

Research Article

Investigating Changes in River Flow and Concentration of Precipitation in Dez Reservoir Basin

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Abstract


In this study, in order to analysis the trend of precipitation and river flow in Dez reservoir basin, the river flow (1963-2019) and precipitation (1971-2019) values of stations of the basin in two monthly and annual scales were used. The distribution of precipitation pattern in the region was also examined using precipitation concentration index (PCI) and for evaluation the trend of changes the modified Mann-Kendall test was used. The results of the trend of precipitation changes showed that a decreasing trend of precipitation occurred in all studied stations, especially in March. These changes are evident on a monthly and annual scale. Decreasing trend of the precipitation of the study area have started since 1991. Decreasing trend of the precipitation have a direct effect on flow rate. It caused decreasing trend of the flow rate in Tele Zang, Sepid Dasht Sezar, Tang Pang Bakhtiari and Tang Pang Sezar stations. On a monthly scale, the decreasing trend were more significant in the first half of the year (April to October) and also March. The results of precipitation concentration index (PCI) showed that all stations, that were faced with a decreasing trend of precipitation during the statistical period, experienced an increase in PCI values. The increase in PCI values indicates the occurrence of extreme values of precipitation in recent years.

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1- Introduction

The advancement of technology and consequently the industrialization of countries in the last century has increased the concentration of greenhouse gases and the consequences of climate change in different parts of the world, of which Iran is no exception. One of the important factors in this field is the change in long-term values of hydrological and meteorological parameters. These changes also upset the water balance in the basins. Changes in various parameters have caused changes in the hydrological behavior of the basins. Humans, on the other hand, have added to these problems by changing the course of rivers and changing their regimes ([Khalili et al., 2016](#)).

Another factor influencing the change of trends in each region is the discussion of non-stationary in the time series. Trend of change and study of precipitation pattern is one of the most important studies in the field of study of changes in meteorological and hydrological values in each region, which can be done using Mann-Kendall test and precipitation concentration index, respectively. Various researchers have widely used the Mann-Kendall test in different parts of the world to evaluate significant changes and trends in meteorological and hydrological time series. For example, The trend of precipitation changes in Sirikanka was also studied by [Herath and Ratnayake \(2004\)](#) in the statistical period 1964 to 1993.

The results of their study showed that precipitation in the study area has a decreasing trend during the studied statistical period. [Khalili et al. \(2016\)](#) examined the trend of temporal and spatial changes of 50-year precipitation in Iran using the modified Mann-Kendall test and the precipitation concentration index (PCI). Based on the results, the PCI index in the central and southern regions of the country, including the provinces of Kerman, Bandar Abbas, Yazd, Zahedan, Shahrekord, Birjand, Bushehr, Ahvaz and Isfahan shows high irregularity in precipitation and in none of the studied stations, no uniform concentration ($PCI < 10$) was observed on an annual scale. Also in winter, which provides most of the country's water needs, 64% of stations have experienced a decrease in precipitation, which has subsequently increased the PCI index in Iran. [Ahmadi et al. \(2018\)](#) used modified man-Kendall and regional Kendall methods to study the trend of point and regional changes in annual precipitation of Iranian synoptic stations during the last half

century. To study the trend of the mentioned variable on a regional scale, first, using fuzzy clustering, the studied stations were divided into 5 regions and numbered. On a regional scale, a significant decreasing trend was observed in the northwestern, central and southwestern regions of the country, a non-significant decreasing trend was observed in the western regions of Iran and a non-significant increasing trend was observed in the northern regions and the Caspian Sea areas. [Zamani et al. \(2018\)](#) examined the temporal and spatial variations of precipitation in the Jharkhand state, Indian on a daily, seasonal and annual time scale using precipitation concentration index. The results of their research showed significant changes in precipitation in the study state. The results also showed that the concentration index and precipitation concentration index in rainy areas well explain the distribution and concentration of precipitation. [Khozaymehnezhad and Tahroudi \(2019\)](#) evaluated the changes in the pattern of precipitation in Iran and neighboring countries with a focus on Iran in the statistical period of 1970-2014. In their study, the trend of pattern and concentration changes of precipitation in Southwest Asia (4152 stations) in both annual and monthly scales were studied. The results of the annual trend of changes in the amount of precipitation in Southwest Asia showed that among the studied countries, the trend of changes in Iraq and Iran is more critical than other countries and had decreasing about 1.2 and 1.03 mm of total annual precipitation each year, respectively. The declining trend of precipitation has covered all areas of the two countries on an annual scale, and it can even be said that the center of the crisis is the lack of precipitation in these two countries. [Modi et al. \(2021\)](#) studied the trend of flow rates of the Ramganga River in India in the statistical period of 1982-2013.

The results showed a declining trend in the Ramganga River Basin, which was attributed to human activities and the resulting climate change. [Alahacoon et al. \(2022\)](#) examined variability and precipitation trends in the African continent using TAMSAT data from 1983 to 2020 using the Mann-Kendall test and the trend line slope. The results showed that the highest annual precipitation trend were occurred in Rwanda (11.97 mm per year), the Gulf of Guinea (river basin 8.71 mm per year), tropical rainforest climate zone (8.21 mm Per year),

and the Central African region (6.84 mm per year). [Ahmadi et al. \(2022\)](#) studied the trend of temperature and precipitation in Khuzestan province in the period 1988 to 1397 in six synoptic stations. The change in time series and precipitation concentration and temperature of the study area were also analyzed using Pettitt test, precipitation concentration index (PCI) and temperature concentration index (TCI), respectively. The results showed that there is a direct relationship between increasing temperature and decreasing precipitation in the study area. The annual temperature has increased significantly, while the annual precipitation at all stations has decreased significantly. On the other hand, the results of evaluation the PCI and TCI indices showed that the climate of the study area is changing and the tendency to climatic irregularities is increasing.

