ISSN: 2538-2152; ECOPERSIA 2024;12(3):219-231.

Tarbiat Modares University

Flood Peak Discharge Trend over Iran

ARTICLEINFO

Article Type
Original Research

Authors
Mehdi Vafakhah, *Ph.D.*[1*]
Hamed Beigi, *Ph.D. Student*[2]
Kazem Sadeghian, *Ph.D. Student*[2]
Hamid Khodamoradi, *Ph.D. Student*[2]
Samira Karimi Breshneh, *Ph.D. Student*[2]
Fatemeh Daeichini, *Ph.D. Student*[2]
Samira Hossinpour, *Ph.D. Student*[2]
Saied Derakhti, *Ph.D. Student*[3]

How to cite this article
Vafakhah M., Beigi H., Sadeghian K., Khodamoradi H., Karimi Breshneh S., Daeichini F., Hossinpour S., Derakhti S., Flood Peak Discharge Trend over Iran. ECOPERSIA 2024;12(3): 219-231.

DOI:
10.22034/ECOPERSIA.12.3.219

[1] Professor, Department of Watershed Management Engineering, Faculty of Natural Resources, Tarbiat Modares University, Noor, Mazandaran, Iran.
[2] Ph.D. Student of Watershed Management Sciences and Engineering, Department of Watershed Management Engineering, Faculty of Natural Resources, Tarbiat Modares University, Noor, Mazandaran, Iran.
[3] Ph.D. Student of Watershed Management Sciences and Engineering, Faculty of Natural Resources, Sari Agriculture Science and Natural Resource University, Iran.

**** Correspondence***
Address: Professor, Department of Watershed Management Engineering, Faculty of Natural Resources, Tarbiat Modares University, Noor, Mazandaran, Iran.
Tell: +989123179699
Fax: 01144554399
E-mail: vafakhah@modares.ac.ir

Article History
Received: March 11, 2024
Accepted: September1, 2024
Published: September 14, 2024

ABSTRACT

Aims: Studying flood peak discharge trends is crucial to disaster risk reduction in developing countries like Iran. This study aims to analyze the instantaneous peak discharge trend in 301 hydrometric gauge stations using Mann Kendal (MK) and Sen's Slope estimator tests over Iran.
Material & Methods: Data on all existing hydrometric gauge stations in Iran were downloaded from Iran Water Resources Management Company. The hydrometric gauge stations with at least 20 years of data were selected, and the stations that were then affected by the dams were removed. Trend analyses of instantaneous peak discharge were conducted using MK and Sen's slope estimator tests.
Findings: The results showed that out of 301 hydrometric stations, 259 stations have no trend, only three stations have a decreasing trend, and 39 stations have an increasing trend. This trend is more evident in southwestern Iran, where the increase in agriculture, human activity, and climate change is more evident. In the watershed of the eastern border, only one station has a decreasing trend; in the central plateau, four stations have a decreasing trend, and the rest have no trend.
Conclusion: Due to the importance of peak discharge in flood damage, this research can help managers and decision-makers in integrated watershed management. For example, in flood control projects, as well as designing the dimensions of structures such as retard dams, levees, the height of flood control walls, and bridges.

Keywords: Climate Change; Mann-Kendall; Integrated Watershed Management; Flood; Iran.

CITATION LINKS

[1] Norouzi G., Taslimi M. The impact of flood damages on production of Iran's Agricultural Sector.... [2] Pawar U., Try S., Muttil N., Rathnayake U., Suppawimut W.... [3] Saatsaz M. A historical investigation on water resources management in Iran. Environ. Dev. Susta... [4] Madani K., AghaKouchak A., Mirchi A. Iran's... [5] Collins G. Iran's Looming Water BankruptcyJames A. Baker III Institute for Public Policy. 2017; ... [6] Ketabchy M. Investigating the impacts of the political system components in Iran on the existing... [7] Goharian E., Azizipour M. Integrated Water Resources Management in Iran: Cases from Africa, Asia... [8] Zhang X., Harvey K.D., Hogg W.D., Yuzyk T.R. Trends in Canadian streamflow. Water Resour. Res. 2... [9] Gharekhani A., Ghahreman N. Seasonal and annual trend of relative humidity and dew point tempera... [10] Feizi V., Mollashahi M., Farajzadeh M., Azizi G. Spatial... [11] Nazeri Tahrudi M., Khalili K., Ahmadi F. Spatial and... [12] Ahmadi F., Nazeri Tahroudi M., Mirabbasi R., Khalili K., Jhajharia D. Spatiotemporal trend and a... [13] Yacoub E., Tayfur G. Trend analysis of temperature and precipitation in Trarza region of Maurita... [14] Yousefi Malekshah M., Ghazavi R., Sadatinejad S. Evaluating the Effect of Climate Changes on Run... [15] Das S., Banerjee S. Investigation of changes in seasonal... [16] Khosravi A., Azari M. Spatio-temporal trend and change detection of temperature and precipitatio... [17] Bazarzhapov T.Z., Shiretorova V.G., Radnaeva L.D., ... [18] Bayat-Afshary N., Danesh-Yazdi M. Are the magnitude and frequency of floods increasing in Iran d... [19] Najafi M.S., Alizadeh O. Climate zones in... [20] Yue S., ... [21] Gilbert R.O. Statistical methods for environmental pollution monitoring: John Wiley & Sons. 1987... [22] Sen P.K. Estimates of the regression coefficient based on Kendall's tau. J. Am. Stud. 1968; 63(3... [23] Hirsch R.M., Slack J.R., Smith R.A. Techniques of trend analysis for monthly water quality data.... [24] Vafakhah M., Bakhshi T.M., Khazaei M. Analysis of rainfall and discharge trend in Kashafrood Wat... [25] Bihrat Ö., Bayazit M. The power of statistical tests for trend detection. Turk. J. Earth. Sci. 2... [26] Hamed K.H., Rao A.R. A modified Mann-Kendall trend test for autocorrelated data.J. Hydrol. 1998;... [27] Alijani B., Mahmoudi P., Chogan A. A study of annual and seasonal precipitation trends in Iran u... [28] Masoudi M., Elhaeesahar M. Trend assessment of climate changes in Khuzestan Province, Iran. Nat.... [29] Nazeri Tahrudi M., Ahmadi F., Khalili K. Evaluation the trend and trend chang point of Urmia Lak... [30] Rahimi D., Khoshhal Dastjerdi J., Rahimi D. Trend analysis of maximum flood in the Karkheh basin... [31] Moradi M., Bazrafshan O., Bahremand A., Esmailpour Y. ... [32] Pirnia A., Habibnejad Roshan M., Solaimani K. Investigation of precipitation and temperature cha...

