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ORIGINAL PAPER

The analysis of trend variations of reference evapotranspiration via eliminating the significance effect of all autocorrelation coefficients

Babak Amirataee[1] · **Majid Montaseri**[1] · **Hadi Sanikhani**[2]

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Abstract Reference evapotranspiration (ET_0) is considered a key parameter for evaluating the climatic changes as well as spatial and temporal patterns of parameters influencing the eco-hydrological processes. The analysis of trend variations of this index can be used to determine appropriate strategies in planning and management of water resources. In this paper, the trend variations of monthly and annual ET_0 in Urmia Lake basin, located in the northwest of Iran, have been analyzed using data from 14 synoptic stations in the study area. Regarding the significant effect of autocorrelation coefficients with different lags on trend variations of ET_0, this paper has resorted to modified Mann–Kendall test via eliminating the significance effect of autocorrelation coefficients with different lags to analyze the trend variations. Furthermore, Theil–Sen estimator has been used to determine the slope of trend line of ET_0. The results indicated an increasing trend in ET_0 values at all the studied stations. Having used the modified Mann–Kendall test, the values of significant increasing (positive) trend, which were estimated using common Mann–Kendall test, dramatically decreased. As such, the values of only 7 stations have been significant at 95 % level. The results confirmed the need for eliminating the significance effect of autocorrelation coefficients with different lags to determine and evaluate the trend of hydrological variables.

✉ Babak Amirataee
babak.amirataee@gmail.com

[1] Department of Water Engineering, Urmia University, Urmia, Iran

[2] Young Researchers and Elite Club, Saveh Branch, Islamic Azad University, Saveh, Iran

1 Introduction

Climate changes that occur due to anthropogenic emissions of greenhouse gases are considered as one of the important environmental concerns in the twenty-first century. The average temperature of the earth has increased up to 0.6 °C over the last 100 years, and 1998 was the warmest year hitherto (Tabari et al. 2012). Generally speaking, many processes in the biosphere have been influenced in some way by climate changes. Furthermore, the negative impact of climate changes on the environment and water resources is a felt concern (Abdul Aziz and Burn 2006). One of the major challenges of recent hydrological modeling activities is devoted to assess the impacts of climate changes on the water cycle (Bormann 2011). Broadly speaking, climate changes have dramatic impacts on hydrological parameters, including runoff, evapotranspiration, soil moisture, and groundwater (Goyal 2004).

Reference evapotranspiration (ET_0) is considered a key parameter for evaluating the climatic changes as well as spatial and temporal patterns of parameters influencing the eco-hydrological processes. Similarly, the analysis of trend variations of this index can be used to determine appropriate strategies in planning and management of water resources (Shadmani et al. 2011). Climatic observations of many stations report that temperature has increased in the last decades (IPCC 2007). However, changes in the components of hydrological cycles, such as ET_0, show diverse increasing and decreasing patterns (i.e., Chattopadhyay and Hulme 1997; Thomas 2000; Chen et al. 2006; Gao et al. 2006; Xu et al. 2006; Zhang et al. 2007, 2009; Donohue et al. 2010; Li et al. 2010; Liu et al. 2010). Regarding limited water resources, it is very important to understand and analyze this phenomenon, particularly in arid and semi-arid regions such as Urmia Lake basin, located in northwest of Iran. Thus, investigating and evaluating the impact of climate changes on evapotranspiration parameters can be effective in order to reduce the potential damages.

Many parametric and non-parametric methods have been used for detecting significant trends throughout meteorological and hydrological time series (Zhang et al. 2006; Chen et al. 2007). Although parametric methods are more powerful than non-parametric ones in terms of determining the trend of variables, the latter categories are independent and follow normally distributed data. Accordingly, parametric methods are less applicable. Meanwhile, non-parametric methods require independent data, can tolerate outliers, and are not sensitive to the type of statistical data distribution (Hamed and Rao 1998; Yue and Wang 2002; Chen et al. 2007). The Mann–Kendall (MK) and Spearman's Rho tests are among the most known and common non-parametric tests used to determine the trends of hydrological variables. It has been indicated that these two tests have similar power in detecting the trends of hydrological time series data (Yue and Wang 2004; Novotny and Stefan 2007).