Since the study of the trend of changes in different meteorological and hydrological values together provides more accurate results of the hydrometeorological status of the basin, in this study, the trend analysis of discharge and

precipitation at Dez reservoir basin, and the precipitation distribution and concentration assessment have been considered at the same time. This study actually tries to compare the changes in river flow in the studied basin with the behavior of changes in precipitation and changes in the concentration of precipitation patterns.

2-Methodology

2-1-The case study

Dez basin is located in the geographical range of 48 degrees and 10 minutes to 50 degrees and 21 minutes east longitude and 31 degrees and 34 minutes to 34 degrees and 7 minutes north latitude in the western regions of Iran. The area of this basin is equal to 21720 square kilometers and its average height is about 1600 meters. The trend of changes in the average values of river flow affected by the average precipitation of the study basin was done on a monthly scale. Fig. 1 shows the location of the study area. Table 1 also presents the statistical characteristics of the data.

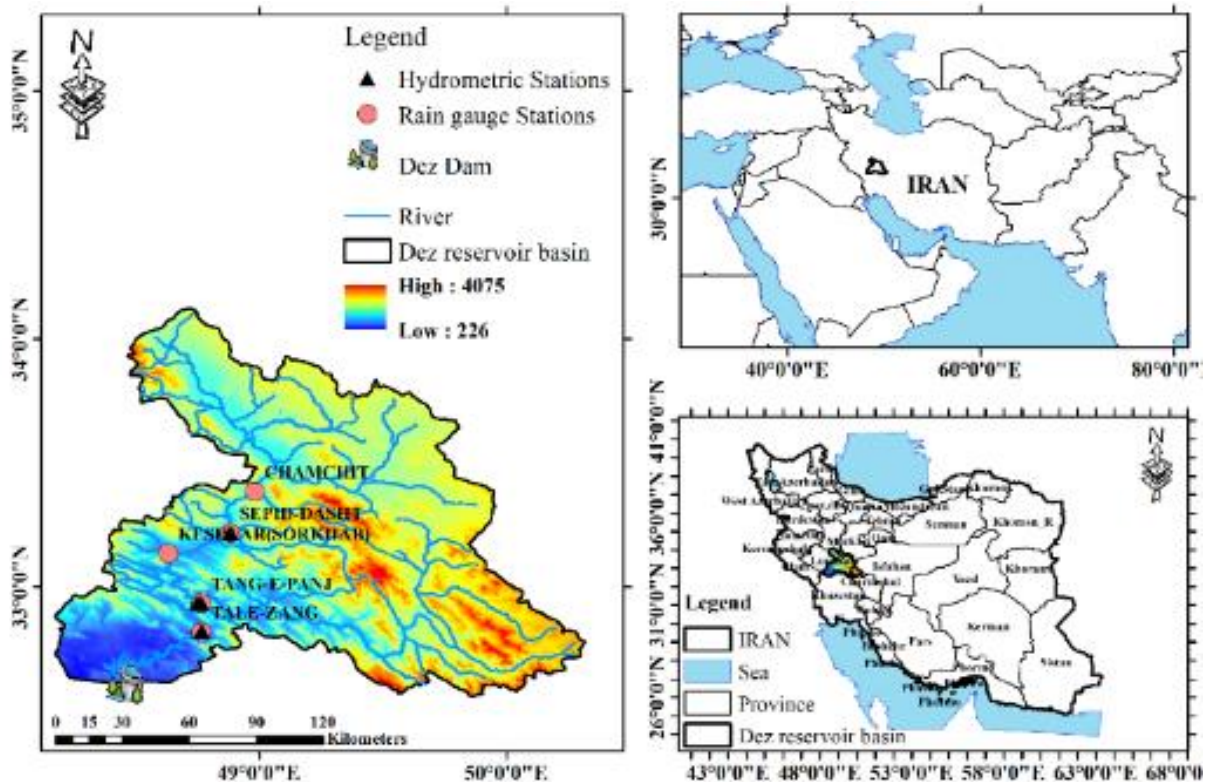


Figure 1. Location map of the study area

Table 1. Statistical characteristics of the studied data on an annual scale

Min	Max	Average	Station	Period	Parameter
85.57	570.47	234.87	Talezang		
16.65	99.93	40.22	Sepid Dasht Sezar		
6.71	41.21	17.96	Sepid Dasht Zaz	1963-	River flow
49.70	352.58	133.53	Tang Pang	2019	(m ³ /s)
			Bakhtiari		
29.58	290.85	93.30	Tang Pang Sezar		
399.3	1491.4	825.9	Talezang		
534.0	1818.5	1086.0	Tang Pang		
			Bakhtiari	1971-	Precipitation
327.5	1191.5	647.6	Sepid Dasht Sezar	2019	(mm)
513.0	1543.0	955.7	Keshvar		
397.0	1142.0	733.7	Cham Chit		

2-2-Trend analysis

One of the fundamental approaches in monitoring network and water resources in each basin is to discuss the trend of changes and study it. In this study, the trend of time series changes is examined by modified non-parametric Mann-Kendall test. This test has been widely used in hydrological studies (e.g., Khalili et al., 2016). In the conventional Mann-Kendall test, each value in the time series is compared continuously and sequentially with the other values in the series. The statistic *S* was considered as follows:

