



## **USING RDI TO PREDICT DRY AREAS FOR THE PERIOD (2000-2025) AND FORECAST DROUGHT UNDER CLIMATE CHANGES CONDITIONS FOR THE PERIOD (2025-2044), NAJAF CITY, IRAQ**

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**Cite This Article:** Rusul A Al-Ameri, Ban Khalid Ammar, Ghufran Ahmed Jawad Al-Baaj & Hyder H. Abd Balla, "Using RDI to Predict Dry Areas for the Period (2000-2025) and Forecast Drought Under Climate Changes Conditions for the Period (2025-2044), Najaf City, Iraq", *International Journal of Advanced Trends in Engineering and Technology*, Volume 11, Issue 1, January - June, Page Number 31-37, 2026.

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**Type of Review:** Peer Reviewed as per |C|O|P|E| Guidance.

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**DOI:** <https://doi.org/10.5281/zenodo.18708887>

### **Abstract:**

Drought is defined as a period of unusually dry weather, caused by low precipitation and high temperatures. It is also defined in terms of its impact on agriculture, when crops fail due to a lack of soil moisture, which leads to food shortages and serious humanitarian impacts, such as famine in severe cases.

This paper aims to study the historical time series of Al-Najaf Al-Ashraf Governorate for the period from 2000 to August 31, 2025. The average precipitation amounts which were obtained from the NASA POWER DATA website, were studied throughout this period and represented on a precipitation distribution map across the governorate using GIS 10.3 software. The results showed that the period from 2000 to 2017 had less average precipitation than the period from 2018 to August 31, 2025, the average amount of precipitation was concentrated in the northern and northeastern regions of the governorate, the lowest average precipitation amounts was 26 mm in the year 2001 and the highest average precipitation amounts reached 171.6 mm in the year 2023. The Reconnaissance Drought Index (RDI) was computed by DrinC software based on the governorate's average maximum and minimum temperatures, evapo transpiration, and average precipitation. The results showed that the RDI value for the first period, from 2000 to 2017, ranged between moderate wet and mild drought, while for the second period, from 2018 to 2024, all RDI values were near normal. Near normal values were also distributed across the southern and southeastern regions and parts of the northern regions; the rest of the governorate areas were experiencing mild drought. For the future period extending from 2025 to 2044, the climate model from the NSF National Center for Atmospheric Research website (NCAR) was used, and the results showed a decrease in rainfall amounts by 30.8%, and that the period extending from where the lowest average rainfall amounts was 48.5 mm in the year 2026 and the highest average rainfall amounts reached 118.9 mm in the year 2030. The RDI index was also calculated for the future period based on the average of future maximum and minimum temperatures and the calculation of evapo transpiration as well as the average precipitation amounts. The results showed that the period extending from 2025 to 2035 had an index value ranging between near normal and mild drought, while the second period extending from 2036 to 2044 had all mild drought except for the year 2043, which was near normal.

### **1. Introduction:**

A shortage of water resources across a wide geographic region and for an extended length of time is linked to the recurrent natural occurrence known as drought (Rossi, 2000). One of the most complicated natural risks is most likely drought. Drought has been described as a "creeping natural hazard" since it is frequently impossible to anticipate when it ends (Wilhite, 1993). According to the opinions of several specialists, drought is defined significantly differently. For a meteorologist, it may be a departure from typical precipitation; for a hydrologist, it could be a decline in lake level, stream flow, or groundwater level; for an agricultural scientist, it could be a shortage of soil. Dracup et al. (1980) describe a lack of tap water for urbanites, a hunger situation for economists, and moisture to support crop development.

Drought indices have historically been employed to evaluate the severity of droughts. Over the past forty years, many indexes have been introduced. The Reconnaissance Drought measure (RDI) is a recently developed meteorological drought measure that shows promise. This index uses precipitation and possible evapo transpiration at the same time. Because of this, drought monitoring using the RDI must be predicated on a network of appropriate precipitation gauges and an evapo transpiration monitoring network, (Tsakiris et al., 2008). RDI has been used in a number of research projects for regional analysis and trend identification. By using PCA and cluster analysis on RDI time-series, (Kanellou et al., 2012) were able to identify five different areas in Greece. (Zarei et al., 2016a, b) and (Kousari et al., 2014) effectively employed RDI for evaluating the severity of the drought as well as its trend and regional analysis in Iran's dry and semi-arid regions. Except for the time when a declining trend in PET was confirmed in China's non-arid areas.

