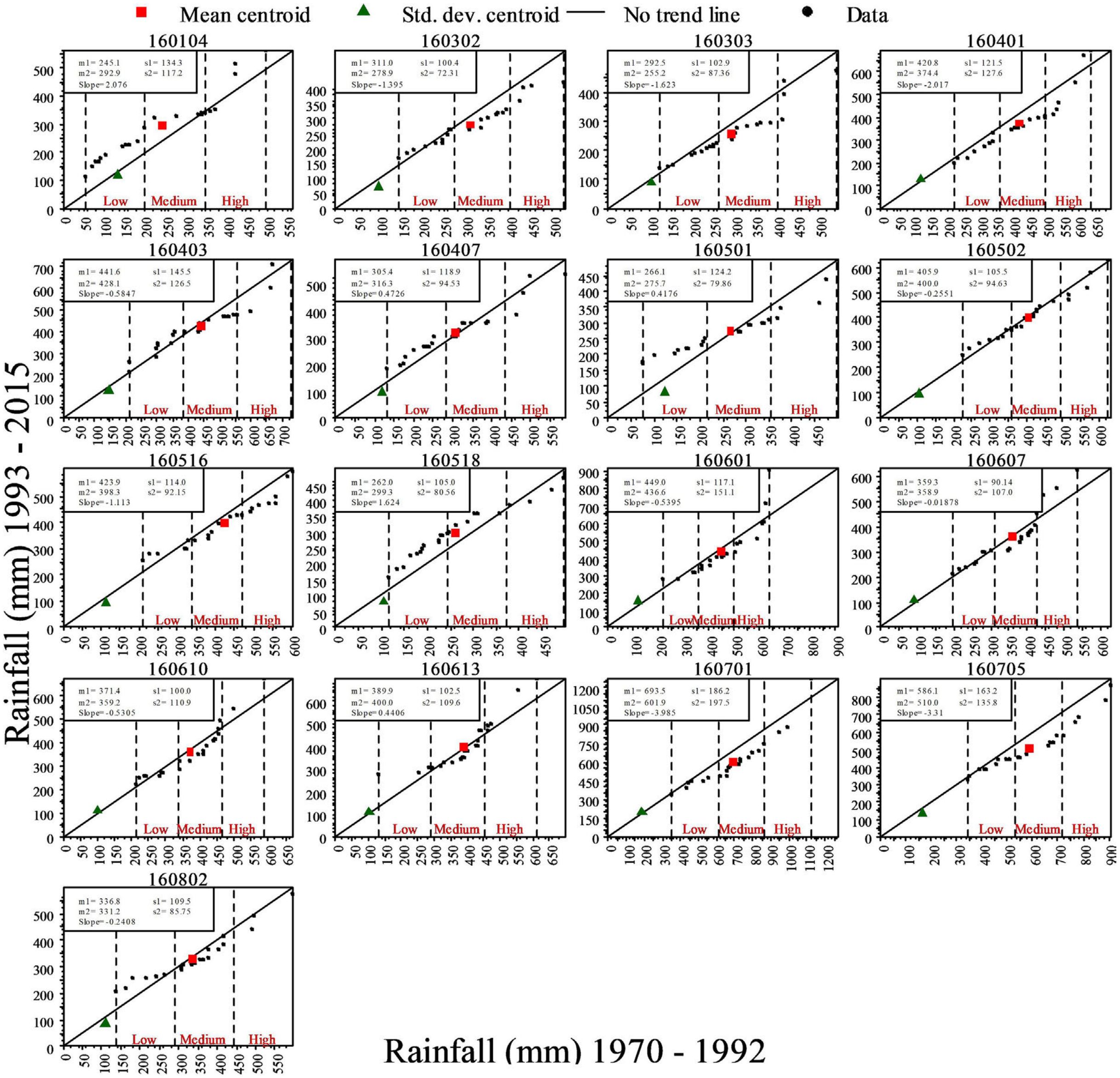

Figure 7 - Annual rainfall trend.

Table 1 - Innovative trend analysis parameters (winter rainfall).

