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Exploration of Classic Models of Precipitation in Iran: A Case Study of Sistan and Baluchestan Provinces

Mohammad Borhani, Ahmad Jamshidzaei, Mehdi Koohsari

***Abstract*—**The study of climate has captivated human interest throughout history. In response to this fascination, individuals historically organized their daily activities in alignment with prevailing climatic conditions and seasonal variations. Understanding the elements and specific climatic parameters of each region, such as precipitation, which directly impacts human life, is essential because, in recent years, there has been a significant increase in heavy rainfall in various parts of the world attributed to the effects of climate change. Climate prediction models suggest a future scenario characterized by an increase in severe precipitation events and related floods on a global scale. This is a result of human-induced greenhouse gas emissions causing changes in the natural precipitation patterns. The present study focused on examining the trend of monthly, seasonal, and annual precipitation in Sistan and Baluchestan provinces. The study employed data obtained from 13 precipitation measurement stations managed by the Iran Water Resources Management Company, encompassing daily precipitation records spanning the period from 1997 to 2016. The results indicated that the total monthly precipitation at the studied stations in Sistan and Baluchestan province follows a sinusoidal trend. The highest intense precipitation was observed in January, February, and March, while the lowest occurred in September, October, and then November. The investigation of the trend of seasonal precipitation in this province showed that precipitation follows an upward trend in the autumn season, reaching its peak in winter, and then shows a decreasing trend in spring and summer. Also, the examination of average precipitation indicated that the highest yearly precipitation occurred in 1997 and then in 2004, while the lowest annual precipitation took place between 1999 and 2001. The analysis of the annual precipitation trend demonstrates a decrease in precipitation from 1997 to 2016 in Sistan and Baluchestan province.

***Keywords*—**Climate change, extreme precipitation, greenhouse gas, trend analysis.

I. Introduction

CLIMATE is the changes in the weather of an area compared to the behavior that is observed during a long-term horizon of information. Basically, the main cause of climate change is greenhouse gases, which have increased the temperature of the earth [1]. It is one of the most important challenges in the present era that has affected all aspects of sustainable development [2]. In recent years, torrential rains have increased in frequency, duration, speed, and intensity in most parts of the world due to the effects of climate change. Most importantly, floods are predicted to increase in the future based on climate prediction models around the world [3].

The Intergovernmental Panel on Climate Change (IPCC) reported global warming in 2001. The average global temperature has increased since 1861, and even in the 20th century, the increase was between 0.6 ± 0.2 °C [4]. According to the IPCC report, greenhouse gas emissions are estimated to increase the Earth's temperature by 1 to 3.5 °C by 2100. Implementing preventive measures to limit temperature increase to 1.5 °C instead of 2 °C would bring significant benefits for both people and nature [5]. The issue of climate change has been recognized as a major environmental crisis by the World Meteorological Organization because its consequences can significantly affect various socio-economic components and the ecosystem of a region [6].

Iran is located in the region of West Asia; this region is included among the arid and semi-arid regions of the world in the climate zoning of IPCC. Meteorological observations and forecasts made in the country indicate climate change and the continuation of these changes in the future [7]. In Iran, with the increase in temperature and decrease in precipitation, these changes are observed in most regions of the country [8].

In order to reduce the effects of climate change, depending on the goals of the countries, two categories of preventive measures can be mentioned: 1) reducing greenhouse gas emissions of human origin, 2) adapting to the expected climate changes and predicting them [9], [10].

One of the most variable key elements of climate that affects the spatial and temporal pattern of access to water resources is precipitation [11]. Compared to other climatic elements, precipitation has significant behavioral complexity, Iran is one of the regions where precipitation has significant temporal and spatial changes, so knowing the precipitation trends of each region is important for management and environmental [12]. This issue doubles the importance of examining the trend of changes in climatic parameters such as precipitation to know the future situation and make correct management decisions. Meanwhile, Sistan and Baluchistan province has not been exempted from the negative effects of climate change, that is why this study was focused on examining the precipitation trend of this province, which is one of the important climatic components.

