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Assessment of pan evaporation changes in South Western Iran

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Evaporation is an important component in irrigation scheduling. Due to climate change, understanding of change in evaporation is critical for long term agricultural and environmental planning. The objective of this research is the investigation of temporal and spatial changes in pan evaporation in the Karun & Dez watershed. Our criteria to choose stations are access to data and suitable statistical record length. Geographic, seasonal and annual changes are studied in this research. As a result of performing trend tests, negative trend is found in 66% of the studied seasonal and annual time series, while the remaining cases had positive trends. Investigated time series showed 26 and 12% statistically significant negative and positive trends, at the 0.95 confidence level, respectively and the remaining 62% of time series had non-significant trends. Lali and Abbaspour stations have highest negative and positive slope in most studied time series respectively. Stations in the centre of the watershed showed positive trends while others showed negative or no trends.

Key words: Pan evaporation, trend, south western Iran.

INTRODUCTION

There is not a method to develop the point scale evaporation quantities to surface ones, when the ground surface conditions are not Uniform (Tebakari et al., 2005). Often, long term time series of this parameter is not in hydrologic parameters measurement stations and even if the short time series is available, it will have the mentioned limitation. In addition, lots of observations have been accomplished at small spatial scales. Pan evaporation is quantity that has long term time series with more suitable spatial distribution due to measurement simplicity. Pan evaporation has been found to be proportional to actual evaporation of moist surfaces, such as lakes or irrigated fields (Kahler and Brutsaert, 2006). Many recent publications have reported changes in pan evaporation over the last few decades. Xu (2001) affirmed the relation between a decreasing trend in

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evaporation with an increasing trend in precipitation in Japan and China. Peterson et al. (1995) used the trend test for pan evaporation in several regions of the United States, Europe, Central Asia and Siberia from 1951 until 1990. They reported a decreasing trend in pan evaporation in every one of these regions except Central Asia. In addition, they observed a positive correlation between the pan evaporation decrease and the flow discharge increase in some regions of Europe and north of United States. They also grasp that there is a high correlation between pan evaporation decrease and daily temperature range. Liu et al. (2004) documented that pan evaporation measurements at many weather stations in China had decreased over the last 4.5 decades. Roderick and Farquhar (2004) found that pan evaporation in Australia decreased. Similar reports of decreasing pan evaporation have also come from Canada (Burn and Hesch, 2007), India (Chattopadhyay and Hulme, 1997), Venezuela (Quintana-Gomez, 1998), Italy (Moonen et al., 2002), Turkey (Ozdogan and Salvucci, 2004), Puerto Rico (Harmsen et al., 2004), New Zealand (Roderick and Farquhar, 2002; Roderick and Farquhar, 2004; Rotstayn et al., 2006; Roderick et al., 2007), Thailand (Tebakari et al., 2005), Japan (Xu et al., 2005) and the Tibetan plateau (Zhang et al., 2007). Tabari and Marofi (2011) investigated changes of Pan Evaporation in the West of Iran and revealed a significant increasing trend in 67% of the studied stations. The objective of this article is to investigate the temporal and spatial changes of pan evaporation in the Karun & Dez watershed in south western Iran while considering prior studies.

MATERIALS AND METHODS

The study area

The Karun & Dez watershed has an area of approximately 67,500 km^2 between geographic coordinates of 30° to 34°15$^/$ N latitude and 48° to 52°E longitude; it includes areas of different topographies and includes parts of Chaharmahal Bakhtiari, Lorestan, Kohgiluyeh and Boyer Ahmad, Isfahan and Khuzestan provinces and it drains to the Persian Gulf. Elevation levels variety and Zagros mountain features effects on this region climate causes relative heterogeneity in climatic characteristics. Temperature variation in the region is high due to elevation. The temperature varies from an extremely hot, dry summer accompanied by air temperatures as high as 54°C to mild winter with sub-zero temperatures for most areas of the region. The annual pan evaporation varies between 1500 to 2200 mm. The climate of study area is mostly semi-arid and the mean annual precipitation is 665 mm. The precipitation in the months of January through June consists of more than 70% of the annual precipitation in this basin, which includes both snow accumulation and snow melt seasons. The rivers system supplies the water demands of 16 cities, several villages, 300000 ha of agricultural lands, and several hydropower plants. The increasing water demands at the project development stage including agricultural networks, fish hatchery projects, and inter-basin water.