Introduction

In today's society, floods and storms have the biggest losses and destructive damages among natural disasters, according to statistics provided by the United Nations. Iran is experiencing an increase in the frequency of severe floods that cause significant environmental harm. The losses include human damage, flooded houses, residential and industrial places, and farms [1]. To be prepared to deal with this problem, conducting relevant research is necessary. To manage water availability, it is vital to understand river flow fluctuations and the variables that generate them. Additionally, severe rainfall incidents across a river watershed coupled with floods are the most repeated, fatal, and pervasive natural hazards worldwide, causing significant damage to life and financial losses [2]. Incorporating such challenges with political, wellness, environmental, and long-term stability matters has significantly raised the demand for problem management [3]. Furthermore, in today's world, growing populations, industrial expansion, and unprecedented civilization have created numerous challenges for the water services sector, in addition to drought and changing climates. Iran is facing a massive problem and an extreme water shortage situation. This is commonly referred to as water scarcity or bankruptcy [4,5,6]. Iran is placed in an arid and semi-arid environment; the current water issue results from human and natural factors. While natural causes are beyond human control, integrated water resources management solutions can help achieve sustainable planning and management of water resources [7]. Due to the importance and applicability of the topic, various research studies about determining the monthly, seasonal, and annual trends of rainfall, temperature, and discharge variables have been conducted worldwide. In Europe and North America, the changes in the observed data of minimum and average annual flows in 21 stations were considered over a statistical period of more than 100 years. The trend of changes was determined using the Mann Kendal (MK) test and linear regression. Their results indicated no significant trend in streamflow[8]. Also, in a study in Canada, the changes in trends in 11 hydroclimatology variables over 243 hydrometric gauge stations were examined over a statistical period of 30 to 50 years. MK test was used after removing the effect of data autocorrelation. According to the results, it was shown that the mean annual streamflow in the study area has a significant negative trend.The meteorological variables trend were investigated in several climatic regions in Iran using the MK test, Spearman correlation coefficient, and regression methods [9]. Based on the result, the highest increasing trend occurred in the summer, and the lowest decreasing trend happened in the fall. The trend of temperature and precipitation in Iran in 60 stations using the MK test was investigated. The results showed that the studied parameters showed a significant trend [10]. In another study in Iran, the annual rainfall trend was analyzed on 31 synoptic station data using fuzzy clustering and the MK test. The studied stations were divided into five regions. A decreasing trend in station and regional scales was confirmed in northwest Iran [11]. The trend of temperature data in Iran was analyzed using the MK test. The results demonstrated that the temperature increased in autumn, spring, and summer during the statistical period of 1961-2010. The most frequent change points occurred between 1986 and 1994 [12]. Climatic parameters such as precipitation and temperature trends in Mauritania were studied. The results revealed that during the statistical period of 1970-2013, there was an increasing trend for both precipitation

[DOI: 10.22034/ECOPERSIA.12.3.219]

and temperature variables [13]. Analyses and predictions of temporal pattern changes in runoff, maximum discharge, and drought indexes were also conducted. The findings indicate that there will be more flood dangers and river overflow in the future (2021–2080) than during the observation period[14]. MK test was explored to examine seasonal flow changes with sediment load. The outcomes showed that the upstream flow has been substantially reduced [15]. In another study, the trend of precipitation and temperature were examined in the Kasha River basin during the statistical period of 1986-2017. The results of the MK and Pettit tests stated that there is no significant precipitation trend. Meanwhile, the temperature is increasing on an annual scale[16]. Following similar research, precipitation and runoff at hydrometric gauge stations were studied. Runoff analysis revealed negative trends at the two stations[17]. Finally, another study evaluated the relationship between climate change and flood frequency. This study examined the spatial distribution, slope, and relevance of long-term trends in extreme precipitation and the spatial distribution of long-term trends for flood volume and frequency using 50 years of precipitation and streamflow data collected throughout Iran. In 60% of Iran's sub-watersheds, the trend for extreme precipitation was declining, but the trend for flood magnitude was rising [18]. There have not been many attempts to analyze Iran's peak discharge problem. Nevertheless, the study deficit exists because these studies have mostly concentrated on certain watersheds or aspects of the issue. In this way, the process of changes in instantaneous peak discharge has not been widely done in Iran so far, and due to the importance of the role of peak discharge in the occurrence of floods as well as the damages, this is the first study that analyzes peak discharge in Iran's scale. This study aims to analyze instantaneous peak discharge in the country and the reasons for its changeability. investigating the trend of peak flood discharge can help managers and decision-makers in integrated watershed management for controlling the flood and flood plains projects. Therefore, the main objective of this paper is to shed light on the investigation of the trend of instantaneous peak discharge in the whole country using the MK test and Sen's slope estimator.

Materials & Methods

Study Area

This research examined trends in the data on instantaneous peak discharge over the 1,648,195 km2 territory of Iran. Iran is located in the northern hemisphere, with latitudes between 25° and 40° N and longitudes between 44° and 63.5° E. Iran's climate can be divided into six distinct zones: cool and sub-humid, warm and semi-arid, cool and arid, warm and hyper-arid, and mild and humid. The Caspian Sea's southern coastal lowlands, known for their moderate and humid environment, receive the most precipitation. In contrast to northwest Iran, which has a cold, temperate, and semi-arid climate, western Iran has a cool, sub-humid climate. Iran's southwest is thought to have a mild, semi-arid climate, but the country's northeast has a cool and arid environment. The climates of central and southeast Iran are both hot and extremely dry. The months of March (48.6 mm) and winter (134.2 mm), together with summer (28.0°C), have the most significant monthly and seasonal precipitation and seasonal mean temperature values over Iran. Seasonal variation shows that the southern Caspian Sea coastal plains receive the most precipitation in the autumn, while southwest Iran receives the least in the summer [19].

Data Collection and Statistical Analysis

In the current research, data from all existing hydrometric gauge stations from 1996-

[DOI: 10.22034/ECOPERSIA.12.3.219]

Table 1) Results of Mann-Kendall (MK) and Sen slope tests in the river gauge stations.