Recent studies conducted in the domain of climate changes have mainly focused on long-term variations of temperature and precipitation. Evapotranspiration, as the third important climatic factor to control energy and interchange the mass between the Earth's ecosystem and the atmosphere, has received less attention (Chen et al. 2006). Palle and Butler (2001) reported a decreasing trend of sunny hours and an increasing trend of cloudy hours at 4 stations in Ireland. Garbrecht and Van Liew (2004) conducted a study in the Great Plains in the USA to analyze precipitation, streamflow, and ET_0 trends. They concluded that increased amount of precipitation over the last two decades of the twentieth century has led to a disproportionate increase in streamflow and a lower relative increase in ET_0. Xu et al. (2006) analyzed 150 meteorological stations in the Chang Jiang basin (Yangtze River). The results indicated that there was an annual decreasing trend in both ET_0 and basin evaporation. They concluded that this decreasing trend was mainly caused by a significant decrease in the net total radiation and, to a lesser extent, a decrease in the wind speed in the basin. Dongsheng et al. (2007) made use of Mann–Kendall and Linear Regression methods and concluded that there were significant increases in annual temperature, average annual rainfall, annual potential ET_0 and soil moisture at the northeastern regions of China from 1961 to 2004. Bandyopadhyay et al. (2009) estimated the ET_0 at 133 selected stations in India using FAO-56 Penman-Monteith (FAO-56 PM) and Mann–Kendall methods. They found a significant decreasing trend in ET_0 in the study areas which was mainly due to a significant increase in the relative humidity and decrease in the wind speed in the study areas. Tabari et al. (2011) evaluated the annual, seasonal and monthly trends in ET_0 in the western region of Iran using Penman–Monteith, MK and Linear Regression methods. The results of Mann–Kendall test indicated that there was a positive annual trend in ET_0 at 70 % of the stations. Furthermore, the results of Linear Regression method pointed out that there was a positive annual trend in ET_0 at 75 % of the stations. Besides, it was found that although the majority of stations have had significant trends in ET_0 in February, there have been some stations with significant trends in November. In another study, Tabari and Marofi (2011) made use of Mann–Kendall and linear regression methods to evaluate the temporal variations of basin evaporation at 12 stations in Hamedan province from 1982 to 2003. They concluded that there was a significant increasing trend in basin evaporation at 67 % of stations at 95 and 99 % confidence levels. Yin et al. (2010) studied the ET_0 trend from 1961 to 2008 in China and confirmed that there was a decreasing trend in ET_0. Conversely, Abtew et al. (2011) pointed out that South Florida has experienced an increasing ET_0 trend. Jhajharia et al. (2011) estimated trend variations in ET_0 at a wet climatic region located in the northern part of India using the Mann–Kendall test via eliminating the significance effect of lag-1 autocorrelation coefficient. The results indicated that annual and seasonal ET_0 have significantly decreased at 6 selected stations. Tabari et al. (2012) evaluated the time series trends in ET_0 in the west and southwest of Iran from 1966 to 2005 using Mann–Kendall and Spearman's Rho tests via eliminating the significance effect of lag-1 autocorrelation coefficient. They indicated that the existence of autocorrelation coefficient in ET_0 series increased the possibility and potency of Mann–Kendall and Spearman's Rho tests to reject the null hypothesis on the existence of no trend in this domain. They also found that, compared to the Spearman rank method, Mann–Kendall test was more sensitive to the existence of autocorrelation. Having used stepwise regression, they concluded that wind speed has had the most effect on the significant increase in ET_0.

The majority of studies conducted to evaluate the trend variations of ET_0 have been based on the common non-parametric Mann–Kendall and/or Spearman's Rho methods. Meanwhile, these studies have not gauged the impact of autocorrelation coefficients with different lags (i.e., in other hydrological time series: Guo and Xia 2014; Subash and Sikka 2014; Yao and Chen 2014). Only in limited studies, the first order (lag-1) auto correlation is considered, and the effect of that was eliminated in examination of time series trends (Tabari et al. 2012; Mondal et al. 2014; Palizdan et al. 2014; Sayemuzzaman et al. 2014). Actually, it seems that the autocorrelation with different lags has a significant effect on the trend variations of ET_0 (Von Storch 1995; Yue and Wang 2002; Yue et al. 2003; Yue and Hashino 2003; Khaliq et al. 2009). Therefore, eliminating the impact of autocorrelation with different lags (i.e., 1, 2, … months) can be important for determining the temporal changes of ET_0.