Station	1970-1992		1993-2015		Trend	Variation		Interpretation			
N°	Mean (mm)	Std. D. (mm)	Mean (mm)	Std. D. (mm)	Slope (-)	Mean (%)	Std. D. (%)	Low	Medium	High	Station trend
160104	93.2	69.8	97.6	56.7	0.194	4.72	-18.77	+	+	-	+
160302	114.3	60.5	100.3	53.3	-0.610	-12.25	-11.90	-	+	-	-
160303	117.1	62.1	88.1	50.1	-1.257	-24.77	-19.32	-	-	-	-
160401	171.8	84.5	132.9	84.3	-1.689	-22.64	-0.24	-	-	-	-
160403	196.3	105.9	151.2	85.0	-1.959	-22.98	-19.74	-	-	-	-
160407	124.8	72.4	113.7	66.8	-0.481	-8.89	-7.73	-	+	-	-
160501	110.5	71.6	99.3	54.9	-0.487	-10.14	-23.32	-	-	-	-
160502	167.6	87.3	146.8	84.9	-0.907	-12.41	-2.75	-	-	-	-
160516	175.2	81.1	141.7	78.0	-1.456	-19.12	-3.82	-	-	-	-
160518	112.1	49.5	116.7	64.6	0.201	4.10	30.51	-	+	+	+
160601	185.5	87.8	154.1	78.9	-1.365	-16.93	-10.14	-	-	-	-
160607	141.7	65.2	126.6	72.0	-0.657	-10.66	10.43	-	0	-	-
160610	157.8	68.1	136.1	73.9	-0.945	-13.75	8.52	-	+	-	-
160613	155.0	67.6	153.5	79.2	-0.068	-0.97	17.16	-	+	-	-
160701	294.2	151.2	221.6	126.7	-3.156	-24.68	-16.20	-	-	-	-
160705	232.4	125.1	183.6	100.7	-2.119	-21.00	-19.50	-	-	-	-
160802	135.9	58.4	126.1	66.5	-0.424	-7.21	13.87	-	-	-	-

Table 2 - Innovative trend analysis parameters (spring rainfall).

Station	1970-1992		1993-2015		Trend	Variation		Interpretation			
N°	Mean (mm)	Std. D. (mm)	Mean (mm)	Std. D. (mm)	Slope (-)	Mean (%)	Std. D. (%)	Low	Medium	High	Station trend
160104	58.4	55.0	53.9	40.9	-0.196	-7.71	-25.64	+	-	-	-
160302	83.2	54.9	48.2	32.8	-1.521	-42.07	-40.26	-	-	-	-
160303	71.8	49.5	39.5	29.1	-1.407	-44.99	-41.21	-	-	-	-
160401	90.5	58.7	71.3	55.6	-0.837	-21.22	-5.28	-	-	-	-
160403	86.5	64.8	81.6	54.7	-0.216	-5.66	-15.59	+	+	-	-
160407	73.9	63.2	60.1	44.6	-0.599	-18.67	-29.43	-	-	-	-
160501	61.6	63.6	47.7	33.4	-0.604	-22.56	-47.48	0	-	-	-
160502	98.9	77.3	73.1	49.8	-1.122	-26.09	-35.58	-	-	-	-
160516	99.0	79.3	75.0	50.4	-1.046	-24.24	-36.44	-	-	-	-
160518	49.0	36.9	45.8	34.0	-0.138	-6.53	-7.86	-	-	-	-
160601	97.0	56.5	94.0	87.6	-0.130	-3.09	55.04	-	-	-	-
160607	84.1	47.6	63.6	36.7	-0.894	-24.38	-22.90	-	-	-	-
160610	76.3	43.8	63.7	42.6	-0.545	-16.51	-2.74	-	-	-	-
160613	82.4	50.3	64.6	39.4	-0.773	-21.60	-21.67	-	-	-	-
160701	158.1	110.6	112.2	73.2	-1.998	-29.03	-33.82	-	-	-	-
160705	137.1	83.7	101.7	63.8	-1.536	-25.82	-23.78	-	-	-	-
160802	70.0	44.5	48.5	33.0	-0.934	-30.71	-25.84	-	-	-	-

Table 3 - Innovative trend analysis parameters (summer rainfall).