Province	Code	Station Name	MK Statistics	Sen Slope	Province	Code	Station Name	MK Statistics	Sen Slope
	12-005	Tamar	-1.85^{nst}	-4.5		42-029	Bandpaeen	0.02^{nst}	0.09
	12-017	Nodeh	1.36^{nst}	3.35	Yazd	42-930	-	-0.04^{nst}	-0.04
	12-021	Ramyan	0^{nst}	0.06		46-063	Menshad	-0.18^{nst}	-0.39
	12-033	Taghiabad	0.08^{nst}	0.11		21-423	Tang zardalo	-0.12^{nst}	-0.44
Golestan	12-043	Naharkhoran	-0.98^{nst}	-0.18		21-575		0.03^{nst}	0.01
	12-049	Ghazmahlah	-0.2^{nst}	0.73	Esfehan	42-005	Eskandari	0.16^{nst}	0.73
	12-052	Bagho	0.98^{nst}	0.18		42-011	Polkaleh	-0.11^{nst}	-0.5
	12-071	Zaringol	0.19^{nst}	0.28		42-049	Lanj	0.15^{nst}	0.69
	12-085	Sangsorakh	-0.83^{nst}	-0.29		19-011	Baronchai	0.29^{nst}	0.41
	21-105	Sangsorakh	-0.12^{nst}	-0.11		19-013	Mako	-0.45^{nst}	-0.63
	21-381	Jafarabad	-0.68^{nst}	-0.18		19-031	Mosagholi	-1.97^{N*}	-2.44
	41-035	Yalfan	0.45^{nst}	0.26		19-039	Mozafarabad	-1.52^{nst}	-1.05
Hamedan	41-039	Taghsimab	-1.02^{nst}	-0.16		19-075	Badvi	0.37^{nst}	1.02
	41-041	Solan	-0.42^{nst}	-0.04		19-081	Badlan	0.23^{nst}	1.09
	41-045	Bahadurbek	-0.98^{nst}	-0.39		19-087	Malhazan	-0.08^{nst}	0.42
	41-263	Ekbatan	1.52^{nst}	0.19		19-914	Bashkand	0.54^{nst}	4.76
	41-059	Razin	0^{nst}	0		19-963	Mazraeh	-1.44^{nst}	-2.12
Markazi	41-203	Azadshahr	-1.19^{nst}	0.04		21-005	Grzhal	-0.61^{nst}	-2.42
	41-859	Razaghan	-1.22^{nst}	-0.03		33-021	Safakhaneh	-0.08^{nst}	-0.17
	15-003	Absefid	0.91^{nst}	0.12	West Azerbaijan	33-912	Alasghal	-1.15^{nst}	-0.14
	41-109	Solekhan	-0.35^{nst}	-0.33		33-916	Alasghalrast	0.62^{nst}	1.68
	41-111	Kahrizak	0.45^{nst}	0.96		33-917	Nezamabad	0.53^{nst}	3.28
	41-115	Kamarkhani	-0.94^{nst}	-0.26		33-923	Chanagha	1.67^{nst}	1.77
	41-117	Rodak	0.52^{nst}	1		33-985	Polboukan	0.77^{nst}	10.15
	41-127	Sharifabad	-1.52^{nst}	-3.93		34-011	Payghale	-0.57^{nst}	-0.94
Tehran	41-143	hafthoz	-1.33^{nst}	-0.25		34-013	Glazchai	0^{nst}	0
	41-149	Pol Djrish	1.46^{nst}	0.3		35-001	Ghasemlo	-0.23^{nst}	0.5
	41-159	Najarkala	0.21^{nst}	0.43		35-003	Bibkaran	0^{nst}	-0.04
	41-161	Narvan	-0.56^{nst}	0.01		35-005	Uromyeh	-0.41^{nst}	1.41
	41-163	Aliabad	-2.58^{N**}	-0.78		35-007	Babarod	0.7^{nst}	1.86
	41-191	Qalak	-1.82^{nst}	-0.35		35-037	Aslan	0.21^{nst}	0.44

* Significant in 0،95, ^{nst} = No significant trend, ** Significant in 0،99, ^{N}= Negative, ^{P} = Positive

[DOI: 10.22034/ECOPERSIA.12.3.219]

Table 1 Continued) Results of Mann-Kendall(MK) and Sen slope tests in the river gauge stations.

Province	Code	Station Name	MK Statistics	Sen Slope	Province	Code	Station Name	MK Statistics	Sen Slope
Tehran	41-573	-	-0.52^{nst}	-0.16	West Azerbaijan	35-039	Kalhor	-0.04^{nst}	0.23
	41-575	-	0.23^{nst}	0.02		36-001	Charigh	-1.59^{nst}	-1.66
	41-870	-	-1.3^{nst}	-0.68	Lorestan	21-163	Syab	0.86^{nst}	2.38
	41-905	Rohafza	1.14^{nst}	0.62		21-169	Kakareza	-0.05^{nst}	-1.56
	41-907	Nazarabad	-0.36^{nst}	-0.11		21-257	Sarabsefid	-0.32^{nst}	-0.09
	41-929	Ah	-1.36^{nst}	-0.13		21-259	Galehrod	-0.36^{nst}	-0.13
	41-955	Bomhen	-1.14^{nst}	0.07		21-265	Biaton	0.41^{nst}	0.06
	41-990	Nawab Safavi	0.03^{nst}	0.01		21-267	Tireh	0.05^{nst}	0.21
	47-005	Firouzkoh	-2.45^{N*}	-1.09		21-271	Chamzaman	-0.68^{nst}	-0.31
	47-007	Nimrod	-2.37^{N*}	-1.24		21-273	Kamandan	1.04^{nst}	0.39
	47-011	Simindasht	-0.49^{nst}	-0.41		21-275	Darehtakht	1.04^{nst}	0.2
	47-013	Simindasht	0.14^{nst}	0.39		21-277	Takht Valley - Marbareh	0.59^{nst}	0.71
Semnan	12-137	Pol Madrese	-0.31^{N*}	-1.07		21-461	Tang MohammadHaji	-0.5^{nst}	-0.43
	12-139	Dorahi	-0.06^{nst}	-0.14		21-966	Chenar Khoshke	-0.32^{nst}	-0.96
	47-031	Magan	-0.07^{nst}	-0.18	Mazandaran	13-005	Sefidchah	0.87^{nst}	0.75
	47-035	Farahzad	-0.15^{nst}	-0.18		13-013	Ablo	-0.61^{nst}	-3.31
	47-963	Tash sofla	-0.07^{nst}	-0.06		13-017	Darabkala	1.52^{nst}	1.42
Guilan	16-055	Drazlat	0.66^{nst}	2.78		13-021	Vastan	0.23^{nst}	0.02
	16-059	Samosh	-0.54^{nst}	-0.49		14-001	Talar	0.29^{nst}	0.6
	16-061	Shalman	0.86^{nst}	9.48		14-005	Kasilian	-1.65^{nst}	-2.62
	16-091	Bajigvar	-0.95^{nst}	-0.31		14-011	Gharan	-2.3^{N*}	-3.53
	16-093	Kelchal	-1.69^{nst}	-3.22		14-024	Sarukala	-0.68^{nst}	1.17
	16-205	Totki	-0.87^{nst}	-1.01		15-013	Baladeh	1.33^{nst}	0.45
	17-033	Gilvan	0.05^{nst}	8.01		15-015	Razan	-0.68^{nst}	0.64
	17-041	Loshan	0.37^{nst}	2.69		15-017	Karehsang	1.12^{nst}	2.32
	17-045	Tonekabon	0.37^{nst}	0.51		15-027	Chelav	0.86^{nst}	1.09
	17-055	Pashaki	-2.68^{N**}	-10.43		15-041	Bliran	-2.69^{N**}	-1.27
	17-057	Sefidrod	-1.13^{nst}	-2.01		16-011	Korkorsor	-0.49^{nst}	-0.25
	18-019	Rodbarsara	0.7^{nst}	0.29		16-019	Doab	0.03^{nst}	0.01

