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Investigating the Impacts of Climate and Land Use Change on the Hydrologic Characteristics in the Sub-Basins of the Dez River, Middle East

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Abstract

Human activities and the climate change affects the river flow therefore monitoring flow rate of river for an extended period can reveal the detail of involved mechanisms in these changes. The previous studies show impact of human activities and climate change on river temporal variations varies in different locations. Water scarce is one of most problem in this area therefore finding affected parameters in water accessibility is important for water management in Middle East. This study aimed to investigate the trend of annual and monthly flow changes in the Dez River branches in southwestern Iran by several nonparametric methods. A structural equation model was used to assess the effects of land use and climate changes on river discharge. The study results showed that the annual precipitation at all stations has no significant trend, but temperature and evaporation at most stations increased significantly. Additionally, more than 30% of the study area's rangeland and forestlands have been converted into agricultural and residential lands. The results showed that land use and climate can determine 43.2% of discharge changes. Also, land use changes are more effective than climate change on river discharge changes.

Keywords: Climate Change, Discharge, Land Use, Non-Parametric Methods, Structural Equation Model.

1. Introduction:

The study of the river flow rate requires evaluating the environmental parameters and human activities that are affecting it, including climate factors and land use.

In many parts of the world, the effect of climate changes, such as precipitation, precipitation patterns, and temperature, are sensible (Chim et al., 2021; Gebremichael et al., 2022). These changes are sometimes accompanied by periods of climatic drought and have very devastating effects. The changes in climate parameters such as temperature, evaporation rate, and precipitation affect the water cycle in nature and change the water resource availability in different parts of the world. The hydrological regime of rivers has been affected by climate change (Gudmundsson et al., 2021; Kaini et al., 2021). Also, the frequency and severity of the flood, water availability, and sediment yield are a function of climate change (Maharjan et al., 2021; Rajbanshi and Bhattacharya, 2022). Therefore, to investigate the flow rate in the long time series, the climatic parameters should be evaluated. Most studies worldwide have focused on changes in climatic parameters such as temperature, evaporation, and precipitation. Precipitation is the primary supply source for all groundwater and surface water. In addition, precipitation is one of the most tangible and accessible parameters affected by climate change. Precipitation varies across various regions of the world.

it either decreases, increases, or has no change(Abou Rafee et al., 2020; Cherinet et al., 2019; Guo et al., 2019; Higashino and Stefan, 2019; Vafakhah et al., 2013; Xavier et al., 2020; X. Zhang et al., 2019). A study on the Benjo River basin in Japan showed that precipitation has increased in recent years (Higashino and Stefan, 2019); Also, the Abbay River basin in Ethiopia has increasing precipitation (Cherinet et al., 2019). The annual precipitation in the Kashaf-rood River basin in Iran was decreasing in recent years (Vafakhah et al., 2013). A study conducted on the Mediterranean Sea revealed that most of the basins had a decreasing trend in their annual precipitation (Zhang et al., 2019). There is no significant change in the precipitation in some parts of the world, including basins of the Ganjiang river (Abou Rafee et al., 2020; Guo et al., 2019; Xavier et al., 2020).

Air Temperature is another climatic parameter has shown clear impact on water resources. Studies have shown that the temperature either has increases (Nunez et al., 2019; Zhou et al., 2020). Also, the monthly temperature series study indicates the change in the mean temperature of different months and the difference in the minimum and maximum temperature recorded in different areas of the world (Worku et al., 2019).

Evaporation is another climatic parameter that affects water availability. Several studies showed that evaporation would be increased in the future because the rise of the temperature and radiation.(Althoff et al., 2020; Mhawej et al., 2020; Soroush et al., 2020; Stephens et al., 2018). Evaporation also greatly affects the rate of water available and can reduce water resources in an area. Studies in different parts of the world confirm the existence of an increasing trend in the rate of evaporation in months and years (Bahrami et al., 2019; Bai et al., 2019; Dinpashoh et al., 2019; Lotfi et al., 2020; Wang et al., 2019). In addition to climatic factors, land use and human activities also affect the water cycle in basins. (Adeyeri et al., 2020; da Silva et al., 2022; Tao et al., 2011; Wu, 2008; Zhang et al., 2014; Zhang et al., 2020). Investigating of river discharge and land use changes in Brazil showed that, there is significant correlation between river flow, precipitation, land use and land cover (Abou Rafee et al., 2020; da Silva et al., 2022) . Also, some studies in China, Mongolia, Ethiopia and Thailand were identified that landuse and land cover and climate changes could effected in river flow(Dorjsuren et al., 2021; Kuma et al., 2021; Shrestha et al., 2020; Zhang et al., 2020).

most of studies used non parametric methods for identified trend in data series as precipitation, temperature and river flow. Mann Kendall, Sen’s slope and petite are most popular non parametric methods for determined trend and change points in climatical and hydrological data series (Das and Banerjee, 2021; Dorjsuren et al., 2021; Mikaeili and Shourian, 2022; Yangouliba et al., 2022). For instance, Mann Kendall test determined trend in present and future river flow in Cambodia (Chim et al., 2021). likewise, in Awash basin in Ethiopia, Mann Kendal and Sen’s Slope estimator were used for determined trend of daily rainfall (Gebremichael et al., 2022).

Above discussions demonstrate the importance of climate and land use changes on river discharge. Our objective is to investigate the trend of changes in the monthly and annual series of flow and climatic data and land use changes between 1982-2019, in the sub-basins of Dez River and finally determined which one of these parameters have most effect on river discharge in this river as the severe drought in Iran, there is a significant and immediate need to study the water resources in Iran. The Dez basin is one of the most important sub-basins of the Karoon River, which is the biggest river in Iran.

This study stands as the primary examination assessing the impact of climatic factors (evaporation, precipitation, and temperature) as well as land use on the discharge of the Dez sub-basin. The Karoon River in Iran is a vital water resource for planning the exploitation of this river and water supply for extensive agricultural lands belonging to this river and the large population of the exploiter; therefore, it is necessary to conduct studies on the flow of this river.

2. Material and Methods

2.1. Study area

Dez river basin is located in southwestern Iran (32˚ 54´ to 34˚ 8´ N, 48˚ 23´ to 49˚ 54´ E). Dez river basin, the largest branch of the Karoon river, covers an area of 22300 square kilometers. The average annual precipitation is 622 millimeters, and the temporal distribution of precipitation in the basin also shows that 48.8% of annual precipitation occurs in winter, 30.6% in autumn, 20.4% in spring, and only 0.2% in summer. The mean potential temperature and evaporation in the Dez basin are 16.3 ℃ and 2000 millimeters

(Meteorological Organization and Ministry of Energy of Iran).

2.2. Data set

In order to study the changes in the flow of the Dez river according to the construction of several small and large dams and the abnormal trend of the flow, this study examined the flow in the sub-basins that had a natural flow. The selected hydrometric stations had at least 40-year, almost complete monthly data. It should be noted that the selected hydrometric stations are studied at the outlet of the studied sub-basins. The information on climatic parameters was also extracted from stations in the area with long-term and complete statistics. The properties of the meteorological and hydrometric stations studied are given in Table 1, and the position of the stations and sub-basins is given in figure (Fig. 1). The details of stations and sub-basins are provided in Table 1 and 2.