Data used

The pan evaporation time series measurements obtained from the ten meteorological stations with different record lengths of high-quality daily and monthly records positioned within the regions of southwestern Iran that represent a wide region of the watershed. The monthly and daily data used in the analyses were provided by Iran meteorological agency and the stations network of Ministry of Energy of Iran. After normality and homogeneity analysis, records of 10 stations were used for this research. Statistical analyses in this research are performed on records of time series that ended in 2005. The class A pan was chosen as the standard for measuring evaporation in Iran due to it being the international preference. The class A pan is a circular pan made of galvanized iron, with 121 cm diameter and 25.5 cm deep which is supported by a wood frame stand. Figure 1 shows the location of the Karun & Dez watershed in Iran map and the study stations and Table 1 shows the attributes of pan studied stations. The basic climatic data related to the studied stations are summarized in Table 2.

Trend test

Trend has been investigated using the Mann-Kendall test. Mann (1945) originally used this test and Kendall (1975) subsequently derived the test statistic distribution. Its advantage is that it is distribution-free and does not assume any special form for the distribution function of the data, including censored and missing data (Yue et al., 2003) and has been recommended widely by the World Meteorological Organization for public application (Mitchell et al., 1966). Also, Ben-Gai et al. (1999), Yue and Hashino (2003), Singh et al. (2008), Brunetti et al. (2009), Martınez et al. (2010), Tabari and Hossein Zadeh Talee (2011a, b), Tabari et al. (2011a, b) used Mann-Kendall test for evaluation of trend in hydroclimatoligical variables. Thus, the Mann–Kendall test has been found to be an excellent tool for trend detection by other scholars in similar applications. The MK test considers only the relative values of all terms in the series $X = \{x_1, x_2, \ldots, x_n\}$ to be analyzed. The MK test statistic is given by:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \operatorname{sgn}(x_j - x_i) \tag{1}$$

Where x_i and x_j are the sequential data values, n is the data set record length, and

$$\operatorname{sgn}(\theta) = \begin{Bmatrix} 1 & & \theta > 0 \\ 0 & if & \theta = 0 \\ -1 & & \theta < 0 \end{Bmatrix} \tag{2}$$

Under the null hypothesis of no trend, and the assumption that the data are independent and identically distributed, the zero mean and variance of the S denoted by σ^2 is computed as:

$$\sigma^2 = \frac{n(n-1)(2n+5)}{18} \tag{3}$$

The standard normal variant is then used for hypothesis testing, and is designated here as the trend test statistic index Z, as follows:

$$Z = \begin{Bmatrix} \frac{S-1}{\sigma} & & S > 0 \\ 0 & if & S = 0 \\ \frac{S+1}{\sigma} & & S < 0 \end{Bmatrix} \tag{4}$$

Thus, in a two-tailed test for trend, the null hypothesis H_0, that there is no trend in the dataset, is either rejected or accepted depending on whether the calculated Z statistics is more than or less than the critical value of Z-statistics obtained from the normal distribution