* Significant in 0,95, ^{nst} = No significant trend, ** Significant in 0,99, ^{N}= Negative, ^{P} = Positive

[DOI: 10.22034/ECOPERSIA.12.3.219]

Table 1 Continued) Results of Mann-Kendall(MK) and Sen slope tests in the river gauge stations.

Province	Code	Station Name	MK Statistics	Sen Slope	Province	Code	Station Name	MK Statistics	Sen Slope
Guilan	18-021	Ponal	-0.62nst	-1.73	Mazandaran	16-021	Polzoghal	-0.49nst	0.42
	18-027	Asalem	0.7nst	0.59		16-025	Sardabrod	2.3P*	4.06
	18-028	Khalyan	0.25nst	0.16		16-041	Cheshmehkileh	-0.62nst	-0.71
	18-029	Mashinkhaneh	0.45nst	0.88		16-051	Safarod	1.27nst	0.76
	18-035	Ostaghasem	1.28nst	1.54		16-079	Markan	-0.66nst	-0.01
	18-039	Chobar	-0.16nst	-0.05		16-083	Abshar	-0.29nst	-0.26
	18-047	Bash	0.7nst	0.78		16-085	Valat	0nst	1.38
	18-063	Kamadol	0.29nst	0.33		16-089	Azarod	0.23nst	2.76
	18-065	Talasko	-0.04nst	-0.24		16-159	Zarudak	0.77nst	0.63
	18-073	Safar	0.41nst	1.94		16-200	Oskomahaleh	-2.31N*	-0.42
	18-075	Khan	0.14nst	1.49		16-209	Vaspol	0.7nst	0.56
	18-081	Nokhaleh	-1.22nst	-2.6		16-211	Vazak	0.83nst	0.82
	18-087	Chometghal	-0.7nst	-1.03	Khorasan Razavi	64-003	Imamzadeh -Kasfrud	-1.08nst	-2.5
	18-089	Kalsar	-0.12nst	-0.46		64-019	Sarasyab	1.29nst	10.77
	18-090	Kalehsara	1.4nst	3.09		65-001	Chahchahe	-1.21nst	-0.4
	18-091	Khalkaei	-1.11nst	-1.22		66-001	Sangdivar	0.98nst	2.29
	18-093	Marghak	-1.52nst	-1.01		66-003	Qara Tikan	-2.05N*	-1.46
	18-095	Aghamahaleh	-0.45nst	-0.6		66-010	Darband	-0.08nst	0.95
	18-106	Kisham	1.49nst	5.87		66-011	Archangan	-2.02N*	-0.23
	18-950	Baharestan	1.11nst	0.57		67-001	Hatem Qala	0.42nst	1.52
	19-137	Erie	-0.75nst	-0.32		67-003	Kapkan	-0.07nst	-0.01
East Azerbaijan	31-001	Sehzab	1.74nst	1.27		68-003	Golkhandan-Khorasan	-0.68nst	-2.54
	31-011	Nahand	-0.37nst	1.39		68-005	Mohammad Taqi Beyk	-1.19nst	0.63
	31-013	Saidabad	-0.45nst	0.53	South Khorasan	55-009	Khonik	-2.18N*	-0.44
	31-019	Liqwan	-0.49nst	-1.26	Kerman	45-023	Shahdad	-0.12nst	-0.3
	31-113	Diznab	0nst	0.09		45-049	Abgarm	-1.44nst	-0.45
	31-527	sanikh chai	2.24P*	0.34		45-101	Sorakhmar	-2.06N*	-1.59
	32-025	Kahek Daresi	-1.65nst	-0.26		45-209		0.38nst	0.75
	33-001	Maghanjogh	0.56nst	0.42		45-981		-1.03nst	0.28
	38-001	Daryan	1.54nst	2.78		46-003	Jirafto	0.21nst	1.06

* Significant in 0٫95, nst = No significant trend, ** Significant in 0٫99, N= Negative, P = Positive

[DOI: 10.22034/ECOPERSIA.12.3.219]

Table 1 Continued) Results of Mann-Kendall(MK) and Sen slope tests in the river gauge stations.