Station	1970-1992		1993-2015		Trend	Variation		Interpretation			
N°	Mean (mm)	Std. D. (mm)	Mean (mm)	Std. D. (mm)	Slope (-)	Mean (%)	Std. D. (%)	Low	Medium	High	Station trend
160104	18.5	16.3	30.8	25.5	0.535	66.49	56.44	+	+	+	+
160302	17.1	14.5	21.2	22.5	0.179	23.98	55.17	+	+	+	+
160303	11.8	10.4	20.1	30.6	0.363	70.34	194.23	+	+	+	+
160401	24.2	17.1	42.1	25.0	0.782	73.97	46.20	+	+	+	+
160403	19.9	13.6	38.3	25.7	0.801	92.46	88.97	+	+	+	+
160407	10.7	10.4	25.6	22.3	0.649	139.25	114.42	+	+	+	+
160501	12.7	12.7	21.2	23.5	0.368	66.93	85.04	+	+	+	+
160502	13.6	11.6	28.5	22.3	0.649	109.56	92.24	+	+	+	+
160516	20.4	18.0	30.0	25.8	0.417	47.06	43.33	+	+	+	+
160518	15.8	21.5	18.3	16.8	0.108	15.82	-21.86	+	0	-	+
160601	25.1	20.2	33.7	30.0	0.376	34.26	48.51	+	+	+	+
160607	21.8	16.0	33.8	28.8	0.523	55.05	80.00	+	+	+	+
160610	18.7	20.5	26.2	19.3	0.325	40.11	-5.85	+	+	-	+
160613	23.4	19.3	26.2	23.7	0.122	11.97	22.80	+	+	+	+
160701	27.6	26.7	34.0	24.2	0.278	23.19	-9.36	+	+	-	+
160705	27.1	30.5	32.8	22.3	0.248	21.03	-26.89	+	-	-	+
160802	15.2	23.1	18.9	18.4	0.160	24.34	-20.35	+	+	-	+

Table 4 - Innovative trend analysis parameters (autumn rainfall).

Station	1970-1992		1993-2015		Trend	Variation		Interpretation			
N°	Mean (mm)	Std. D. (mm)	Mean (mm)	Std. D. (mm)	Slope (-)	Mean (%)	Std. D. (%)	Low	Medium	High	Station trend
160104	70.0	40.7	100.8	66.4	1.341	44.00	63.14	+	+	+	+
160302	91.5	57.1	97.5	58.7	0.261	6.56	2.80	+	+	-	+
160303	86.7	51.3	97.1	66.4	0.452	12.00	29.43	+	+	0	+
160401	124.1	55.6	115.6	59.5	-0.370	-6.85	7.01	-	-	+	-
160403	130.0	67.1	142.2	86.6	0.53	9.38	29.06	0	+	+	+
160407	90.5	55.5	105.5	67.5	0.651	16.57	21.62	+	+	+	+
160501	74.2	50.0	100.0	64.5	1.119	34.77	29.00	+	+	+	+
160502	119.0	61.7	136.0	79.9	0.740	14.29	29.50	-	+	+	+
160516	119.8	56.9	138.7	68.3	0.822	15.78	20.04	-	+	+	+
160518	85.2	57.0	106.0	67.2	0.905	24.41	17.89	+	+	+	+
160601	134.2	55.0	139.4	74.8	0.224	3.87	36.00	-	+	-	+
160607	104.2	47.4	123.8	67.3	0.850	18.81	41.98	+	+	+	+
160610	112.4	52.5	121.6	65.7	0.396	8.19	25.14	+	+	+	+
160613	124.5	59.5	141.5	73.7	0.739	13.65	23.87	+	+	+	+
160701	195.5	77.5	214.8	129.6	0.839	9.87	67.23	-	+	+	+
160705	172.9	74.3	175.1	96.6	0.093	1.27	30.01	-	+	+	+
160802	111.8	53.8	126.3	72.4	0.630	12.97	34.57	-	+	+	+

Table 5 - Innovative trend analysis parameters (annual rainfall).