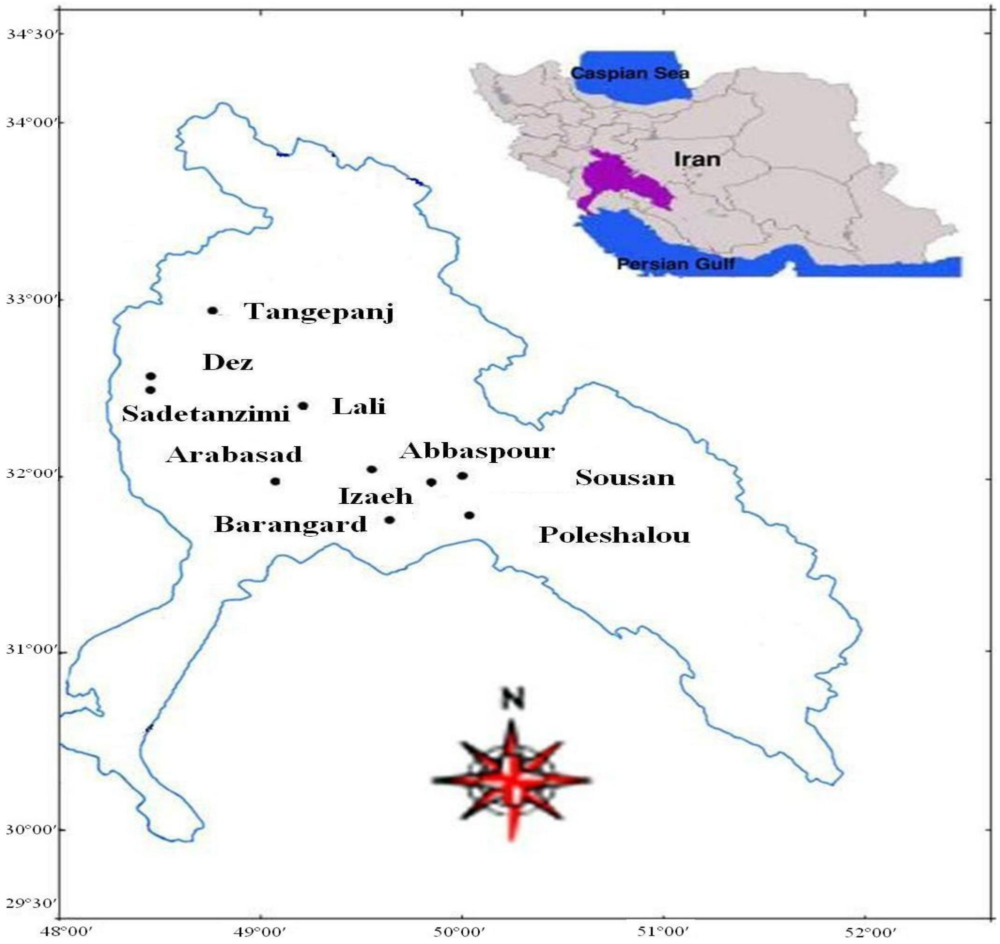

Figure 1. Geographic location of the study region and the stations.

table at 5 and 1% significance level. The positive value of Z shows increasing trend and its negative value shows decreasing trend (Kahya and Kalayci, 2004).

Sen's slope estimator

Slope estimation is used to describe the relationship between one variable with another or other variables of interest. It is often performed to obtain the slope of hydrometeorological variables on time. Positive values of the slope show increasing trend, while negative values of the slope indicate decreasing trend (Tabari and Marofi, 2011). In this study, trend magnitude (slope) is estimated using a nonparametric median based slope method proposed by Sen (1968) and extended by Hirsch et al. (1982):

$$\beta = Median\left[\frac{x_j - x_k}{j - k}\right] \quad for \quad all\ k < j \tag{5}$$

where 1 < k < j < n. β is median of all possible combinations of pairs for the whole data set.

RESULTS

The trends of different pan evaporation time series (Annual, Autumn, Winter, Spring, Summer) determined for the considered stations. The results of the application of the Mann-Kendall test and Sen's slope estimator to determine monotonic trends in the pan evaporation time series is summarized in Tables 3 to 5. These tables show Z–statistic and significant level of different studied time series and their trend slopes. With respect to these tables, it revealed that most studied time series (33 time series, that is, 66%) have negative trends and remaining time series (17 time series, that is 34%) have positive trends. Also, 26% of time series (that is, 13 time series) showed statistically significant negative trends and 12% (that is, 6 time series) showed a statistically significant positive trend. Therefore 62% of time series showed non-significant trends. Figure 2 shows trend lines in the time series of Barangard station.

DISCUSSION

Temporal trend of annual pan evaporation

The trend is determined for the annual pan

Table 1. Characteristics of the stations used in the study.

