University of Birjand

Water Harvesting Research Vol. 6, No. 2, Autumn & Winter 2023, Original Paper p. 226-237

10.22077/JWHR.2024.7339.1130

Investigating Changes in Pan Evaporation Values in Iran, Considering the Autocorrelation Effect

Ali Lalehpour[a], Keivan Khalili[b*], Hossein Rezaie[c], Mohammad Nazeri Tahroudi[d]

[a]Ph.D Student, Department of Water Engineering, Urmia University, Urmia, Iran.
[b]Associate Professor, Department of Water Engineering, Urmia University, Urmia, Iran.
[c]Professor, Department of Water Engineering, Urmia University, Urmia, Iran.
[d]Assistant Professor, Department of Water Engineering, Lorestan University, Khorramabad, Iran.

*Corresponding Author, E-mail address: k.khalili@urmia.ac.ir

Received: 04 January 2024/ **Revised**: 29 February 2024/ **Accepted**: 05 March 2024

Abstract

Investigating the long-term changes of meteorological parameters in each basin or region serves as the first component of the monitoring system. In this study, the trend of changes in pan evaporation values in Iran's meteorological stations (provincial centers) in the period of 1994-2021 was investigated using the modified Mann-Kendall test by removing the effect of data autocorrelation. The results of the investigation of the trend of changes in pan evaporation values in Iran showed that in 54% of the studied stations, the trend of changes in pan evaporation values is increasing and in 46% it is decreasing. But the average changes in Iran are incremental. Significant increasing and decreasing changes were also observed among the studied stations. The capital of Iran, Tehran, obtained the highest increase in pan evaporation among other studied stations according to the slope of the trend line (Sen's slope). The highest rate of reduction in annual pan evaporation is related to Ahvaz station in the southwest of Iran. The results of the regional spatial survey also showed that the main decreasing changes in the amount of pan evaporation values are observed in the southern, southwestern and southeastern regions of Iran. The results of the present study show that despite the increase in temperature in most areas, there is a decrease in pan evaporation values in some areas. This reduction of pan evaporation values is important in studies of water resources and meteorology, considering the arid and semi-arid climate of Iran.

Keywords: Aerosol, Climate Change, Mann-Kendall, Sen's Slope.

1. Introduction

It is crucial to plan for the efficient utilization of water resources to achieve sustainable development (Sabziparvar et al., 2014). The rate of pan evaporation is one of the most important climatic factors in water resource planning, irrigation control and agricultural production, and in long-term analyzes of changes in weather elements, it is a basic prerequisite in studies (Gong et al., 2006). The use of evaporation pans in the estimation of evaporation is common in many countries, and for this reason, it is important to know the trend of time changes of this quantity. The evaporative demand of the atmosphere, as measured by the evaporation pan, has decreased over the past few decades in many parts of the Northern Hemisphere, as well as in parts of the Southern Hemisphere in Australia (Roderick and Farquhar, 2004).

This is despite the fact that based on the majority of studies in Iran and the world, the increasing trend of temperature has been confirmed, which is considered a kind of contradiction. The general scientific belief is that this contradiction can be justified to a large extent based on other atmospheric events, which is mainly the reduction of radiation reaching the earth's surface due to the increase in the concentration of aerosols and cloudeis (Gharekhani et al., 2013). This phenomenon is called Global dimming (Stanhill and Cohen, 2001).

Chattopadhyay and Hulme (1997)

investigated potential transpiration in India under recent and future climate change conditions. The analyzes showed that both pan evaporation and potential transpiration have been decreasing in recent years in India. Lawrimore and Peterson (2000) stated that the reduction in pan evaporation in many regions of the world is evidence of a reduction in the surface evaporation component of the hydrologic cycle. By examining pan evaporation trends in eight regions in the United States, they concluded that warm season precipitation can be used as an indicator of surface evaporation. They also concluded that pan evaporation and actual evaporation have an inverse relationship.

Lawrimore and Peterson (2002) investigated the trends of evaporation from Class A pans in humid and dry regions of the United States, and the results showed a downward trend of pan evaporation. It was also found that pan evaporation and actual evaporation can be related. Adamowski and Bougadis (2003) analyzed the trend of annual extreme precipitation changes using the Mann-Kendall test at 44 rain gauge stations from the province of Ontario, Canada, for a 20-year period. The results of their analysis showed that approximately 23% of the regions had a significant trend. Serial dependence was reported in 2.3% of the data set and spatial correlation in 18% of the regions.

Fu et al. (2009) stated that despite the observed increase in global average temperature, worldwide observations show that regional scale pan evaporation has been steadily decreasing over the past 50 years. They called this the pan evaporation paradox. The results of their research were presented as follows: (1) The three main potential causes of pan evaporation, solar radiation, vapor pressure deficit (VPD), and wind speed, have changed over the past 50 years. The rate of change and importance of each of these three causes varies from region to region, as does the trend in pan evaporation, although there is generally a decreasing trend. (2) Currently, the two existing theories that explain the pan evaporation process have limitations and are valid only in certain regions and seasons. None of them provide a fundamental, physically based theory that can be applied everywhere. (3) More research is needed before we can fully understand global evapotranspiration trends under global warming scenarios.

Kruger et al. (2013) investigated the trend of changes in maximum and minimum extreme daily temperatures in 28 meteorological stations in South Africa during the period of 1962-2009. The general result of their research showed that in all meteorological stations, the intensity of heat increased and the intensity of cold decreased. However, trends vary by region, both in magnitude and statistical significance, broadly showing the western, as well as parts of northeastern and eastern South Africa have experienced a relatively stronger increase in extreme hot areas and a decrease in extreme cold areas. Liu and Sun (2014) investigated the future changes of pan evaporation as an index to measure the evaporative demand of the atmosphere in China. The results of their research showed that pan evaporation values during the periods of 2021-2050 and 2070-2100 will increase compared to the base period, which is mainly due to the predicted increase in air temperature and lack of vapor pressure.