II. Methodology

A. Study Area

Sistan and Baluchistan province is located between 25- and 31-degrees north latitude and 57 to 63 degrees east longitude.

Mohammad Borhani is Master Graduate in Land Assessment and Spatial Planning ،Faculty of Natural Resources, University of Tehran, Iran (e-mail: mohammadborhani13755@gmail.com).

Ahmad Jamshidzaei is PhD Graduate in Petrology, Department of Geology, University of Isfahan, Iran.

Mehdi Koohsari is Master Graduate in Economic Geology, Faculty of Science, University of Sistan and Baluchestan, Iran.

With an area of over 170,000 square kilometers, it is the second largest province in Iran, situated in the southeast. It shares borders with South Khorasan province to the north, Afghanistan and Pakistan to the east, Kerman and Hormozgan provinces to the west, and the Oman Sea to the south.

The primary source of precipitation in the southeast of Iran is the rain systems that enter the region during the cold season with the western winds. The varying effects of Mediterranean systems in different years result in fluctuations in the amount of rainfall in this region, with high levels of variability [13].

Fig. 1 shows the geographical location of the study area in the world and in Iran.

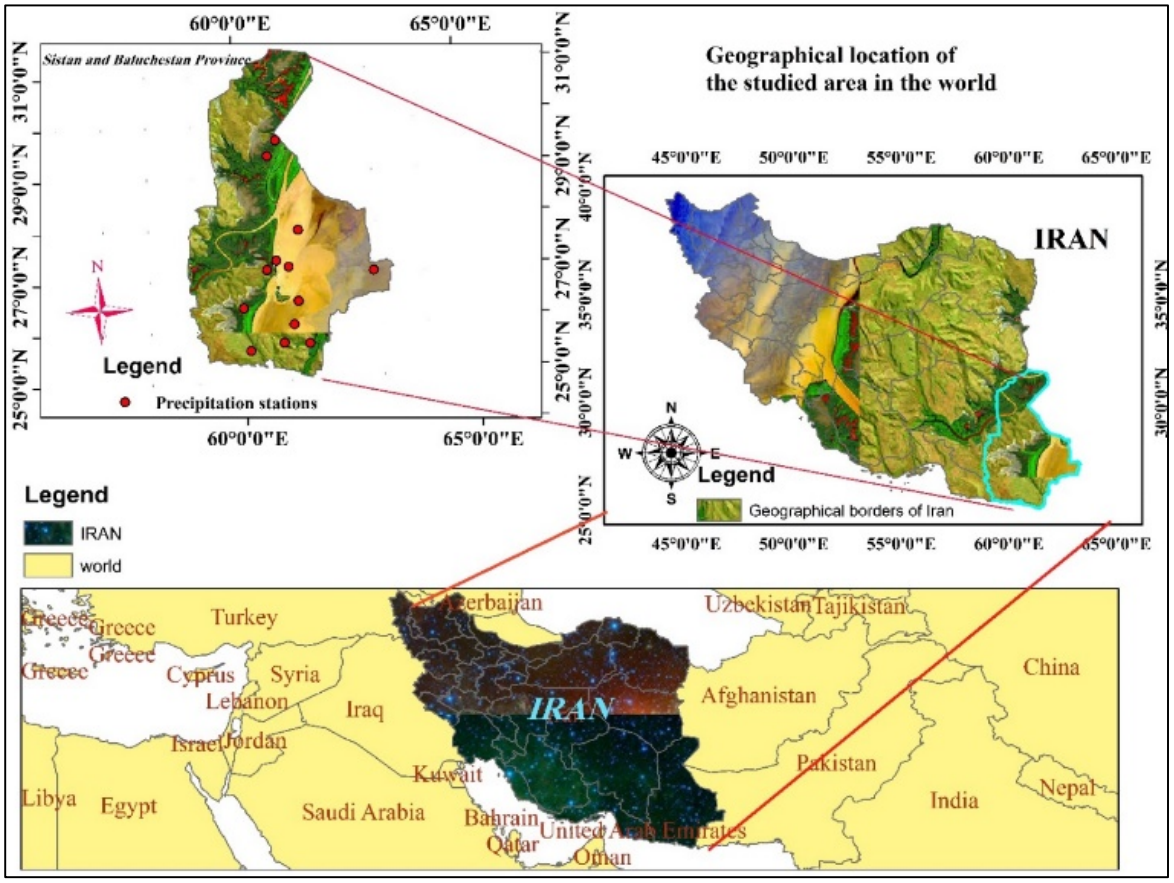

Fig. 1 Study area (Source: authors). basic map of the borders of Iran and Sistan and Baluchistan province was taken from the website of the Ministry of Interior of Iran