Station	Longitude (E)	Latitude (N)	Elevation (m.a.s.l.)	Date
Abbaspour	49° 36′	32° 04′	820	1970-2005
Izeh	49°51′	31° 49′	764	1980-2005
Arabasad	48° 53′	31° 51′	33	1981-2005
Barangard	49° 49′	31° 43′	825	1969-2005
Dez	48° 27′	32° 33′	525	1970-2005
Sadetanzimi	48° 27′	32° 25′	142	1981-2005
Lali	49° 06′	33° 22′	390	1981-2005
Sousan	49° 59′	31° 59′	600	1981-2005
Tangepanj	48° 46′	32° 54′	540	1973-2005
Poleshalou	50° 08′	31° 44′	700	1978-2005

Table 2. Mean annual rainfal, temperature, relative humidity and pan evaporation of studied stations.

Station	Izeh	Barangard	Poleshalou	Tangepanj	Sadetanzimi	Dez	Sousan	Abbaspour	Arabasad	Lali
Mean annual rainfall (mm)	667.1	663.5	767.8	1204.3	392.4	510.4	869.0	596.1	259.4	577.5
Mean annual temperature (°C)	20.3	19.6	22.8	24.2	24.5	24.1	22.2	22.8	24.3	24.9
Mean annual relative humidity (%)	56.6	45.4	50.3	40.5	42.7	43.4	57.76	45.7	58.0	52.0
Mean annual pan evaporation (mm)	1752.4	1675.8	1780.2	1764.9	1800.3	1801.0	1787.8	1787.8	1983.1	1866.6

Table 3. Result of the Mann-Kendall trend test on pan evaporation time series (Z - Statistic)

Time series	Izeh	Barangard	Poleshalou	Tangepanj	Sadetanzimi	Dez	Sousan	Abbaspour	Arabasad	Lali
Annual pan evaporation	-0.37	-4.45	0.02	-0.32	-1.27	-1.27	3.26	3.98	-3.27	-3.48
Seasonal pan evaporation (Summer)	-1.53	-4.12	0.68	-1.11	-1.32	-1.32	1.28	3.34	-2.64	-4.28
Seasonal pan evaporation (Spring)	-0.66	-3.51	-1.14	-0.69	-0.90	-0.90	1.81	3.62	-2.11	-2.91
Seasonal pan evaporation (Winter)	1.69	-2.82	-0.77	2.54	0.79	0.79	-0.09	1.62	-2.14	-0.53
Seasonal pan evaporation (Autumn)	0.03	-3.79	-0.79	0.26	-1.64	-1.64	2.03	1.51	-2.48	-0.73

evaporation time series for the considered stations. The results of the application of the Mann-Kendall to determine trends in the annual pan evaporation were summarized in Tables 3 and 4. These results indicated that there are negative trends at 7 stations, positive trends at 3 stations; however, the negative trends were statistically significant at only 3 stations (Lali, Arabasad and Barangard). Similarly the positive trends were statistically significant at only 2 stations (Abbaspour and Sousan). Therefore half of the investigated stations had statistically significant trends. Trend slopes of annual pan evaporation were between -65.38 mm/year at Lali station and 28.41 mm/year at Abbaspour station by the Sen's

Table 4. Result of the Mann-Kendall trend test on pan evaporation time series (confidence level)

Station	Izeh	Barangard	Poleshalou	Tangepanj	Sadetanzimi	Dez	Sousan	Abbaspour	Arabasad	Lali
Annual pan evaporation		**					**	**	**	**
Seasonal pan evaporation (Summer)		**						**	**	**
Seasonal pan evaporation (Spring)		**						**	*	**
Seasonal pan evaporation (Winter)		**		*					*	
Seasonal pan evaporation (Autumn)		**					*		*	

*Statistically significant trends at the 95% confidence level; ** Statistically significant trends at the 99% confidence level.

Table 5. Values of slope of the Sen's slope estimator for annual and seasonal pan evaporation (mm/year).

Station	Izeh	Barangard	Poleshalou	Tangepanj	Sadetanzimi	Dez	Sousan	Abbaspour	Arabasad	Lali
Annual pan evaporation	-3.26	-24.95	0.07	-10.98	-4.01	-4.01	25.04	28.41	-47.06	-65.38
Seasonal pan evaporation (Summer)	-12.13	-11.33	2.88	-16.77	-2.86	-2.86	8.87	11.00	-17.77	-37.50
Seasonal pan evaporation (Spring)	-4.55	-6.97	-3.89	-4.36	-2.25	-2.25	6.51	9.88	-13.61	-18.60
Seasonal pan evaporation (Winter)	3.06	-1.44	-0.73	4.68	0.47	0.47	-0.09	2.17	-3.74	-0.50
Seasonal pan evaporation (Autumn)	0.18	-5.54	-1.88	0.90	-1.94	-1.94	4.73	3.08	-8.08	-1.90

slope test.

