Annual, seasonal and monthly rainfall trend analysis in the Tafna watershed, Algeria

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Abstract

Scientists, since a long time, have paid attention on climate change and, in particular, rainfall decrease. These changes have resulted in modifications of the rainfall regime in many Mediterranean regions. This work is based on monthly rainfall data from 17 stations located in the Tafna catchment (North West of Algeria). The study aim is to identify long-term (1970–2016) spatial and temporal trends in annual, seasonal and monthly precipitation, using the innovative trend analysis (ITA) method. The approach is used to classify trends into “low”, “medium”, “high”, which should be taken in consideration in future studies on floods (“high”) and drought (“low”). The monthly rainfall shows a decreasing trend in all studied stations (100% of stations) during February, March, April, and May, the same phenomenon observed in the majority of stations for June, July (82% of stations), and December (58% of stations). Seasonal analysis indicates a downward trend in winter and spring. Using annual rainfall, the stations located in the north, west and central part of the Tafna show a decrease in rainfall (59% of stations).

Keywords Spatiotemporal rainfall variability · Rainfall trend · Climate variability · Tafna watershed (Algeria)

Introduction

Water resources are of paramount importance and their need in the future increases due to climate and land use changes that can cause rainfall decrease effects in several countries such as Algeria (Elouissi et al. 2016). The United Nations Framework for Climate Change Conservation (UNFCCC) describes climate change as “climate change caused directly or indirectly by human activities that change the composition of the global atmosphere and add to the natural variability of climate observed over comparable time periods” (Mohorji and Sen, 2017; IPCC 2007, 2013). For the majority of Mediterranean regions, these variations have resulted in significant precipitation decreases, with an augmentation of exceptional phenomena such as severe droughts (Ghenim and Megnounif 2016). Algeria, as other Mediterranean countries, will face a decrease in rainfall of around 5–13% and an increase in temperature of 0.6–1.1 °C in 2020 (Elmeddahi 2016; Nichane and Khelil 2015). Algeria has suffered over the last 25 years (1975–1998), a severe and persistent drought that has affected the entire territory, and has been particularly severe in the western regions (Taibi et al. 2013). It is classified as a country at risk in the Climate Change Vulnerability Index (Maplecroft 2014).

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Fig. 1 Tafna watershed and stations locations

Rainfall is a very important factor for climate and hydro-meteorology (Sayemuzzaman and Manoj 2013). One can now process numerical data as time series using different methodologies to discover internal systematic structures such as trends, which offer scientific information for more effective modelling, prediction and control of the problem (Mohorji and Sen 2017). Spatiotemporal trends of rainfall results are important to climate analysts and water resource strategists (Sayemuzzaman and Manoj 2013). Like other climatic factors, rainfall time series has often inhomogeneities from different sources. The provision of a long-term, continuous and homogeneous time series for rainfall has important benefits for climate scientists (Mekis and Hogg 1999).

The most significant elements of all rainfall time series are seasonal and systematic variations, but the trend factor requires special attention for its identification (Elouissi et al. 2016; Bouklikha et al. 2020).

Several studies have dealt mostly with droughts on the Mediterranean. They observed a marked increase in the frequency, duration and severity of droughts (Merabti et al. 2017). The interannual variability of annual rainfall is considered to be marked by a significant decrease ($> 20\%$). It

was seen in the second half of the 1970s (Meddi et al. 2010). The average precipitation deficit determined after 1970 is between 23 and 36%; it is mostly observed during the rainy season (winter and spring) (Ghenim et al. 2010, 2014; Elouissi et al. 2017). After 1975, rainfall decreased by 26% in Tafna watershed. This decrease translates into a significant reduction in runoff of approximately 62%. The dry years after 1975 are significant at more than 62% (Meddi et al. 2013).

The purpose of this document is to analyze long-term (1970–2016) spatiotemporal trends of annual, seasonal and monthly rainfall in the Tafna watershed using data from 17 stations.