One of the biggest problems facing human societies is the changing global climate and environmental effects of global warming. These modifications show the intricate relationships between the climate system's hydrosphere, lithosphere, cryosphere, biosphere, and atmosphere. To better understand the behavior of the climate system and make better predictions about how it will evolve in the future, theories and approaches for examining interactions and feedback mechanisms among its constituent parts must be developed. Models of the climate system are useful instruments for unbiasedly characterizing interactions within the system and investigating the ways in which these interactions affect climate change. In 2005, The National Climate Center (NCC)

began investigating and creating a new generation of climate model systems. Three second-generation AGCM versions have been created by this program (BCC-AGCM2.0, BCC-AGCM2.1 and BCC-AGCM2.2.), (Wu et al., 2014).

This study focuses on the historical series of Al-Najaf Al-Ashraf Governorate and assessing drought years in spatiotemporal distribution for the period from 2000 to 31 August 2025. The RDI was calculated using GIS 10.3 software for spatial mapping and DrinC for index calculation. For the future period from 2025 to 2044, rainfall and temperature data were obtained from the NCAR website, and the RDI was calculated.

**2. Study Area:**

The study region was Al-Najaf Al-Ashraf governorate is situated in the central Iraqi province. The region inside the Najaf Governorate's official borders serves as a representation of the study area's spatial limits is situated on the eastern border of the alluvial flood basin, south of the capital Baghdad. Its administrative borders are as follows: Karbala Governorate to the north; Anbar Governorate to the northwest; Qadisiyah Governorate to the east; Babil Governorate to the northeast; Muthanna Governorate to the southeast; and the Kingdom of Saudi Arabia to the south and southwest. It is between latitudes 29.50° and 32.21° north and longitudes (42.0° and 44.45°) east. On the map, it fills an area of 29346 km<sup>2</sup>, which is equal to 435244 km<sup>2</sup> in Iraq, (Salih et al., 2024). Figure (1) shows the location of Al-Najaf Al-Ashraf governorate.