In this study, the monthly trend variations of ET_0 in the northwest of Iran were analyzed using FAO-56 Penman–Monteith as well as the modified Mann–Kendall test (via eliminating the significance effect of autocorrelation

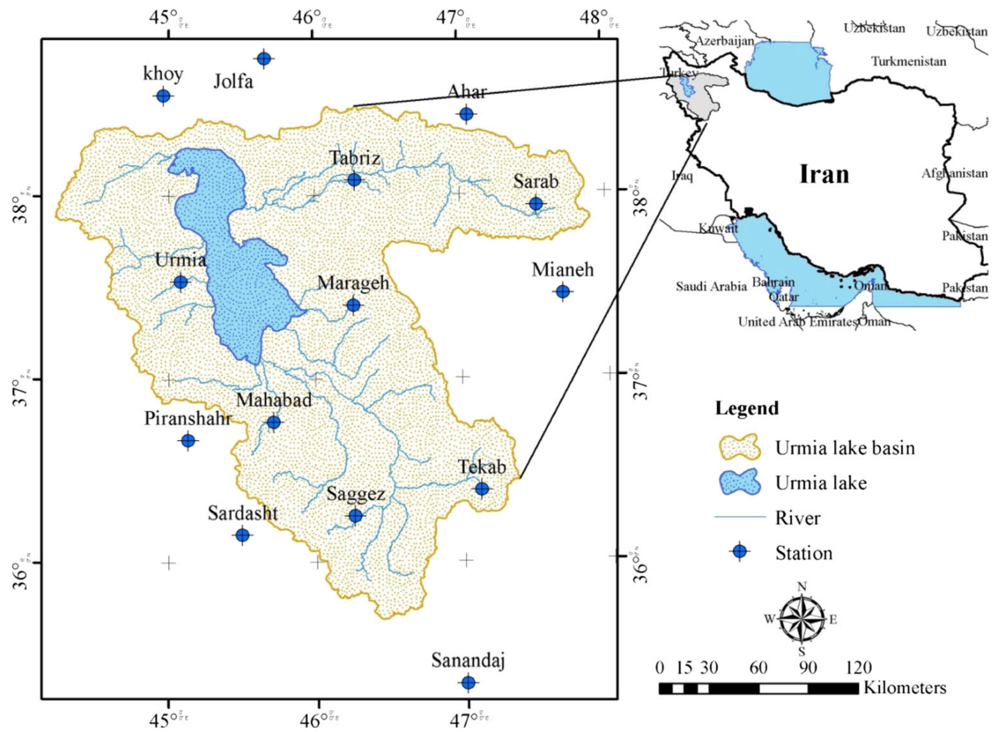

Fig. 1 Study area and location of synoptic stations

coefficients with different lags). Besides, Theil–Sen Estimator has been used to determine the slope of trend line of ET_0.

2 Materials and methods

2.1 Study area and used data

Regarding the environmental importance of the Urmia Lake, the monthly data of 14 synoptic stations, located in Urmia Lake basin (from 1986 to 2010), were used to analyze the trend of reference evapotranspiration. The geographical position and general information of these synoptic stations, located in the study area, have been provided in Fig. 1 and Table 1, respectively. Regarding the initial data analysis, the Double Mass method was used to evaluate the homogeneity of data (Bars 1990). The results confirmed the homogeneity of data with a correlation coefficient of 0.99. Furthermore, Run test was used to test the randomness of data (Adeloye and Montaseri 2002). The test results verified the hypothesis of data randomness.

Table 1 The general characteristics of synoptic stations in study region (1986–2010)

NO.	Station	Longitude (E)	Latitude (N)	Altitude (m)	Mean annual rainfall (mm)
1	Urmia	45° 03′	37° 40′	1328.0	311.3
2	Ahar	47° 04′	38° 26′	1391.0	284.2
3	Piranshahr	45° 08′	36° 40′	1455.0	657.8
4	Tabriz	46° 17′	38° 05′	1361.0	245.5
5	Tekab	47° 06′	36° 24′	1817.2	336.0
6	Jolfa	45° 40′	38° 45′	736.2	205.2
7	Khoy	44° 58′	38° 33′	1103.0	258.7
8	Sarab	47° 32′	37° 56′	1682.0	866.0
9	Sardasht	45° 29′	36° 09′	1556.8	227.6
10	Saqez	46° 14′	36° 15′	1522.8	456.2
11	Sanandaj	47° 00′	35° 20′	1373.4	405.4
12	Marageh	46° 16′	37° 24′	1477.7	300.8
13	Mahabad	45° 43′	36° 45′	1351.8	403.1
14	Mianeh	47° 42′	37° 27′	1110.0	273.2