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

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

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

Mann (1945) and Kendall (1975) showed that when $n \geq 0$, the *S* statistic is distributed almost normally and its mean and variance are as follows:

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

$$F = \left[\begin{matrix} n(n-1)(2n+5) - \\ -\sum_{i=1}^m t_i(t_i-1)(2t_i+5) \end{matrix} \right] \tag{4}$$

$$V(S) = \frac{F}{18}$$

Where t_i is the same number of data in i^{th} category and *m* is equal to the number of pair groups. The standardized statistic of *Z* is calculated as follows:

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

The standardized Mann-Kendall test statistic follows the standard normal distribution with mean zero and variance equal to 1. Assumption zero is accepted if $-z_{1-\frac{\alpha}{2}} \leq Z \leq z_{1-\frac{\alpha}{2}}$. It should be noted

that α is equal to the level of significance. A very useful indicator in the Mann-Kendall test is the trend line slope, or so-called Sen's slope, which indicates the magnitude of a uniform trend. The slope of the trend line was estimated using the method proposed by Theil (1950) and Sen (1968) with the following equation:

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

where β is the trend line slope estimator. Positive values 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 calculation of the modified Mann-Kendall test. The modified Mann-Kendall method is described by Kumar et al. (2009). In this method, the effect of first-order autocorrelation coefficient (r_1) is calculated and if it is significant, it is removed from the data series. In this method, first, the first-order autocorrelation coefficient (r_1) is calculated as follow:

$$r_k = \frac{\left(\frac{1}{n-k}\right) \cdot \sum_{i=1}^{n-k} (x_i - \bar{x}) \cdot (x_{i+k} - \bar{x})}{\text{var}(x)} \quad (7)$$

The data series is assumed to be independent (at a significance level of 10%) if it is true in the condition of

$$\frac{-1-1.645\sqrt{n-2}}{n-2} \leq r_1 \leq \frac{-1+1.645\sqrt{n-2}}{n-2}$$

, otherwise the effect of the first-order autocorrelation coefficient on the data trend is eliminated (Hamed and Rao, 1998). In this step, the trend line slope or β for the data series was calculated from Equation (6) and a new series was obtained as follows.

$$x'_i = x_i - (\beta \times i) \quad (8)$$

At this point, the r_1 of the new series is recalculated. The component of the first-order correlation coefficient AR(1) is removed from the new series as follows, and the series of residuals (y'_i) is obtained from the following equation:

$$y'_i = x'_i - r_1 \times x'_{i-1} \quad (9)$$

Once again, the trend of ($\beta \times i$) was added to the recent series and the final series was obtained as follows:

$$y_i = y'_i + (\beta \times i) \quad (10)$$

Now by applying the Mann-Kendall test to a series of composite data, the presence of a trend in them is checked. This was done by calculating the Z statistic of Mann-Kendall (Equation 5) for the latter series.

If it was calculated to be greater than 1.645, the trend of data was assumed to be significant at the 10% level, and if it was greater than the 1.96 and 2.33, the trend of data was assumed to be significant at the 5% and 1% levels, respectively. Otherwise, the null hypothesis that there is a trend in the data at the desired level of significance is rejected. This method was used by [Burn et al. \(2004\)](#), [Luo et al. \(2008\)](#), [Kumar et al. \(2009\)](#), [Khalilq et al. \(2009\)](#), [Bandiapadhaya et al. \(2009\)](#), [Khalili et al. \(2016\)](#) and [Ahmadi et al. \(2022\)](#).

2-3-Pettitt test

The Pettitt test is a non-parametric test developed in 1979 by Pettitt. This method is used to find change points in a time series. Pettitt test is a rank-based test with no distribution to detect

significant changes in the average of time series, and this is important when there are no hypotheses about the time of the change point. The statistics of Pettitt test is as follows ([Pettitt, 1979](#)):

$$U_{t,n} = \sum_{i=1}^t \sum_{j=i+1}^n \text{sgn}(x_j - x_i) \quad (11)$$

The value of k is calculated from the following equation and replaced by the following equation and the statistic P is obtained:

$$k = \max [U_m] \quad (12)$$

$$P = 2e^{-\frac{6k^2}{n^3+n^2}} \quad (13)$$

In this test, hypothesis H_0 : indicates the homogeneity of data and hypothesis H_1 indicates the year of change point in the studied time series. If the calculated P value is less than α or the level value is significant (0.05), this change point in the series can be considered statistically significant. In fact, the calculated value of P is the amount of risk or error of rejecting the assumption H_0 , which if this error is less than five percent, this change can be considered significant.

