



Investigating the trend of precipitation changes and occurrence of droughts in the Mesopotamian Plain

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ARTICLE INFO	ABSTRACT
<p>Paper Type: Short Paper</p> <p>Received: 30 September 2024 Revised: 24 November 2024 Accepted: 02 December 2024 Published: 24 December 2024</p> <p>Keywords Drought Mesopotamian Plain Precipitation Changes</p> <p>*Corresponding author: A. Danehkar ✉ danehkar@ut.ac.ir</p>	<p>Understanding climate change trends, especially precipitation, has played a significant role in the hydrological cycle and the severity of recent droughts in the Mesopotamian Plain and other western and southwestern regions. In the present study, precipitation changes trend in western and southwestern Iran and the occurrence of droughts in the Mesopotamian Plain from 1989 to 2022 were investigated using the independent t-test in SPSS software, and analyzing statistical variables including mean, median, mode, standard deviation, coefficient of variation, range of variation, skewness, maximum, and minimum. The spatial distribution of annual rainfall has shown a noticeable downward trend, and rainfall in the country has become more concentrated and uniform in terms of time in recent years. The precipitation concentration index also showed that the highest index is related to the southwestern regions, and the lowest concentration index is assigned to the northern regions. Accordingly, the increase in the intensity of seasonality and concentration of precipitation in the southern parts indicates high variability and precipitation irregularity, as a result, an increase in the incidence of drought. The results obtained indicate a decreasing trend in annual and seasonal precipitation and, subsequently, an increase in the occurrence of droughts in the Mesopotamian Plain.</p>

Highlights

- Decreasing rainfall trend in the Mesopotamian Plain (1989-2022).
- Winter precipitation decline drives increased drought occurrence.
- Southwest Iran shows the highest rainfall concentration variability.
- SPI analysis reveals rising drought frequency in recent decades.
- Human activities exacerbate climate-driven drought impacts.



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1. Introduction

Understanding the trend of climate change, and especially precipitation changes is one of the issues that has attracted the attention of many researchers in recent years (Williams et al., 2023; Leddin, 2024), so all countries are seeking to determine the change in climate components and the direction of its change (Debernardi et al., 2024; Abbass et al., 2022). One of the climatic characteristics of arid and semi-arid regions is low precipitation with high fluctuations. Therefore, changes in precipitation patterns, including temporal and spatial changes in precipitation in these regions, are significant (Sari Saraf & Jalali Ansarodi, 2019). In recent decades, the increase in global temperature has disrupted the climate balance and caused

widespread changes in the regions of the Earth (Kabir et al., 2023; Bolan et al., 2024; Shivanna, 2022). The Intergovernmental Panel on Climate Change (IPCC) assessment report also showed that the trend of precipitation changes and global warming is increasing faster than in the past (IPCC, 2021).

Many studies have been conducted to analyze the trend of precipitation time series using parametric and nonparametric models and methods. In this context, Alipour and Malekian (2019) examined the homogeneity and trend of threshold precipitation with a nonparametric statistical approach in northwest Iran. According to the results of nonparametric tests, in all thresholds, precipitation shows a decreasing trend at a

significance level of 0.01 and a sudden downward change at a significance level of 0.05. Torabi Poudeh et al., (2018) studied the trend analysis of total and effective precipitation changes in Iran. The results showed that the average effective precipitation of selected stations in Iran is negative and for this reason, effective precipitation has been accompanied by a decrease. Also, the average total precipitation of the selected stations for the period 1961-2000 is close to zero and is negative in the period 1971-2010.

This study complements other studies in terms of examining the spatial distribution of precipitation, the precipitation concentration index, and the annual and seasonal trends of precipitation over a long period (1989 to 2022). Recent droughts, as well as global warming, have led to climate change and ultimately a decrease in rainfall in the studied watershed. On the other hand, upstream development and activities such as increased agricultural and industrial activities in the region, changes in the level of water bodies in Iraq, increased evaporation levels due to the construction of dams; reduced river flow, and consequently increased salinity of the Arvand river. On the other hand, excessive extraction of surface and subsurface waters and in some cases wrong agricultural development policies in the countries of the region, dam construction, etc., increase erosion and, as a result, the occurrence of dust phenomena (Amini, 2020; Torabi Poudeh et al., 2018). With the aim of understanding and investigating the trend of precipitation changes in the west and southwest of Iran, the present study analyzed the occurrence of droughts in the Mesopotamian Plain by examining the spatial distribution of precipitation, the precipitation concentration index, and the annual and seasonal trends of precipitation in a long-term period (1989 to 2022).

2. Materials and Methods

2.1 Study area

The study area of the research is the Mesopotamian Plain located between the Tigris and Euphrates rivers, and the countries located in this area include Iraq, Turkey, Iran, Syria and Kuwait. In this area, the Tigris and Euphrates rivers originate in Turkey and enter Iraq, and after joining together, they form the Shatt al-Arab and flow into the Persian Gulf. The Mesopotamian Plain drains an area of over 1,500,000 ha and its average annual flow volume is about 82 billion m³ (Kertis, 2020).