A new trend method is used. The innovative trend analysis, which is both simple and effective, is offered by Şen (2012). This technique is used to determine the trend by dividing the original series in two halves and comparing between them (Elouissi et al. 2016). The main novelty of this document is to identify the trend of different categories of rainfall based on the approach developed by Şen (2012). The limited access to the data does not allow to study a higher number of stations and a recent period.

Study area

The Tafna basin, located at the extreme west of Algeria, between 34°35' north latitude and 00°32' west longitude, covers an area of 7245 km² (Aboura 2006) and is composed of eight sub-basins; The basin is delimited by Tlemcen Mountains, it is mainly composed of mountains in the south (800–1400 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.

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 spring-winter with frequent

heavy precipitations. The average annual water 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 of 17 stations were collected from ANRH (National Agency for Water Resources) with data length of 17 years (from September 1970 to August 2016) (Fig. 1).

Methodology

The innovative trend analysis methodology, presented by Şen (2012), is simple and effective, this method has recently been successfully applied in the field of water resources, Şen (2012) indicated that the currently used MK and Spearman rho tests have certain restrictive assumptions, such as independent time series structure, normality of distribution and data length, in contrast to this method. Also, low, medium and high values of a parameter can be evaluated graphically by this method (Kisi and Ay 2013).

In this method, the following steps are performed to obtain a graph that can show possible partial trends for “low”, “medium” and “high” precipitation data (Öztopal and Şen 2016). The first phase is to divide a hydrometeorological time series into two equal parts and arrange them in ascending order. The first semi-serial (X_i ; $i = 1, 2, \dots, n/2$) is

Fig. 2 Innovative trend templates

Table 1 Innovative trend analysis parameters (annual analysis)

Station no	1971–1993		1994–2016		Trend Slope (–)	Interpretation		
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)		Low	Medium	High
160104	245.6	135.321798	292.3	110.139734	0.4579248	+	0	+
160302	311.9	97.5684919	277.8	69.2950921	–0.33428295	0	–	–
160303	293.0	102.028783	254.7	90.4870717	–0.37507147	0	–	–
160401	421.4	118.427108	373.3	124.342985	–0.47105588	0	–	–
160403	427.2	143.631147	427.2	116.38912	–0.15	+	–	–
160407	305.9	114.725961	315.8	92.47833282	0.09676044	0	0	0
160501	266.6	122.723781	275.2	81.4166896	0.0845402	+	0	–
160502	406.4	103.939648	399.4	92.9510423	–0.06830454	0	0	0
160516	424.2	112.123438	397.9	85.1773354	–0.25789216	0	0	–
160601	449.6	118.405964	436.1	141.592225	–0.13248082	0	0	+
160610	371.7	98.1587897	358.9	107.645179	–0.12545112	0	–	+
160613	389.8	100.901592	399.9	113.384993	0.098727	+	0	++
160701	692.5	186.17567	601.8	202.9639	–0.88849568	0	–	+
160705	586.7	160.983678	509.5	138.56057	–0.75688746	0	–	0
160802	337.1	110.124.505	330.9	90.9697301	–0.06026901	+	–	–
160518	262.2	106.396.067	299.1	81.8331278	0.36118172	+	+	–
160607	359.7	87.0083933	358.3	106.253766	–0.01438215	0	–	++

(a) Innovative descending trends

(b) Innovative increasing trends

(c) Innovative trends (no trend)

Fig. 3 a Innovative descending trends. b Innovative increasing trends. c Innovative trends (no trend)

placed on the horizontal axis and the second (X_j ; $j = n/2 + 1, n/2 + 2, n/2 + 2 \dots n$) on the vertical axis to obtain a dispersion diagram. The two axes distance must be the same. The 1:1 straight line (45°) divides the diagram into two equal triangular sections, where the higher (lower) triangular area is for the increasing (decreasing) trend element. If the

scattering points appear on or near the 1:1 straight line (45°), this means that there is no significant trend in the hydrometeorological recordings (time series without trend). 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; Şen 2012, 2014).