Province	Code	Station Name	MK Statistics	Sen Slope	Province	Code	Station Name	MK Statistics	Sen Slope
Kordestan	21-026	Hossein Abad	-0.62^{nst}	-0.1	Kerman	46-005	Qaryt al-Arab -Goli Goto	0.08^{nst}	0.12
	21-339	Tunnel	-1.19^{nst}	-0.66		46-011	Godarzarchoye	-1.19^{nst}	-3.82
North Khorasan	11-021	Babaamn	1.74^{nst}	2.94		46-013	Hejin	0.62^{nst}	1.45
	11-027	Ghatlesh	-0.49^{nst}	-3.83		46-023	Shazadeh Abbas	-1.61^{nst}	-1.84
	11-031	Darkesh	-1.33^{nst}	-4.86	Sistan and Balojestan	29-009	Pirsohrab	-0.77^{nst}	-26.01
	11-033	Shirabad	-2.2^{N*}	-0.94		29-011	Pirdan	0.14^{nst}	1.09
	11-035	Samalghan	-2.02^{N*}	-2.86		29-013	Pishin	-0.21^{nst}	29.13
	11-051	Ayerghayeh	-0.07^{nst}	-0.16		44-015	Daman	-1.36^{nst}	-17.87
North Khorasan	11-300	Gharakhanbandi	-0.7^{nst}	7.67	Boshehr	23-027	Kalal	-0.45^{nst}	-16.16
	11-701	Korkanlo	0.23^{nst}	2.38		23-029	Ahrom	0.91^{nst}	8.6
	11-705	Ghordanlo	-0.42^{nst}	-1.2		24-031	Baghan	1.94^{nst}	19
	47-061	Rouin	0.91^{nst}	2.7	Hormozgan	26-037	Kahoristan	0.53^{nst}	14
	47-063	Sankhast	-0.91^{nst}	-0.26		27-017	Barnetin-Minab	0.62^{nst}	32.57
Chaharmahal and Bakhteiari	21-227	Solgan	-1.22^{nst}	-2.54		27-904	Sikhoran	-1.36^{nst}	-1.22
	21-229	Godarbek	-2.14^{N*}	-2.31		28-011	Mazabi	1.14^{nst}	16.1
	21-231	Armand	-1.36^{nst}	-16.92	Khozestan	21-189	Paul Zal	-2.12^{N*}	-11.61
	21-418	Tang Pardenjan	-0.7^{nst}	0		21-193	Abdul Khan	-2.66 ^{N**}	-13
	21-419	Dezkabad	0^{nst}	-0.16		21-197	Paul Shawer	-0.98^{nst}	-0.49
	21-425	Beheshtabad	-0.7^{nst}	-0.22		21-199	Hamidiyah	-1.99^{N*}	-10.32
	21-429	Jonqan	-0.91^{nst}	-1.37		21-251	Shushtar-Gargar	-2.69^{N**}	-7.33
	21-431	Zarinderakht	-2.9^{N**}	-0.26		21-254	Wali Abad -Gargar	-1.06^{nst}	-0.7
	21-434	Kaj	-0.74^{nst}	0.63		21-293	Tang Panj-Bakhtiari	-0.54^{nst}	11.4
	21-497	Kohsokhteh	-1.68^{nst}	-0.43		21-295	Talezang	-1.96^{nst}	-143.2
	21-888	Kharaji	-1.25^{nst}	0.08		21-303	Harlem	-2.35^{N*}	-53.83
	21-929	Ghard Bishe	-1.59^{nst}	-0.06		21-305	Bamdej	-2.94^{N**}	-50.53
	21-931	Polkarebast	-1.7^{nst}	-0.55		21-307	Mulasani-Ramin	-3.26^{N**}	-115.3
	42-001	Chalelgard	0.73^{nst}	0.3		21-309	Ahvaz	-3.18^{N**}	-99
Fars	22-071	button	-0.19^{nst}	-13.79		21-441	Dashtbozorg	-2.14^{nst}	-15.04
	23-005	Bushigan	-0.03^{nst}	-0.44		21-443	Arab Hasan-Arab Asad	-3.32^{N**}	-96.67
	23-007	Shakstian	0.24^{nst}	8.42		21-453	Dukohe	-2.66^{N**}	-34.27

* Significant in 0٫95, ^{nst} = No significant trend, ** Significant in 0٫99, ^{N}= Negative, ^{P} = Positive

[DOI: 10.22034/ECOPERSIA.12.3.219]

Table 1 Continued) Results of Mann-Kendall(MK) and Sen slope tests in the river gauge stations.

Province	Code	Station Name	MK Statistics	Sen Slope	Province	Code	Station Name	MK Statistics	Sen Slope
Fars	23-017	Nargesi	-0.02^{nst}	-1.06	Khozestan	21-455	Zorabad	0.54^{nst}	9.38
	23-043	Chitti-Borki	-0.02^{nst}	-2.24		21-489	Nissan	-2.13^{N*}	-6.54
	23-053	Chamchit	-0.07^{nst}	-14.44		21-491	Hofel	-3.15^{N**}	-8.9
	24-001	Bandbahman	-0.17^{nst}	-7.26		21-525	Kanalvasileh	1.29^{nst}	0.35
	24-003	Ali Abad Khafar	-0.12^{nst}	-6.53		21-945	Morghab	0^{nst}	-0.88
	24-021	Hanifqan	-0.22^{nst}	-1.29		21-946	Indica-Tang Dolab	-0.36^{nst}	6.67
	24-027	Ahmedabad	0.07^{nst}	12.5		22-001	Polmanjanigh	-2.17^{N*}	-2.56
	24-065	Dezhgah	-0.11^{nst}	-17.48		22-011	Machine	-2.58^{N**}	-13.13
	24-901	Dehrud	-0.19^{nst}	-10.55		22-013	Joknek	-0.73^{nst}	-8.67
	26-023	Darbghaleh	-0.07^{nst}	-0.89		22-017	Behbahan Tang Takab	-1.63^{nst}	-6.23
	43-011	Jamal Baig	-0.29^{nst}	-2.83		22-021	Cham Nizam	0.35^{nst}	4.5
	43-013	Jamal Baig	-0.14^{nst}	-1.92		22-023	Mishrageh	-2.45^{N*}	-33.5
	43-045	Pol Fasa	0.15^{nst}	0.56		22-027	Gargar	-1.93^{nst}	-3.71
	43-089	Aezm	-0.14^{nst}	-1.64		22-029	Khairabad - sweet water	-2.17^{N*}	-28.07
	43-105	Tangblaghi	0.02^{nst}	0.23		22-107	Paul Flore	-2.35^{N*}	-32
Kohkilooyeh and Boyer Ahmad	22-047	Gach-saran	-1.26^{nst}	-23.48	Kohkilooyeh and Boyer Ahmad	22-213	Haj Qalandar	-1.05^{nst}	-24.91
	22-069	Syedabad	-0.32^{nst}	-2.54		22-523	Nazmakan	0.16^{nst}	0.73

* Significant in 0٫95, ^{nst} = No significant trend, ** Significant in 0٫99, ^{N}= Negative, ^{P} = Positive

2018 in Iran were downloaded from Iran Water Resources Management Company [https://stu.wrm.ir/login.asp]. Low and high data were checked for validity, and a Bolton analysis was performed for outlier data before and after each year. We used instantaneous peak discharge data in this research. All stations with common periods were selected. Hydrometric gauge stations with at least 20 years of data were chosen in the following. The stations that were then affected by the dams were removed because they are manmade, and we just wanted to analyze instantaneous peak discharge without dams' impacts. Pre-whitening (PW) analysis was not performed to remove the impact of serial correlation. According to Yue et al. (2002), the PW technique alters the slope magnitude of the original data series and lessens the value of the trend existing in the original data [20]. The locations of the selected hydrometric gauge stations are shown in Figure 1 Finally, the MK and Sen's slope estimator tests were carried out using MATLAB code. The MK test is the most effective technique for identifying stations with noticeable or large-scale changes and quantifying these alterations.