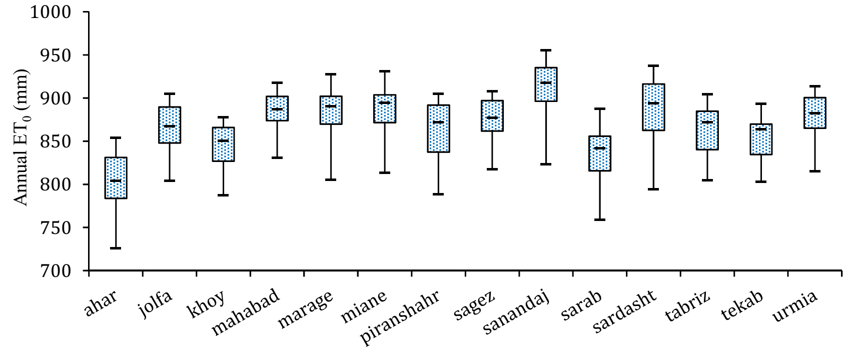

Fig. 2 Box plots of variation of annual ET_0 for all stations

2.2 FAO-56 Penman–Monteith method

The FAO-56 Penman–Monteith standard method (Eq. 1), which has been proposed by Allen et al. (1998), was used to estimate ET_0:

$$ET_0 = \left[\frac{0.408\Delta(R_n - G) + \gamma\left(\frac{900}{T+273}\right)U_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34U_2)} \right] \quad (1)$$

Where, R_n represents net radiation (MJ m^{-2} d^{-1}), T represents the average air temperature (°C), U_2 represents wind speed at 2 m height (m s^{-1}), Δ represents the slope of vapor pressure (kPa $°C^{-1}$), G represents the soil heat flux density (MJ m^{-2} d^{-1}), γ represents the psychometrics constant (kPa $°C^{-1}$), and (e_s-e_a) represents the vapor pressure deficit in kPa. It should be noted that this item is a function of relative humidity (%) and the average air temperature (°C).

2.3 Statistical trend analysis

2.3.1 Mann-Kendall test (MK1)

This test is one of the commonest methods used to determine the linearity or non-linearity of time series trends. This test was firstly proposed by Mann (1945) and was then developed by Kendall (1975). The Mann–Kendall test can be used to determine time series trends that do not follow normal distributions. Similarly, extreme values have negligible impacts on determining time series trends (Xu et al. 2003). The value of Mann–Kendall test for n data can be calculated from the following relations:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} \mathrm{sgn}(x_j - x_i) \quad (2)$$

$$\mathrm{sgn}\,(x_j - x_i) = \begin{cases} +1 & if\,(x_j - x_i) > 0 \\ 0 & if\,(x_j - x_i) = 0 \\ -1 & if\,(x_j - x_i) < 0 \end{cases} \quad (3)$$

$$Var(S) = \frac{1}{18}\left[[n(n-1)(2n+5)] - \sum_{i=1}^{g} e_i(e_i - 1)(2e_i + 5) \right] \quad (4)$$

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & \text{if} \quad S > 0 \\ 0 & \text{if} \quad S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & \text{if} \quad S < 0 \end{cases} \quad (5)$$

Where, x_i and x_j represent successive data in the i and j years, respectively, n represents the duration of statistical period, sgn (x_j-x_i) represents the sign function, $Var(S)$ represents the variance of S which has a zero mean for $n \geq 8$ and follows the normal distribution, e_i represents the number of ties for the ith value, g represents the number of tied data, and Z represents the test statistics. If the value of Z is less or greater than the value of Z for the standard normal distribution at 95 % confidence level, it means that there is a trend in time series data (Kampata et al. 2008). A positive value of Z indicates an