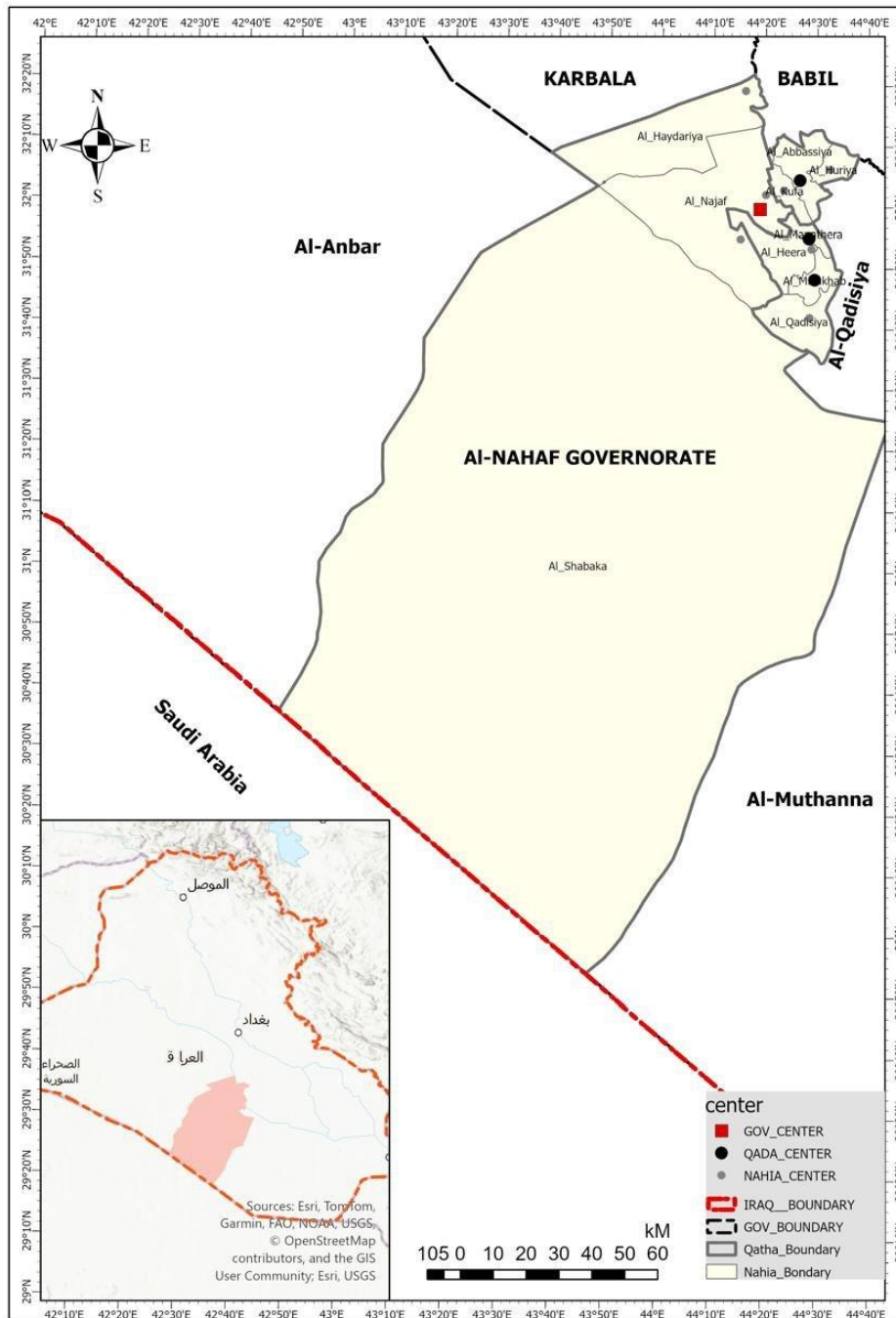


Figure 1: The location of Al-Najaf Al-Ashraf governorate (Ministry of Iraq Planning)

**3. Material and Methods:**

**3.1 Methodology:**

The methodology of this paper is summarized by studying the historical time series of average precipitation were obtained from the NASA Power Data website <https://power.larc.nasa.gov/data-access-viewer/> and representing them in a rainfall

distribution map using GIS 10.3 software. The RDI was calculated based on average precipitation and evapo transpiration, which is calculated based on average maximum and minimum temperatures. Then, the rainfall rates and RDI were studied for the future period (2025-2044) using climate model data from the NSF National Center for Atmospheric Research website (NCAR) <https://ncar.ucar.edu/>.

**3.1.2 Reconnaissance Drought Index (RDI):**

Following a thorough analysis of the several indices used to determine and evaluate the severity of the meteorological drought, it was determined that while each index had its uses, none of them appeared to have universal application. However, throughout the past. Because of its minimal data needs, the SPI has gained a lot of popularity during the past ten years.

A more thorough explanation was provided in other publications (Tsakiris and Vangelis, 2005; Tsakiris et al., 2006), although a novel reconnaissance drought detection and evaluation index was initially introduced at the MEDROPLAN coordinating conference (Tsakiris, 2004). Known as the Reconnaissance Drought Index, or RDI, (Tsakiris et al., 2007). Table (1) illustrates the value of the RDI.

Table 1: RDI values (Shah et al., 2013)

RDI value	Classification
2 or more	Extremely wet
1.5 to 1.99	Very wet
1 to 1.49	Moderately wet
0.99 to 0	Near normal
0 to -0.99	Mild drought
-1 to -1.49	Moderately drought
-1.5 to -1.99	Severely drought
-2 or less	Extremely drought

**4. Results and Discussion:**

**4.1 Spatiotemporal Distribution of Average Precipitation:**

According to average precipitation data from NASA Power for the period from 2000 to August 31, 2025, the period from 2000 to 2017 was the lowest in precipitation, which ranging between 27 mm and 90 mm. The years 2001 and 2017 were the lowest, with precipitation ranging between 26 mm. The period from 2018 to 31 August 2025 is the highest precipitation compared to the previous period, while the years 2018, 2020, and 2023 saw the highest precipitation which ranged between 135 and 172 mm as shown in figure (2) which shows the time series of the average precipitation amounts extending from the period 2000 to 31 August, 2025.