2.2 Research Method

The present study is a descriptive-analytical method that was used to collect the required data to investigate and analyze precipitation changes in the western and southwestern regions of Iran and the drought that occurred in the Mesopotamian Plain using documentary methods. Then, the obtained data were analyzed using quantitative methods. Using the independent t-test (assuming a normal distribution of the data studied) in SPSS software, the temporal changes in the distribution of precipitation during the years studied were examined and statistical variables including the mean, median, mode, standard deviation, coefficient of variation, range of variation, skewness, maximum and minimum were calculated and tested. Furthermore, the spatial distribution of the precipitation concentration index was calculated and tested. For this purpose, rainfall data was collected from 18 synoptic

and selected stations in the region including Tabriz, Urmia, Isfahan, Kashan, Ilam, Tehran, Shahrekord, Ahvaz, Abadan, Zanjan, Qom, Qazvin, Sanandaj, Saghez, Kermanshah, Khorramabad, Arak, and Hamedan by the National Meteorological Organization (NMO, 2021), and the average annual rainfall of each station during the years 1980-2022 was extracted and analyzed.

3. Results and Discussion

According to the results of Table 1, the spatial distribution of annual precipitation has decreased significantly, so that the average precipitation in the first period (1980-2005) is 368.7 mm, while this value reached 343.6 mm in the second period (2006-2022). This decreasing trend of changes indicates that the coefficient of variation of precipitation in the first period was 19.52% and decreased to 18.33% in the second period. Table 1 also shows that the standard deviation of precipitation and the range of its changes in the second period also decreased compared to the first period and decreased from 9 to 24 mm. The skewness index also had a decreasing trend, indicating precipitation events around the mean. Accordingly, rainfall has become more concentrated and temporally uniform in recent decades. These results have also been confirmed in other studies (Hosseini, 2018; Doostan, 2020; Ahmadpari and Khaustov 2025), indicating a decreasing trend in rainfall in the country and an increasingly concentrated distribution of rainfall in these areas.

Table 1 Rainfall distribution (mm) during the studied years (1980-2022)

Statistical parameters	1980-2005	2006-2022	Sum
Mean	368.7	343.6	356
Middle	360	354	357
Mode	263	227	227
Standard deviation	72	63	67
Coefficient of variation	19.52	18.33	18.5
Range of changes	252	228	285
Skepticism	0.46	-0.39	0.24
Maximum	493	452	493
Minimum	262	226	226

As the results indicate, in the spring, precipitation amount in the southwest region is less than 15% of the annual precipitation, which increases with increasing latitude and reaches 35 to 45% in the northwest region (Fig. 1a). In the summer, due to the prevalence of westerly winds and the development of subtropical high pressure, precipitation stops. As can be seen in the map, a narrow strip from the northwest, about 15 to 20% of the annual precipitation, is related to the summer season (Fig. 1b). In the fall, the share of precipitation in the east of the Zagros mountains and the northwest of the country reaches less than 40% per year, with a small part of the southwest of the country benefiting from significant precipitation (50-60%) in this season (Fig. 1c). Finally, except for a narrow strip in the northwest of the country, winter is considered the main rainfall season in other regions, and the share of winter precipitation in the total annual precipitation has increased from 35 percent to 60 percent from north to south of the region (Fig. 1d). In addition, the highest precipitation concentration index is related to the southwestern regions (16

to 20), while the lowest concentration index is assigned to the northern regions (8 to 10). Accordingly, the increase in the intensity of seasonality and concentration of precipitation in the southern parts indicates high variability and irregularity of precipitation (uninform in the precipitation that occurred) and, as a result, an increase in the incidence of drought (Fig. 2). Accordingly, the results obtained indicate a decreasing trend in precipitation, especially in the winter season, followed by an increase in droughts occurring in the Mesopotamian Plain.

These findings are similar to the studies of Lashkari et al. (2021) and Zabihi et al. (2017), which indicate that the highest percentage of precipitation concentration is related to the winter season and the lowest percentage is assigned to the summer season, and most precipitation is uniform in this season.

Fig. 1 Map of the percentage of rainfall in the region during: a) Spring, b) Summer, c) Autumn, and d) Winter