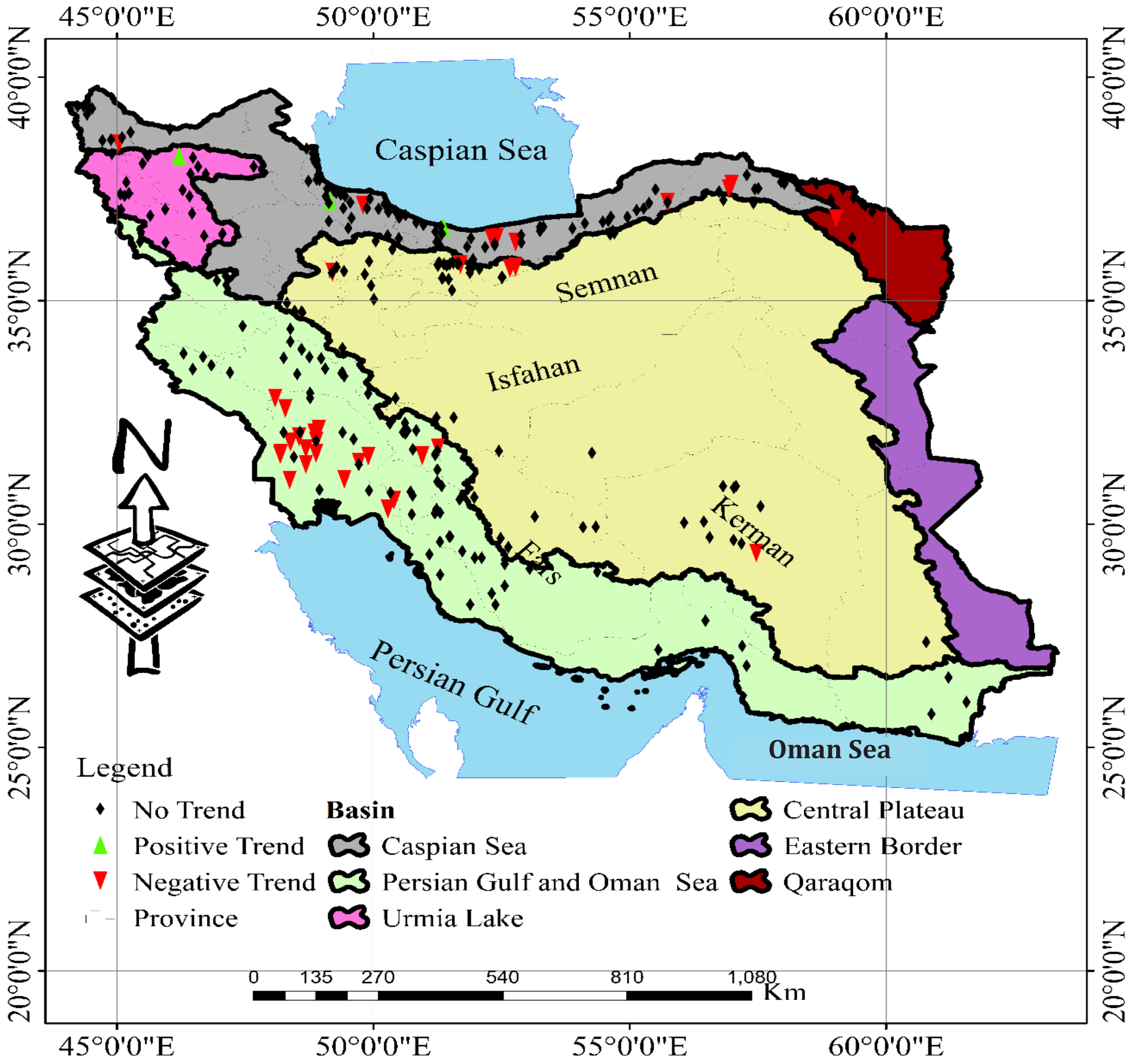

Figure 1) Spatial distribution of trends of hydrometric stations in six large watersheds of Iran.

[DOI: 10.22034/ECOPERSIA.12.3.219]

Mann-Kendall and Sen Slope Estimator Test

Trend analyses of maximum peak discharge from 301 hydrometric gauge stations were conducted using MK and Sen's slope estimators. The MK test [21, 22] is used to statistically investigate whether the variable of interest has a monotonic rising or decreasing trend over time. This test is most commonly viewed as a practical evaluation [23]. Sen's slope estimator test [24] is used in the nonparametric approach to determine the slope of the trend in N pairs of a data sample. Equation 1 is used to determine the trend.

$$\beta = Median(\frac{x_i - x_j}{j - i})$$

where $1 < i < j < n$ Eq. (1)

In this equation, β is Sen's slope estimate. A time series with β>0 demonstrates a rising trend in a time series. Otherwise, the data series shows a declining trend. To determine the proper slope of the trend, equation 2 is applied for linear trends of time series.

$$Q_i = \frac{x_j - x_k}{j - k} \quad \text{for i= 1, 2, ..., N}$$ Eq.(2)

In the equation, x_j and x_k exhibit the values of data at times j and k. Also, n is the number of periods. Equation 3 calculates the Sen's slope estimator.

$$Qmed = \{[[N+1]/2] \quad if \quad s\ odd$$

Eq.(3)

$$\left(\frac{N}{2}\right) + \left(\frac{N+2}{2}\right) \times 2 \qquad if\ N\ is\ even$$

The time series data trend is demonstrated by the $Qmed$sign, whose obtained value indicates steepness. If Qmin and Qmax have equivalent signs, then $Qmed$ slope is statically different from zero [25, 26, 27].