Temporal trend of seasonal pan evaporation

The trend test applied on the pan evaporation time series classified by seasons for the studied stations. Tables 3 and 4 indicate that the sign of seasonal pan evaporation trend is consistent with the annual time series trend in most cases. The time series of summer pan evaporation showed statistically significant trend at 4 (1 increasing and 3 decreasing) stations based on the Mann-Kendall test. Trend slopes were between -37.50 mm/year at Lali station and 11.00 mm/year at Abbaspour station by the by the Sen's slope test. The spring pan evaporation time series showed a statistically significant trend at 4 (1 increasing and 3 decreasing) stations based on the Mann-Kendall tests. Trend slopes were between -18.60 mm/year at Lali station and 9.88 mm/year at Abbaspour station by the Sen's slope test. With respect to result of Mann-Kendall test, It is found there are statistical significant trend at 3 (1 increasing and 2 decreasing) stations in the Winter pan evaporation time series. Trend slopes were between -3.74 mm/year at Sousan station and 4.68 mm/year at Izeh station by the Sen's slope test. Furthermore, the Autumn pan evaporation time series showed statistically significant trend observed at 3 (1 increasing and 2 decreasing) stations. Trend slopes were between -8.08 mm/year at Lali station and 4.73 mm/year at Poleshalou station by the Sen's slope test. Among 40 studied seasonal pan evaporation time series, 26 series show negative trends and 14 series shows positive trend. However, only 10 time series showing positive trends and 4 time series showed negative trend are statistically significant. Barangard, Abbaspour, Arabasad and Lali stations had similar trends among their different seasons but other stations had different trends over different seasons. For the majority of the stations the Spring season had a negative trend at half the studied stations the Winter season showed a positive trend.

Spatial trends of pan evaporation

The spatial distribution of stations given by the geographic coordinates of stations (Figure 1 and Table 1) is nowhere near ideal but these stations cover a wide region of the Karun & Dez watershed. The geographical distribution of the observed trends in pan evaporation time series at the stations is shown in Figure 3. Our analysis of the trends of the pan evaporation showed that there is variability in the trend and magnitude of increase/decrease within the Watershed. According to Tables 3 and 4, and Figure 3 indicated that