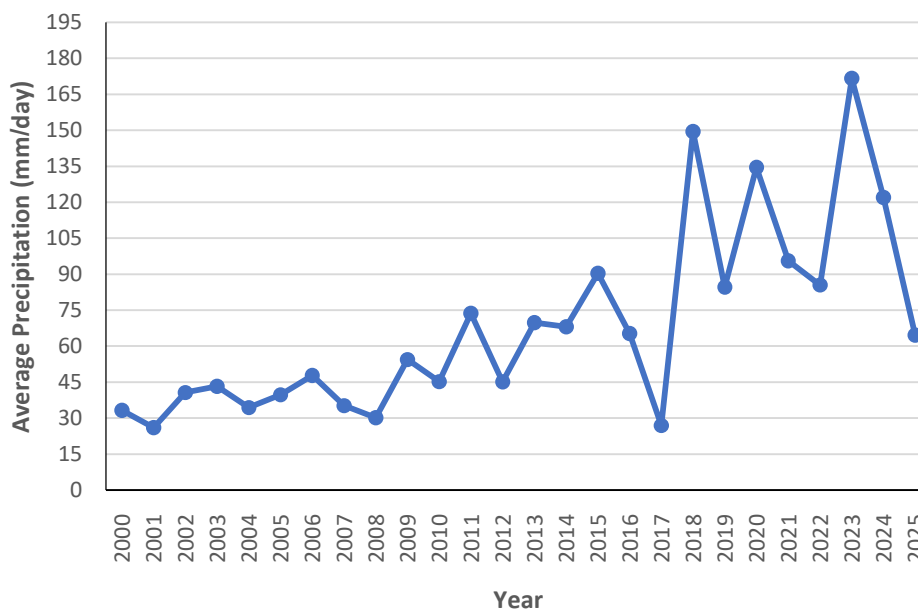


Figure 2: The amount of average precipitation for the period (2000\_31 August 2025).

Ten stations distributed within the Najaf Governorate were taken and average precipitation distribution map was drawn using GIS 10.3 software for the period (2000\_ 31 August 2025). The results showed that the average precipitation varied in values from 42 mm to 78 mm in the southern, southwestern and southeastern regions of the governorate which it is the area with the least precipitation, the majority of these areas represent the Najaf Desert, which it is extends to the areas west of the city (the Najaf Sea area to the borders of Anbar Governorate) and south of the city to the borders of Muthana Governorate. While in the northern region, which is the most governorate region, it receives the most average precipitation. The average rainfall ranged between 97 mm and 123 mm, and these amounts decreased in the center of the governorate to 78 mm and 97 mm. The city's population is concentrated in the north, east and southeast of the governorate. Figure (3) illustrates the spatial distribution of precipitation rate in the governorate

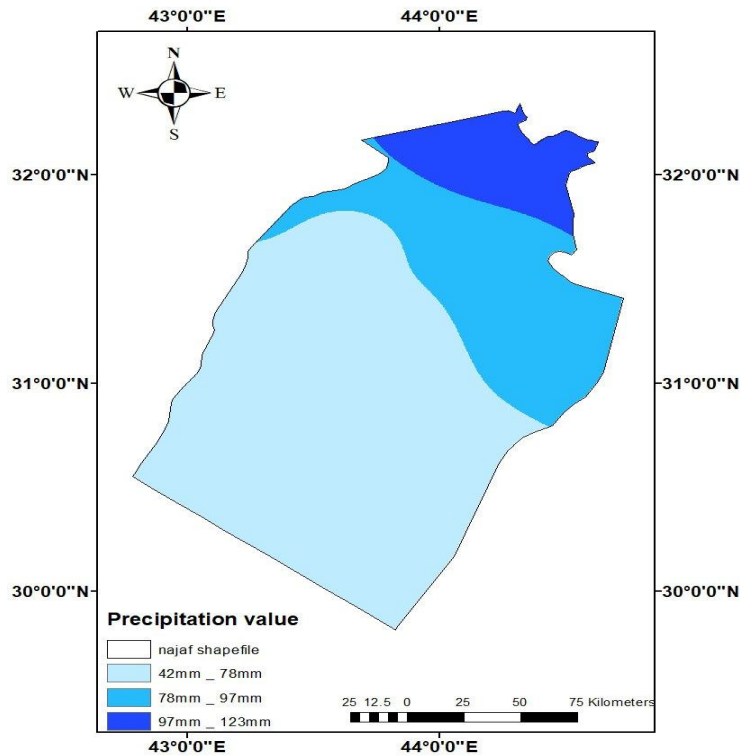


Figure 3: Spatial distribution of average precipitation for the period (2000\_31 August 2025).