Findings

This study investigated the trend of maximum peak discharge changes in Iran's hydrometric gauge stations. Three hundred one hydrometric gauge stations in six large watersheds of Iran wereIran were considered to investigate the trend on a daily scale, and the results related to the stations' trend stations trends are presented in Table 1.

Based on the geographical spread of the trends of the analyzed stations, as shown in (Figure 1), most of the stations in the north, northwest, west, southwest, and center of Iran have no trend, and only a small number of stations have an increasing or decreasing trend. Moreover, most stations have yet to trend in northern Iran, including Mazandaran, Golestan, Guilan, and Azerbaijan Provinces. In Mazandaran, three stations showed a decreasing trend, but one showed an increasing trend. The result of trend analysis in Guilan demonstrated that, out of 33 stations, only one station has an increasing trend, and one station has a decreasing trend. Like the northern part, every station has no trend in the Iranian central plateau. One notable feature of Khuzestan Province in southwest Iran is the decreasing trend observed in most of the region's stations. Twenty of the thirty-one hydrometric gauge stations displayed a declining trend, which may be related to climate change [28]. In addition, except for one station with a decreasing trend in northwest Iran, the other investigated stations have no trend. The results for assessing the trends of instantaneous peak discharge in large watersheds of Iran displayed that there is just one station with a declining trend in the eastern border watershed, four stations with a decreasing trend in the middle plateau, and no trend in the remaining stations. In addition, the survey of large watershed stations in the Persian Gulf and the Oman Sea demonstrated that this watershed has the most significant number of stations with a decreasing trend. What is interesting about the Caspian Sea watershed is that positive and negative trends can be seen in this watershed (Figure 1(, where only two stations have an increasing trend, as well as eight stations have a decreasing trend, and most of the stations in this watershed have no trend.

Further findings showed that the Urmia Lake watershed station had no trend in all the stations investigated in this watershed, unlike the Caspian Sea watershed, except for one station that showed an increasing trend. Based on research by Nazeri Tahroudi et al. (2017), the Accumulation of greenhouse gases, land use change, and global warming phenomenon in the Urmia Lake watershed are among the factors that cause an increasing trend in the region[29]. Together, these results provide important insights into the trend of instantaneous peak discharge and its changeability. The significant point is that they could be effective in future planning and helpful in decisions and management plans. The most significant observation of this study is that the results contrast with previous studies about the impacts of climate change. Most of the stations throughout Iran have no trend, and only in the southwest of Iran, Khuzestan Province, do the stations in this region have a decreasing trend.

[DOI: 10.22034/ECOPERSIA.12.3.219]

Discussion

In general, most of the stations were without trend. All the stations placed on the central plateau of Iran showed no trend. Following the present result, previous studies have demonstrated that the precipitation trend has been decreasing in their study [19, 25]. In recent decades, the amount of rain has decreased, and the air temperature has increased in the long term, significantly reducing the ratio of snowfall to total precipitation. Therefore, according to the climate and the decreasing trend of precipitation, as well as the absence of permanent rivers in most of the central plateau of Iran, it might be the reason for displaying no trend in this area, and the Sen slope was very small and negligible. There are similarities between the findings in this study and those described by other researchers[26]. They investigated the climate change process and the trend of precipitation in Khuzestan. The results showed that the precipitation increased in 7% of the area, 67.2% and 25.8% showed a decreasing trend without significant changes, respectively. Regarding climatic change, 32.7% of the region showed no discernible changes, while 67.2% of the province grew drier. This finding was also reported by Rahimi et al. (2020). They analyzed the trend of maximum annual flood in the Karkheh watershed[30]. The MK test results showed that the average annual discharge trend is significant and decreasing at a significance level of 95%.

The occurrence of consecutive droughts in the last decade dramatically impacts the formation of this trend. A possible explanation for this result might be that land use changes, climate change, and human activities play a key role in water resources management, especially in the maximum peak flow, highlighting the importance of considering these factors in water resources management and decisions in the future which is supported by previous research[27,28]. All the stations under investigation in the northwest of Iran showed no trend, with the exception of one that showed a decreasing trend. This result is consistent with that of [29], whose findings indicated a noticeable downward trend in the minimum flow discharge at most stations. The findings in the Persian Gulf and the Oman Sea large watershed displayed that the most significant number of stations with a decreasing trend are in this watershed. In the research of [31], the results showed a decreasing trend in more than 50% of the stations, and this decrease was mainly in the stations of the central part. The trend of rainfall intensity is increasing, and rainfall duration is decreasing. Therefore, one factor influencing the stream's flooding could be changing the rainfall pattern, i.e., decreasing the rainfall duration and increasing its intensity. Also, the Caspian Sea watershed result showed that most of the stations in this watershed have no trend; only two stations have an increasing trend, and eight stations have a decreasing trend. The results obtained are consistent with the results of [32]. This research studied temperature and precipitation changes in the southern shores of the Caspian Sea. The results proved that the temperature in all the stations of the Caspian watershed increased, except for the Gorgan station, and the precipitation also changed in different stations. These results are likely related to the effect of the increase in greenhouse gases at the local, regional, and global levels, as well as the distance from the vast water source of the Caspian Sea. This is an important issue for future research and needs to be considered properly.

Conclusion

This study aimed to determine the trend of the instantaneous peak discharge and their magnitude in Iran. In the current research, the data from 301 hydrometric gauge stations in Iran from 1998 to 2017 were selected for 20 years, and the MK and the Sen slope test were used to evaluate trends. Based on the obtained results, it can be generally concluded that despite the autumn rainfall regime that covers most parts of Iran, the role of excruciating droughts during the last few decades cannot be ignored. The current research shows that most of Iran's rivers have no trends. Most of the decreasing trends of the investigated stations are located in the Persian Gulf and the Oman Sea watershed, which is mainly in the middle of this sector. However, in the central plateau watershed, all the stations illustrated no trend. However, the absence of analysis of physiographic conditions, land use, and climate variations, as well as the influence of each of the previously mentioned variables to alter the trend of the stations, is one of the research's limitations. Additionally, a longer time period is suggested. Based on this, in future research, the quantification of climate changes and anthropogenic activities needs to be considered nationally and regionally. The results of the present study could be very important for the planners and politicians of the water field to manage water resources for flood control projects, as well as designing the dimensions of structures such as dams and the height of dam walls and bridges. Also, the findings could be beneficial in agricultural sectors and irrigation systems to diminish the damages. Another usage of this study is to provide flood risk zoning in the areas with the highest peak flow.