Borna and Jahan (2015) The trend of changes in temperature and precipitation in 6 meteorological stations of Bushehr province, Iran during the period of 1992-2012 were investigated using the non-parametric Mann-Kendall test. The results of their research showed that the studied area is highly exposed to an increase in the average temperature, the frequency of extreme heating indexes and a decrease in cooling indexes. They also stated that the decrease in the index of cold nights and the increase of warm nights in the studied period was significant. The increasing trend of summer days will prolong the heat period during recent decades. Ghahreman et al. (2016) investigated the effect of climate change on potential evapotranspiration in the Mashhad Plain during the period of 2021-2070 under RCP scenarios. The results of their research showed that the amount of potential evapotranspiration will decrease in the hot months of the year and increase in the cold months of the year compared to the base period.

Khalili et al. (2016) investigated the trend of temporal and spatial changes of precipitation in Iran using the modified Mann-Kendall test and precipitation concentration index. Based on the results, the PCI index in the central and southern regions of the country indicates the presence of high irregularity and high dispersion in atmospheric precipitation.

Nazeri Tahroudi and Khozeymehnezhad (2017) studied the trends of seasonal and annual precipitation changes in Iran and neighboring countries using the modified Mann-Kendall test. The results of the analysis of the annual changes in the amount of precipitation in the region showed that among the countries under investigation, the changes in Iraq and Iran were more critical than other countries, and the annual precipitation decreased by about 1.2 and 1.03 mm, respectively.

Caloiero (2017) analyzed changes in temperature data at 22 observed monthly time series in New Zealand using the nonparametric Mann-Kendall test. They stated that the frequency and intensity of extreme heat regions increased, while most cold extreme regions showed a decreasing trend. Stephens et al. (2018) reexamined pan evaporation trends using 42 years (1975–2016) of Australian pan evaporation data, adding more than a decade of observations to previous analyses. Their analysis confirmed that the decrease in pan evaporation values in southern/western Australia in the period of 1975–1994 was mainly due to a decrease in wind speed.

Goljamjoo et al. (2023) investigated the temporal changes of pan evaporation in the base period (1993-2018) in Iran. The results of the Mann-Kendall test in the base period showed a decreasing trend of pan evaporation in some stations such as Ahvaz, Mashhad, and Bushehr and an increasing trend in Kerman station, among which, they reported the highest decreasing slope based on the Sen's slope method in Bushehr station.

According to the climate changes investigated in Iran and the results presented regarding the increase in temperature changes and the decrease in precipitation values and the subsequent increase in the extreme values, the purpose of this study is to investigate the changes in the trend of pan evaporation values in the meteorological stations of Iran in the period of 1994-2021 at annual scale. In this study, it has been tried to consider the effect of autocorrelation coefficient in the studied data on an annual scale and if necessary, remove it from the historical series.

2. Materials and Methods

2.1. Case Study

In this study, pan evaporation values of 28 meteorological stations in Iran in the period of 1994-2021 have been used on an annual scale. Iran has an area of 1,648,195 km^2 that located between latitudes 24° and 40° N, and longitudes 44° and 64° E. Iran has a diverse climate and all climate categories can be observed in this country. The location of the studied stations in Iran can be seen in Figure 1. Also, in Table 1, the statistical characteristics of the studied data are presented.

2.2.Trend evaluation of the studied data

In this research, the trend of changes in the existing time series was investigated using the modified Mann-Kendall non-parametric test. This test has been widely used in hydrology, climatology and meteorology studies (Mann., 1945; Kendall., 1963; Khalili et al., 2014&2016; Khozeymehnezhad and Tahroudi., 2019; Ahmadi et al., 2018&2022) The necessary condition for using this test is the absence of autocorrelation in the data time series, however, the data may have significant autocorrelation. Therefore, the autocorrelation effect of the data must be removed first to be able to use the Mann-Kendall test (Tahroudi et al. al., 2019b). For this purpose, in this study, instead of the traditional Mann-Kendall test, another version was used, including the Mann-Kendall test with the complete removal of the autocorrelation structure. The Mann-Kendall test methods are described below.

