Desalination and Water Treatment
www.deswater.com
doi: 10.5004/dwt.2017.20883

86 (2017) 285–296
August

Trends of rainfall as a support for integrated water resources management in Syria

Martina Zeleňáková[a,*], Ibrahim Alkhalaf[a], Pavol Purcz[b], Peter Blišťan[c], Pavol Pelikán[d], Maria Manuela Portela[e], Artur Tiago Silva[e]

[a]*Department of Environmental Engineering, Faculty of Civil Engineering, Technical University of Košice, Košice, Slovakia, Tel. +42 155 6024270; emails: martina.zelenakova@tuke.sk (M. Zeleňáková), alkhalaf.ibrahim@gmail.com (I. Alkhalaf)*
[b]*Department of Applied Mathematics, Faculty of Civil Engineering, Technical University of Košice, Košice, Slovakia, email: pavol.purcz@tuke.sk*
[c]*Faculty of Civil Engineering, Technical University of Košice, Institute of Geodesy, Cartography and Geographical Information Systems, Košice, Slovakia, email: peter.blistan@tuke.sk*
[d]*Enviroline s.r.o., Košice, Slovakia, email: pavolpelikan@gmail.com*
[e]*Department of Civil Engineering, Technical University of Lisbon, Lisbon, Portugal, emails: maria.manuela.portela@ist.utl.pt (M.M. Portela), artur.tiago.silva@tecnico.ulisboa.pt (A.T. Silva)*

Received 5 January 2017; Accepted 30 April 2017

ABSTRACT

The objective of this study was to investigate rainfall trends in chosen climatic stations in Syria. Syria is prone to extreme climate events such as drought and flood. Annual as well as seasonal rainfall trends were detected by Mann–Kendall statistical test. The Sen's slope was applied to identify the magnitude of those trends. The results achieved for rainfall revealed more frequent significant decreasing trends. Achieved results can be the basis for the development of water resources management plans and within the framework of risk assessment they will address all aspects of risk management focusing on prevention, protection, preparedness (including forecasts and early warning systems) and taking into account the characteristics of specific area. The Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report concluded that precipitation has generally increased over latitudes north of 30 over the period of 1900–2005 and decrease in the Mediterranean and southern Asia. In the presented paper, we evaluate out coincidence with the IPCC report – decreasing rainfall in Syria.

Keywords: Rainfall time series; Mann–Kendall test; Trend analysis; Water resources management

1. Introduction

Droughts are recurring climatic events, which often hit Syria, bringing significant water shortages, economic losses and adverse social consequences. In the last 10 years, increasing population has added to the growing demand for water and other natural resources in Syria. The latest drought in South Asia (2007–2009) affected more than 1 million people, with severe impacts felt in Al-Hasakah, Ar-Raqqah, Aleppo or Halab, and Deir ez-Zor Governorates, socioeconomic instability, health problems, food insecurity and migration have further exacerbated the effects of drought [1]. The rainfall represents 68.5% of the available water sources in Syria. Due to drought the deficit in available water has been estimated of about 651 million m^3 during the years 1995–2005, and still increasing, with significant impact on the rainfed agriculture areas [1]. During the 2009/2010 growing season, rainfall conditions have been extremely mixed with the most favourable accumulations occurring in western and northwestern regions. Southern, southeastern and northeastern regions all suffered continuing drought conditions and well-below normal rainfall. Rainfed wheat area in these provinces is extremely reliant on timely rainfall during the growing season [1].

* Corresponding author.

Presented at the 13th International Conference on Protection and Restoration of the Environment (PRE-XIII), 3–8 July 2016, Mykonos, Greece.
1944-3994/1944-3986

Integrated water resources management process promotes the coordinated development and management of water and land resources in order to maximize the resultant economic and social welfare in an equitable manner, without compromising sustainability of vital ecosystems. Integrated water resources management is the topic of many scientific studies [2–11]. The knowledge about the temporal and spatial distribution of meteorological and hydrological variables in the country is a primary condition for water resources management. Therefore, the prediction and knowledge about hydrometeorological trends plays an important role in the economic development of a country.

Many researchers have given a great deal of attention to the potential impacts of climatic change and variability in several fields at the international level. Some of them have also investigated the rainfall variability in Southeast Asia. For instance, Endo et al. [12] investigated trends in extreme precipitation using almost the entire network of stations in Southeast Asia. Studies [13,14] gave insight into the recent, past and present climate as well as climate change in the Arabian Peninsula, in particular over Saudi Arabia. The Middle East countries, including those on the Arabian Peninsula, are characterized by large variations in their climatic conditions, and these variations can be significant within a single country [15]. Some studies in Iran have examined the changes in meteorological variables [16,17]. Opposite the expectations, their results showed that there was no statistically significant climate variability but only a slightly decreasing trend in annual precipitation in Iran. The temporal variability in the precipitation was investigated in [18], at 15 stations over the study period of 51 years (1961–2011) in the Swat River basin, Pakistan. The non-parametric Mann–Kendall and Spearman's rho statistical tests were applied at 5% significance level for the detection of trends in monthly, seasonal and annual precipitation. The results pointed out a mixture of positive (increasing) and negative (decreasing) trends in the monthly, seasonal and annual precipitation series. Statistical methods are very often used for solving various complex tasks of water management [19–23].

To the best of authors' knowledge, almost no study was devoted to rainfalls trend or climate variability and its impact in water resources in Syria. The present study analyses rainfall trends over all Syria. The Mann–Kendall test coupled with the Sen's slope was applied to identify the significant trends, as well as their sign (increasing or decreasing) and magnitude. The evaluated period is from 1992 to 2010. Data for evaluation were obtained from Aleppo University in Syria with collaboration of Ministry of Agriculture and Agrarian Reform and Meteorological Center in Syria.

2. Materials and methods

2.1. Study area and precipitation data set

Syria is a country in the Middle East (Fig. 1), bordering the Mediterranean Sea between Lebanon from west, Turkey from north, by Iraq from east and by Jordan and Israel from

