Drought changes over last five decades in Syria

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Drought changes over last five decades in Syria

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Abstract. Global warming is likely to alter patterns of global air circulation and hydrological cycle that will change global and regional precipitation regimes. Mediterranean basin is one of the most prominent hot spot of climate change in the world. Further, extreme climatic events such as drought are expected to become more frequent and intense in this region. To evaluate seasonal and annual droughts, Standardized Precipitation Index (SPI) was computed for 15 meteorological stations covering different climatic zones during the last five decades in Syria. Drought intensity and dry spells were calculated by using the Effective Drought Index (EDI), which depends in its calculation on the daily values of effective rainfall during growing season, in 11 stations during the period 1968-2008. Mann-Kendall test was used to detect any monotonic trend in SPI values, whereas Regime Shift Index (RSI) was applied to determine the years of changes. The results showed negative trends which were statistically significant ($p = 0.05$ and $p = 0.01$) only for some stations by the Mann-Kendall test, but significant negative step changes were detected by Regime Shift Index (RSI) in annual SPI values for all regions. The study on drought duration using EDI showed a positive trend in dry days number, and dry spells seemed to be longer.

Keywords. Drought-trend – Standardized precipitation index – Climate variability – Climate change.

Les modifications de la sécheresse sur les cinq dernières décennies en Syrie

Résumé. *Le réchauffement mondial est susceptible d'altérer les tendances de la circulation globale d'air et du cycle hydrologique, ce qui va modifier les régimes de précipitations globales et régionales. Le bassin méditerranéen est un lieu où le changement climatique sera la plus prononcé du monde, et donc il est attendu que des événements climatiques extrêmes tels que la sécheresse soient plus fréquents et intensifs dans cette région. Pour évaluer la sécheresse saisonnière et annuelle, un indice standardisé de précipitations (SPI) a été calculé pour 15 stations météorologiques couvrant plusieurs zones climatiquement différentes sur les cinq dernières décennies en Syrie. L'intensité de la sécheresse a été calculée en utilisant l'Indice Effectif de Sécheresse (EDI) qui dépend pour son calcul des valeurs quotidiennes et effectives des précipitations pendant la saison de croissance dans 11 stations sur la période 1968-2008. Le test de Mann-Kendall a été utilisé pour découvrir n'importe quelle tendance monotonique des valeurs de SPI. L'Indice de Modification du Régime (RSI) a été appliqué pour déterminer les années de changements. Les résultats ont montré des tendances négatives qui étaient statistiquement significatives (p = 0,05 et p = 0,01) seulement pour quelques stations par le test de Mann-Kendall, mais des changements négatifs significatifs de niveau ont été découverts par l'Indice de Modification du Régime (RSI) pour les valeurs annuelles de (SPI) pour toutes les régions. L'étude de la durée de la sécheresse à l'aide de EDI a montré une tendance positive concernant le nombre de jours secs, et les périodes sèches semblaient être plus longues.*

Mots-clés. *Tendance de la sécheresse – Indice standardisé de précipitations – Variabilité climatique – Changement climatique.*

I – Introduction

Global warming is likely to alter patterns of global air circulation and hydrological cycle that will change global and regional precipitation regimes (Karl and Trenberth, 2003; Dore, 2005; IPCC, 2007). Many researchers suggest that shifts in precipitation regimes may have an even greater impact on ecosystem dynamics than the singular or combined effects of rising (CO_2) and temperature, especially in arid and semiarid environments (Weltzin *et al.*, 2003; Potts *et al.*, 2006). Changes in the seasonality or variability of precipitation –both predictions of most GCMs

(IPCC, 2007; Giorgi and Lionello, 2008) are likely to affect soil moisture and water resources and consequently, distribution, structure, composition, and diversity of plant, animal, and microbe populations and communities and their attendant ecosystems (Weltzin *et al.*, 2003; Huxman *et al.*, 2004). Mediterranean basin is one of the most sensitive areas regarding the future precipitation extreme conditions (Lavorel, 1998; Giorgi, 2006). Drought as an extreme event is a complex phenomenon that is difficult to accurately quantify since its definition is spatially variant and context dependent (Quiring, 2009). Based on the nature of the water deficit, four types of droughts are defined: meteorological, agricultural, hydrological and socio-economic (Wilhite and Glantz, 1985; AMS, 2004). The time scale over which precipitation deficits accumulate becomes extremely important and functionally separates these different types of drought (McKee *et al.*, 1993). Drought impacts must be seen as dynamic, resulting from interactions between supply and demand. Human-use systems can significantly exacerbate the impacts of drought through the unsustainable use of natural resources (Wilhite *et al.*, 2007). Drought is a three dimensional natural phenomenon characterized by its severity, duration and areal extent (Tsakiris *et al*., 2007). The SPI is a valuable tool for quantifying the impacts of drought and comparing the intensity of drought across time and space (Logan *et al.*, 2010). The EDI was designed to overcome the limitations that other drought indices have identifying the start and end of a drought and calculating drought duration (Byun and Wilhite, 1999). It can detect short and long term drought which cannot be detected by other indices (Kim *et al.*, 2009).