Ethical permissions: None declared.

Author Contributions: All authors contributed to the writing of the paper.

Conflict of interests: There is no conflict of interest.

Funding / Support: This work is based upon research funded by Iran National Science Foundation (INSF) under project No.4006075.

References

1. Norouzi G., Taslimi M. The impact of flood damages on production of Iran's Agricultural Sector. Middle East J. Sci. Res. 2012; 12:921-926.
2. Pawar U., Try S., Muttil N., Rathnayake U., Suppawimut W. Frequency and trend analyses of annual peak discharges in the Lower Mekong Basin. Heliyon. 2023; 1;9(9): e19690.
3. Saatsaz M. A historical investigation on water resources management in Iran. Environ. Dev. Sustain. 2020; 22(3):1749-1785.
4. Madani K., AghaKouchak A., Mirchi A. Iran's socio-economic drought: challenges of a water-bankrupt nation. Iran. Studies. 2016; 49(6):997-1016.
5. Collins G. Iran's Looming Water BankruptcyJames A. Baker III Institute for Public Policy. 2017.
6. Ketabchy M. Investigating the impacts of the political system components in Iran on the existing water bankruptcy. Sustainability. 2021; 13(24):13657.
7. Goharian E., Azizipour M. Integrated Water Resources Management in Iran: Cases from Africa, Asia, Australia, Latin America, and the USA. 2020; 101-114.
8. Zhang X., Harvey K.D., Hogg W.D., Yuzyk T.R. Trends in Canadian streamflow. Water Resour. Res. 2001; 37(4):987-998.
9. Gharekhani A., Ghahreman N. Seasonal and annual trend of relative humidity and dew point temperature in several climatic regions of Iran. Soil Water Res. 2010; 24(4):636-646.
10. Feizi V., Mollashahi M., Farajzadeh M., Azizi G. Spatial and temporal trend analysis of temperature and precipitation in Iran. ECOPERSIA 2014; 2(4):727-742.
11. Nazeri Tahrudi M., Khalili K., Ahmadi F. Spatial and regional analysis of precipitation trend over Iran in the last half century. Soil Water Res. 2016; 30(2):643-654.
12. Ahmadi F., Nazeri Tahroudi M., Mirabbasi R., Khalili K., Jhajharia D. Spatiotemporal trend and abrupt change analysis of temperature in Iran. Meteorol. Appl. 2018; 25(2):314-321.
13. Yacoub E., Tayfur G. Trend analysis of temperature and precipitation in Trarza region of Mauritania. J. Water. Clim. Change. 2019; 10(3):484-493.
14. Yousefi Malekshah M., Ghazavi R., Sadatinejad S. Evaluating the Effect of Climate Changes on Runoff and Maximum Flood Discharge in the Dry Area (Case Study: Tehran-Karaj Basin). ECOPERSIA 2019; 7(4):211-221.

[DOI: 10.22034/ECOPERSIA.12.3.219]

15. Das S., Banerjee S. Investigation of changes in seasonal streamflow and sediment load in the Subarnarekha-Burhabalang basins using Mann-Kendall and Pettitt tests. Arab. J. Geosci. 2021; 14(11):946.
16. Khosravi A., Azari M. Spatio-temporal trend and change detection of temperature and precipitation of Kashafroud basin. J. Appl. Res. Geograph. 2022; 22(66):289-306.
17. Bazarzhapov T.Z., Shiretorova V.G., Radnaeva L.D., Nikitina E.P., Sodnomov B.V., Tsydypov B.Z. Trend Analysis of Precipitation, Runoff, and Major Ions for the Russian Part of the Selenga River Basin. Water-Sui. 2023; 15(1):197.
18. Bayat-Afshary N., Danesh-Yazdi M. Are the magnitude and frequency of floods increasing in Iran due to climate change? Implications from a 50-year analysis. Hydrologic. Sci. J. 2023; 68(15): 2243-2261.
19. Najafi M.S., Alizadeh O. Climate zones in Iran. Meteorol. App. 2023; 30(5):e2147.
20. Yue S., Pilon P., Cavadias G. Power of the Mann–Kendall and Spearman's rho tests for detecting monotonic trends in hydrological series. J. Hydrol. 2002; 259(1-4):254-271.
21. Gilbert R.O. Statistical methods for environmental pollution monitoring: John Wiley & Sons. 1987.
22. Sen P.K. Estimates of the regression coefficient based on Kendall's tau. J. Am. Stud. 1968; 63(324):1379-1389.
23. Hirsch R.M., Slack J.R., Smith R.A. Techniques of trend analysis for monthly water quality data. Water. Resour. Res. 1982; 18(1):107-121.
24. Vafakhah M., Bakhshi T.M., Khazaei M. Analysis of rainfall and discharge trend in Kashafrood Watershed. Geography. 2013; 29(10): 21-27.
25. Bihrat Ö., Bayazit M. The power of statistical tests for trend detection. Turk. J. Earth. Sci. 2003; 27(4):247-251.
26. Hamed K.H., Rao A.R. A modified Mann-Kendall trend test for autocorrelated data.J. Hydrol. 1998; 204(1-4):182-196.
27. Alijani B., Mahmoudi P., Chogan A. A study of annual and seasonal precipitation trends in Iran using a nonparametric method [Sen's slope estimator]. J. Climate. 2012; 9(3):106-117.
28. Masoudi M., Elhaeesahar M. Trend assessment of climate changes in Khuzestan Province, Iran. Nat. Environ. Change. 2016; 2(2):143-152.
29. Nazeri Tahrudi M., Ahmadi F., Khalili K. Evaluation the trend and trend chang point of Urmia Lake Basin precipitation. Water Soil. 2017; 31(2):644-659.
30. Rahimi D., Khoshhal Dastjerdi J., Rahimi D. Trend analysis of maximum flood in the Karkheh basin. J. Nat. Environ. Haz. 2020; 9(26):43-58.
31. Moradi M., Bazrafshan O., Bahremand A., Esmailpour Y. Assessing the relationship between the trend of some climatic factors on surface runoff in the watersheds of the southern coast of Iran. Watershed Manag. 2018; 31(119):79-92.
32. Pirnia A., Habibnejad Roshan M., Solaimani K. Investigation of precipitation and temperature changes in Caspian Sea southern coasts and its comparison with changes in the northern hemisphere and global scales. Watershed Manag. 2015; 6(11):90-100.