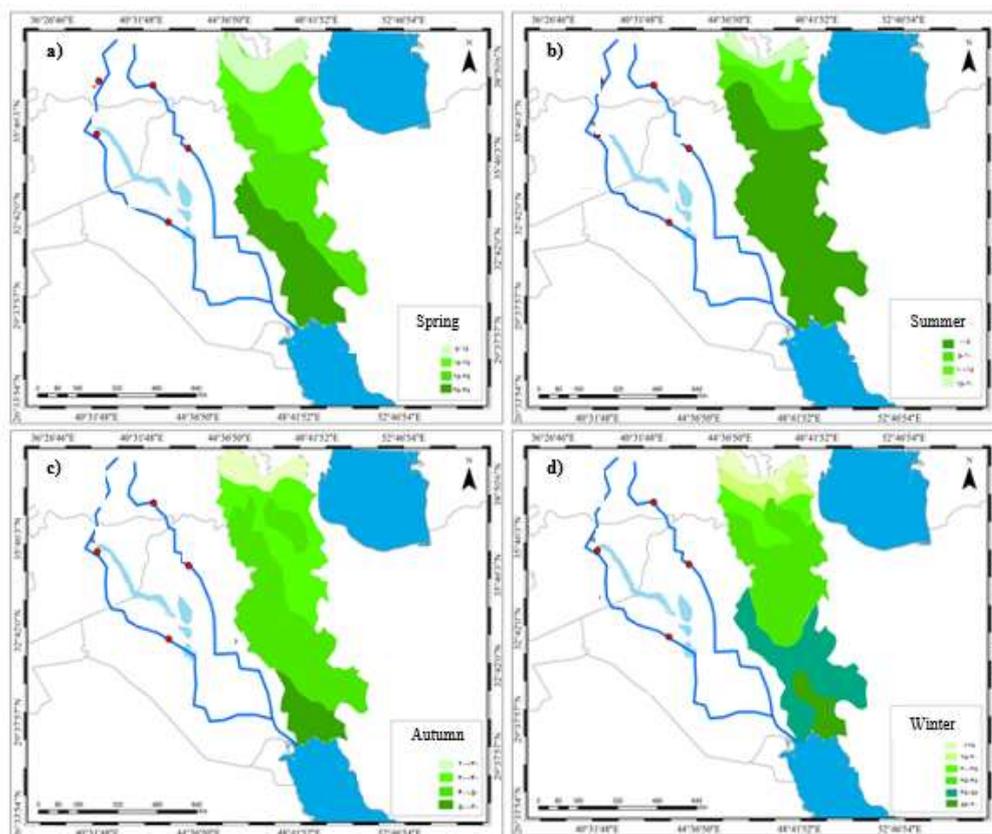
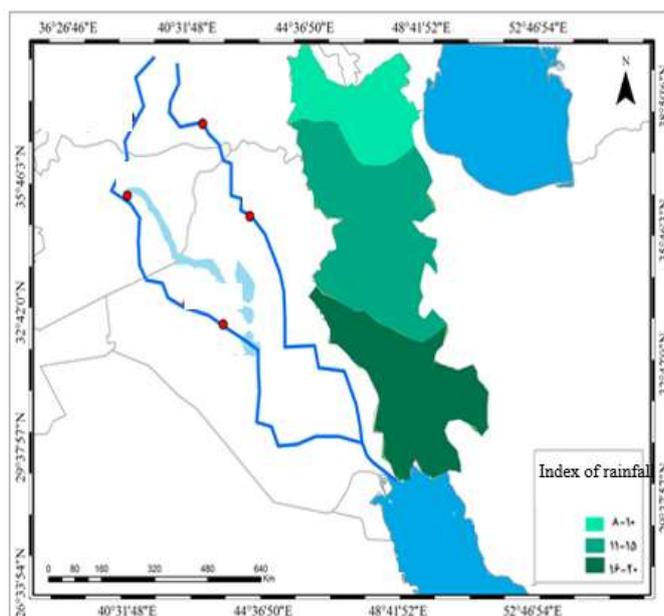


Fig. 2 Map of the uniformity index of rainfall in the region



4. Conclusion

According to the results obtained, the decreasing trend in precipitation changes indicates that in addition to the decrease in average precipitation, the coefficient of precipitation changes has also decreased imperceptibly. Accordingly, it can be concluded that:

1. The precipitation that has occurred during recent decades has become more concentrated and more uniform in terms of time.
2. The highest percentage of precipitation concentration is related to the winter season, and the lowest percentage is assigned to the summer season, and the trend of decreasing precipitation is especially in the winter season, followed by an increase in droughts occurring continuously in the Mesopotamian plain.
3. The highest index of precipitation concentration is related to the southwestern regions, and the lowest index of concentration is assigned to the northern regions. Accordingly, the increase in the intensity of seasonality and concentration of precipitation in the southern parts indicates high variability and irregularity of precipitation and, as a result, an increase in the incidence of drought.

Therefore, the unavailability of climate data and the lack of prediction and modeling of climate change, especially the trend of increasing temperature and decreasing precipitation, have led to an increase in the occurrence of drought and its consequences. Therefore, the suggestions presented in this study include predicting climate change to achieve correct planning and control of the occurrence of droughts, controlling and managing droughts through modeling long-term climate changes and analyzing droughts that have occurred, and monitoring human activities development and the utilization of biological resources, especially water resources and underground reserves.

Statements and Declarations

Data availability

The data used in this research are provided in the text of the article.

Conflicts of interest

The author of this paper declared no conflict of interest regarding the authorship or publication of this paper.

Author contribution

The authors had equal participation in all stages and parts of the research.

AI Use Declaration

This study did not incorporate artificial intelligence techniques; instead, all analyses and optimizations were conducted using conventional and widely accepted analytical methods.

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