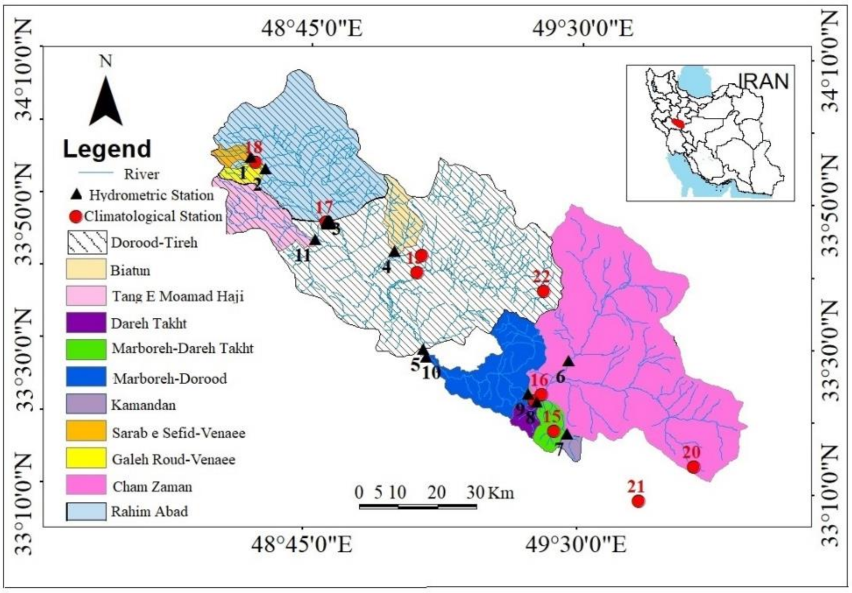


Fig. 1. Locations of study area and main hydrological and climatological stations on the Dez River

Table 1. Geographical characteristics of the hydrological and climatological stations on the Dez River

No.	Station	Latitude	Longitude	station type
1	Sarab e Sefid-Venaee	33 54 51	48 35 57	Hydrological
2	Galeh Roud-Venaee	33 54 08	48 36 24	Hydrological
3	Rahim Abad	33 46 44	48 47 52	Hydrological
4	Biatun	33 42 25	48 58 55	Hydrological
5	Dorood-Tireh	33 42 25	49 03 45	Hydrological
6	Cham Zaman	33 23 29	49 23 52	Hydrological
7	Kamandan	33 18 30	49 26 00	Hydrological
8	Dareh Takht	33 22 34	49 22 49	Hydrological
9	Marboreh-Dareh Takht	33 22 40	49 23 13	Hydrological
10	Marboreh-Dorood	33 28 28	49 04 29	Hydrological
11	Tang E Moamad Haji	33 44 13	48 45 16	Hydrological
12	Dorood	33 42 25	49 03 45	Climatological
13	Maevak	33 40 00	49 03 00	Climatological
14	Dareh Takht	33 22 34	49 22 49	Climatological
15	Kamandan	33 18 30	49 26 00	Climatological
16	Cham Zaman	33 23 29	49 23 52	Climatological
17	Rahim Abad	33 46 44	48 47 52	Climatological
18	Venaee	33 54 51	48 35 57	Climatological
19	Teleh Zang	32 49 00	48 46 00	Climatological
20	Ab Barik	33 13 48	49 49 05	Climatological
21	Kazem Bad	33 09 00	49 40 05	Climatological
22	Ali Abad	33 24 00	49 24 00	Climatological

Table 2. Area of sub-basins in Dez basin

Sub-basin	Area (km^2)
Biatun	119.9
Tang E Moamad Haji	218.0
Cham zaman	2046.9
Dorood-Tireh	3401.7
Marboreh-Dorood	2578.7
Dareh takht	42.8
Marboreh-Dareh Takht	2203.8
Kamandan	27.0
Sarab e Sefid-Venaee	36.6
Galeh Roud-Venaee	44.7
Rahim Abad	1000

In order to study changes in land use, Landsat satellite images from September 1983 to 2019 were used. Satellite images were applied to investigate and compare the changes in land use in the 1983 and 2019 years. Landsat TM and Landsat 8 OLI sensor satellite images were applied for the years 1983 and 2019, respectively. These images were downloaded from the USGS.gov website, and the paths of images were 165 and 166, and path rows were 36 and 37.

2.3. Methods

After completing and revising the data, using some nonparametric tests, changes in the time series of the flow and climate were examined. The climatic data examined included monthly and annual precipitation, temperature, and evaporation data (Table 3). The nonparametric tests selected in this study include Modified Mann-Kendall homogeneity, Sen's slope, and Petite. Modified Mann-Kendall test was used to evaluate the monotonic homogeneity. Sen's slope and Pettitt tests, respectively, were used to determine the actual trend of data and the definition of variation point, which is the indicator of change time in the mean of data.

Table 3. Summary of data in the selected station

Station	Parameter	Time Period	Yearly		
			Mean	Maximum	Minimum
Venaei	Precipitation (mm)	1968-2019	740.4	2059.0	275.0
Tele Zang	Precipitation (mm)	1966-2019	851.7	1666.0	399.3
Marvak	Precipitation (mm)	1971-2019	338.6	538.0	117.0
Kamandan	Precipitation (mm)	1967-2019	709.0	1114.0	261.0
Rahim Abad	Precipitation (mm)	1984-2019	461.7	763.0	258.5
Dorood	precipitation(mm)	1992-2019	660.0	1017.0	374.0
Dareh Takht	Precipitation (mm)	1967-2019	726.5	1255.6	372.0
Cham Zaman	Precipitation (mm)	1966-2019	489.8	822.0	230.0
Ab Baryk	Evaporation (mm)	1972-2019	1729.0	2727.5	911.3
Kazem Abad	Evaporation (mm)	1985-2019	2163.3	3765.9	49.0
Ali Abad	Evaporation (mm)	1994-2019	1754.4	2382.6	1231.1
Rahim Abad	Evaporation (mm)	1989-2019	1864.0	2194.4	1537.6
Ali Abad	Temperature (°C)	1994-2019	17.7	21.1	15.1
Rahim Abad	Temperature (°C)	1989-2019	13.9	16.4	12.2
Kazem Abad	Temperature (°C)	1985-2019	10.4	13.1	8.5
Tele Zang	Temperature (°C)	1994-2019	24.5	26.0	23.3
Tange Mohamad Haji	Discharge (m3/s)	1985-2019	2.4	4.4	0.9
Galeh Roud-Venaee	Discharge (m3/s)	1969-2019	2.1	3.1	1.2
Sarab E Sefid-Venaee	Discharge (m3/s)	1973-2019	1.7	3.0	1.2
Kamandan	Discharge (m3/s)	1967-2019	1.5	2.3	0.7
Dorood-Marbooreh	Discharge (m3/s)	1955-2019	7.9	30.7	2.9
Doorod-Tireh	Discharge (m3/s)	1955-2019	14.1	40.2	3.0
Dareh Takht- Marboreh	Discharge (m3/s)	1958-2019	6.3	21.4	2.6
Dareh Takht-Dareh Takht	Discharge (m3/s)	1955-2019	1.4	2.3	0.6
Cham Zaman	Discharge (m3/s)	1961-2019	2.7	14.6	0.0
Biatun	Discharge (m3/s)	1975-2019	0.4	1.1	0.1
Rahim Abad	Discharge (m3/s)	1977-2019	5.3	27.4	0.0

Source of data: Meteorological Organization and Ministry of Energy of Iran

the processing level in all of the satellite images used is L1TP- T1. Due to the mountainous nature of the main part of the area, September is the most suitable month to study the area's land use, and the vegetation in rain-fed lands and pastures will be clearly separable. Software Envi5.3 was used to prepare land use maps. First elevation and geometric corrections were made on the Landsat TM images. The OLI images were free of any radiometric errors and cloud cover; in addition, these images didn't need geometric corrections. In order to correct the geometry and elevation of the Landsat TM images (using 1: 25000 topographic maps), a digital elevation model of the study area (with an accuracy of 10 meters) was prepared; then some points were selected as training points, and elevation corrections were performed and referred to using these land points. Using the collected data from the field visits, training points in different land-uses were selected. Also, the maximum-likelihood classification method was used to prepare land-use maps for 5 different years (1983-1990-2000-2010-2019) in the Dez river sub-basin. The correctness and accuracy of maps were evaluated using Kapa Coefficient and Overall Accuracy.