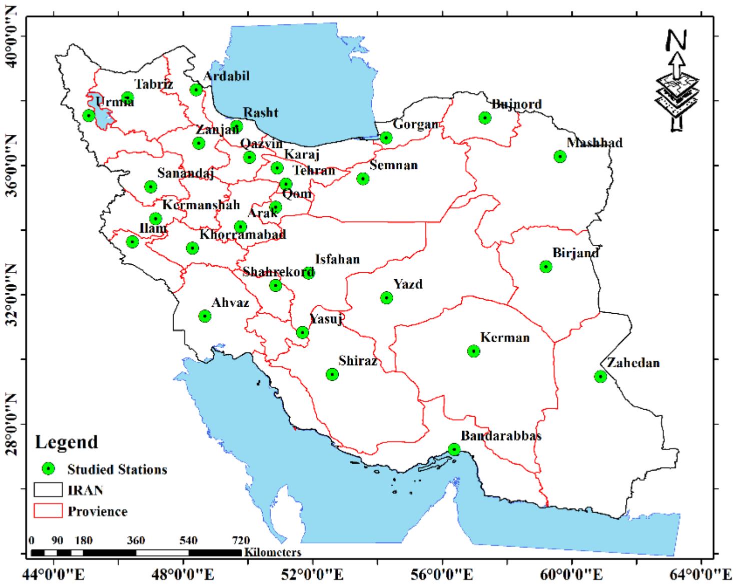

Fig. 1. Location of the studied stations in Iran

Table 1. Statistical characteristics of the studied data at annual scale

Station	Mean Annual PET (mm)	STD	Station	Mean Annual PET (mm)	STD
Ahvaz	3233.6	352.9	**Orumih**	1384.1	120.9
ARAK	2014.0	122.6	**Qazvin**	1650.7	135.6
ARDABIL	1246.1	292.4	**Qom**	2682.1	154.0
Bandar Abbas	2577.6	186.4	**Rasht**	814.4	99.4
Birjand	2770.6	240.2	**Sanandaj**	1974.7	158.8
Bujnord	1677.2	145.4	**Semnan**	2384.8	164.6
Esfahan	2207.4	157.9	**Sharekord**	1980.8	157.9
Gorgan	1370.1	115.8	**Shiraz**	2505.1	279.1
Ilam	2082.3	166.1	**Tabriz**	2078.3	116.3
Karaj	1942.3	198.2	**Tehran**	3464.1	570.4
Kerman	2623.1	176.3	**Yasuj**	1975.7	291.2
Kermanshah	1945.8	218.0	**Yazd**	3229.8	128.4
Khorramabad	1937.1	214.0	**Zahedan**	2967.2	230.0
Mashhad	1972.4	106.9	**Zanjan**	1576.6	121.9

In the traditional Mann-Kendall test, each value in the time series is compared with the other values of the series continuously and consecutively. The statistic is considered as follows:

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

where x_j is the consecutive data values, *n* is the length of the data set and $\operatorname{sgn}(\theta)$ is the sign function which is defined as follows:

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

Mann (1945) and Kendall (1963) showed that when $n \geq 8$, the S statistic is approximately normally distributed and its mean and variance are as follows:

$$E(S)=0 \tag{3}$$

$$V(S)=\frac{n(n-1)(2n+5)-\sum_{i=1}^{m}t_i(t_i-1)(2t_i+5)}{18} \tag{4}$$

Where t_i is the number of identical data in the *i* categories, and *m* is equal to the number of paired groups. The standardized test score

Z is calculated as follows:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}} & S > 0 \\ 0 & S = 0 \\ \dfrac{S+1}{\sqrt{Var(S)}} & S < 0 \end{cases} \qquad (5)$$

The standardized Mann-Kendall statistic test follows the standard normal distribution with a zero mean and variance equal 1 (Nazeri Tahroudi, 2014). The null hypothesis is accepted on the condition that $-Z_{1-\alpha/2} \le Z \le Z_{1-\alpha/2}$. It should be noted that α is significant level. In a situation where *S=0*, the data has no trend and there is no significant or non-significant trend in the data, which is an ideal condition for hydrological data that rarely happens.

But for data that has an increasing trend, the value of *S* is not zero, but has a positive value, and in the equation provided by Mann-Kendall, the *Z* statistic is obtained by subtracting one unit from positive *S* divided by the standard deviation of *S*, and for data that has a decreasing trend, the value of *S* is not zero and has a negative value. In the equation presented by Mann-Kendall test, the *Z* statistic is obtained by adding one unit to the negative *S* and dividing it by the standard deviation of *S* (Khazimehnejad and Tahroudi, 2019).

2.3. Sen's slope estimator

A very useful index in the Mann-Kendall test is the slope of the trend line or the so-called Sen's slope, which shows the magnitude of the uniform trend. The slope value of the trend is calculated using the method provided by Theil and Sen with the following equation (Theil., 1950; Sen., 1968):

$$\beta = Median\left(\frac{x_j - x_i}{j - i}\right) \qquad \forall i < j \qquad (6)$$

where β is the estimator of the slope of the trend line and x_i, x_j are the ith and jth observation values, respectively.

Positive values of β indicate an increasing trend and negative values indicate a decreasing trend. This method has been widely used in hydrological studies. It should be noted that the estimation of the Sen's slope is required for the calculations of the modified Mann-Kendall test.

2.4. Mann-Kendall's test by removing the effect of autocorrelation coefficient

This method is described by Kumar et al. (2009). In this method, the effect of the first order autocorrelation coefficient (r_1) is calculated and if it is significant, it is removed from the data series. For this, the following steps are performed (Kumar et al., 2009):

Step 1: The first order autocorrelation coefficient is calculated from the following equation:

$$r_k = \frac{\dfrac{1}{n-k}\sum_{i=1}^{n-k}(x_i - \bar{x})(x_{i+k} - \bar{x})}{\dfrac{1}{n}\sum_{i=1}^{n}(x_i - \bar{x})^2} \qquad (7)$$

Step 2: The data series are assumed to be independent (at a significance level of 10%) which is $\frac{-1-1.645\sqrt{n-2}}{n-2} \le r_1 \le \frac{-1+1.645\sqrt{n-2}}{n-2}$, in this case the Mann-Kendall test is performed with the classical method, otherwise the effect of the first order autocorrelation coefficient were removed. It should be noted that if r_k applies to the equation, the data will be independent of each other and there will be no need to remove the effect of autocorrelation, but otherwise, this condition should be checked for each order of autocorrelation (*k*) and if the above condition is not met, the data are not independent and the effect of autocorrelation should be removed from the data.