2-4-Estimation of precipitation concentration index

The PCI is part of the popular Fourier index, which has a strong track record in analyzing natural systems such as soil erosion. The results of PCI calculation can be used for hydrological, water and environmental resource management programs as a warning tool for flood or erosion preparedness ([Adegan et al., 2012](#)). This concept can also be used in irrigation planning and design of new systems. Unbalanced distribution of precipitation can reduce crop yields by reducing soil moisture storage and increasing the number of irrigation cycles. In addition, unbalanced distribution of precipitation means drought and precipitation below the regional average may cause dangerous floods. Because soil moisture decreases and as a result vegetation is lost. Eventually, this will increase protection measures in the basin in order to preserve water structures. The PCI index was first proposed as an indicator of rain concentration and dispersion. The monthly and annual scales of this index are calculated as equations 14 and 15, respectively ([Oliver, 1980](#)):

$$PCI_{Seasonal} = \frac{\sum_{i=1}^{12} p_i^2}{\left(\sum_{i=1}^{12} p_i\right)^2} \times 25 \quad (14)$$

$$PCI_{Annual} = \frac{\sum_{i=1}^{12} p_i^2}{\left(\sum_{i=1}^{12} p_i\right)^2} \times 100 \quad (15)$$

where, P_i is the amount of monthly precipitation in the i^{th} month. According to [Oliver \(1980\)](#) proposed formula and preliminary results, the minimum value of PCI theory was 8.3, indicating complete uniformity in precipitation distribution (meaning that the same amount of precipitation occurred each month). A value of 16.7 for PCI indicated that total precipitation was concentrated in one-half of the time interval, and a value of 25 for this index indicated that total precipitation received occurred in one-third of the time interval (Meaning that the total precipitation occurred in 4 months). Based on preliminary results from [Oliver \(1980\)](#), he proposed that PCI values less than 10 be shown as a uniform distribution of precipitation (low precipitation concentration). PCI values from 11 to 15, average precipitation concentration and PCI values of 16 to 20 of this index also indicate irregular concentration of precipitation. According to [Oliver \(1980\)](#) classification, PCI values greater than 20 for the PCI index indicate the existence of an extreme irregularity of precipitation concentration ([Nazeri Tahroudi et al., 2019](#); [Ahmadi et al., 2022](#)). It should be noted that all the calculations performed in this research were done in the MATLAB software environment.

3-Results and Discussion

3-1-Trend Analysis of Precipitation

The results of the study of the trend of changes in precipitation values in the study area using the modified Mann-Kendall test and the Sen's slope are presented in Table 2. According to the results presented in Table 2, it can be seen that at a significance level of 5%, the trend of precipitation in all studied stations is decreasing, among which, the trend of annual precipitation in Telezang stations, Sepid Dasht Sezar and the Keshvar are decreasing and significant. Due to the changes in the trend line slope (Sen's slope), the most decreasing changes among the studied stations were related to the Keshvar station with a decrease of 13.38 mm per year. Annual decreasing changes in Telezang, Tang Pang Bakhtiari, Sepid Dasht Sezar and Cham Chit stations with annual decreases of 6.20, 9.41, 7.86, and 1.99 mm, respectively, during the studied period (1971-2019) has been observed with an average decrease of approximately 300, 450, 370, and 100 mm of precipitation in the studied stations during the last 48 years, respectively. Decreasing changes occurred in the studied stations according to Pettitt test and Table 2 between 1991 and 1994. Considering that Pettitt's test shows the time of change point in the time series, this test shows the year in which the major changes in the time series started. In other words, from what year onwards, a significant change (decrease or increase) has occurred in the time series. The results presented in Table 2 show that there are significant changes in annual precipitation in stations Talezang, Tang Pang Bakhtiari, Sepid Dasht Sezar, Keshvar, and Cham Chit started in 1991, 1993, 1992, 1992, and 1994 respectively.

Table 2. Results of the trend and slope of trend line of the annual precipitation of the studied stations on an annual scale

Station	Time of Change point	Z Statistics	Sen's slop
Talezang	1991	-2.08	-6.20
Tang Pang Bakhtiari	1993	-1.51	-9.41
Sepid Dasht Sezar	1992	-1.99	-7.86
Keshvar	1992	-2.12	-13.38
Cham Chit	1994	-0.57	-1.99

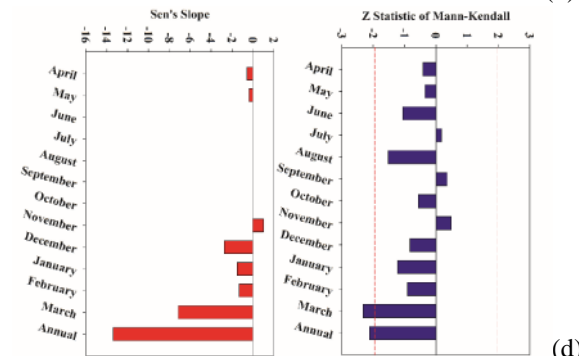
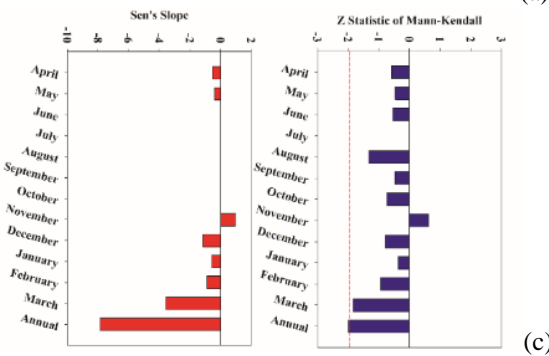
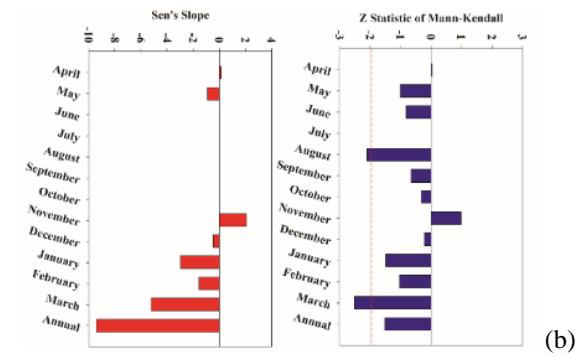
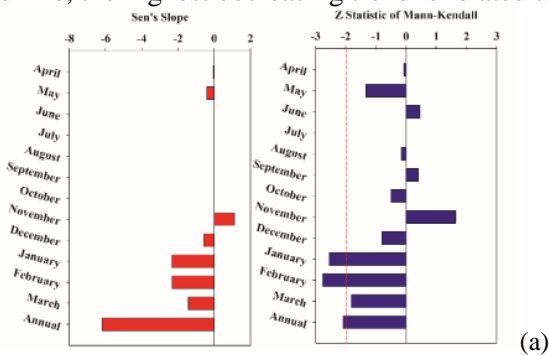
The results of the trend of precipitation values in the studied stations on a monthly scale and the slope of its changes were presented in Fig. 2. At Telezang station (Fig. 2-a), in June, September and November, the trend of monthly precipitation changes is increasing. However, this increase in monthly precipitation is not significant at the level