For assessment of influence of climate and land use on river discharge, structural equation model (SEM) was used. In this research, Smart PLS 4 was implemented for data analysis. the SEM was sonstructed based on conseptual model that showed in figure 2. In conceptual model laten variables include climate, land use and river discharge. annual Precipitation, temperature, evaporation, percent of agriculture, forest and range land, urbane area and river discharge are observed variables.

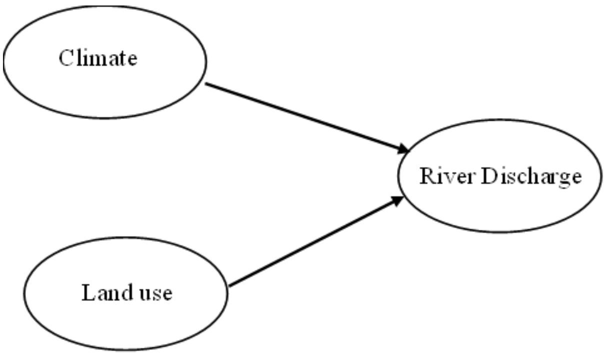


Fig. 2. Conceptual model of the effect of land use and climate parameter on the river discharge

all of sub basins data were interred to the model and model was runed for all sub_basine Percentage of land use area was used for standardized of land use data, and specific discharge was used instead of river discharge. model fit was evaluated by coefficent determination, Goodness of fiting (GOF), Minimum Discrepancy per Degree of Freedom (CMIN/df) and root mean squer error of approximation (RMSEA).Table 4 Showes the adaptation criteria or thresholds.

Table 4. Evaluation metrics of SEM goodness-of-fit-test (Wang et al., 2017)

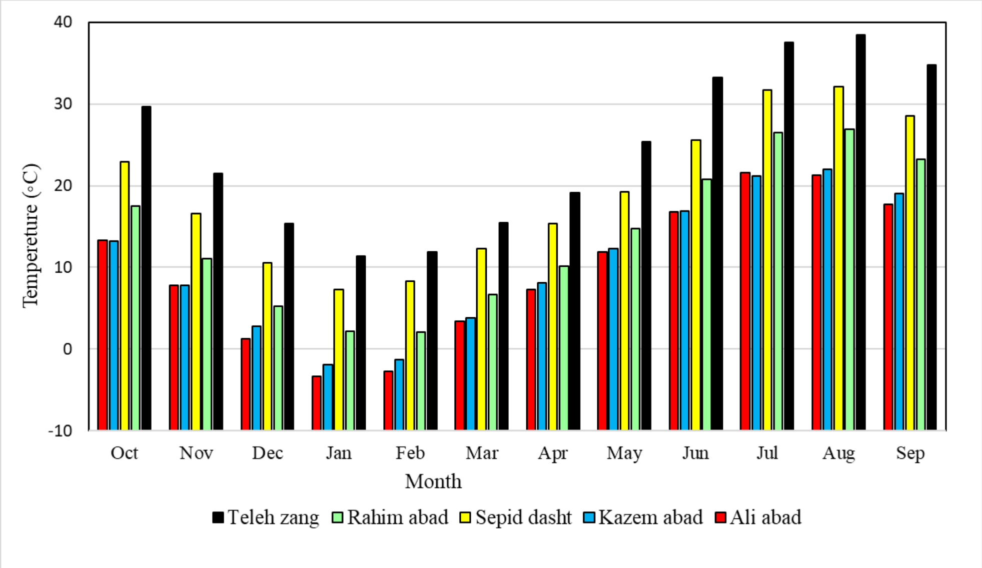
Statistics	Weak	Moderate	Strong
Goodness-of-Fit (GOF)	0.1	0.25	0.36
Root Mean Square Error of Approximation (RMSEA)	>0.1	<0.06	<0.05
Minimum Discrepancy/ Degree of Freedom (CMIN/DF)	>3	3-2	<2

3. Results and Discussion

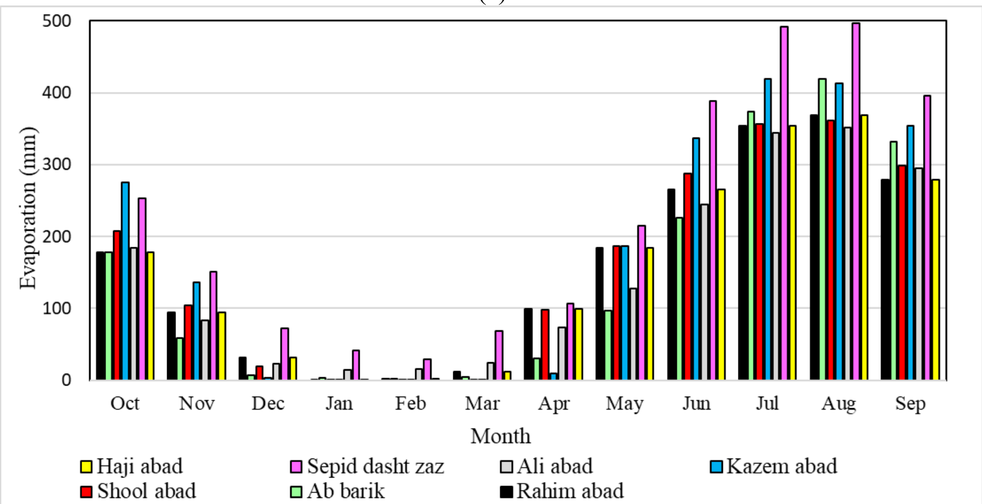
In this section is presented results of trend analysis, land use change and effects of land use and climate changes on river discharge. A summary of hydro-meteorological variables data characteristics used in this study is presented in figure (Fig.3).

Figure 3 shows that all hydrological stations have low discharge in summer and fall; maximum discharges have occurred in winter and spring. Also, this figure illustrates that precipitation in summer is the lowest and in winter is maximum. Temperature and evaporation in winter were low and in summer and spring were high. The p-value based on the modified Mann–Kendall trend test of annual and monthly streamflow are reported in Table 5.

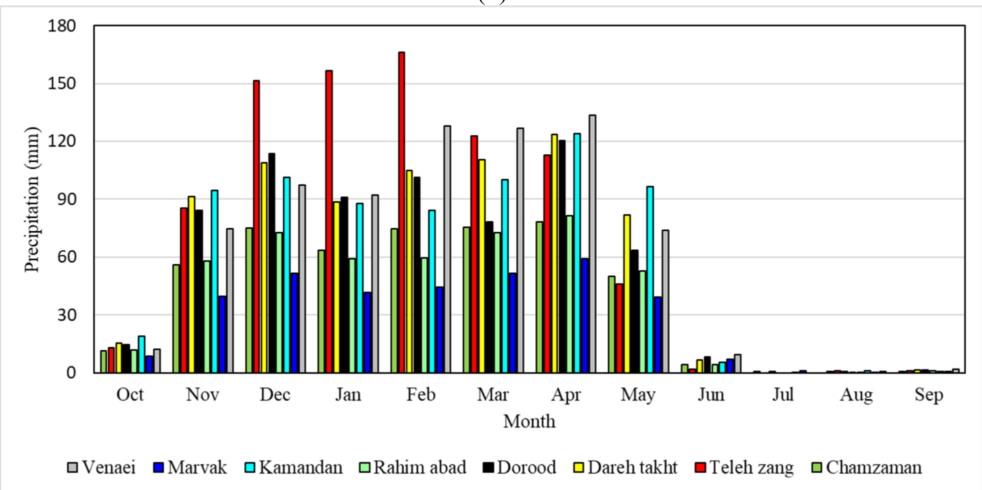
Using the above tests, the time series trend and climate variables were examined in 11 sub-basins of the Dez River. The results of the Modified Mann-Kendall homogeneity test showed that among 11 sub-basins studied, nine sub-basins at 95% confidence level had a significant trend in the annual flow data series, and two sub-basins had no significant trend. Similarly, the results of other studies such as Tuladhar et al. (2019), Cherinet et al. (2019), Meng-Xia et al. (2020), and Zhang et al. (2020), which evaluated the significant reduction in river flow rate, approved the results of the present study.