Step 3: The slope of the trend line or β for the data series is calculated from Eq. 6 and a new series is obtained as follows:

$$x_i' = x_i - (\beta \times i) \qquad (8)$$

Step 4: The data coefficient r_1 of the new series is recalculated:

Step 5: The component of the first-order autocorrelation coefficient AR(1) is removed from the new series as follows, and the residual series (y_i') is obtained from the following equation:

$$y_i' = x_i' - r_1 \times x_{i-1}' \qquad (9)$$

Step 6: Once again, the trend value $(\beta \times i)$ was added to the last series and the final series (y_i) is obtained as follows:

$$y_i = y_i' + (\beta \times i) \tag{10}$$

Now, by applying the Mann-Kendall test to the composite data series, the existence of a trend in them is investigated. This is done by calculating the Mann-Kendall statistic (Eq. 5) for the last series. If the calculated value is greater than 1.645, the data trend is assumed to be significant at the level of 10%, and if the calculated value is greater than 1.96 and 2.33, the trend will be assumed to be significant at level of 5% and 1%, respectively.

Otherwise, the null hypothesis of the existence of a trend in the data at the desired significance level is rejected. The modified Mann-Kendall test was presented by Hamed and Rao (1998) in order to eliminate the full effect of significant autocorrelation coefficients. In this test, all significant autocorrelation structures in the time series are examined and removed.

First, the modified variance $V(S)^*$ introduced by is as follows:

$$V(S)^* = V(S).\frac{n}{n^*} \tag{11}$$

$$\frac{n}{n^*} = 1 + \frac{2}{n(n-1)(n-2)} \times \sum_{i=1}^{n-1} (n-i)(n-i-1)(n-i-2).r_i \tag{12}$$

which n^* is the effective sample size and can be calculated through equation (12), $V(S)$ can be calculated through equation (4) and the autocorrelation coefficient r_i with delay i at a significant level of 10% is calculated from equation (7). To calculate Z statistic of Mann-Kendall, in equation (5), the value of $V(S)$ is replaced by $V(S)^*$. Hamed and Rao (1998) showed that in this method, the significance of the trend is more accurate than the conventional Mann-Kendall method and has no effect on the power of the test (Hamed and Rao., 1998).

3. Results and Discussion

In this study, modified Mann-Kendall test was used considering the autocorrelation effect in order to investigate the trend of changes in pan evaporation values on an annual scale. In order to better understand the trend of changes in pan evaporation in the annual time series, the graph of changes in pan evaporation values of 3 stations (Arak, Tabriz, and Qazvin) is presented as an example in Figure 2. According to Figure 2, it is possible to see the changes in the pan evaporation values in some stations. Visually, it can be seen that the changes in the pan evaporation values in Arak station are decreasing and increasing in Tabriz and Qazvin stations. But the changes cannot be expressed numerically. Based on this, the modified Mann-Kendall statistic was analyzed. By examining the effects of autocorrelation of the data up to lag 3, the trend of changes in pan evaporation values in the studied stations was investigated and presented in Table 2 along with the slope of the trend line.

According to table 2, it can be seen that the changes in the pan evaporation values in Arak, Bandar Abbas, Bujnord, Kerman, Khorramabad, Mashhad, Qom, Shiraz, Yasuj, Yazd, Zahedan and Zanjan stations are decreasing and this changes at Ahvaz and Qom stations are significant at the level of 5%. These changes in pan evaporation values are not consistent with the research results of Gharekhani et al. (2013) in regard the Ahvaz station. Also, the results of this research with Goljamjoo et al. (2023) is also in line.

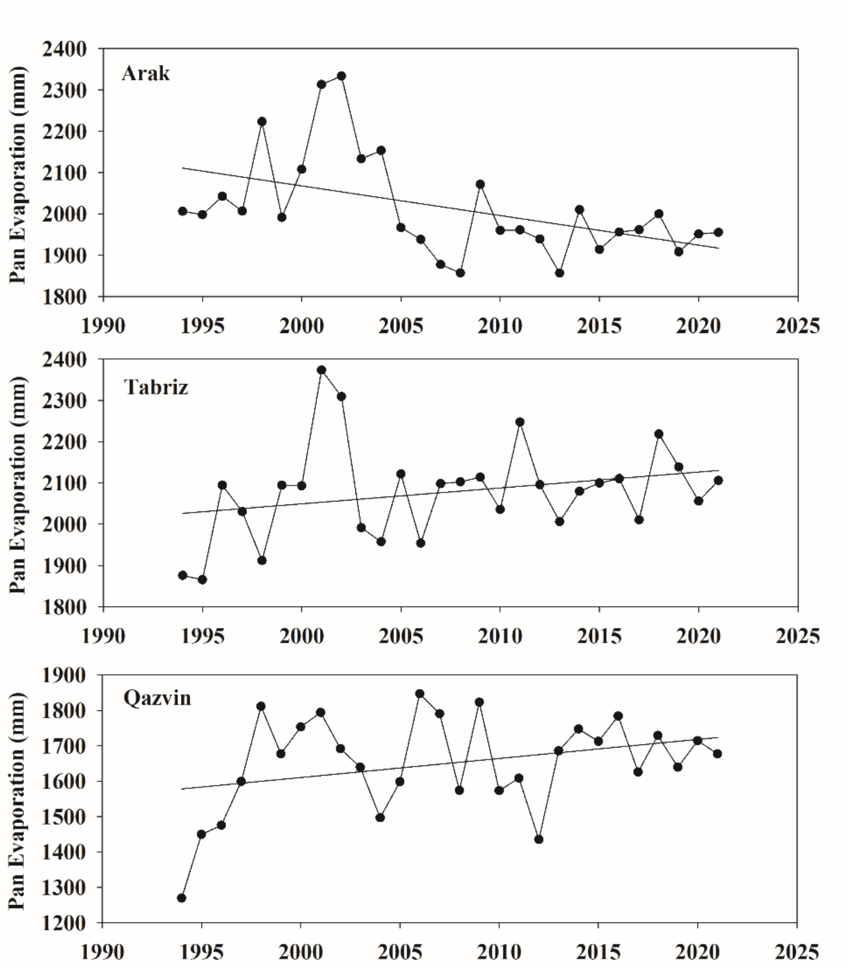

Fig. 2. Changes in the time series of pan evaporation values at Arak, Tabriz and Qazvin stations by applying the trend line