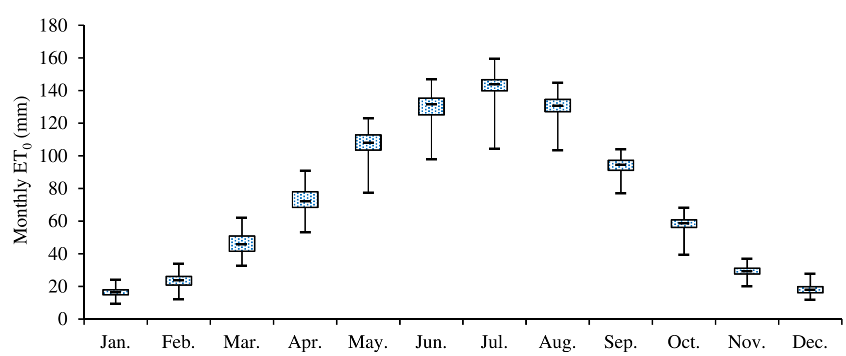

Fig. 3 Box plots of variation of monthly ET_0 for all stations

Table 2 The corresponding values of MK1 and MK2 tests with consideration of significant auto correlation coefficients (at 95 % confidence level)

MK2	MK1	Upper and lower critical range of auto correlation coefficients		significant auto correlation coefficients	Lags of significant auto correlation coefficients	Station
1.74	*2.27*	0.35	−0.43	0.39	1	Urmia
2.08	*2.08*	-	–	–	–	Ahar
2.68	*3.48*	0.36	−0.44	0.45	2	Piranshahr
1.06	1.38	0.35	−0.43	0.38	1	Tabriz
1.39	*2.17*	0.35 0.37	−0.43 −0.47	0.54 0.43	1 4	Tekab
1.76	*2.27*	0.35	−0.43	0.37	1	Jolfa
1.92	*2.64*	0.35	−0.43	0.50	1	Khoy
2.24	*3.41*	0.35 0.36	−0.43 −0.44	0.38 0.42	1 2	Sarab
2.26	*3.53*	0.35 0.36	−0.43 −0.44	0.50 0.36	1 2	Sardasht
1.72	*2.64*	0.35 0.37	−0.43 −0.47	0.51 0.39	1 4	Saqez
2.55	*3.48*	0.35	−0.43	0.49	1	Sanandaj
2.77	*3.76*	0.35	−0.43	0.48	1	Marageh
1.52	*2.31*	0.35 0.36	−0.43 −0.44	0.36 0.44	1 2	Mahabad
2.36	*3.34*	0.35	−0.43	0.57	1	Mianeh

The italicized numbers indicate significant increasing trend at a 95 % confidence level

increasing trend, and a negative value of Z indicates a decreasing trend.

2.3.2 The modified Mann-Kendall test (MK2)

The modified Mann–Kendall test was proposed by Hamed and Rao (1998) via considering the significance of all auto-correlation coefficients in time series. In this method, modified variance ($Var(S)$) is used for calculation of Z statistics of the common Mann–Kendall test.

$$Var(S)^* = Var(S) \times \left(\frac{n}{n^*}\right) \tag{6}$$

$$\left(\frac{n}{n^*}\right) = 1 + \left(\frac{2}{n(n-1)(n-2)}\right) \times \sum_{k=1}^{n-1}(n-k)(n-k-1)(n-k-2)r_k \tag{7}$$

$$r_k = \frac{\frac{1}{n-k}\sum_{i=1}^{n-k}(x_i-\bar{x})(x_{i+k}-\bar{x})}{\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^2} \tag{8}$$

Where, $Var(S)$ is calculated via the Eq. (4), $\left(\frac{n}{n^*}\right)$ represents the modified coefficient of autocorrelated data, r_k represents the autocorrelation coefficient of k^{th}, and $\bar{x}$ represents the mean of time series. The significance of autocorrelation coefficient of k^{th} at 95 % confidence level can be calculated by the following equation:

$$\left(\frac{-1-1.96\sqrt{n-k-1}}{n-k}\right) \le r_k(95\%) \le \left(\frac{-1+1.96\sqrt{n-k-1}}{n-k}\right) \tag{9}$$

If the obtained r_k obeys the above condition, the data will be independent at 95 % confidence level. Otherwise, the data