Tempereture (◦C)
Month
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Teleh zang
Rahim abad
Sepid dasht
Kazem abad
Ali abad

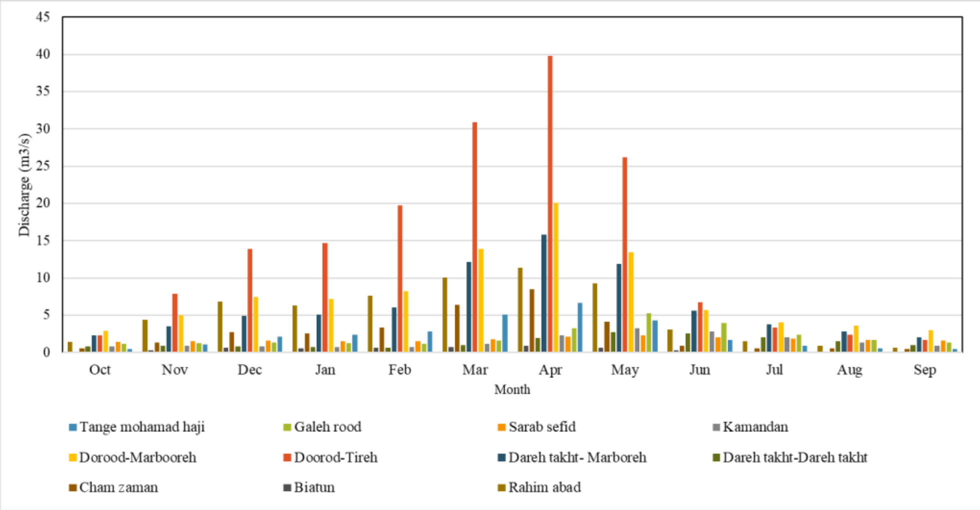
(a)


Evaporation (mm)
Month
Haji abad
Sepid dasht zaz
Ali abad
Kazem abad
Shool abad
Ab barik
Rahim abad

(b)


Precipitation (mm)
Month
Venaei
Marvak
Kamandan
Rahim abad
Dorood
Dareh takht
Teleh zang
Chamzaman

(c)



(d)

Fig. 3. Monthly mean temperature (a), evaporation (b), precipitation (c), and streamflow (d) in climatic and hydrological stations in Dez River sub-basins

Table 5. The p values based on the Modified Mann–Kendall test for the annual and monthly changes of streamflow

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Tang-E-mohamad haji	0.589	0.753	0.003*	0.026*	0.105	0.538	0.94	0.821	0.615	0.138	0.642	0.91	0.021*
Galeh rood	0.445	0.88	0.551	0.696	<0.0001*	<0.0001*	<0.0001*	<0.0001*	<0.0001*	0.023*	0.845	0.797	<0.0001*
Sarab sefid	0.584	0.422	0.611	0.037*	0.055	0.343	0.597	0.86	0.868	0.899	0.132	0.063	0.368
Kamandan	0.046*	0.034*	0.575	0.764	0.018*	<0.0001*	<0.0001*	<0.0001*	0.003*	0.273	0.302	0.211	0.03*
Dorood-Marbooreh	0.173	0.012*	0.012*	0.225	0.078	0.005*	<0.0001*	<0.0001*	0.003*	0.058	0.077	0.031*	0.009*
Doorod-Tireh	0.107	0*	0.007*	0.153	0.023*	0.032*	0.013*	0.014*	0.808	0.913	0.023*	0.004*	0.012*
Dareh takht-Marboreh	0.01*	0.001*	0.001*	0.032*	0.011*	<0.0001*	0.001*	0.001*	0.026*	0.444	0.54	0.002*	0.001*
Dareh takht-Dareh takht	<0.0001*	<0.0001*	0.004*	0.11	0.508	0.001*	0.004*	0.062	0.343	0.5	0.08	0.011*	0.799
Cham zaman	<0.0001*	<0.0001*	<0.0001*	0.039*	0.004*	<0.0001*	<0.0001*	<0.0001*	<0.0001*	<0.0001*	<0.0001*	<0.0001*	<0.0001*
Biatun	0.03*	0.024*	0.049*	0.064	0.168	0.037*	0.529	0.49	0.62	0.292	0.002*	0.005*	0.008*
Rahim abad	0.002*	0.001*	0.008*	0.023*	0.257	0.032*	0.007*	0.006*	0.004*	0.014*	0.188	0.003*	0.001*

*Significant in 95% confidence level

In monthly series, in most sub-basins, a significant trend was observed. In the Sarab e Sefid sub-basin, no significant trend was observed in monthly data. In the Galeroud sub-basin, no significant trend was observed in autumn and winter. Also, in the Biatun sub-basin, only in November, December, February, and March, a significant trend was observed. In general, according to the results of Sen's slope and Mann-Kendall homogeneity tests, it was found that 18% of sub-basins in November and 91% sub-basin in July had a significant reduction in monthly flow rate. Thus, the minimum changes in the data trend occurred during the statistical period examined in November, and the maximum changes occurred in July. Regarding the trend of seasonal changes, it was found that 63% of sub-basins in spring and summer, 36% in autumn, and 54% in winter had a significant reduction in water data series. Some of the Pettitt test Results in monthly flow rate in the sub-basins are evaluated and presented in figure (Fig. 4). The results of the Pettitt test were somewhat similar to that of the Sens slop and Modified Mann-Kendall homogeneity test, showing that in the annual series, the flow of all sub-basins studied except Sarab e Sefid and Dareh Takht showed a significantly decreasing trend at 95% confidence level. The reduction in flow rate in these sub-basins reduced from 19.9 to 77.3% compared to the long-term mean.