Station	1970-1992		1993-2015		Trend	Variation		Interpretation			
N°	Mean (mm)	Std. D. (mm)	Mean (mm)	Std. D. (mm)	Slope (-)	Mean (%)	Std. D. (%)	Low	Medium	High	Station trend
160104	245.1	134.3	292.9	117.2	2.076	19.50	-12.73	+	+	+	+
160302	311.0	100.4	278.9	72.3	-1.395	-10.32	-27.99	0	-	-	-
160303	292.5	102.9	255.2	87.4	-1.623	-12.75	-15.06	-	-	-	-
160401	420.8	121.5	374.4	127.6	-2.017	-11.03	5.02	-	-	-	-
160403	441.6	145.5	428.1	126.5	-0.585	-3.06	-13.06	+	-	-	-
160407	305.4	118.9	316.3	94.5	0.473	3.57	-20.52	+	0	-	+
160501	266.1	124.2	275.7	79.9	0.418	3.61	-35.67	+	-	-	+
160502	405.9	105.5	400.0	94.6	-0.255	-1.45	-10.33	+	0	-	-
160516	423.9	114.0	398.3	92.2	-1.113	-6.04	-19.12	+	-	-	-
160518	262.0	105.0	299.3	80.6	1.624	14.24	-23.24	+	+	-	+
160601	449.0	117.1	436.6	151.1	-0.540	-2.76	29.04	+	+	-	-
160607	359.3	90.1	358.9	107.0	-0.019	-0.11	18.76	0	-	+	-
160610	371.4	100.0	359.2	110.9	-0.531	-3.28	10.90	-	-	+	-
160613	389.9	102.5	400.0	109.6	0.441	2.59	6.93	+	-	+	+
160701	693.5	186.2	601.9	197.5	-3.985	-13.21	6.07	-	-	-	-
160705	586.1	163.2	510.0	135.8	-3.310	-12.98	-16.79	-	-	-	-
160802	336.8	109.5	331.2	85.8	-0.241	-1.66	-21.64	+	-	-	-

high rain categories are the most affected by this decrease (38% each) while the medium categories represent 24% (Table 6). Spring rainfall (Table 2) highlights the decreasing trend for all stations (100%). It affects 30%, 34% and 36% of low, medium and high values respectively (Table 6). Winter and spring rainfall trends are similar to the results of annual rainfall because of the concentrated rainfall in these seasons. For the summer, the situation is completely tilting upwards (100%) (Table 3). The low and medium values are the most affected (39% and 34%) while high categories present 27% (Table 6). Autumn rainfall (Table 4) confirms the growing trend of the previous season (summer). 94% of stations display this property. Only one station (160401 located southeast of the basin) showed a decreasing trend. This growth is visible especially in the medium (41%), high (36%) and low values (23%) (Table 6). The results found perfectly converge with those of Goubanova *et al.* (2007), in the Mediterranean basin.

Figure 8 presents a comparison of seasonal trends in Tafna precipitation. It highlights that the two seasons (winter and spring) have negative trends, while the others (summer and autumn) show an upward trend. These results are perfectly consistent with the work of Elouissi *et al.* (2016), on the Macta watershed, underlying catchment area of the Tafna.

A comparison between the arithmetic means of the two halves shows that the majority of stations are in the decreasing zone in winter and spring, while the situation is reversed in summer and autumn (Fig. 9). The latter two make up for the deficit in the first two.

Using the standard deviation comparison, one can note the decreasing values in winter and spring and increasing in summer and autumn (Fig. 10). The increase

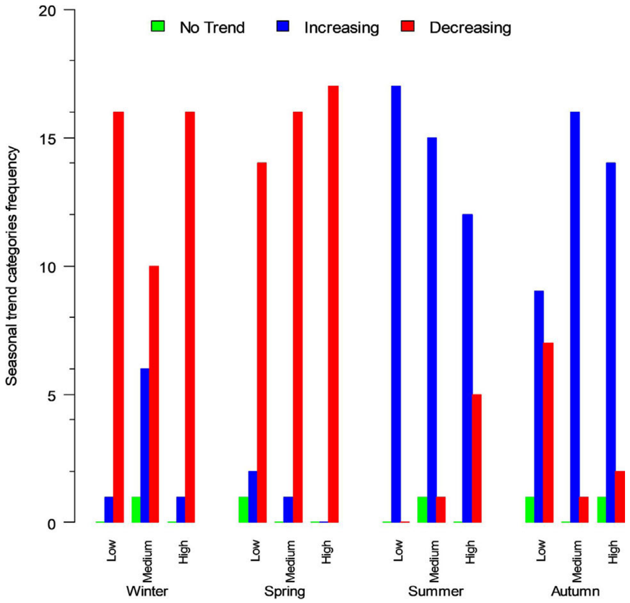

Figure 8 - Seasonal rainfall trends frequencies.