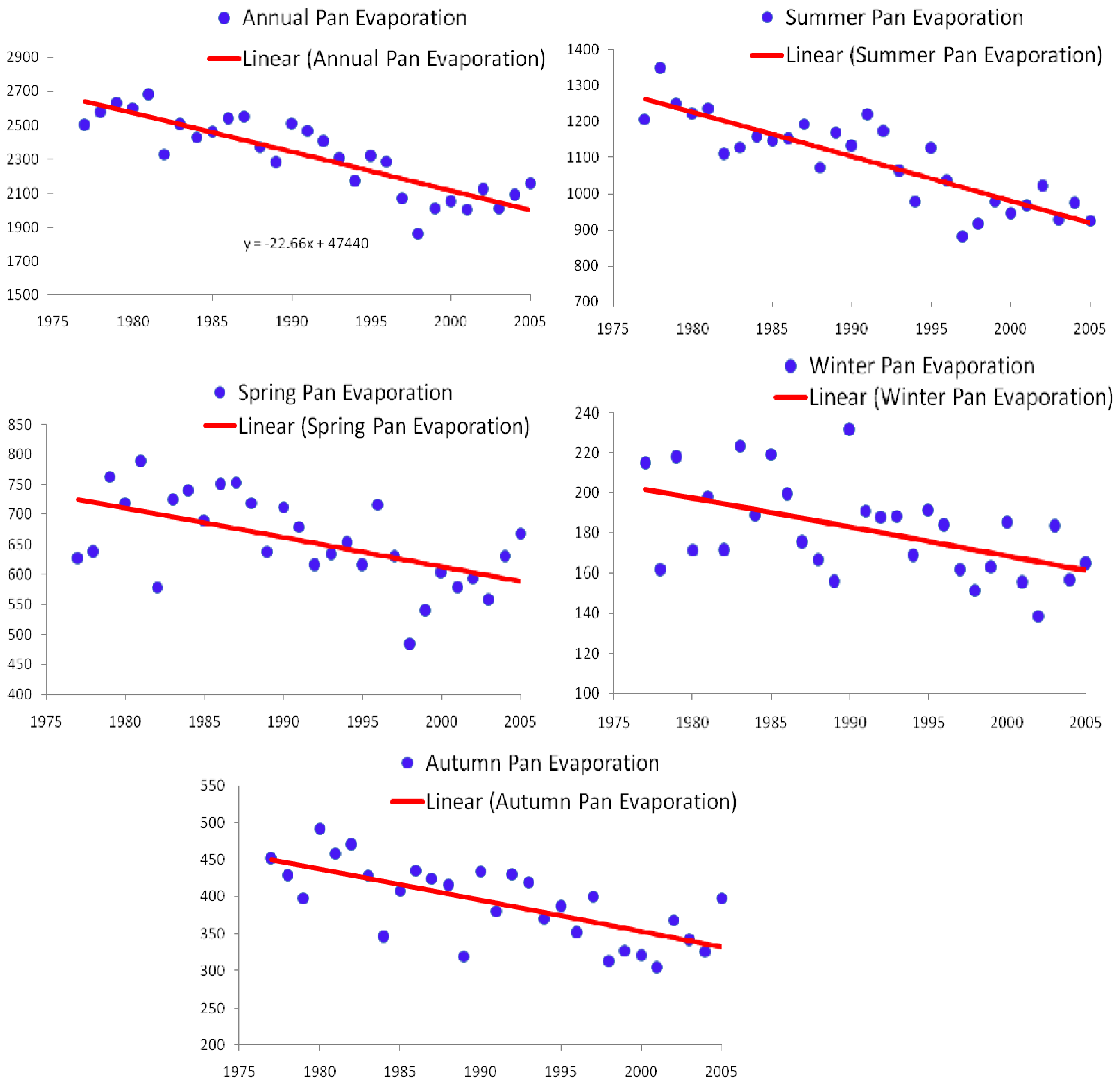

Figure 2. Time series and trend lines of pan evaporation time series at Barangard station.

that the positive trend of time series is often in central parts (longitudinal and latitudinal). The geographical distribution of the changes in the pan evaporation time series at the regional scale showed that a broad decrease in trend occurs across the watershed. The western and southern parts of the watershed experienced significant trends relative to northern and eastern parts. However, detailed deductions about the spatial distribution of trends across the watershed are dependent on access to station time series with a more appropriate spatial distribution.

Conclusion

Evaporation is an important component of the hydrological cycle and its change can has great significance on water resources planning, irrigation