of 5%. The main changes in the amount of monthly precipitation in the Talezang station during the period of 1971-2019 is decreasing. At this station, the trend of decreasing changes in January and February during the studied period is significant at the level of 5%. According to Table 2, the most increasing changes in the Talezang station are

related to November with an annual increase of 1.12 mm. The highest decrease in precipitation at the Talezang station on a monthly scale is related to January with a decrease of 2.34 mm per year on average. According to the 48-year studied period, the increase in precipitation in November is about 54 mm. In April, May, December, January, February and March, on average during the 48 years, the decreasing changes in precipitation were about 3, 19, 27, 112, 110 and 68 mm, respectively. In Tang Pang Bakhtiari station, according to Fig.2-b, increasing changes in precipitation can be observed in November and April, which is significant at the level of 5%. In other months, in Tang Pang Bakhtiari station, the trend of decreasing precipitation is that the decreasing changes of precipitation in March and August are significant at the level of 5%.

Due to the changes in the slope of the trend line, the maximum annual decrease was about 5.23 mm, which according to the 48-year studied period, shows a decrease in precipitation of 250 mm. Fig. 2-c shows the trend changes and slope of trend line values of precipitation in the Sepid Dasht Sezar station in the studied period. The trend of decreasing and increasing changes on a monthly scale in all months is non-significant. Changes in the trend of precipitation in November are increasing and decreasing in other months. Due to the slope of trend line, the highest decreasing trend is related to

March with an average decrease of 3.57 mm per year, which shows a decrease of 170 mm during the studied period. According to Fig. 2-d, the trend of changes in precipitation in the Keshvar station in the studied period in September, November and July is increasing and non-significant and the trend of decreasing changes in March in the level of 5% is significant. Due to the slope of the trend line in the Keshvar station, the largest decrease in precipitation is related to March with an average annual decrease of about 7.15 mm per year, which according to the 48-year studied period, it is about 340 mm. Fig. 2-e also shows the changes in the precipitation trend and the slope of the trend line on a monthly and annual scale at Cham Chit station. According to Fig. 2-e, we can see the decreasing changes in December, January and March, in which the decreasing changes in March are significant at the level of 5%. Increasing changes in other months are also non-significant. The highest decrease in precipitation, like other studied stations, is related to March with a decrease of about 3.21 mm per year, which shows a decrease of 150 mm in the 48-year studied period. In general, the results of the study of precipitation changes in the study area showed that the dominant trend of precipitation changes was decreasing and the greatest effect was observed in March in all stations.



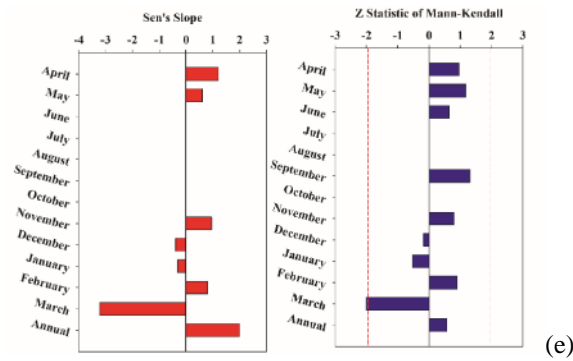


Figure 2. Results of evaluation the trend and slope of trend line of monthly precipitation in studied stations (a: Talezang, b: Tang Pang Bakhtiari, c: Sepid Dasht Sezar, d: Keshvar, e: Cham Chit)

To study the trend of changes in river flow in both monthly and annual scales, the modified Mann-Kendall method was used to eliminate the effects of internal autocorrelation. The results of the study of the trend of river flow in Telezang, Sepid Dasht Sezar, Sepid Dasht Zaz, Tang Pang Bakhtiari and Tang Pang Sezar stations on an annual scale were presented in Table 3. The slope of the trend line and the time

of change point can also be seen in this table. According to the presented results, it is possible to see decreasing trend in the annual scale in all stations except Sepid Dasht Zaz station. Changes in the river flow trend on an annual scale in the studied stations in the statistical period of 1963-2019 at the level of 5% in Telezang, Sepid Dasht Sezar, Sepid Dasht Zaz and Tang Pang Bakhtiari stations are non-significant. The trend of decreasing precipitation in

Tang Pang Sezar station in the studied statistical period is decreasing and at the level of 5% is significant. According to the changes in the calculated slope of trend line, it is possible to estimate the changes in river flow in the Tang Pang Bakhtiari during the 56-year statistical period with an average of about 103 cubic meters per second, which is the most decreasing change among the studied stations. Decreasing changes in river flow in the study area have been started since 1991 at Telezang station. The effect of precipitation reduction in the study area on the river flow during the statistical period according to the time of change point in the precipitation trend is clearly evident in Table 2. The trend of decreasing changes in river flow rate in the studied stations is the result of the decreasing trend of precipitation in the studied stations.