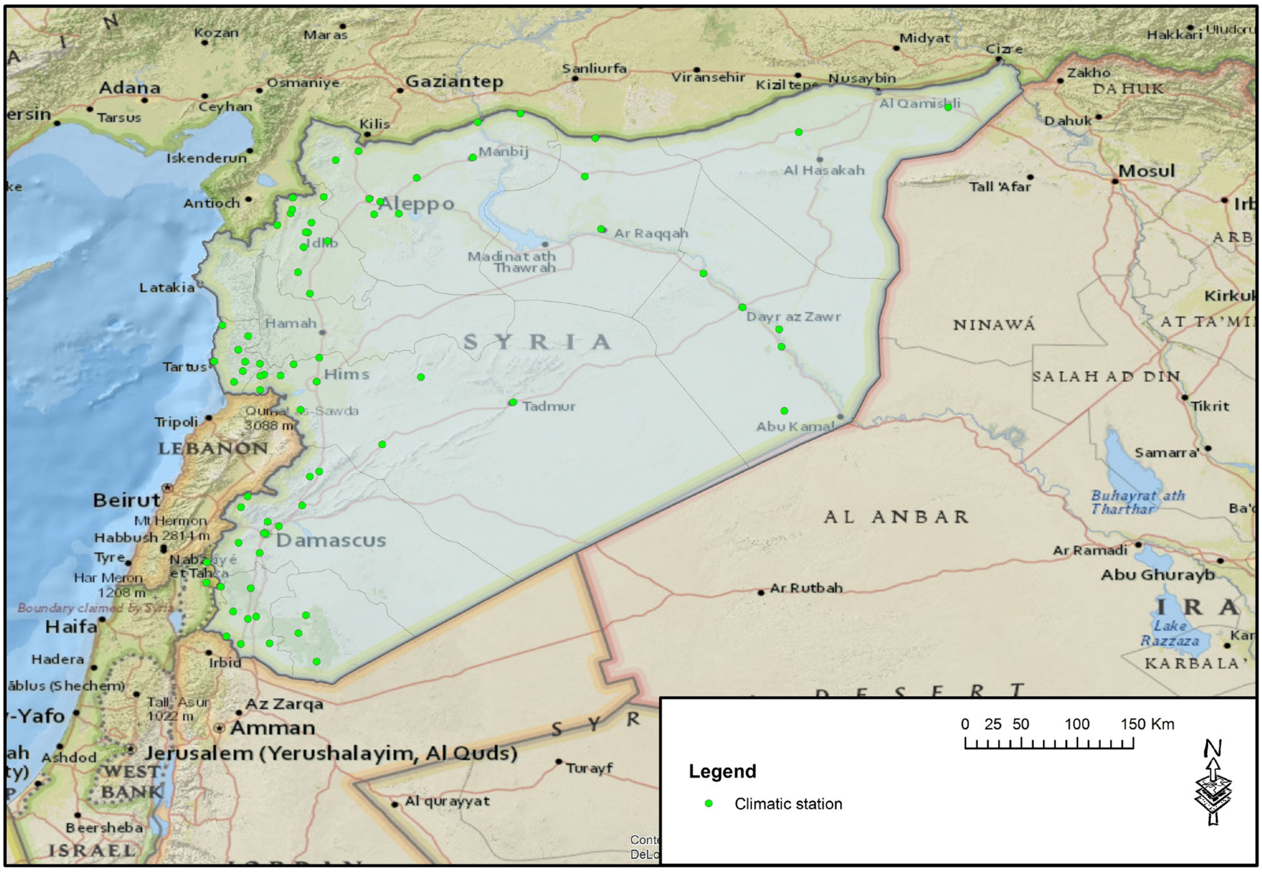

Fig. 1. Study area – location of the 77 climatic stations in Syria.

south. The area of Syria is 185,180 km^2. Terrain is narrow coastal plain with a double mountain belt in the west; large, semiarid and desert plateau to the east. Climate is mostly desert; it has hot, dry, sunny summers (from June to August) and mild, rainy winters (December to February) along coast [24]. The annual rainfall ranges from 99 mm (Palmyra station) to 1,210 mm (Ash Shaykh Badr station).

Data set was compiled for temporal trend analysis that included point measurements from the Meteorological Center in Syria in climatic stations for the period of September 1992 to May 2010 as there are no rainfall during the summer (June–August) in Syria. Daily data were obtained from climatic stations in Syria (Fig. 1; Table 1). Monthly data were compiled from daily data, and the annual data were derived from monthly data, respectively. Statistical trend analysis for the obtained values was performed.

It is important to evaluate how climate has varied and changed in the past. The monthly mean historical rainfall

Table 1
Localization of climatic stations in Syria and annual rainfall

Station	Latitude	Longitude	Altitude (m asl)	Annual rainfall (mm)
Idlib	35°55′58″	36°38′30″	423	484
Armanaz	36°05′09″	36°30′14″	348	553
Addana	36°13′07″	36°46′06″	390	398
Maarrat Misrin	36°00′46″	36°40′17″	340	402
Ebla	35°56′08″	36°37′23″	424	485
Haram	36°12′44″	36°31′12″	163	524
Khan Shaykhun	35°26′31″	36°39′26″	378	359
Darkush	35°59′30″	36°23′37″	115	580
Saraqib	35°51′43″	36°47′52″	358	341
Kafar Takharim	36°07′06″	36°30′58″	482	561
Kafr Nabl	35°36′51″	36°33′39″	637	489
Moh. Wadi Eldaif	35°64′42″	36°70′20″	423	542
Al Qunaytirah	33°07′14″	35°49′31″	832	677
Hader	33°16′56″	35°49′50″	1280	1077
Nada Alsakher	33°05′11″	35°56′32″	826	414
Azaz	36°35′13″	37°02′52″	561	424
Al Bab	36°22′21″	37°30′57″	459	315
Al Safira	36°05′03″	37°22′18″	338	263
Jarabulus	36°49′08″	38°00′27″	356	300
Aleppo International Airport	36°10′50″	37°13′27″	397	320
Kobani	36°53′26″	38°20′59″	515	297
Aleppo	36°12′14″	37°08′02″	401	403
Afrin	36°30′45″	36°51′55″	236	450
Manbij	36°32′10″	37°58′03″	454	262
Al Rastan	34°55′32″	36°44′00″	420	390
Al Quaryatayn	34°13′51″	37°14′18″	750	100
Al Qusayr	34°30′30″	36°34′56″	544	238
Al Mukharram	34°46′19″	37°33′02″	823	267
Al Nasrah	34°47′30″	36°17′24″	596	1,193
Palmyra	34°34′14″	38°17′31″	424	99
Taldou	34°52′24″	36°31′40″	392	495
Tal Kalakh	34°40′06″	36°15′27″	290	893
Homs	34°44′05″	36°42′46″	501	398
Shin	34°46′55″	36°25′21″	830	963
Marmarita	34°46′49″	36°15′36″	552	1,043

(*Continued*)

Table 1 (*Continued*)

Station	Latitude	Longitude	Altitude (m asl)	Annual rainfall (mm)
Izraa	32°50′43″	36°13′30″	568	276
Shaikh Maskin	32°49′40″	36°09′35″	529	318
As Sanamayn	33°04′30″	36°10′53″	640	280
Al Musayrfah	32°37′58″	36°20′00″	692	214
Tal Shihab	32°41′21″	35°59′09″	430	308
Daraa	32°37′36″	36°06′11″	521	240
Nawa	32°53′14″	36°02′25″	566	405
Al Tal	33°36′33″	36°19′02″	1,014	253
Al Qutayfah	33°44′22″	36°35′45″	939	149
Al Kiswah	33°21′32″	36°15′08″	706	176
Al Nabk	34°00′49″	36°44′00″	1,279	149
Duma	33°34′23″	36°24′33″	654	184
Al Zabadani	33°43′34″	36°06′14″	1,211	577
Umuyyad Mosque	33°30′41″	36°18′23″	694	151
Serghaya	33°48′40″	36°09′25″	1,364	613
Qatana	33°26′23″	36°05′02″	893	236
Maysaloon	33°30′59″	36°17′22″	704	385
Yabrud	33°58′22″	36°39′26″	1,375	159
Abu Kamal	34°29′57″	40°28′10″	186	116
Al Busayrah	35°09′17″	40°25′43″	200	136
Al Tebni	35°36′17″	39°49′09″	234	135
Al Mayadin	35°00′59″	40°26′47″	194	139
Deir ez-Zur	35°19′50″	40°08′04″	221	141
Ash Shaykh Badr	34°59′26″	36°04′52″	495	1,210
As Sifsafeh	34°43′58″	36°02′54″	135	1,007
Al Qadmus	35°06′03″	36°09′40″	926	1,181
Baniyas	35°11′08″	35°57′11″	33	813
Draykish	34°53′44″	36°08′07″	427	1,062
Safita	34°49′09″	36°07′08″	314	1,114
Tartus	34°53′49″	35°53′11″	26	774
Mashta Al Hilu	34°52′42″	36°15′17″	518	1,208
Ar Reqqah	35°57′36″	38°59′52″	248	155
Tell Abiad	36°41′32″	38°57′03″	351	243
Ain Issa	36°23′03″	38°52′03″	344	190
As Suwayda	32°42′49″	36°33′58″	1,043	316
Shahba	32°51′26″	36°37′31″	1,075	303
Salkhad	32°29′09″	36°42′42″	1,320	303

data can be mapped to show the baseline climate and seasonality by month, for specific years, and their impact for integrated water management in the country.