Table 2. The results of examining the trend of changes in pan evaporation values at annual scale

Station	Z- statistics of Mann-Kendall	Slop (mm)	Station	Z- statistics of Mann-Kendall	Slop (mm)
Ahvaz	-2.87*	-33.60	**Orumih**	0.02	0.11
Arak	-1.60	-4.27	**Qazvin**	1.13	4.83
Ardabil	2.15*	11.79	**Qom**	-2.27*	-7.98
Bandar Abbas	-0.41	-1.96	**Rasht**	3.04*	5.72
Birjand	2.19*	17.18	**Sanandaj**	0.31	2.09
Bujnord	-1.93	-9.20	**Semnan**	1.14	8.15
Esfahan	1.63	10.33	**Sharekord**	0.70	5.07
Gorgan	1.58	6.48	**Shiraz**	-1.62	-21.73
Ilam	1.48	5.09	**Tabriz**	1.88	3.82
Karaj	1.36	11.48	**Tehran**	1.38	32.57
Kerman	-0.01	-0.26	**Yasuj**	-1.78	-20.93
Kermanshah	0.32	2.71	**Yazd**	-0.06	-0.15
Khorramabad	-0.70	-7.65	**Zahedan**	-1.46	-11.02
Mashhad	-0.10	-0.14	**Zanjan**	-1.24	-4.32

* Significant trend at level of 5%

The changes of pan evaporation values in Ahvaz station in the research of Goljamjoo et al. (2023) also reported a significant decrease. Changes in the trend of pan evaporation values in other stations are also increasing, and these changes in Ardabil, Birjand and Rasht stations are increasing and significant at the level of 5%.

According to various researches that have reported the increasing trend of temperature in different regions of Iran, especially in the southwest (Ahvaz station) (Khalili et al., 2016), there was a contradiction that with the increase in temperature, changes in the trend of pan evaporation values has been reduced. Gharekhani et al. (2013) showed in their studies that this issue could be due to the increase of fine dust and aerosols in the region, while the southwest of Iran is also associated with the increase of fine dust and droughts in recent years.

In order to investigate the spatial changes of pan evaporation values in the studied stations in Iran, the values of the Z statistic of modified Mann-Kendall and also the slope of the trend line were zoned. The results of z-statistics zoning of the modified Mann-Kendall test and also the slope of the trend line in the studied stations were presented in Figures 3 and 4.

The results of examining the trend of changes in pan evaporation values in Iran in the period of 1994-2021 according to Figure 3 showed that the trend of changes of this parameter in the southwest, southeast, part of the northeast and also around Arak station, Iran has a decreasing trend and it is significal at level of 5%. In the south-east and south-west regions of Iran, which are exposed to fine dust, the decrease in pan evaporation values can be attributed to this phenomenon. In general, the southern half of Iran is facing a decrease in the amount of pan evaporation values. This decrease in the amount of pan evaporation values is also observed in the western half of Iran. But the northern areas of Iran, as well as the northwest and parts of the east, have also been associated with an increase in the amount of pan evaporation values. The reduction of pan evaporation values is significant in the stations of Birjand (eastern Iran), the Caspian Sea and the northern border of Iran.