**4.2 Spatiotemporal Distribution of RDI:**

The RDI index was initially calculated based on the evapo transpiration rates, which were calculated based on the maximum and minimum temperatures and the precipitation. The results obtained from the RDI index by using the DrinC software show that the time period is divided into two periods, the first extending from the year 2000 to the year 2017, and the second period extending from the year 2018 to the year 2024 (the year 2025 was not computed because the index is calculated based on 12 months, and the available data is up to 31 August). The results for the first period ranged between moderately wet, near normal, near normal, and mild drought. The years 2002, 2009, and 2013 were moderately wet, while 2011 was near normal, and the remaining years in this period were mild drought, and compared to the precipitation amounts, this period represents less precipitation than the second period. As for the second period, extending from 2018 to 2024, all years were near normal except for 2019, where the index value was -0.03, which represents mild drought. As for the spatial distribution, the regions of the south, east, southwest and southeast were near normal, while parts of the east, southwest and north ranged from near normal to mild drought. As for the rest of the governorate, which represents the north, northeast and west, they were mild drought. The index values do not depend primarily on rainfall amounts alone, but rather on evapo transpiration, the calculation of which depends on the average values of maximum and minimum temperatures to determine whether the year is considered dry or not. The figure (4) and figure (5) illustrates the values of time series and the Spatial distribution of RDI for the period (2000\_2024), respectively.

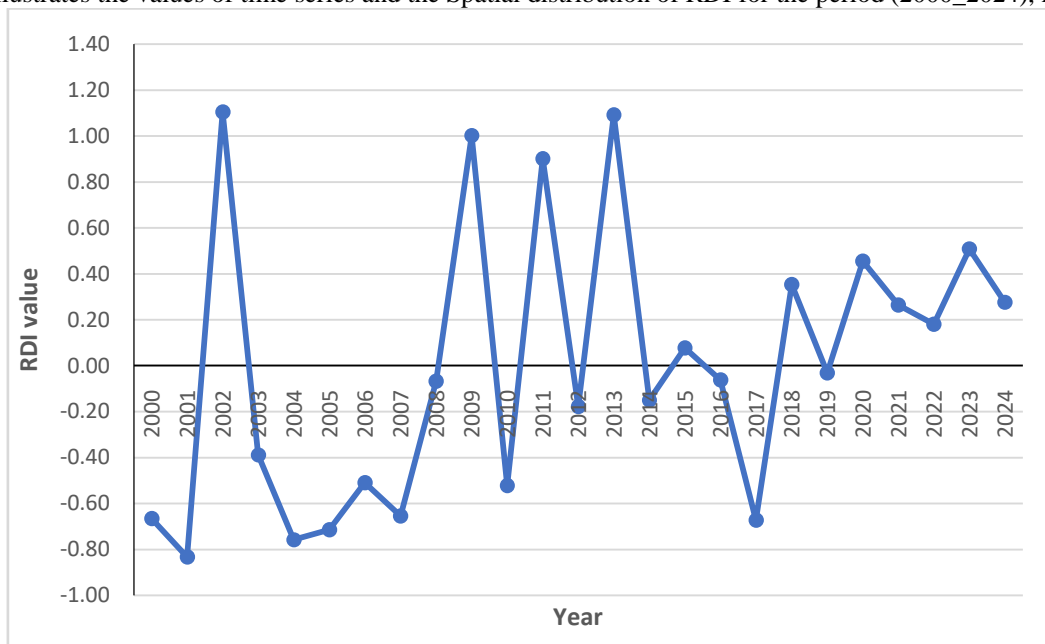


Figure 4: The values of time series of RDI for the period (2000\_2024).