Table 3. Results of the trend and slope of trend line of the annual river flow of the studied stations on an annual scale

Station	Time of Change point	Z Statistic	Sen's slop
Talezang	1991	-0.51	-0.35
Sepid Dasht Sezar	1993	-1.13	-0.14
Sepid Dasht Zaz	1992	1.37	0.08
Tang Pang Bakhtiari	1991	-0.47	-0.14
Tang Pang Sezar	1997	-3.30	-1.84

A monthly scale was used to more accurately study of changes in river flow trend in the study area. The results of evaluation the trend of changes in the river flow in the studied rivers along with the results of estimating the slope of the trend line were presented in Fig. 3. In Telezang station, according to Fig.3-a, during the period of 1963-2019, the trend of river flow changes in November, December and January is increasing and non-significant. In other months, according to Fig. 3-a, the monthly river flow changes are decreasing. In general, decreasing and increasing changes in river flow at the Talezang station are not significant. According to Fig. 3-a, the

highest decrease in monthly river flow at the Talezang station occurred in May, June and March, with an average annual decrease of about 1.96, 1.29 and 1.16 cubic meters per second respectively which shows an average decrease of 110, 72 and 65 cubic meters per second during the 56-year studied period, which is a very large decrease in the river flow in the studied rivers. If we consider the 1991, which has been estimated using the Pettitt test as the time of change point in the river flow in Talezang stations, as a failure in the time series, we can conclude that:

The average river flow in the Talezang station in

the statistical period of 1963-1991 (before failure in time series of river flow) was equal to 250 cubic meters per second, which for the period of 1991-2019 is about 165 cubic meters per second. This represents a 34% reduction in the river flow at the Talezang station.

According to Fig.3-b, it can be seen that the changes in the river flow values in Sepid Dasht Sezar station during the studied statistical period in January and October are insignificant and in other months are decreasing and insignificant. According to Fig.3-b, the largest decrease in river flow is related to April with a decrease of 0.55 cubic meters per second per year. The trend of changes in the river flow values in the monthly scale at the Sepid Dasht Zaz station according to Fig.3-c is decreasing in May, June and July and decreasing in June. The trend of change in other months has also been increasing. In this station, the highest increasing trend is in accordance with the slope of the trend line in April and the highest decreasing trend is related to June and May, which shows a decreasing change of 0.16 and 0.15 m³/s per year. Fig.3-d shows the changes in the river flow trend and the slope of its changes in Tang Pang Bakhtiari station in the studied statistical period on a monthly and annual scale. The trend of river flow changes according to Fig.3-c in the first half of the year (April to October) and also in March has been a decrease, which in June these decreases are significant at the level of 5%.

Due to the slope of the trend line, the most decreasing changes are related to May and June with a decrease of 1.65 and 1.25 cubic meters per second, respectively, which according to the 56-year changes in the time series, shows a decrease of about 92 and 70 cubic meters per second, respectively. In Tang Pang Sezar station, according to Fig.3-e, the trend of river flow changes is decreasing in all months, with decreasing changes being non-significant in August, September, October and November, and a significant decrease in other months. The decreasing changes in the river

flow have the greatest decrease in April and according to the slope of the trend line, these changes are equal to 5.47 cubic meters per second per year. In general, the results of the trend of river flow changes in the study area show a decrease in the river flow in all stations.

3-2-Investigation the precipitation concentration in the study area

In this study, PCI index was used to investigate changes in precipitation pattern in the studied stations. This index shows the distribution of precipitation between the months of the year. The results of PCI index in the studied stations were presented in Fig. 4.

According to Fig.4-a, it can be seen that in the years leading up to the statistical period, changes in PCI values have increased in the Talezang station. This increase indicates an increase in PCI values in the region, which indicates an increase in extreme values. An increase in the amount of precipitation indicates an increase in storms in the region. An increase in storms will increase floods, which will produce runoff, and making the runoff inaccessible. According to the results of Pettitt test, in 1991, significant changes in the amount of precipitation occurred in the Talezang station, based on which, PCI studies were divided into two parts. Based on the results of PCI index, the average changes of PCI index in the statistical period of 1976-1986 and 1986-2019 are equal to 18.75 and 21.18, respectively, which shows an increase of 13%.