TABLE I
PRECIPITATION GAUGES STATION NAMES IN SISTAN AND BALUCHESTAN PROVINCE

No	Names of stations	No	Names of stations	No	Names of stations
1	Esfand	13	Chandokane	25	Kariani
2	Esfandak	14	Daman	26	Bampur Canal
3	Bahou Kalat	15	Rahimabad Nahang	27	Kheir
4	Bozman-e Aliabad	16	Saradan	28	Kooh Gazoo
5	Payab-e Band-e Bampur	17	Band-e Bampur Dam	29	Gorg-e Heydarabad
6	Pol-e Karvandar	18	Sedkhrooji Dam	30	Gazoo
7	Pirdan	19	Sarbaz Mazenkaou	31	Gourband
8	Pirshehrab	20	Aliabad Bozman	32	Ladeez
9	Pishin	21	Aliabad	33	Lar-e Pain
10	Takht-e Malek	22	Fanooch	34	Nahang
11	Jalg	23	Qasr-e Qand Chandook	35	Nikshahr
12	Jalayi Kalag	24	Karvandar		

B. The Process for Conducting the Study

1. Data Collection

In order to analyze precipitation statistics in Sistan and Baluchistan province, daily precipitation data in this region, which includes 35 rain gauge stations (Table I), was obtained through Iran's Water Resources Management Company. These data were from 1962 to 2016.

2. Data Analysis

In the next step, the precipitation data were analyzed, and stations without statistical gaps were identified for evaluation in this study from 1997 to 2016. And average monthly precipitation of rain gauge stations was calculated using Office 2016 software.

3. Investigation of Precipitation Trends

Using Golden Software Grapher 12.7.855, monthly precipitation diagrams were drawn separately for each month.

III. Results and Discussion

This study was a descriptive-analytical type, which was conducted using the precipitation data from the rain gauge stations of the Iran Water Resources Management Company in Sistan and Baluchistan province.

TABLE II
PRECIPITATION GAUGE STATIONS USED IN THIS RESEARCH

No	Station	Latitude	Longitude
1	Band-e Bampur Dam	27-11-15	60-34-15
2	Pirdan	26-33-15	61-13-19
3	Pirshehrab	25-45-07	60-52-16
4	Pishin	26-06-12	60-06-16
5	Takht Malek	26-27-30	60-01-28
6	Daman	27-21-34	60-46-53
7	Saradan	27-13-43	61-02-48
8	Kehir	25-37-29	60-08-20
9	Gourband	29-24-21	60-42-00
10	Ladeez	27-56-10	61-17-48
11	Lar-e Pain	29-42-21	61-54-12
12	Kariani	25-43-38	59-22-40
13	Bahou Kalat	25-43-13	61-25-18

The daily precipitation data from 1962 to 2016 were obtained from the Iran Water Resources Management Company and were analyzed in this study. According to Table II, a total of 13 precipitation gauge stations data between 1997 and 2016 were used without any missing data.