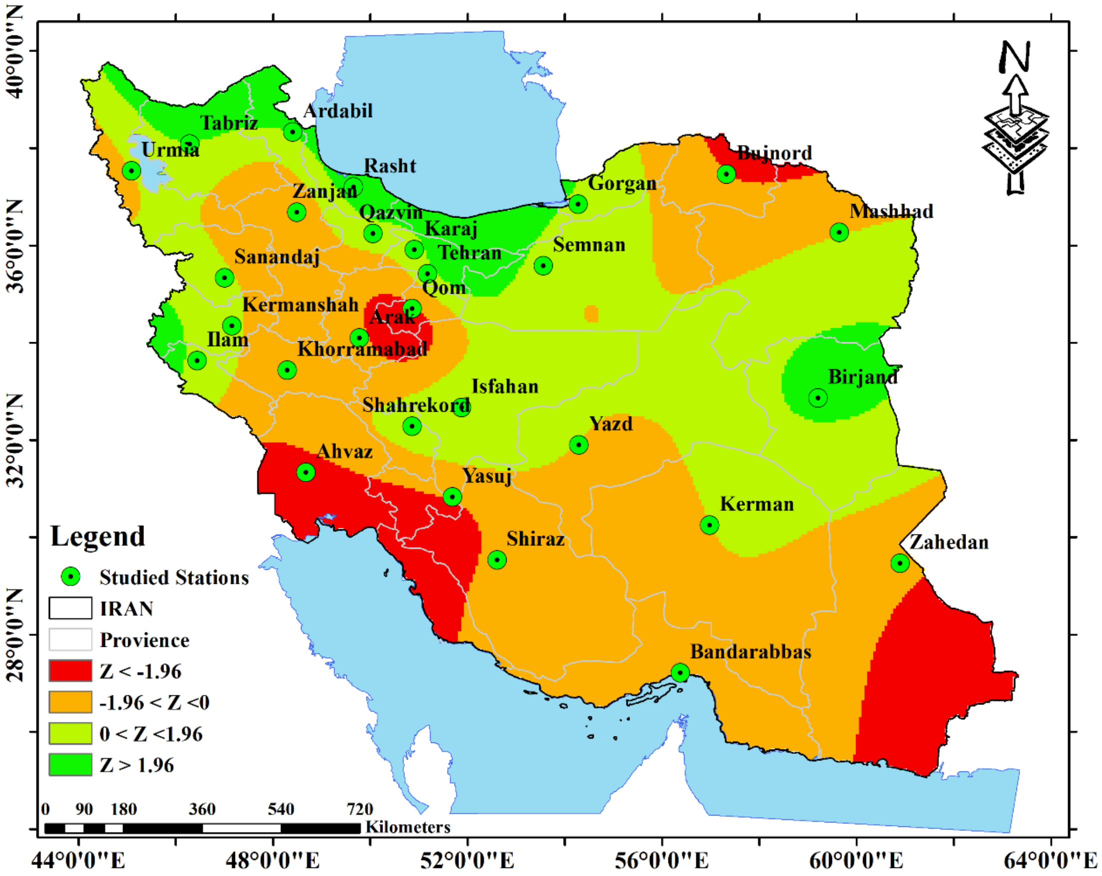

Fig. 3. The results of the Z statistic of the modified Mann-Kendall test in investigation the trend of pan evaporation values in Iran

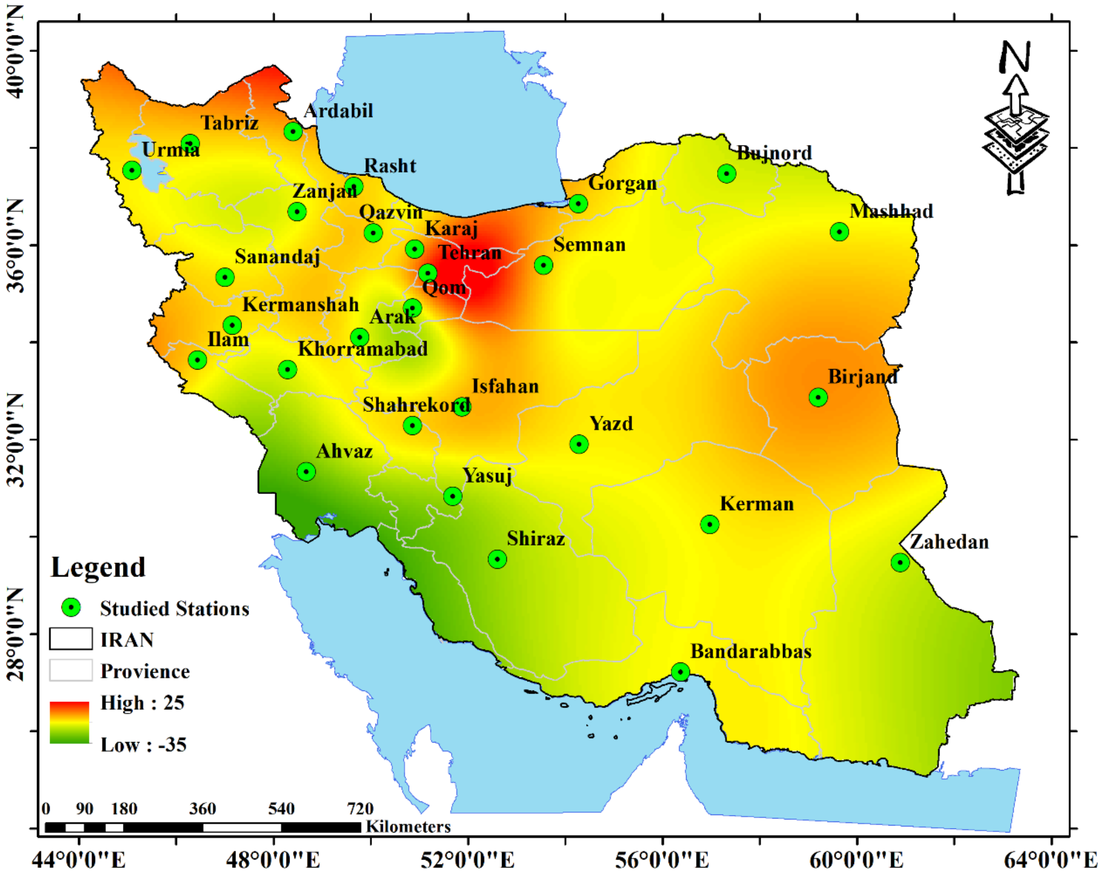

Fig. 4. The results of the Sen's slope test in investigation the amount of changes in pan evaporation values in Iran

According to Figure 4, it is possible to see the slope of the changes in the pan evaporation values in different regions of Iran. These changes range from -35 to 25 mm per year. The largest decrease in pan evaporation values is related to Ahvaz station with -34.6 mm per year, and the largest increase is related to the capital of Iran (Tehran station) with an annual increase of about 24.6 mm per year.

But on average, if all the stations are examined together, the average changes of pan evaporation in Iran will be an increase. 53.6 percent of the investigated stations have an increasing trend in the amount of pan evaporation and 46.4 percent have experienced a decreasing trend. The percentage of decreasing and increasing changes of pan evaporation values using the slope of the trend line can be seen in Fig. 5. According to Fig. 5, the percentage of increasing and decreasing changes can be seen between -25 and 40%.

According to the figure 5, it can be seen that the southwest of Iran gave the greatest decrease in pan evaporation values during the 2021-1994. In the second place, southeast of Iran has also a greater decrease in the amount of pan evaporation values in the studied period than other studied areas. Figure 5 shows that the highest percentage of increase in the amount of pan evaporation values occurred in the border zone of the Caspian Sea and the southern provinces of the Caspian Sea, including Qom, Tehran and Karaj.