Quality control and homogeneity of the climate series are necessary to guarantee a reliable analysis. We applied a homogeneity test to verify the rainfall data quality prior to the analysis, namely the Buishand range test [25] on a monthly basis, from September to May, for n = 19 (time period from 1990 to 2010). The critical values were obtained by linear interpolation for 90% = 1.327; 95% = 1.415 and 99% = 1.579, based on reference values provided by Buishand [25].

2.2. *Statistical analysis – non-parametric trend tests*

The non-parametric Mann–Kendall trend test is the most common of the various statistical procedures used to analyze time series data sets [26–34]. This technique was first developed by Mann [35], with Kendall [36] deriving the distribution of the test statistic. The use of non-parametric techniques tends to be a more robust option when testing data that differ from “normality”. Furthermore, the use of non-parametric techniques is known to be more resilient to outliers [29]. In the Mann–Kendall trend test, the null hypothesis H0 of the trend test is that there is no trend and that the data are random and independent; alternate hypothesis H1 is that a trend is present in the time series. If $n \geq 10$, the test statistic can be approximated using normal distribution and the normalized test statistic Z can then be computed [35–37]. In a two-tailed test, $|Z| > Z_{1-\alpha/2}$ indicates that the null hypothesis has been rejected with α being the significance level of the test. For this study, significance levels of 0.05 were utilized. The non-parametric estimate of the trend magnitude of the slope, β of linear trend, was taken to be the Theil–Sen's slope as proposed by Theil [38] and Sen [39]. Theil–Sen's slope (β) is calculated as the median of all possible slopes.

3. Results

The results of the homogeneity analysis are shown in box plots of test statistics (Fig. 2), as well as the fraction of values above critical for each month. The rejections rates are always approximately equal to or lower than the expected type-I error probability, hence the hypothesis of homogeneity is not rejected.

Results of rainfall analysis – annual trends and seasonal trends are presented in Table 2. As previously mentioned, monthly data series for the 19 years period, from 1992 to 2010, were considered for trend detection. The evaluation was done for the period from September to May (IX–V) and its three months' subperiods or seasons as rainfall in other months is almost zero. Bold values indicate statistical significance at 95% confidence level as per the Mann–Kendall test (+, for increasing and −, for decreasing). Magnitude of the trend is expressed by Sen's estimator of the slope of all the data points.

From Table 2, it is obvious that no significant trends in rainfall data series were detected at the annual level, although the trends are mainly decreasing. The period from

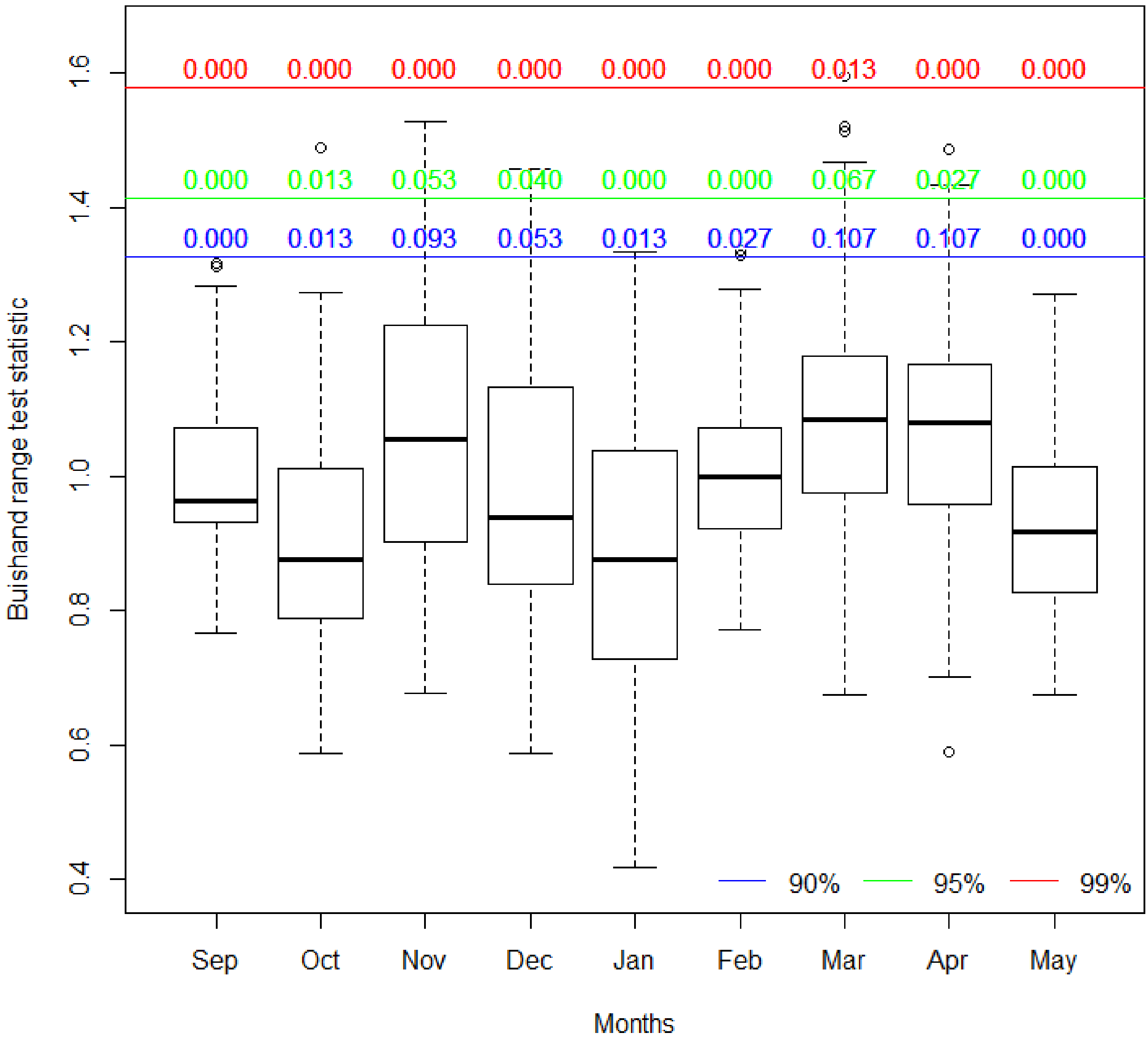

Fig. 2. Box plots of Buishand's range test statistic; fraction of values above critical for levels 90%, 95% and 99%.

September till November showed increasing trends in rainfall, with significant ones at the stations of Tal Kalakh, Al Tebni, Al Qadmus and Baniyas, situated in the southwestern part of the Syria at Mediterranean seaside (Fig. 3). Only the station of Al Nabk denoted a significant decreasing. The winter season – from December to February – showed mostly decreasing trends in rainfall in the evaluated 19 years period. The significant negative trends occurred at the stations of Ar Reqqah and Ain Issa. During the period from March to May in all stations exhibit decreasing trends which were significant at the stations of Arihah, Ebla, Khan Shaykhun, Al Quaryatayn, Al Busayrah proved significant decreasing trends in rainfall. All these stations (except Al Quaryatayn) are situated in the northwestern part of the country (Fig. 5).