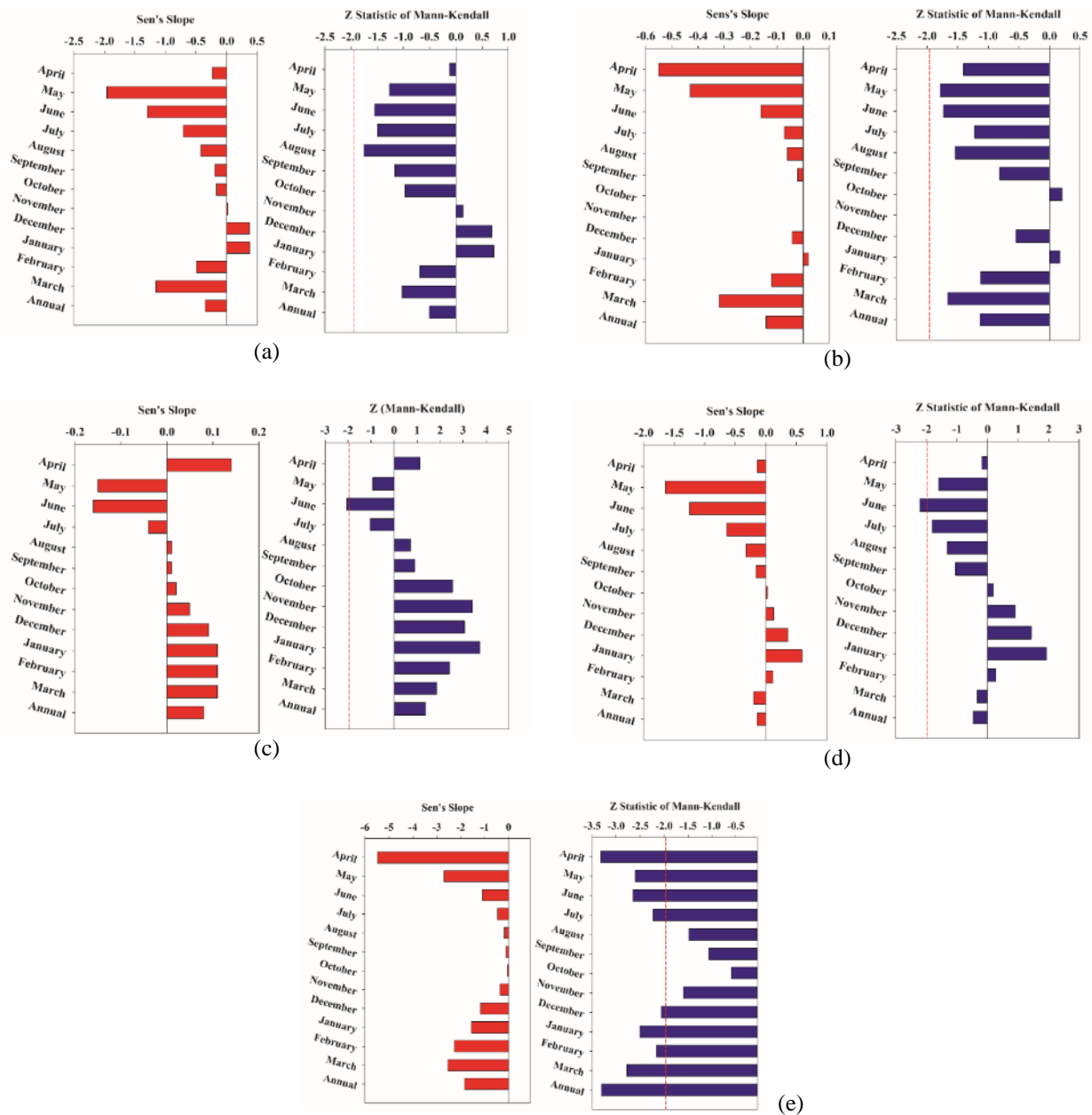


Figure 3. Results of evaluation the trend and slope of trend line of monthly river flow in the studied stations (a: Talezang, b: Sepid Dasht Sezar, c: Sepid Dasht Zaz, d: Tang Pang Bakhtiari, e: Tang Pang Sezar)

In fact, it can be concluded that the classification of this index has also changed and has changed from a state of irregular concentration to a state of extreme irregularity. According to Fig.4-b, it can be seen that in Tang Pang Bakhtiari station, PCI index has an increasing trend during the statistical period and in recent years, irregularities in the distribution of precipitation pattern have increased. The average change of PCI index in Tang Pang Bakhtiari station before and after the change of trend (1993) has increased by about 10%. According to Fig.4-c, changes in PCI values at Sepid Dasht Sezar station,

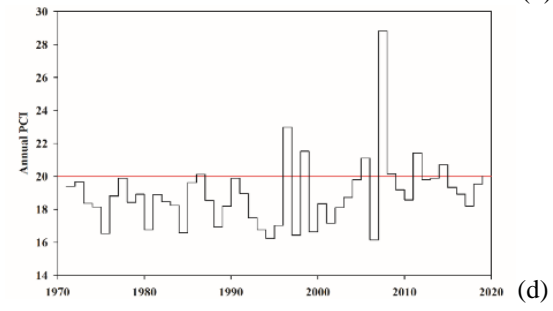
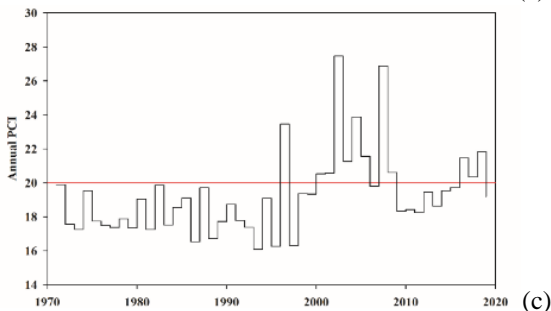
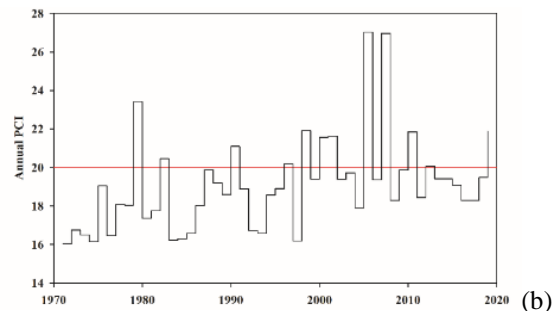
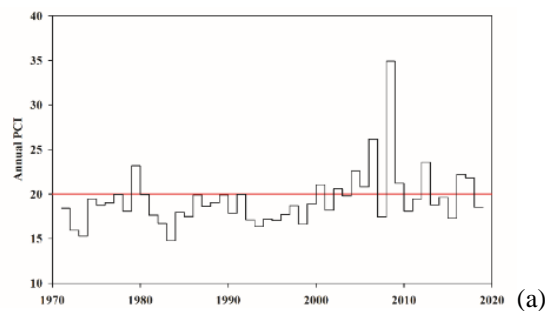
like other studied stations, have increased in recent years and precipitation irregularities in the study area have increased sharply. The average changes in PCI values before and after the trend change year (1992) were about 18.09 and 21.25, respectively, which shows an increase of about 17%. The results of PCI index in the Keshvar station according to Fig.4-d showed that PCI changes in this station have increased in recent years, which shows an irregularity in the pattern of precipitation in the region in recent years. According to the Pettitt test and the introduction of 1371 as the time of change