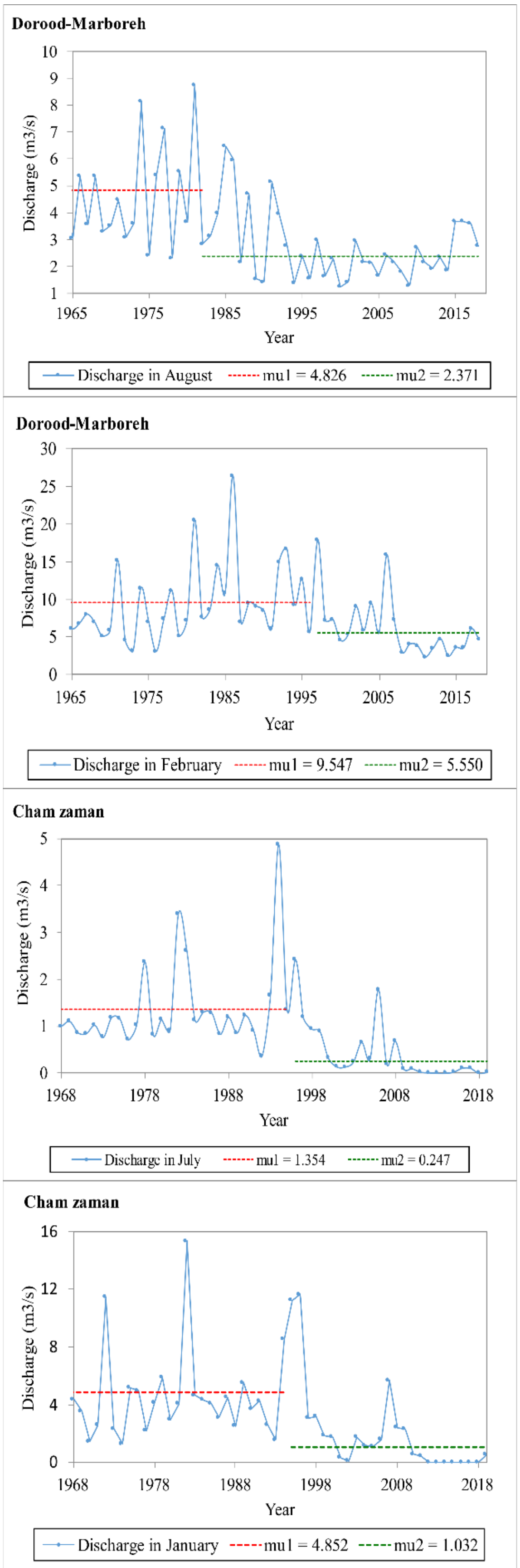


Fig. 4. The Pettitt test Results in monthly discharge in some of the sub-basins

The monthly series of 36% of sub-basins in October and 90% of sub-basins in August had significant changes at a 95% confidence level. A study of the annual and quarterly data series using this test revealed that 73% of the sub-basins in the annual data, 90% of the sub-basins in summer and spring, and 63% of the sub-basins in autumn and winter had significant changes in seasonal flow data at 95% confidence level. According to Table 6, 64.6% of sub-basins, the years 1994 and 1995, have been introduced as the years of changing in the annual flow data trend. In the other sub-basins, the years 1997, 1998, 2007, and 1971 have been determined as years of change in the flow rate trend.

Table 6. The years of changing the annual flow data in study stations

Station	Year
Rahim abad	1997
Tange mohamad haji	1998
Galeh rood	1994
Sarab sefid	1984
Kamandan	1994
Dorood-Marbooreh	1994
Dorood-Tireh	1997
Dareh takht- Marboreh	1995
Dareh takht-Dareh takht	1971
Cham zaman	1995
Biatun	2007

Using the Modified Mann-Kendall test, Sen Slope, and Pettitt test, the changes in the annual and monthly data for precipitation, temperature, and evaporation in eight weather stations in the eight regions were evaluated. Results of Modified Mann-Kendall and Sen Slope and Pettitt test in the annual precipitation are presented in Table 7. Results showed no significant changes in the annual rain in all stations, except in Venaee Teleh zang and Cham zaman, which had a significant decreasing trend, and Sen's slop showed all stations have a decreasing trend except in Marvak. Other studies also showed that in the world, the amount of precipitation does not have a significant decreasing trend(Abou Rafee et al., 2020; Cherinet et al., 2019; Guo et al., 2019; Higashino and Stefan, 2019; Vafakhah et al., 2013; X. Zhang et al., 2019).

The results for the monthly series are similar in three methods. The precipitation has a significant (P<0.05) decreasing trend in Venaee and Cham zaman stations during January and February (Fig. 5). In three stations, Kamndan, Rahim adab, and Dorood, not a decreasing trend were observed during any month. The decreasing trend was observed in other stations during the dry month (September). One station (Marvak) showed a significant increasing trend in the rain during the high rain month (March), but the increase was not high enough to increase the annual rain.

Table 7. Amount of Sen's Slope, P values of Modified Mann-Kendall and Pettitt test in the annual precipitation data.

Station	Cham zaman	Teleh zang	Dareh takht	Dorood	Rahim abad	Kamandan	Marvak	Venaee
Modified Mann -Kendall test	0.021*	0.091	0.086	0.180	0.420	0.408	0.948	**0.035***
Sen's slope test	-3.70	-5.58	-4.32	-8.04	-1.33	-2.64	0.07	**-5.80**
Pettitt's test	0.065	0.035*	0.070	0.084	0.250	0.296	0.419	**0.002***

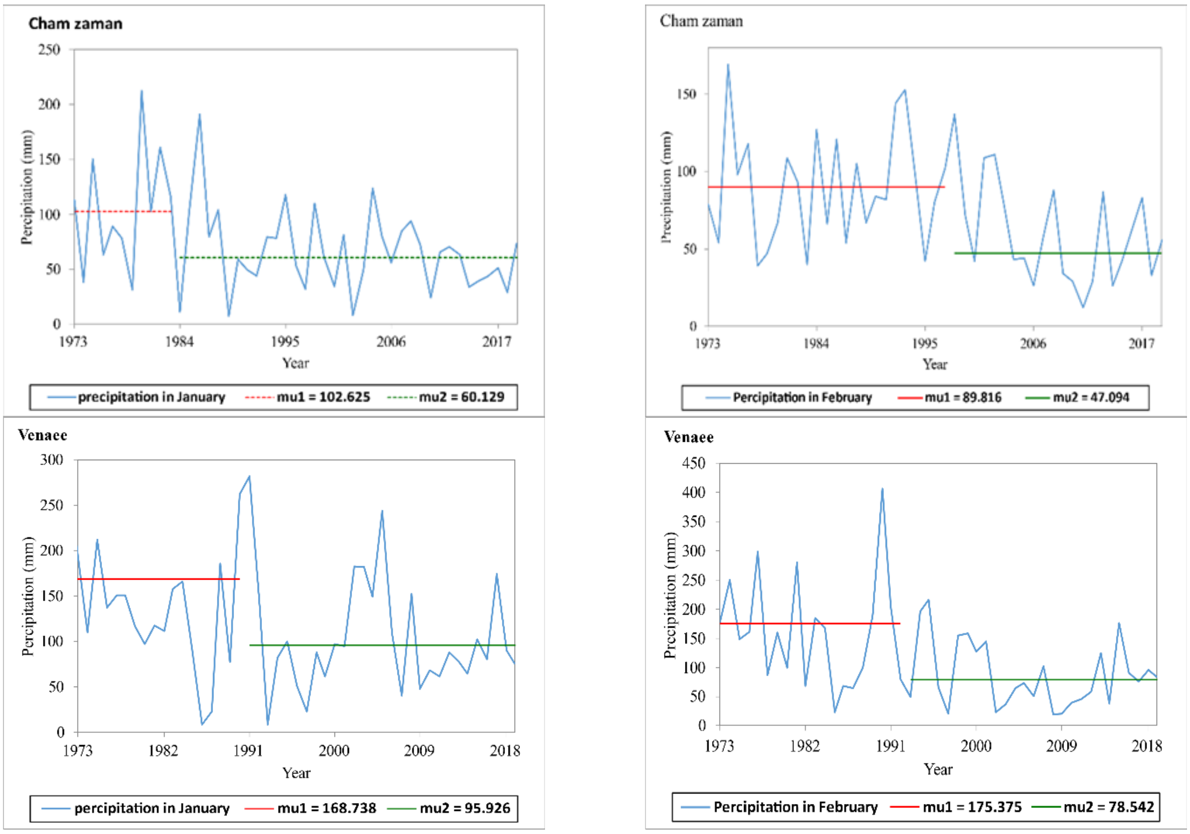


Fig. 5. The Pettitt test results in monthly precipitation in some of the stations.