II – Methodology

Rainfall time series data was arranged into hydrological years (September-August). Standardized Precipitation Index (SPI; McKee *et al*., 1993), for seasonal (3 months) and annual (9 months) rainfall data have been computed from 1958-1959 till 2007-2008 for 15 stations covering different climatic zones in Syria (Fig. 1). To avoid inhomogeneity in data, homogeneity test was applied for series by means the Standard Homogeneity Normal Test (SHNT; Alexanderson, 1986). Effective drought index (EDI; Byun and Wilhite, 1999) was also calculated using daily precipitation data during the period 1968-1969 to 2007-2008. Mann-Kendall statistic test (Westmacott and Burn, 1997), was used In order to detect any monotonic trends in SPI values. The occurrence of shifts was then confirmed. This method is based on a regime shift index (RSI) combined with a sequential "t" test (Rodionov, 2004). Absolute value of RSI indicates magnitude of shift while its sign indicates change in direction of mean between regimes.

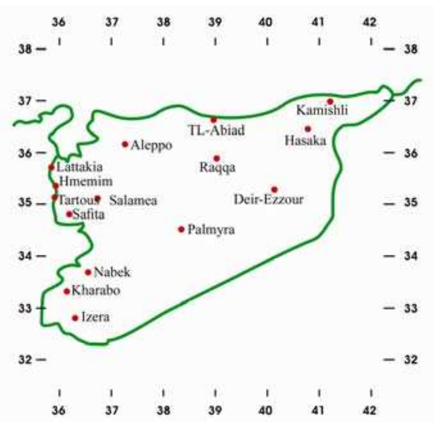

Fig. 1. Geographical coordinates of selected stations.

III – Results

The descriptive statistics of annual rainfall which presented in Fig. 2, demonstrate high variability in all stations. The mean annual rainfall for these stations ranged from 1085.7 mm in Safita to 116.8 mm in Nabek.

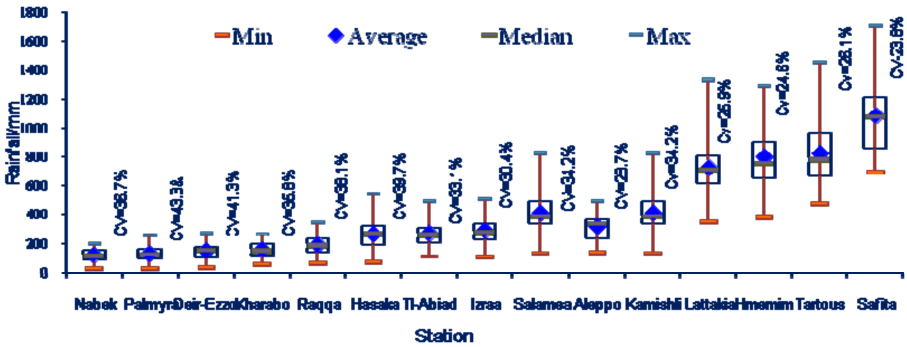

Fig. 2. Statistical characteristics for the annual rainfall in selected stations.

The most extreme drought in terms of intensity, duration and areal extent corresponds to (1998-1999), (1972-1973), (2007-2008) and (1999-2000) respectively (Figs 3 and 4), where most regions experienced droughts less than -2.1, including some regions facing very extreme drought with SPI values less than -3.5.