Fig. 4 Spatial trend partition of the Tafna watershed area

Results and discussion

Stations with more than 10% gap were removed. Therefore 17 stations were selected. Outliers detection and filling gaps were applied using Hydrolab Excel Macro (Hydrolab 2010). This software uses the principal component analysis (PCA) (Elouissi et al. 2017).

Monthly values were summed to obtain seasonal and annual precipitation. The seasons were defined as follows: winter (January, February, March); spring (April, May, June); summer (July, August, September) and autumn (October, November, December) (Sayemuzzaman and Manoj 2013).

The application of the innovative trend analysis is presented for 17 weather stations dispersed at different areas of Tafna catchment (Fig. 1). Trend and interception calculations are made using Excel and results are given in figures and tables below.

The arithmetic means ($m1$ and $m2$), standard deviations ($s1$ and $s2$) of the half-series (1971–1993 and 1994–2016) and the trend slope (S) are represented in Fig. 2. The latter is calculated using the following expression (Elouissi et al. 2016; Şen 2014):

$$S = \frac{(m2 - m1)}{\left(\frac{n}{2}\right)} \quad (1)$$

n is the number of data.

Results

Annual precipitation trends

The innovative model offers linguistic interpretation possibilities for the trend. The following steps are performed to obtain a graph that shows possible partial trends,

The largest range of data values is divided into three equal parts,

Each part has three sections (“low”, “medium” and “high”), which provide an interpretation domain for each type of group trend,

Each part is compared with the straight line at 45° (Öztopal and Şen 2016).

The basic characteristics of the stations are presented in Table 1; the last column shows the necessary interpretations, where 0 indicates no significant trend, + (–) indicates a significant increasing (decreasing) trend, ++ (–) indicates a more important increasing (decreasing) trend than the previous part. Finally (+++) (–) implies a very important increasing (decreasing) trend compared to the two previous parts (Elouissi et al. 2016). Figure 3a indicates the stations with a decreasing trend, where most of the scatter points are below the 1:1 line. The Stations (160302, 160303, 160401, 160403, 160802) show decreases in medium and high precipitation, while stations (160501, 160516) show decreases in high precipitation only, there are also decreases in medium precipitation (160610, 160701, 160705).

Table 2 Innovative trend analysis parameters (autumn season)

Station no	1971–1993		1994–2016		Trend Slope (–)	Interpretation		
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)		Low	Medium	High
160104	67.3	39.664933	105.8	62.6535507	0.37769239	+	++	+
160302	90.6	57.4924776	101.0	54.9188237	0.10186804	+	+	0
160303	86.3	51.4854759	100.0	63.3554887	0.13466657	0	+	+
160401	126.9	54.9472811	119.1	54.4915365	–0.07671489	0	0	0
160403	128.7	68.3368844	145.9	81.9361821	0.169394741	0	+	+
160407	89.0	56.3325323	108.8	63.8378609	0.19339301	+	++	+
160501	74.4	49.8852759	102.2	61.7611263	0.27196561	+	+	++
160502	117.0	63.3022585	140.1	74.89062001	0.22642708	0	+	+
160516	118.7	57.9783483	142.0	62.8386912	0.22855636	0	+	0
160601	132.1	57.3237612	143.7	69.0570215	0.11364024	0	+	++
160610	112.2	52.758606	124.9	61.0936416	0.12443467	0	0	++
160613	124.8	59.1994387	144.4	69.1350044	0.19181711	0	+	++
160701	206.3	83.1252803	219.8	122.95152	0.12188427	0	+	0
160705	172.5	74.840355	179.3	90.5308809	0.06670929	0	0	0
160802	109.2	54.2016849	132.0	66.9807709	0.2237517	0	+	+
160518	83.7	57.1473159	110.2	63.1540816	0.25977158	+	+	0
160607	104.1	47.4642513	125.9	63.8780477	0.21352223	+	+	++

Fig. 5 **a** Innovative increasing trends. **b** Innovative trends (no trend)

Fig. 6 Spatial trend partition of the Tafna watershed area (autumn season)

Figure 3b represents stations with increasing trends; the stations (160104, 160613) have increasing trends in low and high precipitation. Some stations display increases in high precipitation only with decreasing trends in medium precipitation (160601, 160607), while there are stations showing increases in low and medium precipitation and decreases in high precipitation (160518).