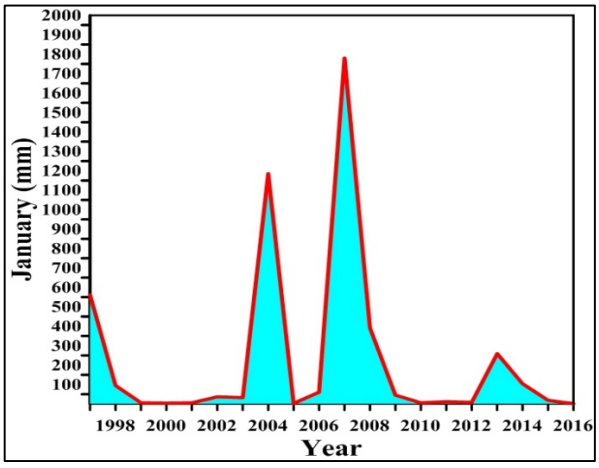

Fig. 2 Total average precipitation in January

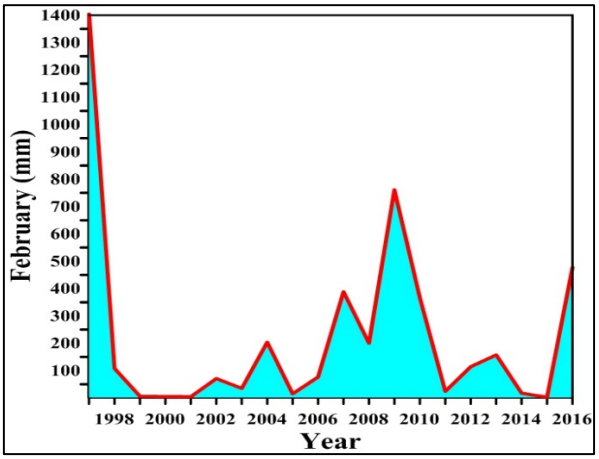

Fig. 3 Total average precipitation in February

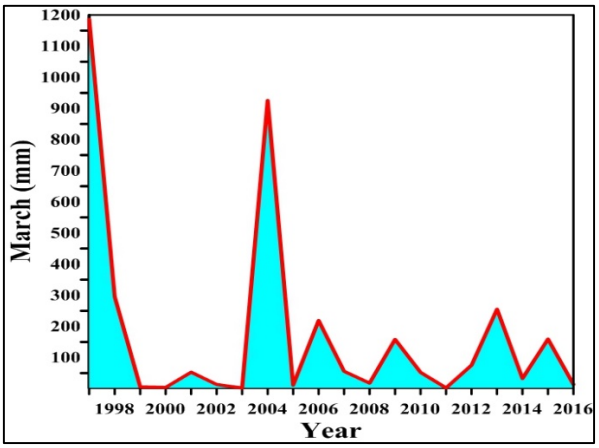

Fig. 4 Total average precipitation in March

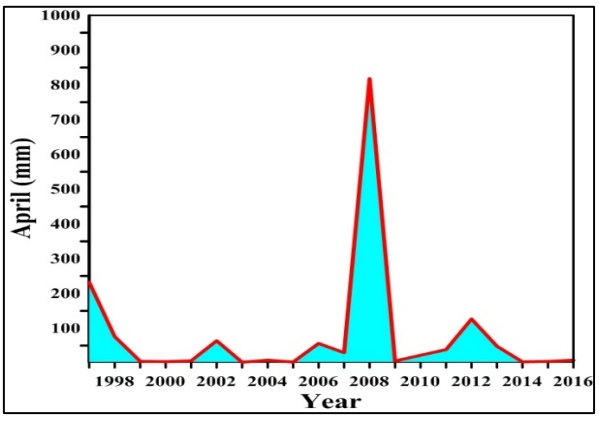

Fig. 5 Total average precipitation in April

To investigate the precipitation trend in Sistan and Baluchistan province, the total average monthly precipitation (the sum of monthly precipitation for the studied period was calculated, and ultimately the average for each month was obtained) the total average monthly precipitation in Sistan and Baluchistan province is shown in Figs. 2-13, separated by each month.