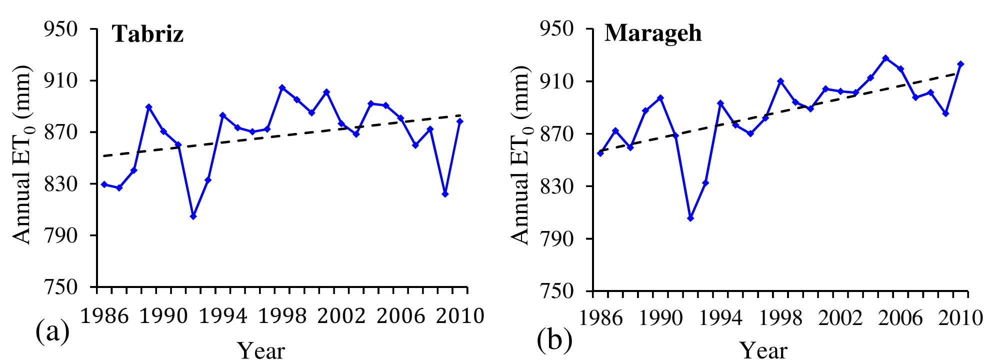

Fig. 4 The temporal variation of trend for annual ET_0 time series **a** minimum increasing trend (Tabriz station), **b** maximum increasing trend (Marageh station)

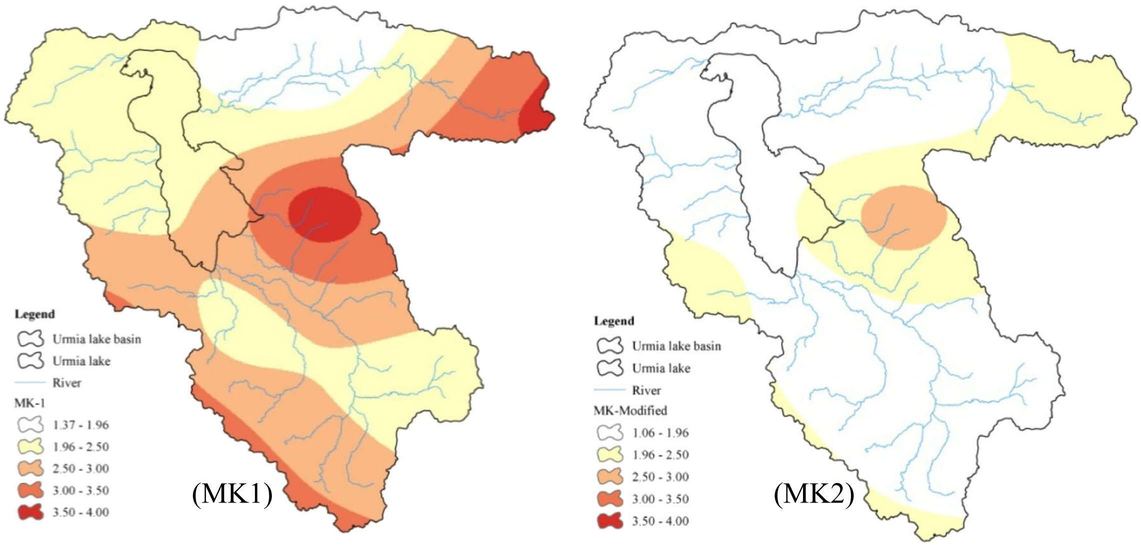

Fig. 5 The spatial variation of trend for annual ET_0 time series based on MK1 and MK2

are not independent and the effect of autocorrelation coefficient with different lags should be eliminated to determine the time series trend. Finally, the value of $Var(S)^*$ substituted $Var(S)$ in Eq. (5) and the value of Z is calculated. If the value of Z is less or greater than the value of Z value of standard normal distribution at 95 % confidence level, it means that there is a trend in time series data.

2.3.3 Trend slope

The slope of trend line was estimated on the basis of investigations conducted by Theil (1950) and Sen (1968), as stated in the following equation:

$$\beta = \text{Median}\left(\frac{x_t - x_s}{t - s}\right), \quad \forall s < t \tag{10}$$

Where, $1<s<t<n, \beta$ represents the estimator of trend line, and x_t represents the observed t^{th} data. The positive value of β indicates an increasing trend and a negative value of β indicates a decreasing trend (Yue et al. 2003).

In this study, monthly and annual ET_0 values were estimated based on PM method using CROPWAT Model in terms of four main parameters of relative humidity, sunny hours, and minimum and maximum air temperature. Then, the Mann–Kendall (MK1) and modified Mann–Kendall (MK2) tests were used to determine the significant trend variations of ET_0 values in Urmia Lake basin. Before analyzing the trend, the significance effect of autocorrelation coefficients with