Finally, Fig. 3c shows no trend stations; the scatter points are on/or near to the line (1.1) (160407, 160502).

Analysis of the annual precipitation time series found that 59% of stations has a decreasing trend (160302, 160303, 160401, 160403, 160802, 160501, 160516, 160610, 160701, 160705); they are mainly found in the north, west and middle part of the Tafna catchment (Fig. 4). One can also find stations with decreases but a slight increase for the low values.

The stations with an increasing trend present 29% of the stations, the majority are located in the eastern part of the basin, (160104, 160613, 160601, 160607, 160518), and most of its stations show a decrease in medium precipitation. Meddi et al. (2013) found a similar result on annual rainfall.

Seasonal precipitation trends

For each station, we have calculated the cumulative rainfall for a season.

Autumn

As can be seen in Table 2 the interpretations for the autumn season, a very large number (88%) of stations were found with increasing trends (160104, 160302, 160303, 160403, 160407, 160501, 160502, 160516, 160601, 160613, 160610, 160701, 160802, 160518, 160607) as shown in Fig. 5a. Several stations show important significant increasing trends (++) at high precipitation values (160501, 160601, 160610, 160613, 160607), the stations (160407, 160104) have important significant increasing trends (++) in medium precipitation, while others have an increasing trend (+) in low and medium precipitation values, we can also find increases in medium precipitation only. Figure 5b doesn't show a clear trend (no trend) (160401, 160705). No decreasing trend was marked as shown on the map in Fig. 6.

Winter

The winter season represents a decrease in rainfall in the majority of stations, 14 of 17 (82%) (Table 3). The stations (160303, 160403, 160407, 160701, 160705, 160401) indicated important significant decreasing trends (–) in high precipitation, and decreasing trends (–) in medium and low precipitation, while the stations (160104, 160302, 160501, 160502, 160516, 160601, 160613) have decreasing trends (–) in high precipitation only. The station (160610) has

Table 3 Innovative trend analysis parameters (winter season)

Station no	1971–1993		1994–2016		Trend Slope (–)	Interpretation		
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)		Low	Medium	High
160104	96.6	70.2230342	100.4	53.093895	0.03793417	+	0	–
160302	113.9	60.523756	105.4	48.708925	–0.0833044	0	0	–
160303	116.5	62.1867031	93.1	46.4718727	0.22941913	–	–	–
160401	175.2	83.9771027	138.2	79.2295417	–0.36311834	–	–	–
160403	198.0	105.754435	158.5	78.3796232	–0.38682864	0	–	–
160407	124.5	72.404158	119.0	62.05831	–0.05353794	0	0	–
160501	111.7	71.2394393	102.7	50.6864273	–0.08815004	0	0	–
160502	166.5	87.1417425	155.1	79.0479715	–0.11182455	0	0	–
160516	175.9	81.0416791	148.9	71.7365183	–0.26538348	0	0	–
160601	188.7	87.9675657	160.8	71.3766315	–0.27352941	0	0	–
160610	158.7	67.7341568	141.4	67.7932469	–0.16921433	0	–	–
160613	156.8	66.7911798	158.1	72.5924736	0.01262122	0	0	–
160701	304.8	145.363524	225.9	120.353012	–0.77313428	–	–	–
160705	237.0	125.712506	192.3	92.3850569	–0.43853367	0	–	–
160802	138.1	57.7822921	130.2	61.0378392	–0.07766947	0	0	0
160518	111.0	48.9415152	123.1	59.6132351	0.11565541	0	+	+
160607	143.9	64.6555956	131.1	66.8035246	–0.12527702	0	0	0

decreasing trends (–) in medium and high precipitation (Fig. 7a).

Only one station showed increasing trends in medium and high precipitation (160518) as found in Fig. 7b. For stations (160802, 160607) no trend was marked (Fig. 7c). The map in Fig. 8 reveals that decreasing trend affect almost all station.