Table 2
Annual and seasonal trends of rainfall in climatic stations in Syria

Station	Period			
	IX–V	IX–XI	XII–II	III–V
Idlib	–0.0003	0.1261	–0.1091	–0.0500
Armanaz	0.0000	0.0000	0.1056	–0.2058
Addana	0.0189	0.0588	0.0586	–0.0625
Maarrat Misrin	–0.0108	0.1357	–0.0196	–0.2931
Ebla	–0.0135	0.1460	0.0759	**–0.3556**
Haram	–0.0055	0.0000	0.1106	–0.1875
Khan Shaykhun	–0.0110	0.1552	–0.0520	**–0.2973**
Darkush	0.0287	0.1245	0.6024	–0.2368
Saraqib	–0.0092	0.0956	–0.0293	–0.1667
Kafar Takharim	0.0274	0.0909	0.2818	–0.1818
Kafr Nabl	–0.0051	0.1833	0.1250	–0.2949
Moh. Wadi Eldaif	0.0089	0.3161	0.2759	–0.3000
Al Qunaytirah	–0.0006	0.0840	–0.3621	–0.1550
Hader	0.0000	0.1522	0.0949	–0.2143
Nada Alsakher	–0.0101	0.0178	–0.3762	–0.1000
Azaz	–0.0181	0.0490	–0.1269	–0.1250
Al Bab	–0.0083	0.0111	–0.0050	–0.0294
Al Safira	–0.0213	0.0353	–0.1944	–0.1218
Jarabulus	–0.0142	0.0000	0.0128	–0.1326
Aleppo International Airport	0.0054	0.0250	0.0140	–0.0564
Kobani	–0.0095	0.0000	0.0294	–0.2308
Aleppo	0.0503	0.1207	0.3278	0.1111
Afrin	0.0448	0.1275	0.3571	–0.0357
Manbij	–0.0294	0.0000	–0.1087	–0.2178
Al Rastan	0.0206	0.1467	0.2000	–0.1361
Al Quaryatayn	–0.0041	0.0000	0.0020	**–0.0100**
Al Qusayr	–0.0048	0.0000	0.0917	–0.0625
Al Mukharram	0.0065	0.0392	0.0130	–0.0667
Al Nasrah	0.0046	0.4792	0.4875	–0.5750
Palmyra	–0.0028	0.0000	–0.1000	0.0000
Taldou	0.0154	0.0517	0.0737	–0.1231
Tal Kalakh	0.0709	**0.7228**	1.0171	–0.1481
Homs	0.0218	0.1000	0.0333	–0.1200
Shin	0.0183	0.3964	0.2175	–0.3054
Marmarita	–0.0062	0.2286	0.0258	–0.3975
Izraa	0.0000	0.0000	0.0588	–0.0828
Shaikh Maskin	0.0075	0.0000	0.0400	–0.0706

(*Continued*)

Table 2 (*Continued*)

Station	Period			
	IX–V	IX–XI	XII–II	III–V
As Sanamayn	0.0000	0.0000	–0.4000	0.0000
Al Musayrfah	0.0000	0.0000	0.0885	–0.0333
Tal Shihab	0.0078	0.0000	0.1029	0.0000
Daraa	–0.0010	0.0000	0.0200	–0.0588
Nawa	0.0047	0.0000	–0.3120	–0.0700
Al Tal	–0.0020	0.0000	–0.4074	–0.0588
Al Qutayfah	–0.0049	0.0000	–0.1635	–0.0109
Al Kiswah	–0.0011	0.0000	–0.2974	0.0000
Al Nabk	–0.0205	**–0.1667**	0.0000	–0.0500
Duma	–0.0010	0.0038	–0.2372	–0.0294
Al Zabadani	–0.0186	0.0000	–0.2143	–0.1700
Umuyyad Mosque	0.0008	0.0000	–0.0227	0.0000
Serghaya	–0.0220	0.0064	0.1647	–0.2512
Qatana	–0.0068	0.0000	–0.2000	–0.0781
Maysaloon	–0.0213	0.0000	–0.3833	–0.1111
Yabrud	–0.0071	0.0000	–0.0600	–0.0422
Abu Kamal	0.0000	0.0000	–0.0250	–0.0622
Al Busayrah	–0.0089	0.0000	–0.1600	**–0.0950**
Al Tebni	0.0000	**0.0029**	–0.0385	–0.0780
Al Mayadin	–0.0046	0.0000	–0.0611	–0.1133
Deir ez-Zur	0.0000	0.0000	–0.0871	–0.0698
Ash Shaykh Badr	0.0342	0.6444	–0.1471	–0.5588
As Sifsafeh	–0.0094	0.4643	–0.9412	–0.3939
Al Qadmus	0.0116	**0.8182**	–0.2553	–0.7353
Baniyas	0.0397	**0.4545**	–0.3263	–0.2192
Draykish	–0.0083	0.0351	–0.0760	–0.3250
Safita	0.0158	0.5600	–0.2167	–0.4889
Tartus	0.0158	0.7360	–0.1818	–0.1474
Mashta Al Hilu	–0.0118	0.4650	–0.7111	–0.6583
Ar Reqqah	–0.0163	0.0000	**–0.2613**	–0.1120
Tell Abiad	–0.0412	0.0000	–0.3061	–0.1500
Ain Issa	–0.0185	0.0000	**–0.3143**	–0.0308
As Suwayda	–0.0124	0.0000	–0.3146	–0.0913
Shahba	–0.0180	0.0000	–0.3269	–0.0595
Salkhad	–0.0105	0.0000	–0.1163	–0.0500

Figs. 3–5 summarize the significant rainfall trends (decreasing or increasing) for the different three months' periods analyzed.

The next trend analysis focused on the monthly trends from September to May as during June, July and August there are almost no rainfall in Syria. The results achieved are synthetized in Table 3.

The analysis of the monthly rainfall data (Table 3) showed that there is a clear decreasing trend in May and clear increasing trend in September. Statistically significant negative trends are identified mainly in climatic stations Qatana and Maysaloon which are situated in mountainous area near capital city Damascus and in the north of the country (Manbij). The highest decrease of rainfall – up to 4.67 mm/month (December), that corresponds to 5% of December's rainfall during the evaluated period – occurs in Maysaloon climatic station. An increase of rainfall up to 3 mm/month (April), what correspond to 10% of April's rainfall during the evaluated period, was found in stations Tal Kalakh and Shin which are situated near Homs, near Mediterranean.

4. Discussion and conclusion

The Intergovernmental Panel on Climate Change (IPCC) [40] provides a comprehensive review of the potential impacts on climate. Climatic change is considered likely