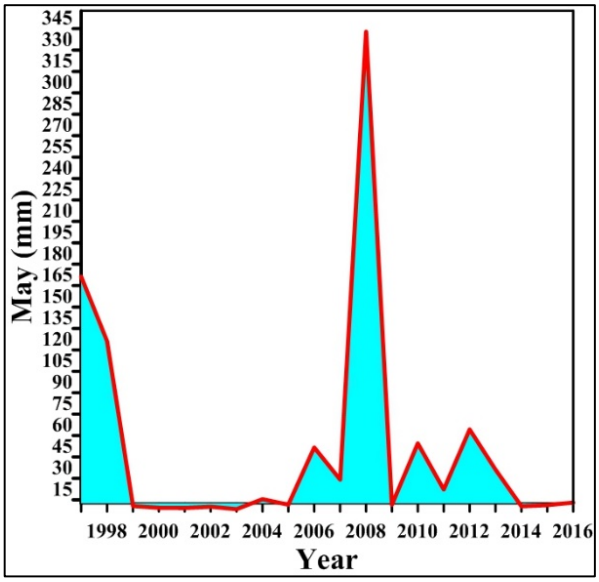

Fig. 6 Total average precipitation in may

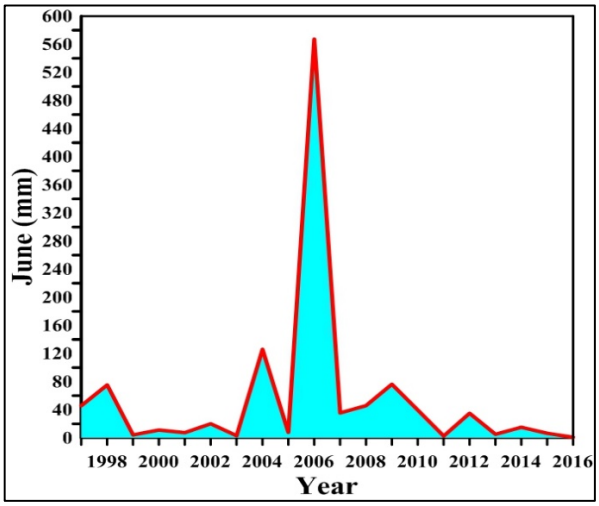

Fig. 7 Total average precipitation in June

The analysis of the precipitation trend for different months showed that the total monthly precipitation at the studied stations in Sistan and Baluchistan province follows a sinusoidal trend, as observed in Figs. 2-4. The highest precipitation occurs in January, February, and March in this province, and the highest extreme fluctuations in precipitation are also observed in these months.

As shown in Figs. 10-12, the overall lowest extreme fluctuations in monthly precipitation were observed in September, October, and then November. According to Table III, the analysis of the seasonal precipitation trend in this province showed an upward trend in the autumn season, reaching its peak in the winter season, and then decreasing again in the spring and summer seasons.