Spring

The interpretation made for the spring season shows a behavior similar to the winter (Table 4); the only particularity is that the decreasing trend affects all the stations in the watershed as depicted in Figs. 9 and 10.

The majority of stations showed important significant decreasing trends (–) in high precipitation and significant decreasing trends (–) in medium precipitation (160104, 160403, 160407, 160502, 160516, 160701, 160705, 160802, 160607) as represented in Table 4, while the stations (160302, 160303, 160401, 160501) showed important significant decreasing trends (–) in medium and high precipitation, some stations showed decreases (–) in medium and high precipitation.

Summer

The summer season is marked by an increase in rainfall in 82% of the stations (Table 5); seven stations show important significant increases (++) (160104, 160303, 160403, 160407, 160502, 160516, 160607) (Fig. 11a). However, the stations (160401, 160501) show increasing precipitation (+) in low, medium and high values, there may also

be increases (+) in low, medium, or high precipitation only (160302, 160601, 160610, 160613, 160701).

In Fig. 11b, 17% of the stations have significant decreases in high precipitation (160705, 160802, 160518) located in the north of the Tafna catchment area mapped in Fig. 12.

Monthly precipitation trends

September month

The September month results are illustrated in Fig. 13. With increasing trends in the majority of stations, the affected stations are (160104, 160302, 160303, 160401, 160407, 160501, 160502, 160516, 161601, 160610, 160613, 160701, 160705, 160607), while the stations (160403, 160802, 160518) have decreasing trends.

October month

Most stations in Fig. 14 have increasing trends; the stations concerned are (160104, 160401, 160403, 160407, 160501, 160502, 160516, 160601, 160610, 160613, 160705, 160802, 160607). We notice decreasing trends in the stations (160302, 160303, 160701, 160518).

November month

November is also marked by an increase in rainfall (Fig. 15), the stations (160104, 160302, 160302, 160303, 160407, 160501, 160516, 161601, 160610, 160613, 160802, 160518, 160607) have increasing trends; however, three stations have

Fig. 7 **a** Innovative descending trends. **b** Innovative increasing trends. **c** Innovative trends (no trend)

decreasing trends (160401, 160502, 160701). The station 160705 shows no trend.

December month

In Fig. 16, ten stations show a decrease in rainfall. These are (160302, 160303, 160401, 160403, 160407, 160501, 160502, 160516, 160705, 160518), and an increase in rainfall for seven stations (160104, 160601, 160610, 160613, 160701, 160802, 160607).

January month

January month indicates an increase in rainfall in all stations as represented in Fig. 17

February month

The month of February, in contrast to January, has the aspect of a decreasing trend for all stations (Fig. 18), except the station (160518), which made the exception by an increase in rainfall.

Fig. 8 Spatial trend partition of the Tafna watershed area (winter season)

March month

March (Fig. 19) gives almost the same results as February, with a decreasing in rainfall in all stations of Tafna watershed.

April month

All stations in April month showed a decrease in rainfall (Fig. 20) except the station 160601, which did not represent any trend.

May month

This month also represents a decrease in rainfall for all stations (Fig. 21).

June month

The month of June is marked by a decrease in rainfall in most stations (Fig. 22) (160104, 160302, 160303, 160401, 160501, 160502, 160516, 160610, 160613, 160701, 160705, 160802, 160518, 160607); however, the stations (160403, 160601) made the exception by an increase in rainfall. The station (160407) has no trend.

July month

July month shows a decrease in rainfall, almost the same result as June (Fig. 23) (160104, 160302, 160303, 160401,

160403, 160502, 160516, 160601, 160610, 160613, 160701, 160705, 160802, 160518). The stations (160407, 160501) have an increase in rainfall, and no trend was observed for the station (160607).

August month

This month has a remarkable increase trend in most stations (Fig. 24) (160104, 160302, 160401, 160403, 160407, 160502, 160516, 160610, 160613, 160705, 160802, 160518, 160607), and a decrease in rainfall for the stations (160303, 160501, 160601, 160701).