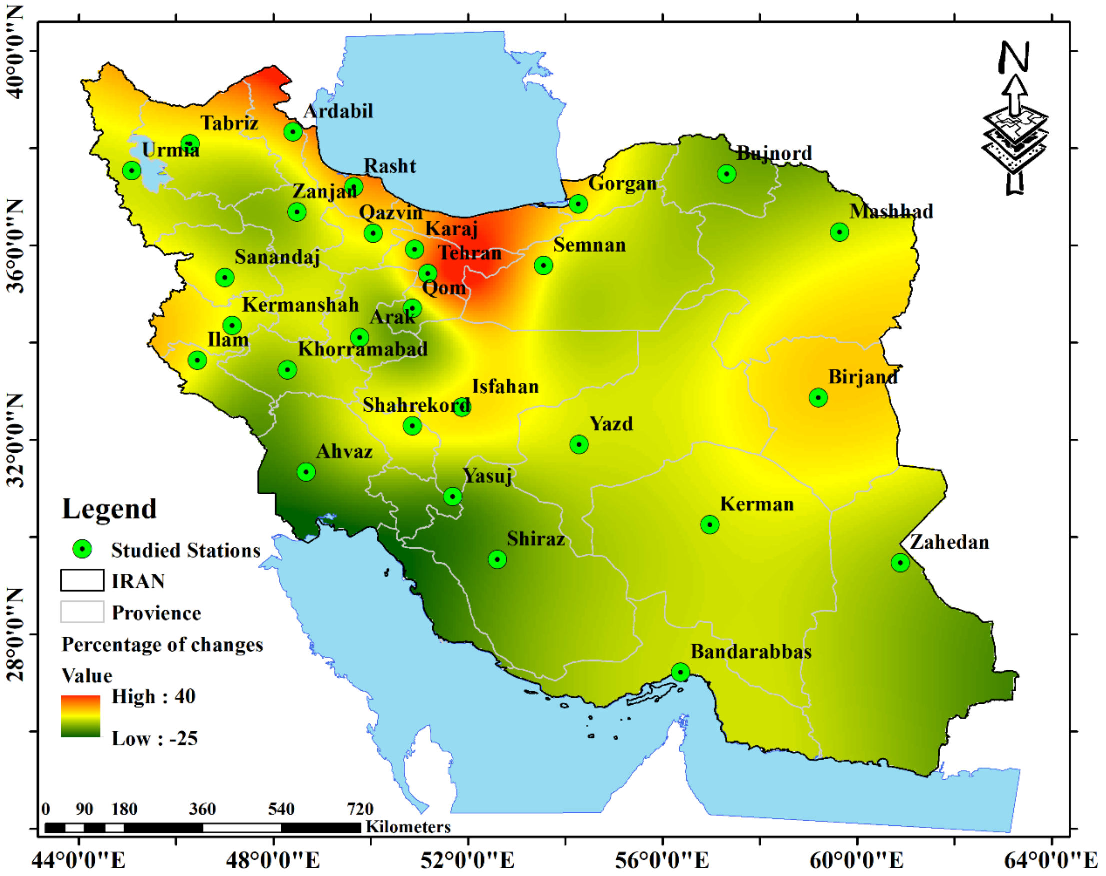

Fig. 5. The percentage of decreasing and increasing changes in pan evaporation values using the slope of the trend line

4. Conclusion

In this study, the trend of changes in pan evaporation values in Iran's meteorological stations in the period of 1994-2021 was investigated in an annual scale using the modified Mann-Kendall test by removing autocorrelation effects. In this study, 28 stations across Iran were used. The results of the investigation of the changes in the pan evaporation values in Iran showed that the majority of the changes are increasing, but a significant decrease was also observed in several stations. This significant reduction in the trend of changes in the pan evaporation values seemed unreasonable due to climate changes.

According to the studies conducted regarding climate change, the results showed that the important factor in this regard is the increase of fine dust, which disrupts the sun's energy and its movement path. The main changes in evaporation from pans in Iran were an increase, which was observed more in the eastern regions as well as in the north and northwest of Iran. Incremental changes according to the slope of the trend line up to 25 mm increase per year were also observed, which happened in Tehran station. The results of the investigation of the changes in the pan evaporation values, which is one of the main and influential components in the evaporation from the reservoirs and the rivers, showed that the changes of this variable in the studied period in the northwestern regions and the Caspian Sea border strip are increasing.

One of the effects of this increase in the amount of pan evaporation is the reduction of the river flow and the reduction of the reservoirs, although this changes in the face of climate change and the decrease of rainfall as well as the change of the rainfall pattern (Khalili et al., 2016; Khozeymehnezhad and Tahroudi., 2019; Tahroudi et al., 2018) does not have much impact, but it should not be ignored. Gharekhani et al. (2013) stated that the trends of these changes are statistically closely correlated with annual rainfall and vapor pressure values. Investigating the reduction of pan evaporation, along with the effect of other meteorological variables such as temperature and wind speed, as well as relative humidity and dew point temperature, is important and can be of great help in understanding the meteorological behavior of the basin. Considering the arid and semi-arid climate of Iran, which has fragile and sensitive ecosystems, as well as many limitations in the management of water resources will be of great help in planning water resources and agriculture.

5. Disclosure statement

No potential conflict of interest was reported by the authors

6. References

Adamowski, K., & Bougadis, J. (2003). Detection of trends in annual extreme rainfall. *Hydrological Processes*, *17*(18), 3547-3560.

Ahmadi, F., Nazeri Tahroudi, M., Mirabbasi, R., & Kumar, R. (2022). Spatiotemporal analysis of precipitation and temperature concentration using PCI and TCI: a case study of Khuzestan Province, Iran. *Theoretical and Applied Climatology*, *149*(1-2), 743-760.