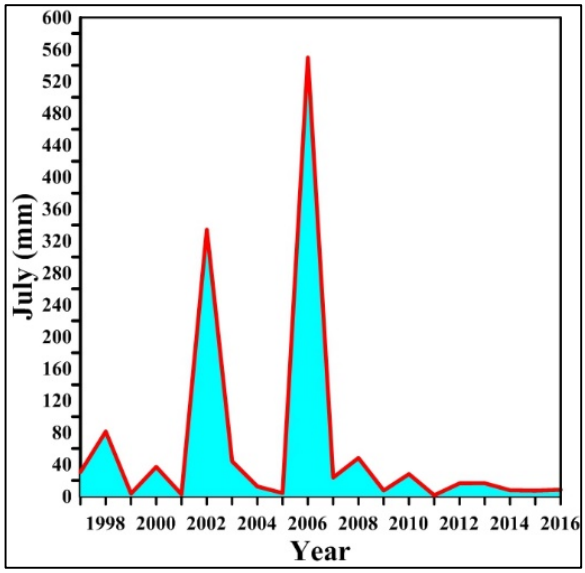

Fig. 8 Total average precipitation in July

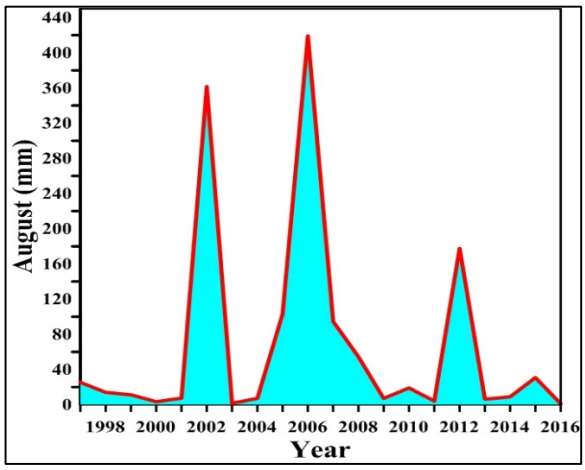

Fig. 9 Total average precipitation in August

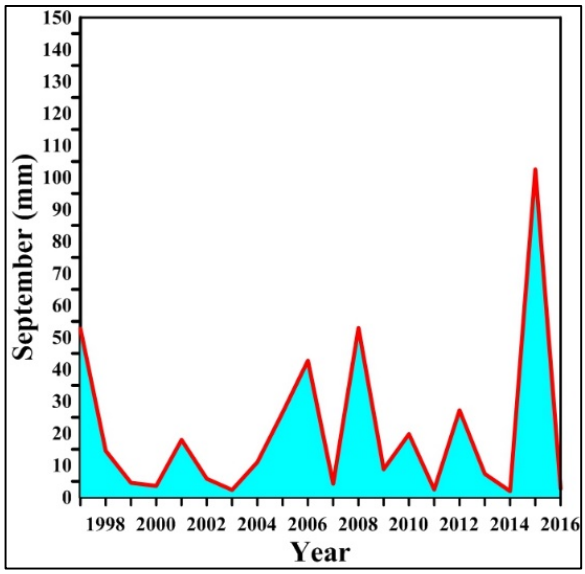

Fig. 10 Total average precipitation in September

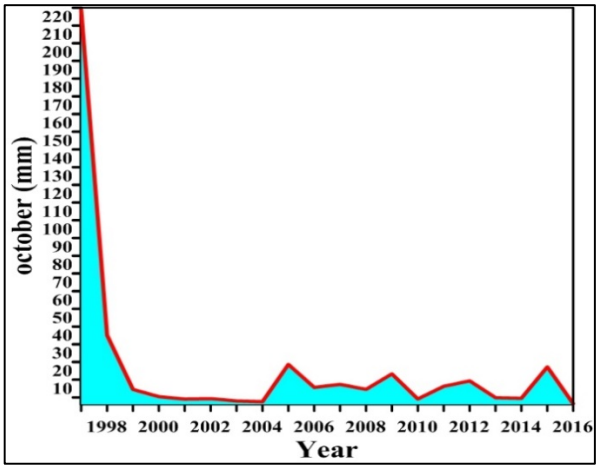

Fig. 11 Total average precipitation in October

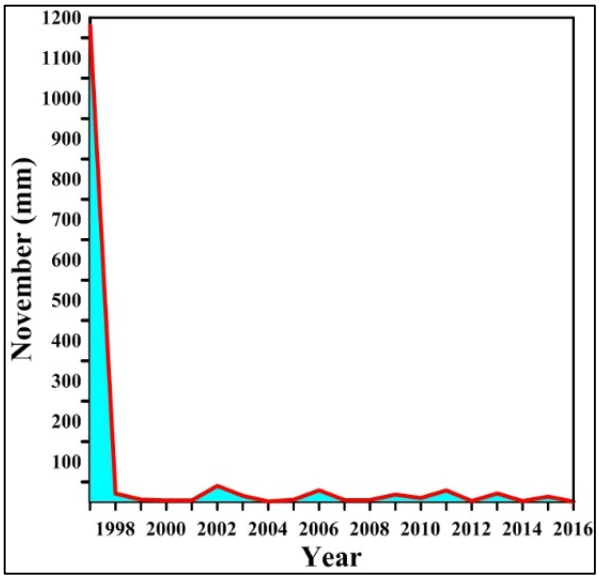

Fig. 12 Total average precipitation in November

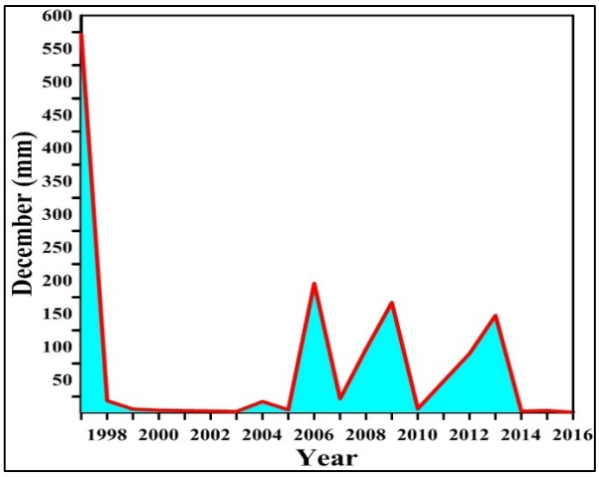

Fig. 13 Total average precipitation in December

This analysis of the total annual average precipitation, according to Fig. 14, showed that the highest yearly average occurred in 1997 and then in 2004, while the lowest yearly precipitation occurred in the years 1999 to 2001. As shown in Fig. 14, the trend line indicates a decrease in precipitation from 1997 to 2016.

TABLE III
EXTREME PRECIPITATION VALUES FOR DIFFERENT MONTHS BY EACH SEASON

Season	Month	Min (mm)	Max (mm)
	January	1.760077	1780.039
Winter	February	2.667385	1404.188
	March	2.270692	1185.809
	April	2.092231	818.2144
Spring	May	0.975100	335.3679
	June	0.881385	567.4175
	July	1.524462	549.9855
Summer	August	1.070462	419.2869
	September	1.917462	102.5509
	October	1.459769	223.5169
Autumn	November	1.233077	1180.155
	December	1.397154	571.7038

This analysis of the total yearly average precipitation, according to Fig. 14, showed that the highest yearly precipitation occurred in 1997 and then in 2004, while the lowest yearly precipitation occurred in 1999 to 2001. As shown in Fig. 14, the trend line indicates a decrease in precipitation from 1997 to 2016.