Most stations showed no significant trend in the monthly temperature and the evaporation, but Sen Slop showed an increasing trend. Other studies also showed that the amount of evaporation and temperature have an increasing trend (Bahrami et al., 2019; Bai et al., 2019; Dinpashoh et al., 2019; Lotfi et al., 2020; Wang et al., 2019). Average monthly amount temperature and evaporation Sen's Slop in all stations showed in figures (Fig 6 and 7).

According to the results obtained from the studied sub-basins, the changes in flow rate and climatic parameters were examined in each sub-basin. The results of the tests showed that in Marboreh- Dareh Takht sub-basin, a decreasing trend was observed in all months of the year except November and October. The flow rate reduced significantly from 34 to 65% in different months of the year, compared to the long-term mean of the same months according to the Pettitt test. The results also showed that in this sub-basin, monthly evaporation series in all months of the year except November, December, January, and February had a significant increasing trend in other months of the year so that evaporation in this area increased from 30 to 80% to the long-term mean of the same months.

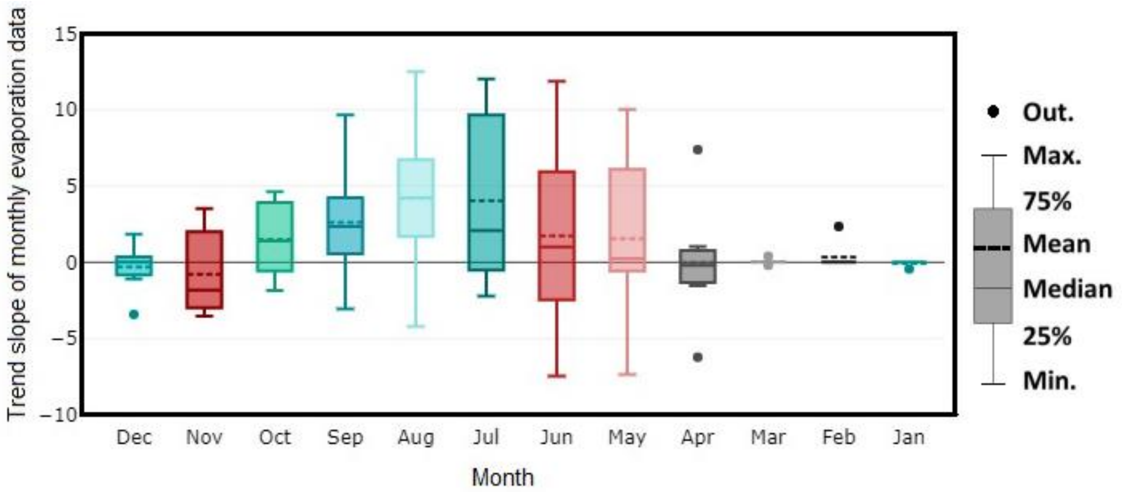


Fig. 6. The box plot of the trend by Sen's Slop test for the mean monthly evaporation data in all station

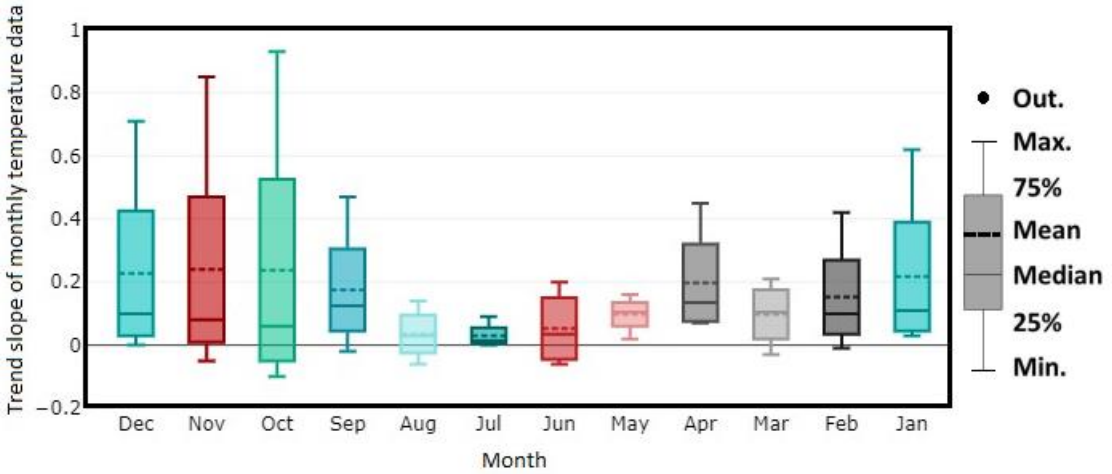


Fig. 7. The box plot of the trend by Sen's Slop test for the mean monthly temperature data in all station

However, the mean monthly temperature in this area in most months of the year showed no significant trend at 95% confidence level, but the increasing trend according to Sen's slope test results can be observed in this area. Also, precipitation showed no significant decreasing or increasing trend.

In Dareh Takht - Dareh Takht sub-basin, the results of the Modified Mann-Kendall homogeneity test showed that in July and August, the changes in the series of monthly flow at 95% confidence level has a significant decreasing trend. In December, January, February, and March, the flow rate showed a significant increasing trend. No significant trend is observed in other months of the year and annual series. The results of the Pettitt test showed that in June, July, and August, the flow rate reduced by 36.6, 63.1, and 65.7%, respectively, compared to the long-term flow of the same months, and increased in March, January and February by 54, 58 and 65%, respectively. For evaporation in this sub-basin, it can be said that a significant increasing trend was observed in all months of the year, according to Modified Mann-Kendall homogeneity and Sen's slope tests. In addition, the results of the Pettitt test showed that in this basin, evaporation in spring, summer, and mid-autumn months has increased from 30 to 80% compared to the mean of similar periods. The annual temperature also had an increasing trend, and the annual temperature in this area has increased by 2.4 degrees in recent years compared to the long-term period. Also, precipitation had no significant trend.

In the Galeroud Venaee sub-basin, a significant reduction was observed in May to October, which was up to 50% in annual flow and 53 to 64% in monthly flow compared to the long-term mean in similar series. Precipitation in this sub-basin in April and March had a significant reduction so that according to the results of the Pettitt test, annual precipitation of 354 mm from 1986 to 2017 has reduced compared to the mean of the whole study period. Also, in March and February, it reduced by 76 and 56%, respectively, compared to the long-term mean in the same months. An increasing trend can also be seen in the time series of temperature, but this trend is not significant. Since June to September, the mean evaporation rate showed a significant increase by 23 to 38% compared to the long-term mean in the same months according to the Pettitt test and reduced significantly by 64 and 29%, respectively in December and November.

In Ab Sefid Venaee sub-basin during the study period, no significant trend was observed in the monthly and annual data series of flow rate, but in April, Modified Mann-Kendall homogeneity and Sen's slope tests showed a significant increase in flow rate. In this area, Modified Mann-Kendall homogeneity and Pettitt tests showed no significant trend in evaporation and temperature series data. In addition, no significant trend was observed in precipitation data, but the decreasing trend can be seen in these data according to Sen's slope.

The results of Modified Mann-Kendall homogeneity and Sen's slope tests showed that a significant decreasing trend was observed in the Kamandan sub-basin in all months of the year and the annual series, except for the months of autumn, March, and April. The results of the Pettitt test showed that the flow rate had a significant 27% annual reduction compared to the long-term mean. From May to September, the flow rate has shown a significant reduction of 33 to 59 percent compared to the long-term mean of similar months, and in January and February, it has increased significantly by 40 to 45%. A study of precipitation time series also showed that no significant trend was observed in time series in this sub-basin. The rate of evaporation in all months of the year except September and November showed a significant increasing trend. Pettitt test showed an increase by 24 to 86% in evaporation in the months of the year except for January and February compared to the long-term mean of similar months. Also, temperature showed an increasing trend according to the tests performed in most months of the year.