Table 6 - Trends frequencies by rainfall category.

		No trend	Increasing	Decreasing
Winter	Low	0	1	16
	Medium	1	6	10
	High	0	1	16
Spring	Low	1	2	14
	Medium	0	1	16
	High	0	0	17
Summer	Low	0	17	0
	Medium	1	15	1
	High	0	12	5
Autumn	Low	1	9	7
	Medium	0	16	1
	High	1	14	2
Annual	Low	2	9	5
	Medium	2	3	11
	High	0	4	12

in standard deviation shows the phenomenon of increase in extreme rain trend mentioned by Benzater *et al.* (2019). Summer recorded the maximum increase in arithmetic average (+139.25%) (at station 160407) and standard deviation (+194.23%) (at station 160303). It is the season, which currently presents the flooding risk (Li *et al.*, 2020). On the other hand, spring is the season with the greatest decrease in arithmetic average (-44.99%) (at station 160303) and standard deviation (-47.48%) (at station 160501). This indicates that rainfall, in this season, tends, for the most part, to belong to the low category (Wu *et al.*, 2020).

4.2 Annual trends

Annual rainfall of most stations (12 stations, 71%) exhibits downward trends, while 5 stations (29%) (160104, 160407, 160501, 160518, 160613) have an increasing trend (Table 5). Mainly the medium and high rainfall are affected by the decrease (39% and 43%). The

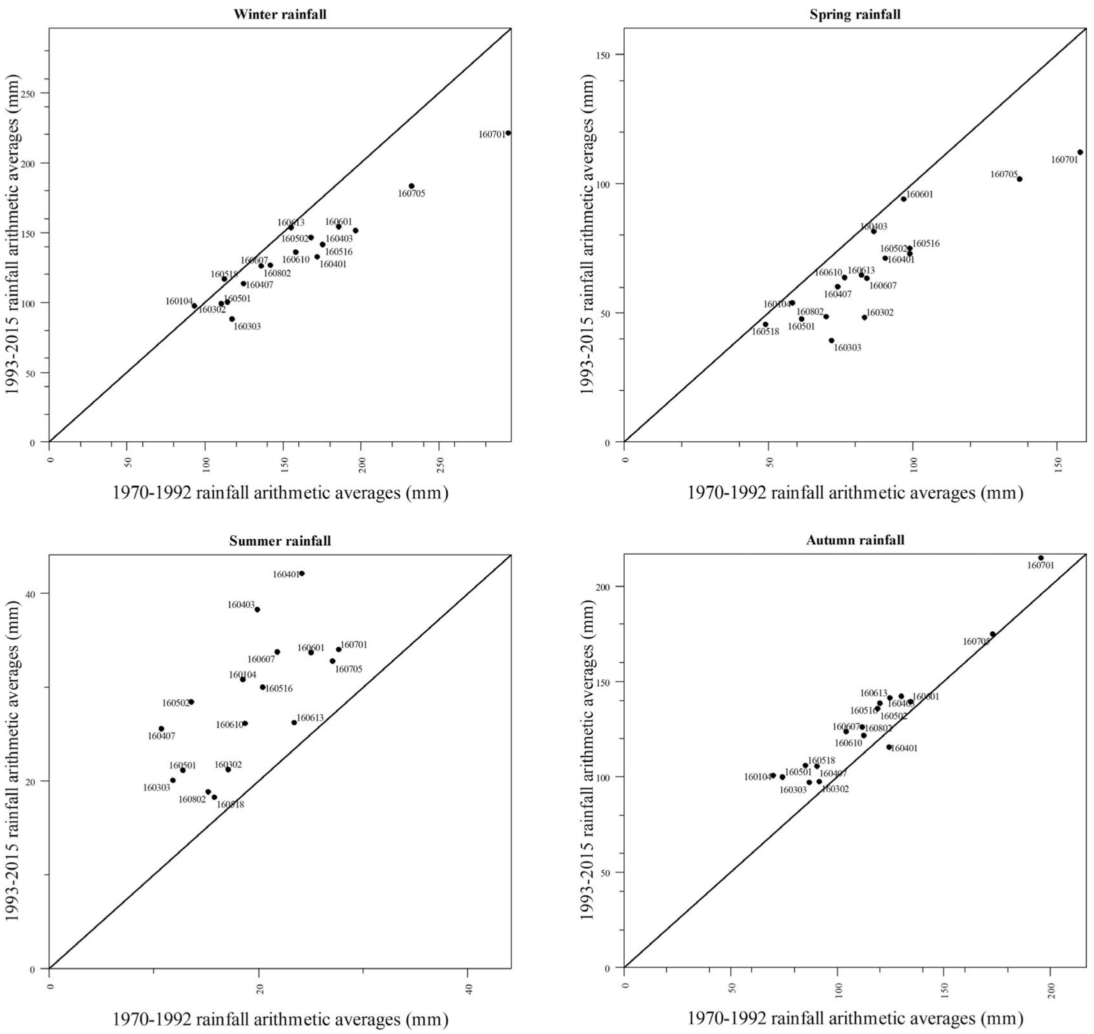
Winter rainfall
Spring rainfall
Summer rainfall
Autumn rainfall