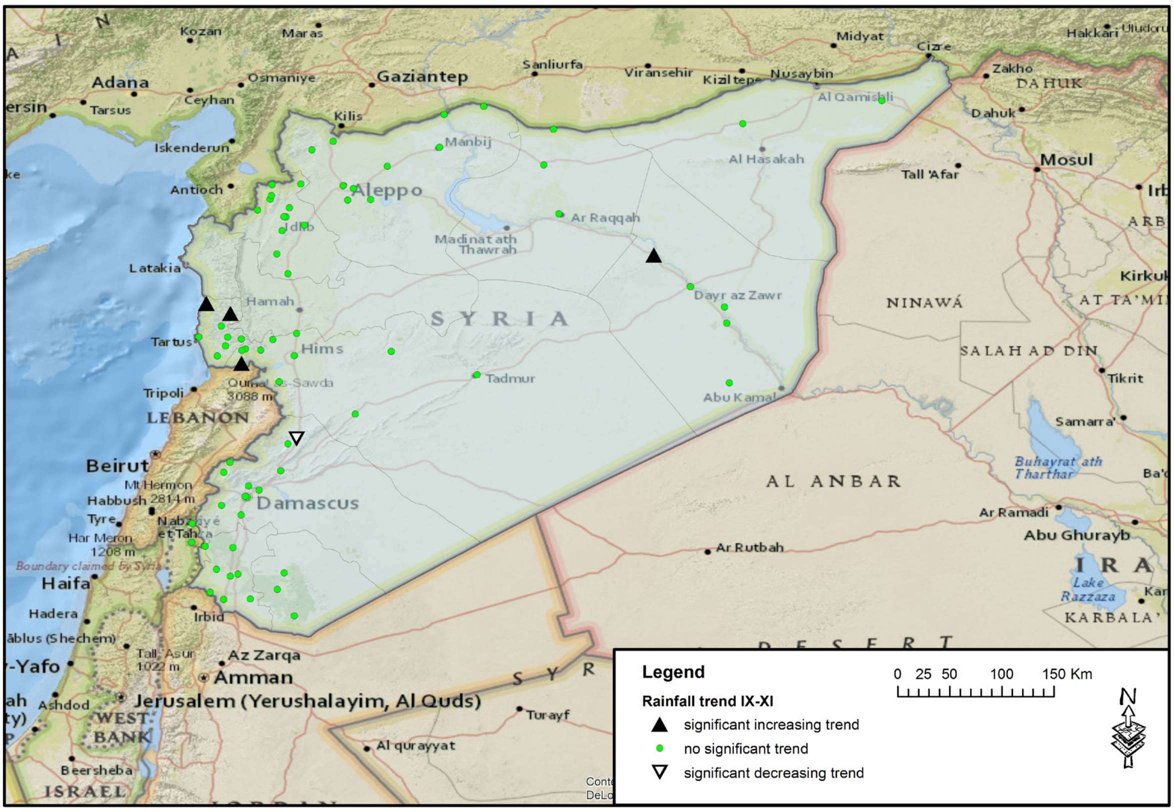

Fig. 3. Rainfall trends from September till November.

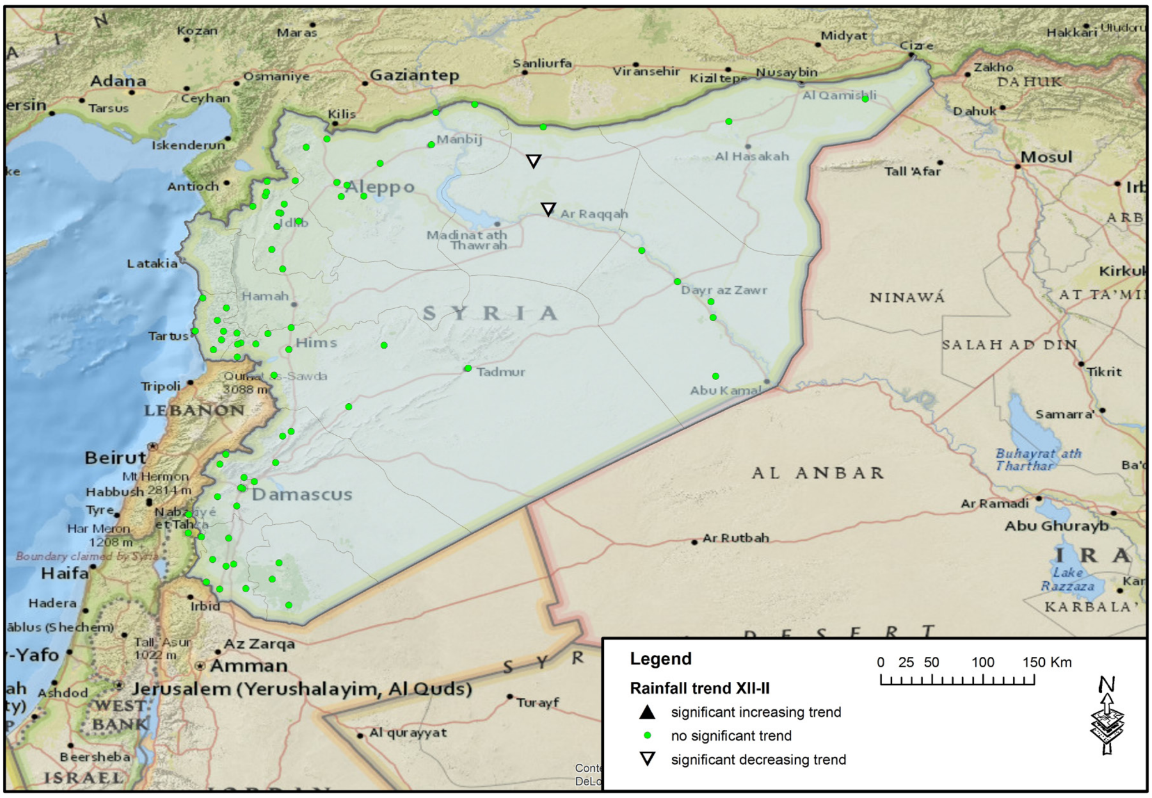

Fig. 4. Rainfall trends from December till February.

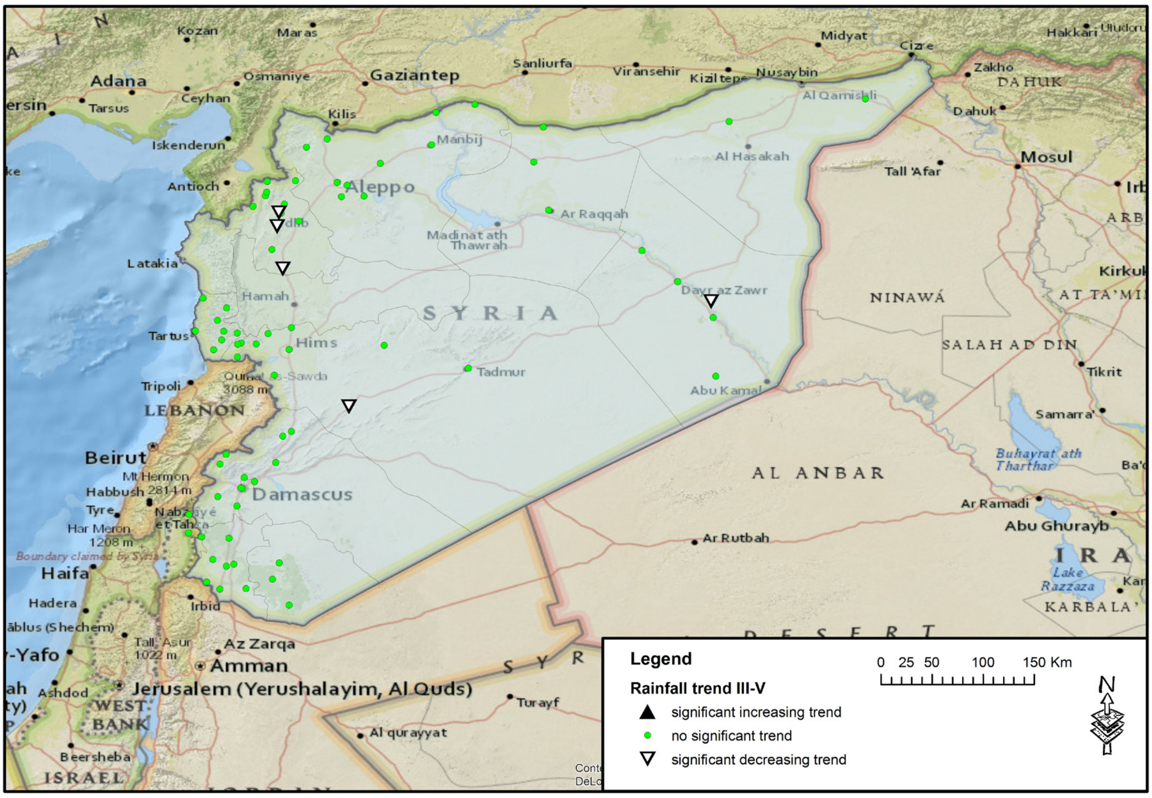

Fig. 5. Rainfall trends from March till May.