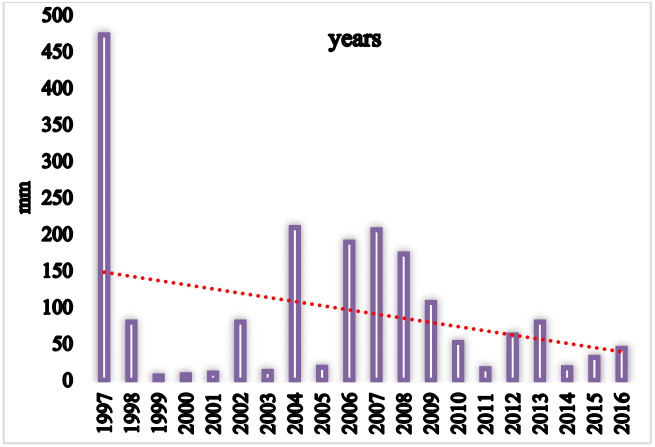

Fig. 14 Total average yearly precipitation in Sistan and Baluchistan

Reference [14] analyzed the climate variable in Sistan and Baluchestan province. They attributed the increase and decrease in heavy precipitation in Sistan and Baluchestan to climate change, which was consistent with the present study's findings, indicating a significant decrease and increase in precipitation. Reference [15] predicted the highest decrease in precipitation in March and January up to 2055 based on climate change modeling and scenario analysis. However, according to the results of this study, the highest precipitation occurred in these months until 2016, which may be due to climate change causing this shift in precipitation [14].

In [16], they calculated the irregular distribution of heavy precipitation and the irregular distribution of precipitation as features of the climate in Sistan and Baluchestan province, and

they calculated the yearly average precipitation of the province to be 100 mm. However, in the present study, it was calculated to be 94 mm. This slight difference may be due to variations in precipitation measurement stations. Reference [16] used stations from Iranian Meteorological Organization, while the present study utilized precipitation measurement stations from the Iran Water Resources Management Company for its analyses.

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