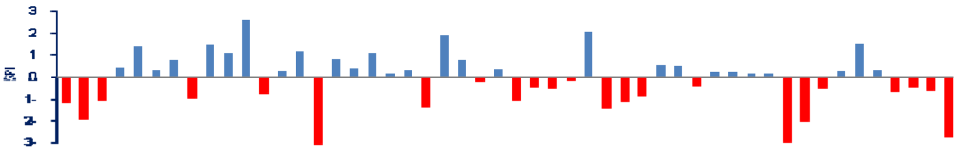

Fig. 3. Annual SPI values for all stations.

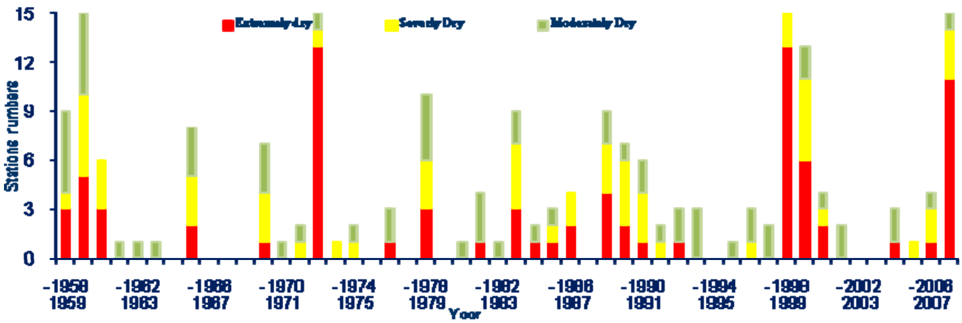

Fig. 4. Areal extent of annual droughts in different severities SPI during 1959-2008 in Syria.

In coastal region, extreme droughts have been also observed during 2000-2001 in which mean SPI value was less than -2.3. Application of EDI reveals that drought duration in these years lasted for a long period and exceeded 200 days in most regions and 230 days in others.

As seen in Fig. 5, seasonal and annual extreme droughts were frequent in most regions, whereas, severe droughts were frequent in all ones. Analysis of seasonal and annual SPI time series values showed negative trends for winter, spring and rainy season in all regions, whereas positive trends in 10 stations were observed in autumn (Table 1). The results of Mann-Kendall test on monotonic trend indicated statistically significant trends for only 4 stations at p = 0.05, and one station at p = 0.1 for annual SPI values, whereas three stations were statistically significant at p = 0.05 and 2 at p = 0.1 in spring. Only one station showed significant positive trend at the level (p = 0.1) in autumn.

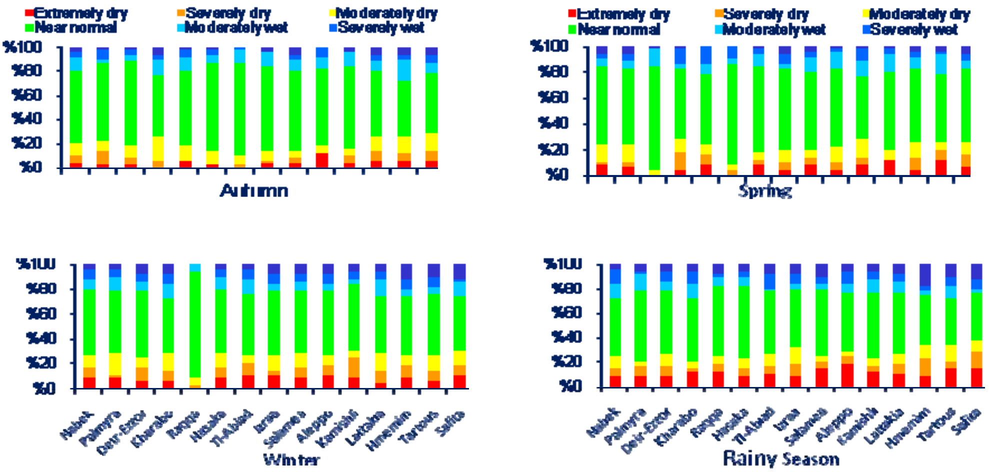

Fig. 5. Areal extent of annual drought in different SPI severities during 1959-2008 in Syria.