Table 3 The monthly values of MK2

Station	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Ahar	0.16	1.00	*2.73*	0.49	−0.05	1.33	1.19	1.11	0.86	*3.11*	0.89	−0.51
Jolfa	−1.21	0.00	1.92	0.02	1.38	*2.62*	0.72	0.71	*2.20*	*3.15*	1.87	0.09
Khoy	−0.56	0.16	*2.10*	0.49	0.49	*2.24*	0.00	0.85	*2.59*	*3.44*	*2.29*	0.23
Mahabad	0.37	1.21	*2.62*	1.31	−0.44	*2.01*	−0.84	1.59	1.95	*2.01*	0.58	0.04
Marageh	0.65	*2.27*	*2.40*	*2.01*	0.38	*3.36*	1.14	0.47	1.77	*3.53*	*2.17*	0.30
Mianeh	0.65	*2.10*	*2.69*	1.17	0.84	*2.20*	1.52	1.63	1.73	*3.32*	1.87	−0.19
Piranshahr	1.43	1.63	*2.32*	1.73	1.38	*3.06*	1.49	1.12	*2.69*	*2.60*	0.98	1.06
Sagez	0.58	1.38	*2.39*	1.31	0.20	*2.80*	0.51	−0.68	1.00	*2.00*	0.72	0.38
Sanandaj	0.89	1.17	*3.11*	1.66	0.44	*2.52*	*2.24*	1.03	*2.20*	*2.74*	1.52	0.50
Sarab	0.65	1.33	*2.47*	1.17	0.00	*2.15*	1.47	0.62	1.92	*3.06*	0.98	0.00
Sardasht	1.56	1.14	1.89	1.05	1.06	*2.80*	1.68	1.70	*2.08*	*2.62*	1.56	*2.81*
Tabriz	0.49	1.75	*2.57*	0.77	−0.60	1.46	1.00	0.28	0.72	*2.05*	0.89	−0.02
Tekab	1.26	*2.08*	*2.20*	1.70	0.82	*2.11*	0.78	−0.53	−0.13	0.89	−0.42	0.35
Urmia	0.42	1.19	*2.83*	1.14	−0.04	*2.10*	−0.08	0.40	*2.01*	*3.11*	1.94	0.57

The italicized numbers indicate significant increasing trend at a 95 % confidence level

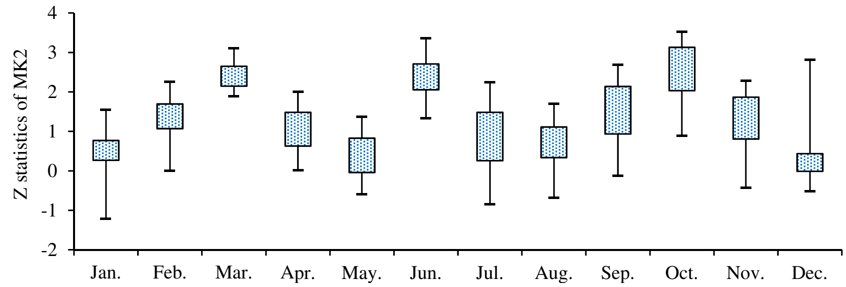

Fig. 6 The monthly variation of MK2

different lags was checked. Accordingly, if the autocorrelation coefficient was not significant, the MK1 would be used and if the autocorrelation coefficient was significant, the MK2 would be used thereof. Besides, the Theil–Sen's estimator was used for determining the slope of ET_0 trend variations.

3 Results

3.1 Annual and monthly time series of ET_0

Time series of annual and monthly ET_0 for all the selected stations are presented as box plots in terms of maximum, 75, 50, 25 %, and minimum values (Figs. 2 and 3, respectively). As can be seen, the maximum and minimum estimated values belong to Sanandaj (955.4 mm) and Ahar (726.2 mm) stations, respectively. The minimum value of ET_0 is 9.3 mm for January, and its maximum value is 159.65 mm for July.

3.2 Trend analysis of ET_0

Table 2 depicts the results of trend variations of annual ET_0 in Urmia Lake basin using the MK1 and MK2 test along with significant autocorrelation coefficients with related lags. Regarding the results of the MK1 test, there are increasing (positive) trends in all the selected stations, and all these trends, except in the Tabriz station, are significant at 95 % confident level. Similarly, the values of significant autocorrelation coefficients along with the related lag at 95 % confidence level have been presented in Table 2. Since the significance effect of autocorrelation coefficients has been eliminated, the values of trend have changed in accordance with the MK2. Although, there is an increasing (positive) trend in all the selected stations, their values have been decreased. Accordingly, these values are significant only in 7 stations at 95 % confidence level. This latter fact emphasizes on the dire need to pay attention to the dependence of data to autocorrelation coefficients with different lags to determine time series trend.