Table 3
Monthly trends of rainfall in climatic stations in Syria

Station	Month								
	IX	X	XI	XII	I	II	III	IV	V
Idlib	0.0000	0.8250	–0.7250	–1.6750	0.2250	0.3333	–0.1333	–0.1333	–0.3444
Armanaz	0.0000	0.0000	–0.4235	–0.0600	2.2546	0.6769	–1.8875	0.2300	–0.1250
Addana	0.0000	0.5000	0.1111	–0.7000	0.7333	0.3571	–0.7083	0.7000	–0.5000
Maarrat Misrin	0.0000	0.5556	–0.1667	1.1923	–0.5000	–0.3000	–1.5909	–0.6667	–0.7500
Ebla	**0.5455**	0.1667	–0.2500	1.0000	0.1667	0.4000	–2.2133	–0.1667	–0.5000
Haram	0.0000	0.0909	–1.0871	0.5000	2.3953	0.3333	–1.5000	1.1667	–0.8214
Khan Shaykhun	**0.0100**	0.6267	0.1000	0.8333	–0.1800	–0.9545	–1.0357	0.6222	–0.5403
Darkush	0.0000	0.1200	0.9000	2.3071	2.5583	2.0400	–0.7500	–0.3827	–0.8182
Saraqib	**0.0000**	0.2500	–0.3000	1.5000	–1.1818	0.0588	–1.4545	–0.1364	–0.4000
Kafar Takharim	0.0000	0.4000	–0.2375	0.0222	2.9607	1.0625	–0.8875	0.3000	0.0000
Kafr Nabl	0.0000	0.6111	–0.5000	1.9500	–0.6923	0.5000	–1.5714	0.0000	–0.8571
Moh. Wadi Eldaif	**0.0110**	0.9500	0.4583	1.4667	0.5000	0.2500	–2.4083	–0.4159	–0.3500
Al Qunaytirah	0.0000	0.5000	–2.7000	–4.3250	0.4929	1.2375	–1.7455	0.2800	–0.1875
Hader	0.0000	0.8000	–4.3824	–3.3375	–0.3462	4.0727	–1.3571	2.0833	–0.0909
Nada Alsakher	0.0000	0.0222	–0.8819	–1.8059	–1.2688	0.5000	–1.2643	0.1133	0.0000
Azaz	0.0000	0.6176	**–1.4647**	–0.8250	1.2857	–0.6176	–0.1250	0.0333	**–0.8125**
Al Bab	0.0000	–0.1500	–0.8111	–0.1917	0.4500	–0.5444	–0.1059	–0.1667	–0.6167
Al Safira	**0.0110**	0.5000	–1.0500	–0.2118	–0.4500	–1.4756	0.1333	–0.2909	–0.5200
Jarabulus	0.0000	–0.0400	0.0444	0.1400	0.7300	–0.5000	0.3222	–0.6625	–0.2857

(Continued)

Table 3 (*Continued*)

Station	Month								
	IX	X	XI	XII	I	II	III	IV	V
Aleppo International Airport	0.0000	0.5000	–0.4857	0.3889	0.1333	–0.1500	0.2000	–0.2000	–0.3333
Kobani	0.0000	0.0000	0.0000	0.5714	0.2750	–0.4500	–0.2000	–1.2500	–0.6667
Aleppo	0.0000	0.3857	0.2222	1.3333	1.1917	0.3556	0.7400	1.8118	–0.4063
Afrin	0.0000	1.2000	–0.3571	0.3750	2.3500	0.5000	0.4167	0.9643	–0.2500
Manbij	**0.0455**	–0.1300	–0.3077	0.0385	–0.1000	–0.5757	–0.3333	–0.1583	**–1.0375**
Al Rastan	0.0000	0.6333	0.2000	0.9615	0.6500	1.0167	–1.6000	0.7778	–0.2000
Al Quaryatayn	0.0000	0.1500	–0.1500	0.6667	0.3000	–0.6611	**–0.6000**	–0.1000	0.0000
Al Qusayr	0.0000	0.1000	–0.5333	0.1000	0.3071	0.7667	–0.7985	0.7500	0.0000
Al Mukharram	0.0250	0.1167	0.0250	–0.2286	1.3538	–0.5000	–1.1333	0.2400	0.0000
Al Nasrah	0.0000	0.1333	3.8938	2.3222	2.4286	0.7100	–1.9133	2.4412	–1.1398
Palmyra	0.0000	0.4250	–0.4714	–0.4333	–0.9889	–0.1714	–0.0214	0.0000	0.0000
Taldou	0.0000	0.0000	0.3556	0.6429	1.3750	–0.2167	**–2.4882**	0.5266	–0.3333
Tal Kalakh	0.3333	0.3273	2.8250	2.0500	3.3750	2.9286	–0.9500	**3.1625**	**–0.7571**
Homs	0.1286	0.6000	0.0333	0.1000	0.9571	0.0000	–1.0333	1.1545	0.0000
Shin	0.0000	0.7000	1.7733	2.8000	–0.0929	0.5000	–1.2500	**3.0000**	**–0.9400**
Marmarita	0.0833	–0.2353	1.3833	2.2500	–0.8538	0.2727	–2.2200	1.5714	**–1.7500**
Izraa	0.0000	0.1000	0.3000	0.1563	–0.2017	0.5267	–0.4133	–0.2286	0.0000
Shaikh Maskin	0.0000	**0.2400**	0.2000	0.4286	–1.9143	1.1667	–0.7778	0.0333	–0.1538
As Sanamayn	0.0000	0.0000	0.1429	–1.1400	–0.5750	–1.3500	–0.2533	0.0313	0.0000
Al Musayrfah	0.0000	0.0000	**1.7500**	0.3667	–1.1371	0.3375	–0.7813	0.0000	0.0000
Tal Shihab	0.0000	0.1875	0.0000	0.2167	–1.9333	1.5333	0.0500	0.1000	0.0000
Daraa	0.0000	0.0467	0.6250	0.3333	–1.8091	0.5333	–0.8500	0.1214	–0.0333
Nawa	0.0000	0.2111	0.5000	–0.0909	–3.6083	0.3000	–0.6250	–0.1667	0.0000
Al Tal	0.0000	0.3571	–0.2765	–2.3000	–1.0571	–0.5765	–1.0846	0.1667	0.0000
Al Qutayfah	0.0000	0.0000	–0.2875	–1.3750	–0.6870	0.0214	–0.2500	0.0889	–0.0833
Al Kiswah	0.0000	0.2385	0.3000	–2.0545	–0.5067	–0.3563	–0.4667	0.1167	0.0000
Al Nabk	0.0895	**–1.6000**	–0.5500	0.5786	–0.7636	–0.2333	–0.3714	0.1250	–0.1857
Duma	0.0000	0.1471	–0.9636	–1.1667	–0.5730	0.1429	–0.6889	0.0750	0.1000
Al Zabadani	0.0000	0.3000	–1.3400	–2.8000	0.3500	1.6267	–2.4444	0.6875	–0.2813
Umuyyad Mosque	0.0000	0.1071	0.3750	–0.7462	0.0270	–0.0706	0.0846	0.0167	0.0000
Serghaya	0.0000	0.5706	–1.5833	–1.5800	1.2700	2.4750	–2.6538	1.0900	–0.5556
Qatana	**0.0100**	0.0000	–0.8692	**–3.5000**	1.1800	0.5000	**–1.7188**	0.0000	0.0000
Maysaloon	0.0000	0.0714	–1.9857	**–4.6750**	–0.1000	0.6200	**–2.4250**	0.2600	–0.0333
Yabrud	0.0000	0.0154	–1.3500	–0.6375	0.8475	0.1000	–0.5938	0.2222	–0.2400
Abu Kamal	0.0000	0.1000	–0.1667	–0.1786	–0.1200	0.0111	–0.4000	–0.1438	–0.0800
Al Busayrah	0.0000	**0.2533**	0.0778	–0.5375	–0.5600	–0.5000	–0.1417	–0.2833	–0.1000
Al Tebni	**0.0120**	**0.3455**	0.0000	–0.2600	0.0333	–0.2833	–0.2000	–0.0800	0.0000
Al Mayadin	0.0000	**0.3222**	0.1824	0.0250	–0.2250	–0.5500	–0.3333	–0.2500	0.0000
Deir ez-Zur	0.0000	**0.2667**	0.0875	–0.1900	0.1769	–0.8111	–0.1575	–0.1833	0.0000
Ash Shaykh Badr	0.5000	1.8444	2.6400	–2.1385	2.0909	–0.3857	–3.7385	2.7615	–1.4900
As Sifsafeh	**0.5714**	1.4722	1.0938	–3.2353	–1.1818	–1.8571	–2.8235	0.4545	–1.0000
Al Qadmus	**0.8429**	2.1429	1.4000	–2.7727	0.5000	0.6154	–2.1000	1.9167	–1.0240
Baniyas	0.9500	**2.300**0	0.5125	–1.6667	1.0000	–2.1000	–1.8125	0.6333	–0.1667
Draykish	**1.3000**	–2.2667	–3.3900	2.0500	0.9706	–2.3000	1.4000	–1.6917	0.0000
Safita	**1.1091**	1.6778	4.5286	–2.2615	0.3357	0.9375	–2.8462	1.1091	–0.7000
Tartus	0.0000	1.8933	0.7667	–3.8444	1.5250	–1.3385	–1.3385	0.3000	–0.3000
Mashta Al Hilu	**1.1857**	0.8400	1.0167	–1.5500	–4.2500	–0.3462	–3.7444	3.5333	–2.1800
Ar Reqqah	0.0000	0.1667	–0.5800	0.0300	**–1.2667**	–0.8600	–0.1938	–0.3667	–0.0286
Tell Abiad	**0.0100**	–0.0889	–0.6000	0.0833	–1.7333	–0.9182	–0.0353	0.2000	–0.5250
Ain Issa	0.0000	–0.0833	–0.6667	–0.4000	–1.3333	–0.8769	0.0714	–0.0909	0.0000
As Suwayda	0.0000	–0.2143	0.7800	–1.2444	–2.5000	1.3500	–0.8375	0.5800	–0.1833
Shahba	0.0000	0.0000	0.1733	–1.6267	**–3.6684**	0.3235	–1.0929	0.0000	0.0000
Salkhad	0.0000	–0.0636	–0.7500	–1.7273	–2.0850	1.5938	–0.8462	0.5000	0.0000