Table 1. Trends per decade of seasonal and annual SPI values during the study period

Station	Autumn	Winter	Spring	Rainy season	Station	Autumn	Winter	Spring	Rainy season
Safita	+0.06	-0.04	-0.22*	-0.14	Tl-Abiad	+0.08	-0.18	-0.09	-0.17
Tartous	+0.01	-0.07	-0.15*	-0.19*	Hasaka	+0.09	-0.19	-0.26**	-0.17
Hmemim	+0.07	-0.15	-0.24**	-0.26*	Raqqa	-0.05	-0.09	-0.21	-0.27**
Lattakia	+0.005	-0.20	-0.23	-0.31*	Kharabo	+0.03	-0.09	-0.20	-0.13
Kamishli	-0.09	-0.17	-0.35*	-0.31*	Deir-Ezzor	+0.11	-0.05	-0.13	-0.05
Aleppo	+0.28**	-0.14	-0.07	-0.01	Palmyra	+0.02	-0.05	-0.05	-0.08
Salamea	-0.10	-0.06	-0.35	-0.08	Nabek	-0.07	-0.12	-0.09	-0.12
Izraa	-0.01	-0.04	-0.19	-0.13					

*p = 0.05; **p = 0.01.

Step change analysis with Regime Shift Index showed statistically significant shifts in annual SPI values at (p = 0.1) in all stations. Some of them (8 stations) showed significant change at the level (p = 0.05) in same years as seen in Table 2. Detected changes in some regions are illustrated in Fig. 6.

Table 2. Years of regime shifts detected in the mean annual values of SPI (p = 0.1; cut-off length = 25)

Station†	Change point	RSI	Station†	Change point	RSI
Safita	1988-1989	-1.16	*Tl-Abiad*	2005-2006	-1.64
Tartous	1988-1989	-2.28	Hasaka	1998-1999	-1.20
Hmemim	1988-1989	-2.74	Raqqa	1983-1984	-0.16
Lattakia	1988-1989	-2.30		2006-2007	-1.30
Kamishli	1998-1999	-2.59	Kharabo	1998-1999	-1.14
Aleppo	2007-2008	-1.00	*Deir-Ezzor*	2007-2008	-1.10
Salamea	2007-2008	-0.57	*Palmyra*	2007-2008	-1.00
Izraa	1998-1999	-1.49	*Nabek*	1998-1999	-1.99

†Regime shift was detected at p = 0.05 for the stations highlighted in italics.

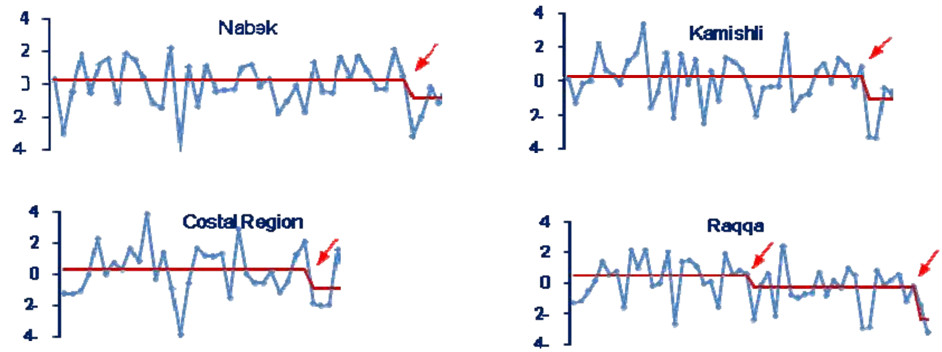

Fig. 6. Regime shifts detection in SPI for some stations (cut-off length 25 year).

Dry spells calculated by EDI showed positive trends for all stations which indicated that the number of dry days and maximum consecutive dry days increased in all studied regions over last decades (Table 3).

Table 3. Detected changes in dry days during 1969-2008

Station	Changes in dry days during rainy season	Changes in maximum consecutive dry days	Station	Changes in dry days during rainy season	Changes in maximum consecutive dry days
Lattakia	+22.7	+25.7	Raqqa	+28.0	+34.4
Kamishli	+29.4	+20.1	Kharabo	+22.6	+20.0
Aleppo	+4.5	+9.0	Deir-Ezzor	+18.7	+33.8
Salamea	+17.2	+16.3	Palmyra	+2.2	+3.0
Tl-Abiad	+17.1	+6.0	Nabek	+9.0	+15.9
Hasaka	+32.4	+20.0			

IV – Conclusion

Application of Mann-Kendall test and Regime Shift Index to detect changes in seasonal and annual SPI values showed significant step changes in all regions, while monotonic trends were detected only in some stations. There is an increasing tendency in annual and seasonal drought intensity in all regions corresponding with an increasing dry days number in rainy season.

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