Furthermore, it has been found that the correlation coefficient between the standard deviation of annual time series in ET_0 and the values of MK1 is 0.59. However, this value has increased for MK2 up to 0.67.

Regarding the results of MK2 for annual time series trend, it has been found that Maragheh station has had the maximum significant increasing trend value (2.77) and Tabriz station has had the minimum significant increasing trend value (1.06). The time series trend variations in ET_0 for these stations are depicted in Fig. 4.

Figure 5 depicts the values of spatial trend variations for annual ET_0 time series over the study region based on MK1 and MK2 tests. As can be seen, the increasing trend of ET_0 in the south and southeast of the study area has been significant when MK1 test has been used. However, the significant increasing trend has been confined to some eastern regions when the significance effect of autocorrelation coefficients has been eliminated thereof.

Table 3 presents the values trend variations for monthly ET_0 time series at different stations based on MK2. Regarding the values inserted in this table, the maximum value of MK2 is estimated for Maragheh station in October (3.53) and the minimum value of MK2 is estimated for Jolfa station in January (−1.21).

Regarding the Fig. 6 (box plot), it has been found that the values of MK2 have increasing trends in all months, and these increasing trends have been significant at majority of stations at 95 % confidence level in March, June, and October. Actually, there have been increasing trends at 99.1 % of all months, and only 8.9 % of months depict decreasing trends.

The values of slope of annual ET_0 trend variations, based on Sen's estimator, have been presented in Table 4. As can be

Table 4 The values of trend slope for annual ET_0 time series (mm/year)

Station	β	Station	β
Urmia	1.87	Sarab	2.23
Ahar	1.82	Sardasht	3.21
Piranshahr	3.12	Sagez	1.80
Tabriz	1.04	Sanandaj	2.61
Tekab	1.64	Marageh	2.45
Jolfa	1.97	Mahabad	1.52
Khoy	1.93	Mianeh	2.35

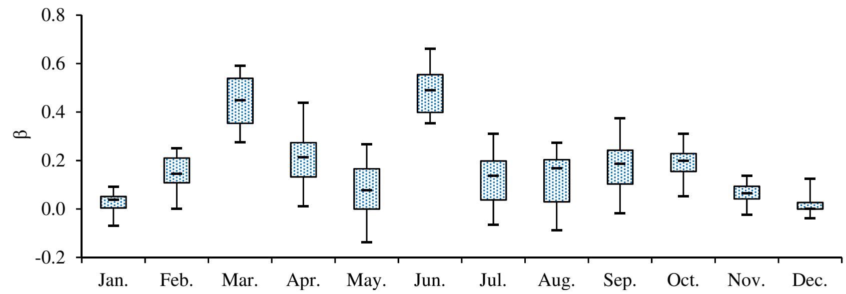

Fig. 7 The trend slopes of monthly ET_0 time series

seen, the slope of the trend line is positive for all the stations. Furthermore, the maximum and minimum values of slope are related to Sardasht (3.21 mm/year) and Tabriz (1.04 mm/year) stations, respectively. The correlation coefficient between the values of trend slope and standard deviation of annual ET_0 time series is as 0.81.

Figure 7 depicts the box plot of trend slope of the monthly ET_0 time series. As can be seen, the majority of months have a positive trend slope. The maximum and minimum values of trend slope are estimated for Saradasht station in June (0.661 mm/year) and Tabriz station in May (−0.138 mm/year), respectively.

4 Conclusions

This study evaluated the trend of annual and monthly ET_0 time series using Mann–Kendall test via eliminating the significance effect of autocorrelation coefficients with different lags in Urmia Lake basin. Having used the modified Mann–Kendall test, the values of significant increasing (positive) trend, which were estimated by common Mann–Kendall test, dramatically decreased. Accordingly, these values dramatically decreased over the study area and the values of only 7 stations were significant at 95 % level. This latter fact emphasizes on dire need to pay attention to the dependence of data to autocorrelation coefficients with different lags as well as necessity to eliminate such an effect to determine and evaluate the trend of hydrological variables. The results of this research, which have been mainly based on the modified Mann–Kendall test, indicate that there has been an increasing trend in annual and monthly time scales. Generally speaking, the latter increasing trend in annual time scale has been found significant at 50 % of all the studied stations.

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