point, a 3% increase in the average change in PCI values in the study station is evident. Cham Chit station also had a trend change in precipitation values in 1994. According to Fig.4-e, PCI values in this station also increased by about 7% compared to the period before time of change point. According to Fig.4-c, incremental changes can be observed in the PCI values at the Cham Chit station. In general, the increase in PCI values in each region indicates the extent of precipitation. Extreme values of precipitation also causes runoff loss due to flooding. As the amount of precipitation increases, the need for watershed management plans becomes more apparent. This index has been studied in various studies and in all studies, usually in Iran, increasing values of extreme precipitation and increasing PCI values have been reported in recent years (Ahmadi et al., 2022; Khalili et al., 2014 and 2016; Nazeri Tahroudi et al., 2019 and Ramezani et al., 2020). Ahmadi et al. (2022) also reported the extreme values of rainfall in recent years in their research regarding changes in PCI values in the study area.

In this study, the trend of changes in precipitation and river flow values as well as

changes in precipitation pattern and its concentration in stations of Dez reservoir basin in the statistical period of 1963-2019 for river flow and 1971-2019 for precipitation values were investigated. In this regard, the modified Mann-Kendall test was used to eliminate the effects of self-autocorrelation. The results of evaluation of the trend of changes in annual precipitation in the study area using the modified Mann-Kendall test showed that at a significance level of 5%, the precipitation changes of the studied stations in the statistical period 1971-2019 is decreased (significant and non-significant).

Decreasing changes in precipitation in Telezang, Tang Pang Bakhtiari, Sepid Dasht Sezar, Keshvar and Cham Chit stations occurred in 1989, 1993, 1992, 1992 and 1992, respectively, which increased the average changes in PCI values in the region about 13, 10, 17, 3 and 7%, respectively. On a monthly scale, a significant decreasing trend can be seen in January and February at Tele Talezang station, March and August at Tang Pang Bakhtiari station, March at Keshvar and Chamchit stations.



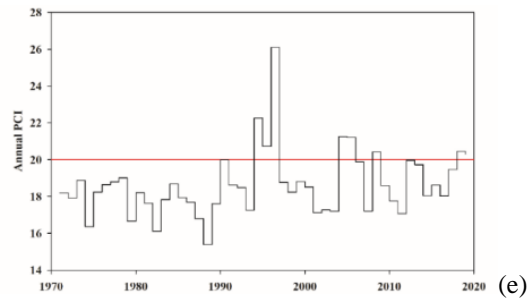


Figure 4. Results of the annual PCI at Cham Chit station (a: Talezang, b: Tang Pang Bakhtiari, c: Sepid Dasht Sezar, d: Keshvar, e: Cham Chit)

4- Conclusions

The result of decreasing changes in precipitation values can be clearly seen in the river flow values, which its results is a decrease in river flow in Talezang, Sepid Dasht Sezar, Tang Pang Bakhtiari and Tang Pang Sezar stations. For example, due to the change in the decreasing trend in 1989, the average decrease in the river flow in the Talezang station has decreased by about 85 cubic meters per second. On a monthly basis, there is a significant decrease in the river flow in the studied stations in most months. What can be seen in most stations, the decreasing changes in April and May are more than other months according to Pettitt test. Changes in precipitation pattern in the study area were performed to identify the type of precipitation and their distribution among the months of the year using PCI index. The results of PCI index in the study area showed that the changes in this index in the studied stations during the statistical period have been increasing and its values have exceeded 20 in recent years. This increase in PCI values at the studied stations in recent years indicates an increase in extreme values of precipitation. This does not mean an increase in rainfall and it shows that the amount of rainfall that should have happened in one year has happened in several extreme events. Increasing the extreme values will also increase the floods. Also, the increase in PCI values shows that the distribution of precipitation pattern is not the same between the months of the year and the precipitation values have occurred in several events. Examining the changes in meteorological and hydrological values is the first step in monitoring the changes in the aforementioned values in each region, and the modified Mann-Kendall test is the best option in this regard. This test does not have any geographical and climatic limitations.

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Competing interest

This expression states that there is no conflict of interest to disclose.

Authors contribution

M.N.T and F.A conceived of the presented idea. F.R developed the theory and performed the computations. M.H.D.B verified the analytical methods. Also, M.N.T, F.R, and FA investigated of computation results of this work. All authors discussed the results and contributed to the final manuscript

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