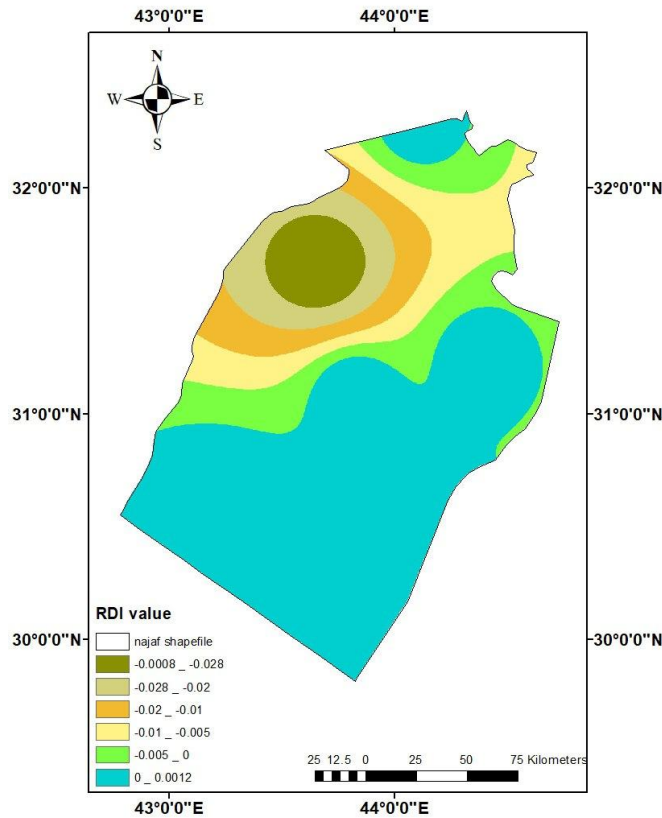


Figure 5: Spatial distribution of RDI for the period (2000\_2024).

**4.3 Result of Climate Change Model for the period (2025-2044):**

The results of the climate model show that during the future period extending from 2026 to 2044, there is a decrease in the average precipitation amounts for this period by 30.8%, as the average precipitation amounts ranged from 48.5 mm in 2026, which is the lowest value among years, to 118.9 mm in 2030, which is the highest value among years, while in the past period the highest value of the average precipitation was 172 mm. While the rest of the years during this period, the precipitation amounts ranged between 60 mm and 114 mm, it is worth noting that during the last period, extending from 2036 to 2044, the average precipitation amounts did not exceed 97 mm and did not fall below 63.6 mm. This decrease has a significant impact on the environment and agriculture, and this impact may lead to Serious dangers. Figure (6) shown the amount of average precipitation for the period (2025-2044).

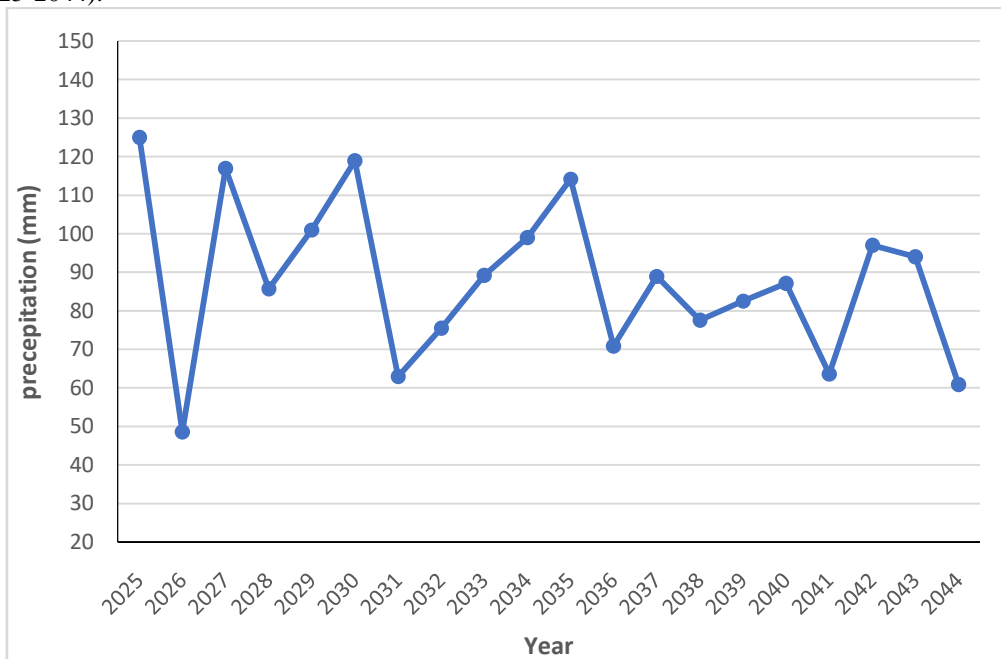


Figure 6: The amount of average precipitation for the period (2025-2044).