The Modified Mann-Kendall homogeneity test results in the Marboreh-Dorood sub-basin showed that a significant decreasing trend was found from June to September and in winter. Also, the annual flow rate has shown a significant decreasing trend and reduced by 54%. Precipitation in this sub-basin only in March has shown a significant decreasing trend that Pettitt test estimated this change in the mean precipitation as 55 to 560% in these two months. Evaporation has shown a significant increase in all months of the year except January and February, and temperature also showed a significant increasing trend in monthly and annual series.

At hydrometric station Cham Zaman, a significant reduction was observed in flow rate in all months of the year, as well as in the annual series. In the months of the year, the reduction was 79 to 95% lower than the pre-change period, and the annual flow rate was 80% lower than before the change. Also, evaporation had a significant increasing trend in almost all months of the year. However, precipitation showed a significant decreasing trend in March and February, with the Pettitt test showing a 55 and 56% reduction in precipitation compared to similar months in the long run. According to the results of Modified Mann-Kendall homogeneity and Sen's slope tests, the annual precipitation has also shown a significant decreasing trend.

No significant trend was found in the monthly series of flow in Tang e Mohamad Haji sub-basin according to the Modified Mann-Kendall homogeneity test, but Sen's slope indicated a decreasing trend in flow rate in all months of the year. The annual flow rate in the post-change period has reduced by 79%. Pettitt test also showed a significant decreasing trend in April, May, March, and October, which is up to 81% compared to the period before the change. Evaporation and temperature in July and August had a significant increasing trend, but no significant increase was observed in the annual data. Also, precipitation showed no significant increasing or decreasing trend.

The results of Modified Mann-Kendall homogeneity and Sen's slope tests in the Biatun sub-basin showed that in June, April, December, January, February, and March, a significant decreasing trend was observed in the monthly series of flow. The annual data also showed a significant decreasing trend. The results of the Pettitt test showed that in

March, February, December, and January, flow data had a significant reduction of at least 25 to 41%. The mean annual flow has reduced by 35% since the data trend changed. The temperature in this sub-basin had no significant increasing trend, but Sen's slope showed a slight increase in all months of the year. Evaporation has increased significantly in most months of the year. Also, precipitation showed no significant trend in either method.

In the Tireh-Dorood sub-basin, it was found that the decreasing trend of flow is observed in all months of the year, but in September, April, October, and January, the trend was not significant. Pettitt test showed no significant trend in October and September, but in other months of the year, the decreasing trend is significant, and the mean monthly reduction in flow is 45 to 83%. The annual flow has reduced by 48% compared to the pre-change period. The temperature in this sub-basin showed no significant change in the trend, but the rate of evaporation in all months of the year had a significant increasing trend. Precipitation also lacked a significant increasing or decreasing trend.

The Sarab e Sedif and Dareh Takht are the smallest sub-basin in the Dez basin. In these sub-basins, the annual discharge did not change significantly. These sub-basins are located in mountainous areas, the population is small, and agriculture is not widespread. Consequently, water demand in these sub-basins is low. Therefore, in these sub-basins, no significant change in annual discharge was observed during the study period.

Given the jump time in flow data in each sub-basin, land use maps were prepared before the change using Landsat satellite images. Given that the year of change in most sub-basins was in the 1994 to 1998 period, the images related to 1983 were selected as before the change, and the images of 2019 were selected for the images of the period after the change.

In order to evaluate the change in the land application, the land application maps for the period between 1983, 1990,2000,2010 and 2019 were applied. Table 8 includes the results regarding the accuracy of the application.

Table 8. Overall accuracy and Kappa coefficient for classified images by maximum likelihood method

Year	Kapa Coefficient	Overall accuracy (%)
1983	0.88	90.2
1990	0.84	89.3
2000	0.89	90.4
2010	0.90	92.8
2019	0.90	92.5

The percentage of land use is presented in figure (Fig. 8), which shows that ranges and forests decreased in 37 years in all sub-basins. The ranges and forests lands areas turned to agricultural and urban areas in some of the sub-basins. Land use maps are provided in the current context and before the change in figures (Figs. 9 and 10).

The maps show that 30% of rangeland has been converted to agricultural land during the study period, as well as residential areas that have developed significantly over the years. The results of the SEM coefficient evaluation were showed in Table 9. This model represented that all of the coefficient paths for observed variables significantly affect later variables (Fig. 11). Also, the model showed that land use had a significant negative effect (0.05>P), and climate variables had a significant positive impact (0.1>P) on river discharge. Also, results showed that the increase in agriculture and the urbane area negatively affected river discharge as water consumption is high in urban and agricultural areas.

On the other hand, the correlation between climate and land use and discharge was 0.43, which indicates that climate and land use can partially determine the discharge variance. Therefore, we concluded that an effective factor on the river flow rate is the land-use change and this result was approved by some researches (Adeyeri et al., 2020; Tao et al., 2011; Wu, 2008; Zhang et al., 2014; Zhang et al., 2020).

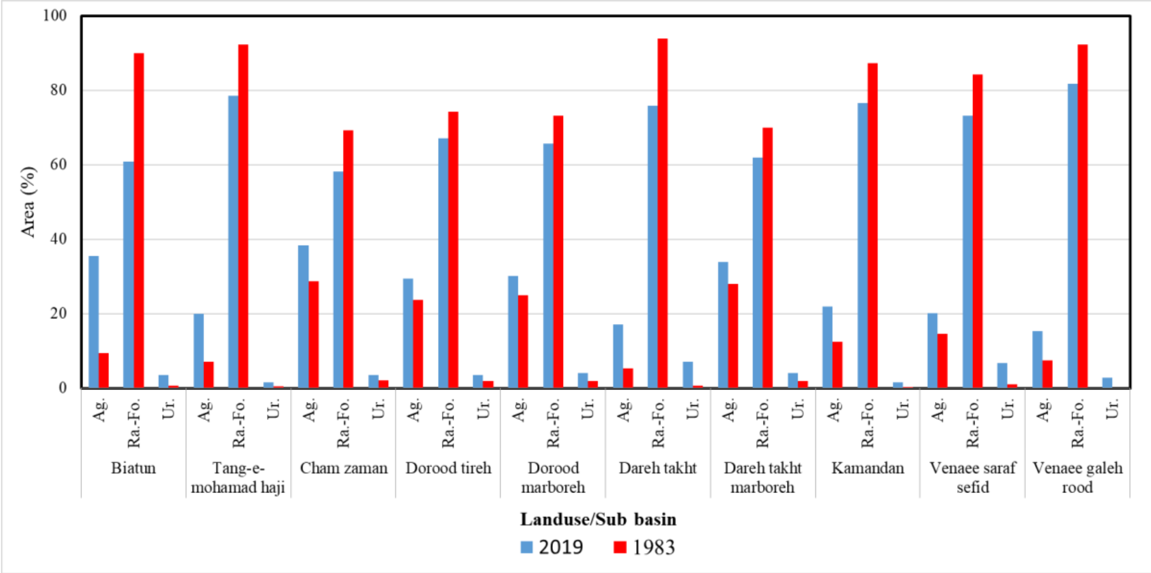


Fig. 8. Percent of the land-use area in 1983 and 2019 on sub-basins. (Ag. = Agricultural, Ra. Fo. = Rangeland and forest, Ur. =Urban)