to increase runoff in the higher latitude regions because of increased rainfall on the other hand flood frequencies are expected to change also in some locations and the severity of drought events could increase as a result of those changes in both rainfall and evaporation. Almost regardless of the expected change, the "main issue" is the effect of global warming and its impacts on the environment and water resources in particular. Rainfall is one of the most important variables for climate and hydrometeorology. Changes in precipitation pattern may lead to floods, droughts, loss of biodiversity and agricultural productivity. Therefore, to understand the spatial and temporal trends of precipitation are important for climate analyst and water resources planner [33,41]. Precipitation has changed worldwide during the last decades mainly due to climate variability. Climate change studies have demonstrated that the land-surface precipitation shows an increase of 0.5%–1% per decade in most of the Northern Hemisphere mid and high latitudes, and annual average of regional precipitation increased 7%–12% for the areas in 30°–85° N and by about 2% for the areas 0°–55° S over the 20th century [42,43]. Most of the recent studies about climate change suggest that the behaviour of some of the climatological variables has already changed and will continue to change towards increasing or decreasing magnitudes and frequencies, depending on the type of variable. Increased rainfall and floods are expected in some regions while other regions will experience smaller rainfall and longer droughts, meaning water scarcity.

The temporal and spatial variation of precipitation in the Syria was investigated based on 77 climatic stations with daily precipitation records from 1992 to 2010. Non-parametric Mann–Kendall test and Theil–Sen analysis methods were applied for significant trend detection and magnitude of trends, respectively. Negative trends of annual rainfall were found in the analyzed climatic stations, denoting a decrease in rainfall in almost all climatic stations, especially in the north (mountainous) and western (coastline) parts of the country. In conclusion, Syria shown decreasing trend of rainfall, in accordance with previous IPCC results. The study presented extends the previous rainfall trend analysis [26] and provides new insights regarding the seasonal and monthly time scales. Significant increasing (decreasing) rainfall trends in September (May) were found at the 95% confidence interval. We did not identify from our analysis any dependency between altitude and total rainfall or altitude and significant trends.

The amount of rainfall received over an area is an important factor in assessing the amount of water available to meet the various demands of agriculture, industry and other human activities. Achieved results are observable along with decreasing crop production which relate to decreasing amount of water resources, as stated in [1]. Availability, and the presence of sufficient water resources in the environment and landscape is an essential condition of life, social and ecological stability as well as economic prosperity. Water is a strategic and irreplaceable natural resource. Constrains in water management are mainly due to unequal distribution of water in the area. The rational use of water is adapting to its natural occurrence in the area. This fact needs to be taken into account mainly during the development of urban areas. In the course of the year the amount of water in the area is usually significantly changing. This phenomenon is closely related to the change of water quality. Excess of water is causing problems to the population, farmers, industries and municipalities. The same problem also causes water shortages. The best option is if the sufficient amount of water resources throughout the year without undue variations in both terms of quality and quantity is presented in the environment.

The archived results are a basement for integrated water resources management in the country. Public interest in the protection and use of water resources in the areas is consistent protection of water and soil, and the sustainable management of water and land resources in the individual settlements and their origin. Public interest further includes ensuring people's access to drinking water, provision of waste water treatment, minimizing hydrological risks in river basins and in the municipalities.

Acknowledgements

This work has been supported by the Slovak Research and Development Agency bilateral project between Slovakia and Portugal SK-PT-2015-0007 and by the Scientific and Educational Grant Agency of Ministry of Education Of the Slovak Republic under project VEGA 1/0609/14.

References

[1] E. Wadid, Drought Vulnerability in the Arab Region, Case Study – Drought in Syria, Ten Years of Scarce Water (2000-2010), The Arab Center for the Studies of Arid Zones and Dry Lands, Syria, 2011.

[2] A.K. Biswas, Integrated water resources management: a reassessment, Water Int., 29 (2004) 248–256.

[3] A.K. Biswas, Integrated water resources management: is it working?, Int. J. Water Resour. Dev., 24 (2008) 5–22.

[4] C. Mounira, A. Seddini, S. Benameur, Relieving the water shortage crisis of Algeria by reusing treated wastewater lagoons, Desal. Wat. Treat., 57 (2016) 15250–15262.

[5] H.H.G. Savenije, P. Van der Zaag, Integrated water resources management: concepts and issues, Phys. Chem. Earth, Parts A/B/C, 33 (2008) 290–297.