Discussion

Annual precipitation shows decreasing trend in 59% of stations, in these graphs, the arithmetic average and standard deviation centroids are below the no-trend line, which indicates a downward trend. In contrast, the arithmetic average and standard deviation of the increasing trends are above the zero trend line.

It is evident that in case of high precipitation the trend is more effective, because the points of high precipitation are further from the straight line 1.1, in comparison with precipitation values “low”, “medium”. This case is valid for stations (160613, 160601, 160607).

For information, six of the ten stations of the decreasing trend have an altitude of less than 600 m, the principal reason, in our opinion, is that the impact of climate change

Table 4 Innovative trend analysis parameters (spring season)

Station no	1971–1993		1994–2016		Trend Slope (–)	Interpretation		
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)		Low	Medium	High
160104	63.1	56.7399442	55.1	39.6160464	–0.07809929	0	–	–
160302	90.2	59.5328966	50.1	31.1374842	–0.39247193	–	–	–
160303	78.6	55.1134195	41.2	27.7615593	–0.36720372	–	–	–
160401	94.8	59.2321566	73.5	53.5989706	–0.20950759	–	–	–
160403	96.1	74.2107684	83.6	52.338947	–0.12225264	0	–	–
160407	81.5	69.7486243	62.1	42.7413288	–0.19015345	0	–	–
160501	67.7	67.3933146	49.1	31.9608029	–0.18299233	0	–	–
160502	109.2	87.0469034	75.7	47.2650457	–0.32804774	0	–	–
160516	108.9	85.7450265	76.8	48.2446503	–0.31508069	0	–	–
160601	104.1	62.6133915	96.9	85.4162908	–0.07063086	0	–	+
160610	81.9	48.8190201	66.1	40.3659315	–0.15528246	–	–	–
160613	84.2	53.6710584	71.2	40.7200633	–0.12774068	0	–	–
160701	153.7	109.718762	122.1	72.7281165	–0.31033178	0	–	–
160705	149.6	94.3718547	104.9	60.2222487	–0.43844585	0	–	–
160802	74.7	45.6000052	49.8	31.5675385	–0.24416027	–	–	–
160518	51.7	38.265056	47.4	32.5861188	–0.04222067	0	–	–
160607	904	53.8172687	66.3	34.0035638	–0.23581754	0	–	–

Fig. 9 Innovative descending trends

is apparently hard in low altitude areas than in the high altitude areas.

Similar results are found in different studies. Esteban-Parra et al. (1998) showed a long-term annual decrease in rainfall for the Mediterranean coast and inland. Meddi et al. (2013) reported a reduction in rainfall of 20–30% in north Algeria. Many other studies have also highlighted this phenomenon in North Africa in particular and in the Mediterranean in general (Longobardi and Vallani 2001; López-Moreno et al. 2010; Goubanova and Li 2007; Meddi et al. 2010).

At the seasonal scale, the results showed a decreasing trend at almost all stations in winter and spring. The Mediterranean oscillation (MO) and the North Atlantic Oscillation (NOA) have an impact on precipitation in the western

regions because they are closer to the Atlantic, especially rainfall in wet periods in winter.

Several studies have found that the MO and NAO indices influence the seasonal variability of precipitation in the Mediterranean basin, particularly in winter (Lopez-Bustins 2007; Salameh 2008; López-Moreno et al. 2010; Meddi 2009; Taibi et al. 2014). Results of this paper are in line with others, Goubanova and Li (2007) and Toggweiler and Key (2001) have also observed that rainfall intensity will be decreased mainly from February to May, using downscaling statistics.

Monthly rainfall study is marked by seven months with decreasing trend: February, March, April, May (100% of stations). June, July (82% of stations). December (58% of stations) (Goubanova and Li 2007; Toggweiler and Key 2001).

Fig. 10 Spatial trend partition of the Tafna watershed area (spring season)

In general, it is clear that the monthly rainfall in north-west Algeria is also influenced by the Mediterranean Oscillation (MO) and the North Atlantic Oscillation (NAO) (Taibi et al. 2014).