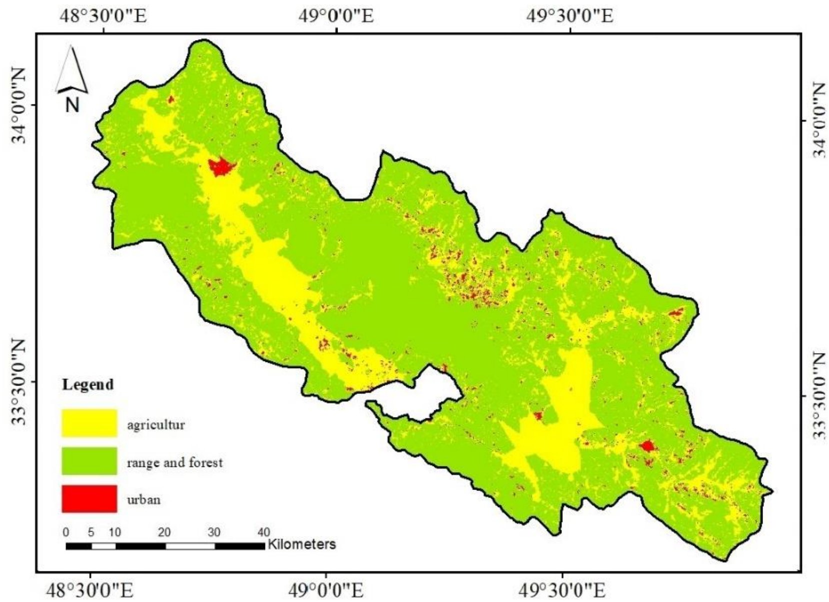


Fig. 9. Land use map of the study area in 1983

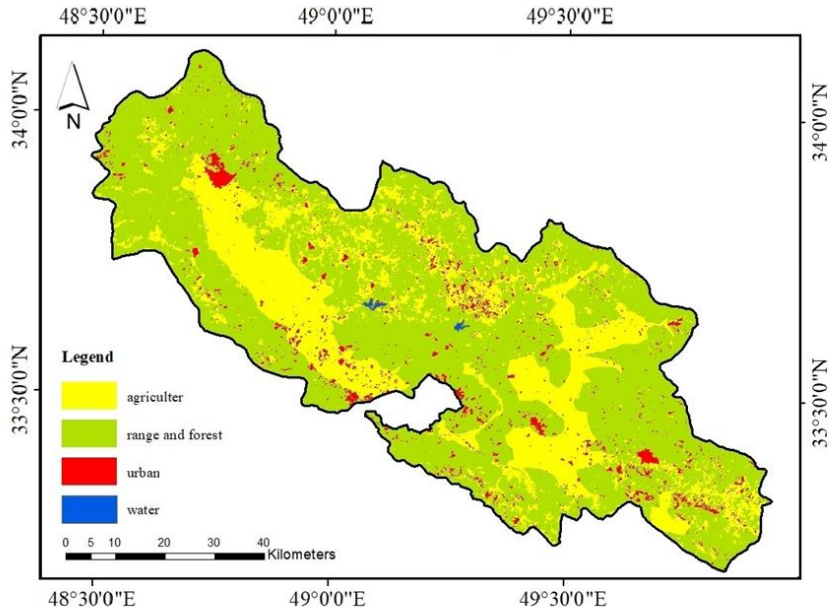


Fig. 10. Land use map of the study area in 2019

Table 9. Structural equation model coefficient

latent variable	observed variable	Outer Loadings	Outer Weights	total effect
Land use	Agriculture area	0.92	0.59	-0.59
	Forest and range land area	-0.83	-0.45	
	Urbane area	0.55	0.15	
Climatic parameter	Precipitation	0.63	0.68	0.16
	Temperature	0.58	0.59	
	Evaporation	0.52	0.44	

In order to verify the credibility of model results, were selected RMSEA, GOF and CMIN/DF values. The results for RMSEA, GOF and CMIN/DF are shown in Table 10. GOF showed that this model structur was strong in the study area and RMSEA and CMIN/DF sugessted moderate performance of the model structure.

Table 10. Fit statistics for structural equation model

statistic	Value
GOF	0.522
RMSEA	0.067
CMIN/df	2.306

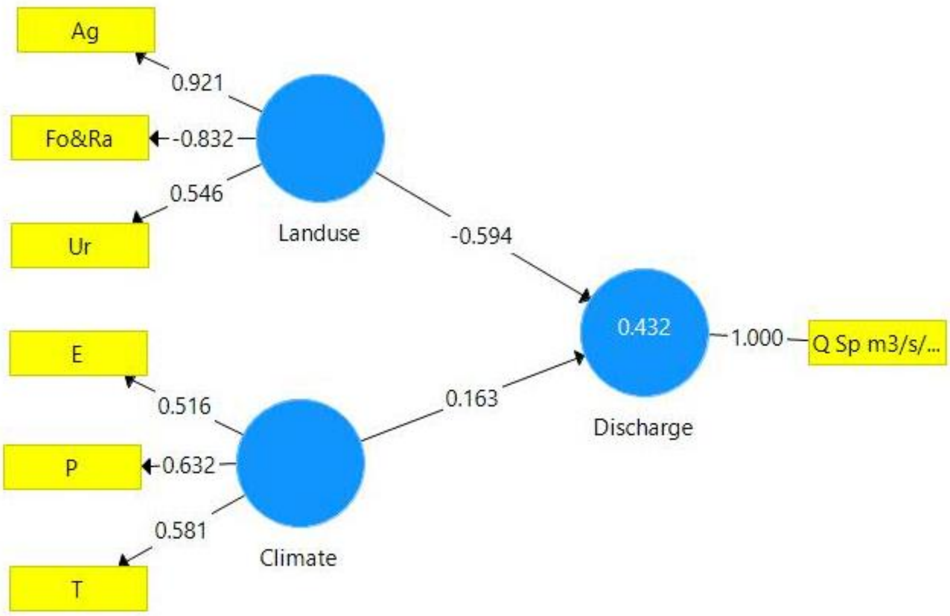


Fig. 11. Final SEM for river discharge, Ev: evaporation, P: precipitation, T: temperature, Ag: Agriculture area percentage, Fo&Ra: Forest and rangeland area percentage, Ur: Urbane area percentage, Q: River discharge.

According to the SEM results, land use and climate could identify just 43% of discharge variance and for obtain the better model for simulate river discharge must inter other parameters like soil, geology, slope to model.

4. Conclusions

Climate change and human activities worldwide have affected various phenomena, including the water cycle and available water resources. The water crisis and lack of available water resources are among the most critical problems in Iran. Results showed that the annual flow rate had a decreasing trend and there is no significant decrease in precipitation in all stations. In addition, the annual and monthly temperature and evaporation series at most stations significantly increased. Also, land use changes were occurred intensively and results of SEM showed that The direct, indirect and total effects of land use types and climate factors on discharge were detrenined, and ingeneral land use types had significant negative direct impacts on discharge.

The results of this study provide a new insight on how to quantify the impact of human activities and climate change on the hydrology of the riverdischarge, and can also be used as a scientific reference for water resources planning and management decisions of other similar regions.

landuse changes affect the amount of water demand and water usage because of increasing the temperature and evaporation. To accurately evaluate the river flow changes, the alteration of the cultivated area of different crops, the water demand of different crops, the amount of water abstraction from rivers, and human effects should be known. These data are not available for the Dez River basin.

This study recommends that authorities consider land use, water usage, and climate change to estimate water availability, water management and preserve this area from the water crises on these sub-basins.

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6. Disclosure Statement

No potential conflict of interest was reported by the authors

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