[6] E. Hatzigiannakis, A. Filintas, A. Ilias, A. Panagopoulos, G. Arampatzis, I. Hatzispiroglou, Hydrological and rating curve modelling of Pinios River water flows in Central Greece, for environmental and agricultural water resources management, Desal. Wat. Treat., 57 (2016) 11639–11659.

[7] E. Moussoulis, I. Zacharias, N.P. Nikolaidis, Combined hydrological, rainfall–runoff, hydraulic and sediment transport modeling in Upper Acheloos River catchment, Desal. Wat. Treat., 57 (2016) 11540–11549.

[8] P. Stålnacke, G.D. Gooch, Integrated water resources management, Irrig. Drain. Syst., 24 (2010) 155–159.

[9] R.A. Mcdonnell, Challenges for integrated water resources management: how do we provide the knowledge to support truly integrated thinking?, Int. J. Water Resour. Dev., 24 (2008) 131–143.

[10] J. Gupta, P. van der Zaag, Interbasin water transfers and integrated water resources management: where engineering, science and politics interlock, Phys. Chem. Earth, Parts A/B/C, 33 (2008) 28–40.

[11] A. Lamei, P. van der Zaag, E. von Münch, Water resources management to satisfy high water demand in the arid Sharm El Sheikh, the Red Sea, Egypt, Desal. Wat. Treat., 1 (2009) 299–306.

[12] N. Endo, J. Matsumoto, T. Lwin, Trends in precipitation extremes over Southeast Asia, SOLA, 5 (2009) 168–171.

[13] M. Almazroui, N.M. Islam, P.D. Jones, H. Athar, A.M. Rahman, Recent climate change in the Arabian Peninsula: seasonal rainfall and temperature climatology of Saudi Arabia for 1979–2009, Atmos. Res., 111 (2012) 29–45.

[14] M. Almazroui, Calibration of TRMM rainfall climatology over Saudi Arabia during 1998–2009, Atmos. Res., 99 (2011) 400–414.
[15] R. Ragab, C. Prudhomme, Climate change and water resources management in arid and semi-arid regions: prospective and challenges for the 21st century, Biosyst. Eng., 81 (2002) 3–34.
[16] R. Modarres, V.P.R. Silva, Rainfall trends in arid and semi-arid regions of Iran, J. Arid Environ., 70 (2007) 344–355.
[17] H. Tabari, P.H. Talaee, Temporal variability of precipitation over Iran: 1966-2005, J. Hydrol., 396 (2011) 313–320.
[18] I. Ahmad, D. Tang, T.F. Wang, M. Wang, B. Wagan, Precipitation trends over time using Mann-Kendall and Spearman's rho tests in Swat River basin, Pakistan, Adv. Meteorol., 2015 (2015) 1–15.
[19] G. Lee, F. Othman, S. Ibrahim, M. Jang, Determination of the forecasting-model parameters by statistical analysis for development of algae warning system, Desal. Wat. Treat., 57 (2016) 26773–26782.
[20] L.V. Melo, M.D. de Oliveira, M. Libânio, S.C. Oliveira, Applicability of statistical tools for evaluation of water treatment plants, Desal. Wat. Treat., 57 (2016) 14024–14033.
[21] A. Sentas, A. Psilovikos, T. Psilovikos, N. Matzafleri, Comparison of the performance of stochastic models in forecasting daily dissolved oxygen data in dam-Lake Thesaurus, Desal. Wat. Treat., 57 (2016) 11660–11674.
[22] M. Ghodbane, A. Boudoukha, L. Benaabidate, Hydrochemical and statistical characterization of groundwater in the Chemora area, Northeastern Algeria, Desal. Wat. Treat., 57 (2016) 14858–14868.
[23] A. Sfikas, P. Angelidis, D. Petridis, A statistical approach for identification of potential pollution incidents due to lignite mining activity in a surface water stream, Desal. Wat. Treat., 57 (2016) 18606–18618.
[24] Nations Online, One World, The Nations Online Project: Get In Touch with the World, 2016. Available at: http://www.nationsonline.org/oneworld/map/syria-map.htm
[25] T.A. Buishand, Some methods for testing the homogeneity of rainfall records, J. Hydrol., 58 (1982) 11–27.
[26] M. Zeleňáková, I. Alkhalaf, P. Purcz, P. Blišťan, M.M. Portela, Evaluation of Rainfall Time Series by Statistical Methods, International Conference on Protection and Restoration of the Environment, Thessaloniki, Grafima Publications, Greece, 2016, pp. 508–514.
[27] D.H. Burn, M.A. Hag Elnur, Detection of hydrologic trends and variability, J. Hydrol., 255 (2002) 107–122.
[28] J.R. Johnes, J.S. Schwartz, K.N. Ellis, J.M. Hathaway, C.M. Jawdy, Temporal variability of precipitation in the Upper Tennessee Valley, J. Hydrol.: Reg. Stud., 3 (2015) 125–138.
[29] J.R. Lanzante, Resistant, robust and non-parametric techniques for the analysis of climate data: theory and examples, including applications to historical radiosonde station data, Int. J. Climatol., 16 (1996) 1197–1226.
[30] D.P. Lettenmaier, E.F. Wood, J.R. Wallis, Hydro-climatological trends in the continental United States, 1948–88, J. Clim., 7 (1994) 586–607.
[31] T. Partal, E. Kahya, Trend analysis in Turkish precipitation data, Hydrol. Process., 20 (2006) 2011–2026.
[32] A. Sarkar, R.D. Singh, N. Sharma, Climate Variability and Trends in Part of Brahmaputra River Basin, India Water Week 2012 – Water, Energy and Food Security: Call for Solutions, New Delhi, 2012.
[33] M. Sayemuzzaman, M.K. Jha, Seasonal and annual precipitation time series trend analysis in North Carolina, United States, Atmos. Res., 137 (2014) 183–194.
[34] Q. Zhang, C. Liu, C.Y. Xu, Y. Xu, T. Jiang, Observed trends of annual maximum water level and streamflow during past 130 years in the Yangtze River basin, China, J. Hydrol., 324 (2006) 255–265.
[35] H.B. Mann, Non-parametric tests against trend, Econometrica, 13 (1945) 245–259.
[36] M.G. Kendall, Rank Correlation Measures, Charles Griffin, London, 1975.
[37] B. Önöz, M. Bayazit, The power of statistical tests for trend detection, Turk. J. Eng. Environ. Sci., 27 (2003) 247–251.
[38] H. Theil, A rank-invariant method of linear and polynomial regression analysis, Netherlands Academy of van Wetenschappen, Series A, 53 (1950) 386–392.
[39] P.K. Sen, Estimates of the regression coefficient based on Kendall's tau, J. Am. Stat. Assoc., 63 (1968) 1379–1389.
[40] Intergovernmental Panel for Climatic Change (IPCC) Working Group II: Impacts, Adaptation and Vulnerability, Extreme High Temperature and Precipitation Events. Available at: http://www.ipcc.ch/ipccreports/tar/wg2/index.php?idp=625
[41] M. Zeleňáková, P. Purcz, I.A.K. Gargar, H. Hlavatá, Comparison of Precipitation Trends in Libya and Slovakia, River Basin Management 7, WIT Press, Southampton, 2013, pp. 365–374.
[42] J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, K. Maskell, Climate Change 1995: The Science of Climate Change, Working Group I, Second Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press, UK, 1996.
[43] Z.X. Xu, K. Takeuchi, H. Ishidaira, J.Y. Li, Long-term trend analysis for precipitation in Asia Pacific Friend river basin, Hydrol. Process., 19 (2015) 3517–3532.