Figure 9 - Seasonal arithmetic average comparison.

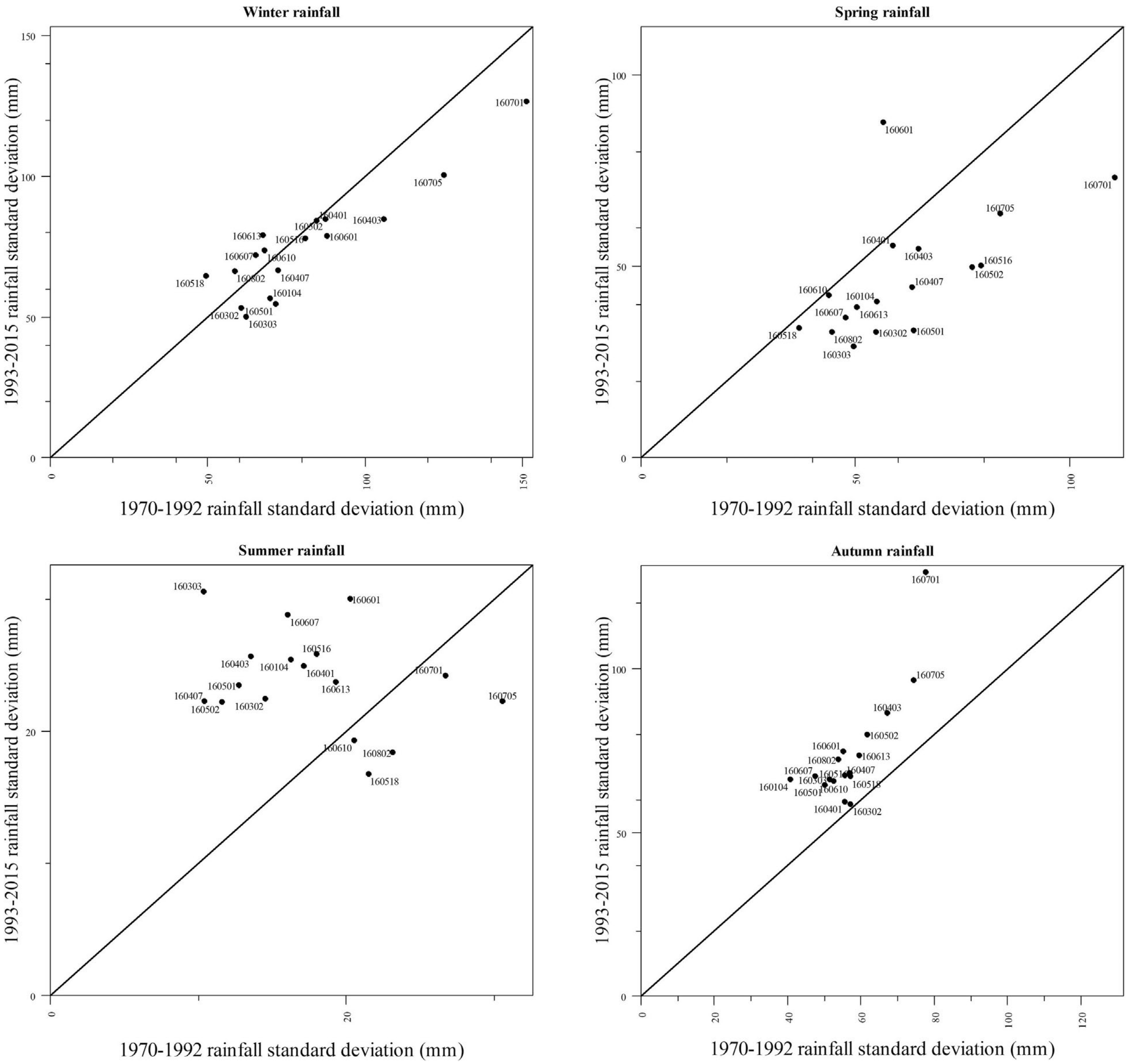

Figure 10 - Seasonal variability comparison.

low categories represent only 18% (Table 6 and Fig. 11). These results imply that the decreasing annual trends at most stations is due largely to winter and spring rainfall. These results confirm those found by Taibi *et al.* (2013); Meddi *et al.* (2013) and Ghenim *et al.* (2014; 2010).

Using arithmetic averages, 11 stations (160303, 160302, 160802, 160610, 160401, 160516, 160612, 160403, 160601, 160705 and 160701) in the Tafna watershed area have quantitative decreasing as the Fig.12a reveal, because the scatter points fall under the no trend line of 1:1 straight line. Stations 160701 and 160705 (center of the Tafna basin) show the greatest decrease (-13.21% and -12.98% from Table 5), while at the south of Tafna, station 160104 show the greatest increase (+19.50%). From a dispersion view