Conclusion

The innovative trend analysis applied to the 17 stations of Tafna catchment (western Algeria) is one of the fundamental ways to identify the impacts of climate change on hydro-meteorological data. Climate change in the study area has a negative impact on the rainfall cycle, including the entire water resource. The reduction in precipitation clearly produces in annual rainfall study which showed decreasing trend in 59% of stations, mainly located in the north, middle and west part the catchment. Increasing trend is established in eastern part and

affects 29% of studied stations. The seasonal study showed decreasing trend in almost all stations in winter and spring seasons. However, autumn and summer seasons showed an increasing trend in the majority of stations. Finally, monthly trend analysis indicates a decrease in all studied stations in February, March, April, and May; these are the months most affected by climate change. We noticed the same phenomenon for June and July (82% of stations), and December (58% of stations). January was characterized by an increase in all stations (100%). September, October, November and August have a lower increasing trend than January, with a respective stations percent (82%, 76%, 76%, 76%, 82%).

The consequences of these water shortages are changes in the environmental balance, which will therefore affect various human activities, in particular the supply of water availability for domestic and industrial consumption as well as for the agricultural economy.

Table 5 Innovative trend analysis parameters (summer season)

Station no	1971–1993		1994–2016		Trend Slope (–)	Interpretation		
	Mean (mm)	SD (mm)	Mean (mm)	SD (mm)		Low	Medium	High
160104	18.7	18.7662165	31.0	20.2391604	0.12039752	+	+	++
160302	17.3	13.6007166	21.3	21.4436263	0.03962535	0	+	+
160303	11.5	12.4914453	20.4	27.2134012	0.0868848	+	++	+
160401	24.4	19.1637736	42.6	22.0918716	0.17828495	+	+	+
160403	19.8	12.9170369	39.1	24.285096	0.18968457	+	++	+
160407	10.9	11.1551172	25.9	20.9894628	0.14705882	++	++	+
160501	12.7	14.3273833	21.3	19.7573432	0.08371697	+	+	+
160502	13.7	12.0385481	28.5	18.8349446	0.14514066	+	++	+
160516	20.7	14.140213	30.2	23.3223815	0.09401566	0	++	+
160601	24.7	23.6998357	34.7	28.3123718	0.09803922	+	0	+
160610	18.9	21.1973204	26.5	19.7234483	0.074611	+	+	0
160613	24.0	18.8698854	26.2	23.49154	0.02202935	0	+	+
160701	27.7	28.0798508	34.1	21.8086704	0.0630861	+	0	0
160705	27.6	23.7561592	33.1	20.1285346	0.05338277	+	–	–
160802	15.1	23.3785821	18.9	16.7317301	0.03780904	+	+	–
160518	15.8	21.8093841	18.3	14.9519322	0.0249754	+	0	–
160607	21.3	16.5703788	34.9	26.8047488	0.13319018	+	++	+

Fig. 11 a Innovative increasing trends. b Innovative descending trends

Fig. 12 Spatial trend partition of the Tafna watershed area (spring season)

Fig. 13 Spatial trend partition of the Tafna watershed area (September month)

Fig. 14 Spatial trend partition of the Tafna watershed area (October month)

Fig. 15 Spatial trend partition of the Tafna watershed area (November month)

Fig. 16 Spatial trend partition of the Tafna watershed area (December month)

Fig. 17 Spatial trend partition of the Tafna watershed area (January month)

Fig. 18 Spatial trend partition of the Tafna watershed area (February month)

Fig. 19 Spatial trend partition of the Tafna watershed area (March month)

Fig. 20 Spatial trend partition of the Tafna watershed area (April month)

Fig. 21 Spatial trend partition of the Tafna watershed area (May month)

Fig. 22 Spatial trend partition of the Tafna watershed area (June month)

Fig. 23 Spatial trend partition of the Tafna watershed area (July month)

Fig. 24 Spatial trend partition of the Tafna watershed area (August month)

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Declarations

Conflict of interest The authors declare that they have no conflict of interest.

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