Ahmadi, F., Nazeri Tahroudi, M., Mirabbasi, R., Khalili, K., & Jhajharia, D. (2018). Spatiotemporal trend and abrupt change analysis of temperature in Iran. *Meteorological Applications*, *25*(2), 314-321.

Borna, R., & Jahan, A. (2015). Trend Analysis of Extreme Climate Changes Index’s in Precipitation and Temperature in Bushehr Province. *Physical Geography Quarterly*, *8*(28), 43-64.

Caloiero, T. (2017). Trend of monthly temperature and daily extreme temperature during 1951–2012 in New Zealand. *Theoretical and Applied Climatology*, *129*, 111-127.

Chattopadhyay, N., & Hulme, M. (1997). Evaporation and potential evapotranspiration in India under conditions of recent and future climate change. *Agric. For Meteorol, 87*, 55-73.

Fu, G., Charles, S. P., & Yu, J. (2009). A critical overview of pan evaporation trends over the last 50 years. *Climatic change*, *97*(1-2), 193-214.

Gharekhani, A., Ghahreman, N., & Bazrafshan, J. (2013). Trend analysis of pan evaporation in different climates of Iran. *Watershed Management Researches*, *26*(1), 85-97. SID. https://sid.ir/paper/200636/en. [in Persian].

Goljamjoo, A., Ghahreman, N., & Bakhtiari, B. (2023). Trend Analysis of pan coefficient and projection of pan evaporation in selected stations of Iran. *Journal of Agricultural Meteorology*, *10*(2), 58-65. 10.22125/agmj.2023.369069.1143

Gong, C., Xu, C., Chen, D., Halldin, S., & Chen, Y.D. (2006). Sensitivity of Penman Monteith reference evapotranspiration to key climatic variables in the Changjiang (Yangtze River) basin. *Journal of Hydrology 329*, 620-629.

Hamed, K. H., & Rao, A. R. (1998). A modified Mann-Kendall trend test for autocorrelated data. *Journal of Hydrology, 204*(1-4), 182-196.

Kendall, M. G. (1963). The advanced theory of statistics: in 3 volumes. C. Griffin.

Khalili, K., Esfandiary, S., Khanmohammadi, N., & Nazeri Tahrudi, M. (2014). Half-century air temperature trends in Iran. *J Middle East Appl Sci Technol*, *8*(4), 208-213.

Khalili, K., Tahoudi, M. N., Mirabbasi, R., & Ahmadi, F. (2016). Investigation of spatial and temporal variability of precipitation in Iran over the last half century. *Stochastic Environmental Research and Risk Assessment*, *30*(4), 1205-1221.

Khozeymehnezhad, H., & Nazeri Tahroudi, M. (2019). Annual and seasonal distribution pattern of rainfall in Iran and neighboring regions. *Arabian Journal of Geosciences*, *12*, 1-11.

Kruger, A. C., & Sekele, S. S. (2013). Trends in extreme temperature indices in South Africa: 1962–2009. *International Journal of Climatology*, *33*(3), 661-676.

Kumar, S., Merwade, V., Kam, J., & Thurner, K. (2009). Streamflow trends in Indiana: effects of long term persistence, precipitation and subsurface drains. *Journal of Hydrology*, *374*(1-2), 171-183.

Lawrimore, J. H., & Peterson, T. C. (2000). Pan evaporation trends in dry and humid regions of the United States. *Journal of Hydrometeorology*, *1*(6), 543-546.

Lawrimore, J., & Peterson, T. (2002). Pan Evaporation trends in dry and humid regions of the United States. *Journal Hydrometeor, 14*, 18-31.

Mann, H. B. (1945). Nonparametric tests against trend, Econometrica. *Journal of the Econometric Society*, 245-259.

Nazeri Tahroudi, M., & Khozeymeh Nejad, H. (2017). Evaluation the Trend of South-West of Asia Precipitations. *Water and Soil, 31*(5), 1511-1525. doi: 10.22067/jsw.v31i5.62604

Nazeri Tahrudi, M. (2014). Compared to the normal mechanism becomes the normal monthly rainfall data from different regions of Iran. *Water and Soil*, *28*(2), 365-372.

Roderick, M., & Farquhar, G. (2002). The cause of decreased pan evaporation over the past 50 years. *Science, 298*, 1410-1411

Sabziparvar, A., Khataar, B., Sadeghifar, M., Saghaei, S., Ershadfath, F., & Norooz Valashedi, R. (2014). Estimating daily pan evaporation from some existing time-series models. *Watershed Engineering and Management*, *6*(1), 42-51.

Sen, P. K. (1968). Estimates of the regression coefficient based on Kendall's tau. *Journal of the American statistical association*, *63*(324),1379-1389.

Stanhill, G., & Cohen, S. (2001). Global Dimming: A review of the evidence for widespread reduction in global radiation with discussion of its probable causes and possible agricultural consequences. *Agric For Meteorol, 107*, 2555-278.

Stephens, C. M., McVicar, T. R., Johnson, F. M., & Marshall, L. A. (2018). Revisiting pan evaporation trends in Australia a decade on. *Geophysical Research Letters*, *45*(20), 11-164.

Tahroudi, MN., Khalili, K., Ahmadi, F., Mirabbasi, R., Jhajharia, DJ. 2018. Development and application of a new index for analyzing temperature concentration for Iran’s climate, International Journal of Environmental Science and Technology, 16(6), 2693-2706.

Theil, H. (1950). A rank-invariant method of linear and polynomial regression analysis, 3; confidence regions for the parameters of polynomial regression equations. *Indagationes Mathematicae*, *1*(2), 467-482.