point, the majority of stations have a reduction in their standard deviation (Fig. 12b). This shows that annual rainfalls are close to their average. Station 160501 (160601) presents the maximum decrease (-35.67%) (Increase) (+29.04%).

5. Conclusion

The concept of the ITA method was applied to 17 seasonal and annual rainfall series, located in the Tafna watershed (Northwest Algeria). The observation period is 46 years (1970 to 2015). The seasonal study showed that winter and spring present a decreasing trend of 88% and 100% respectively. For winter, the “Low” (38%) and “High” (38%) values categories are the most affected by the decrease, while for spring, it is the “Medium” and

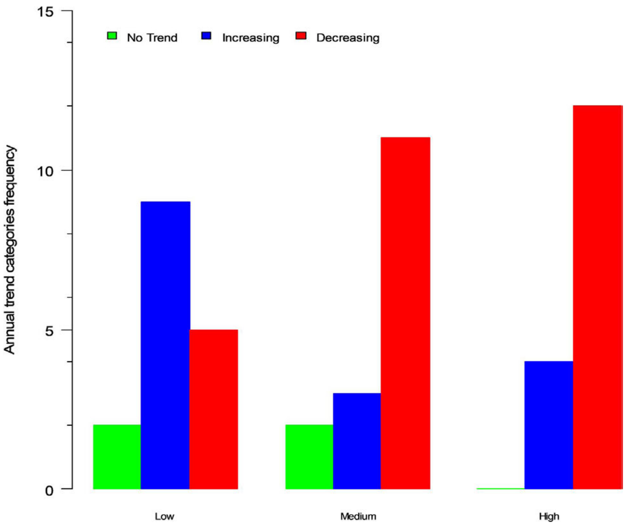

Figure 11 - Annual rainfall trends frequencies.

“High” values, which are affected. In addition, spring is the season with the greatest decrease in arithmetic average (-44.99%) and standard deviation (-47.48%).