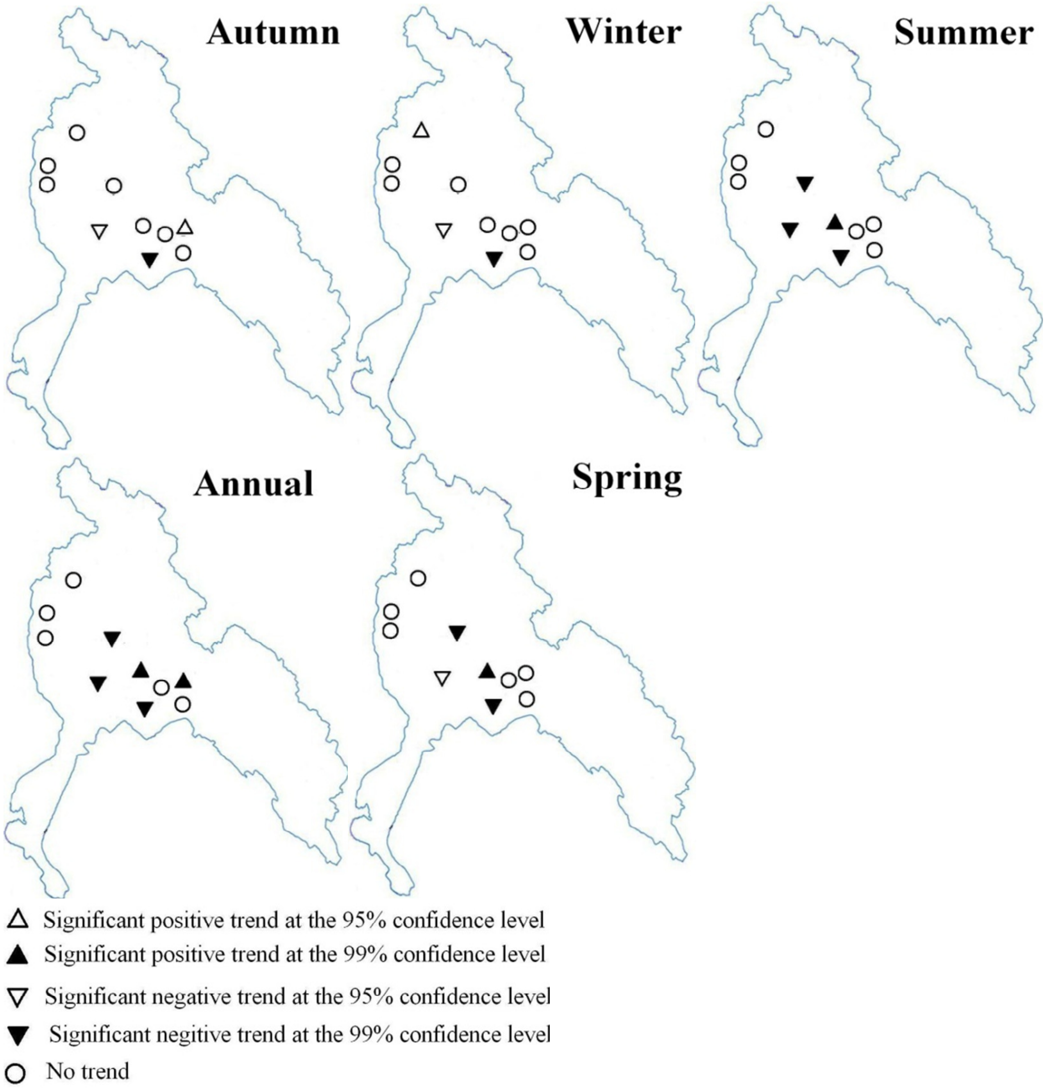

Figure 3. Geographical distribution of results of the Mann-Kendall trend test on pan evaporation time series.

control and agricultural production (Tabari and Marofi, 2011). In this research, the pan evaporation is considered as an index of actual evaporation and its spatial and temporal distribution is investigated to find spatial and temporal trends of the evaporation in the Karun & Dez watershed in south west of Iran. Temporal trend analysis requires access to long term data series therefore 10 stations is selected with respect to available recorded time series. The average annual pan evaporation values in investigated stations are in the wide range of 2409 to 3763 mm. Annual pan evaporation in the studied stations lay in a very wide range, particularly in the middle of the watershed. Trend in pan evaporation time series were investigated by applying Mann-Kendall non-parametric trend test and trend slope is estimated by the Sen's slope test. Test results indicate that negative trends occur in most cases (66% of time series), while positive trends occur in the remaining time series. Also, 26% of time series show statistically significant negative trend and 12% show a statistically significant positive trend. Therefore 62% of time series showed non-significant trends. However the general negative trend of pan evaporation with time in this watershed is in accordance with recent research results elsewhere in the world (Liu et al., 2004; Roderick and Farquhar, 2004; Tebakari et al., 2005; Burn and Hesch, 2007; Zhang et al., 2007), but it is not in accordance with the results of Tabari and Marofi (2011) who reported a positive trend in pan evaporation at the majority of the studied stations in the West of Iran. In addition, Sen's slope estimator revealed that Lali and Abbaspour stations have highest negative and positive slope in most studied time series respectively. The spatial distribution of the investigated stations was not ideal but positive trends found in the central region surrounded by negative and no trends.

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