Ghenim *et al.*, 2014 confirmed that there is a deficit in rainfall for the wet season (winter and spring) in the Tafna watershed. This decrease is also linked by, the Mediterranean Oscillation (MO) and the North Atlantic Oscillation (NAO) in the western regions, because they are closer to the Atlantic, particularly with regard to rainfall during wet periods in winter. Several studies have demonstrated that the MO and NAO indices influence the seasonal variability of precipitation in the Mediterranean basin (Lopez *et al.* 2010; Taibi *et al.* 2014).

The frequency of low precipitation tends to increase in the other two seasons, summer and autumn, the situation completely shifted towards the growing trend (100% and 94%). In summer, the categories most affected by this increase are the “Low” (39%) and “High” (36%) values, while for autumn; these are the “Medium” (41%) and “High” (36%) values. Summer recorded the maximum increase in arithmetic average (+139.25%) and standard deviation (+194.23%), and may present a flooding risk in future.

On a yearly scale, a decreasing trend was detected in 71% of the stations. The categories most affected by this downward are the “Medium” (39%) and “High” (43%) values. Most stations are marked by a decrease in their annual arithmetic means. Also, it is noted a dispersion decrease. This can be explained by the geographic location of the Tafna watershed in north-western Algeria, which is influenced by the Mediterranean climate on the one hand, and by the North Atlantic Oscillation (NAO) on the other hand (Hurrell *et al.*, 2003; Xoplaki *et al.*, 2003).

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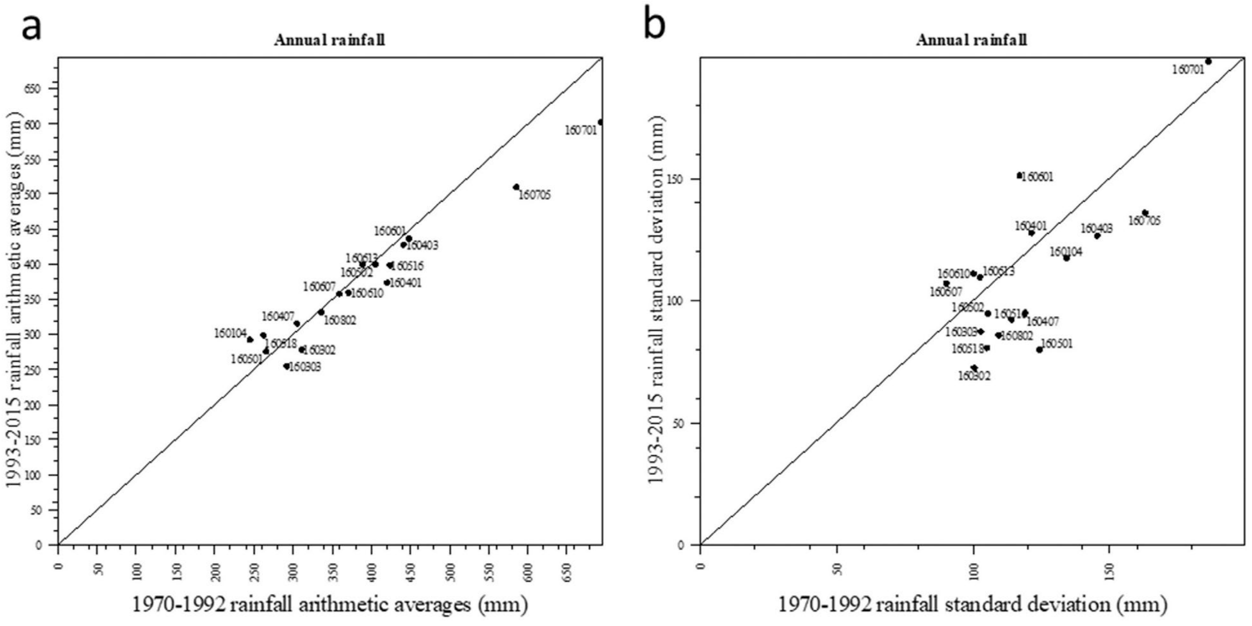

Figure 12 - Annual variability comparison.

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