As for the results obtained from the RDI index for the future period extending from 2025-2044, the index results did not exceed near normal and mild drought, as the index values did not increase above 0.68 and did not fall below 0.44 throughout the study period. The driest year recorded by the index was 2026, where the value of the index was -0.44, followed by 2044 with a value of -0.31, then 2040, where the value of the index was -0.30, and the wettest year was 2025, where the value of the index was 0.69, followed by 2027 with an index value of 0.44, then 2030 with an index value of 0.38, as shown in Figure (7), which shows

the time series of RDI values for the period (2025-2044). Compared to the past period, the index value exceeded near normal to moderate wet, as the index value reached 1.1, and the period from 2018 to 2024 was all near normal. However, the future period, as previously shown, did not exceed near normal, and the most recent period extending from 2036 to 2044 was all mild drought, except for the year 2043.

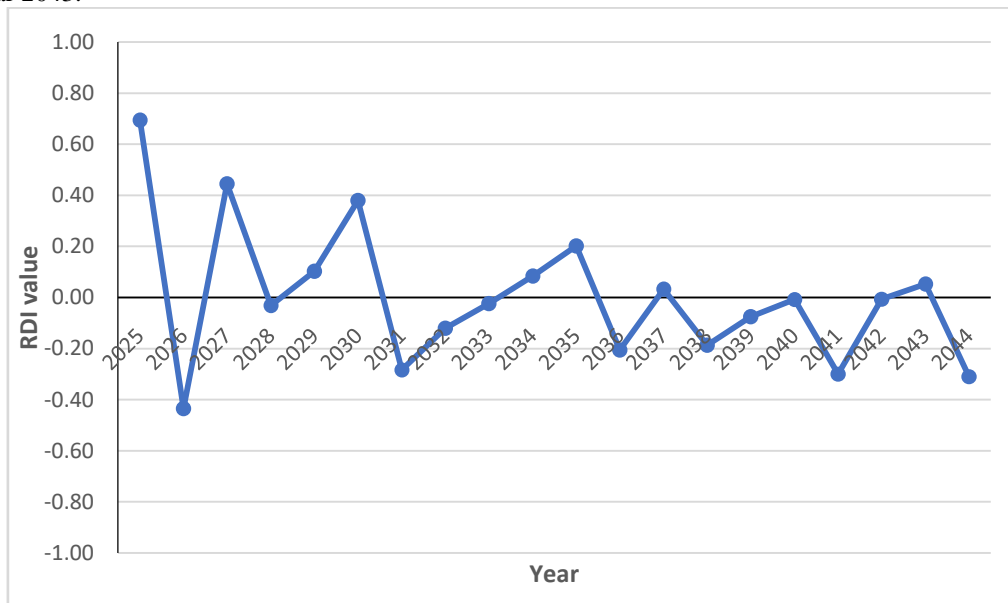


Figure 7: The values of time series of RDI for the period (2025-2044).

## 5. Conclusion:

Recent decades have witnessed significant and growing global interest among climate, population, economic, and agricultural experts in studying drought and scarcity disasters, given the significant risks they pose to the economic, social, political, and environmental conditions of countries.

In this study, GIS10.4 was used to map the distribution of average precipitation rates in Al-Najaf Al-Ashraf Governorate for the historical time series extending from 2000 to 31 August 2025, which was obtained from NASA POER DATA website. The RDI was computed by using DrinC software based on the average maximum and minimum temperatures and the average precipitation amounts. For the future period extending from 2025 to 2044, the average precipitation amounts were studied, and the RDI was computed from climate model data from the NCAR website. The conclusions were as follows:

- The historical period of the governorate is divided into two parts. The average precipitation for the first period, extending from 2000 to 2017, ranged between 26 mm and 90.4 mm. The second period, extending from 2018 to August 31, 2025, ranged between 64.6 mm and 171.6 mm. The highest rates were concentrated in the northern and northeastern regions of the governorate.
- The RDI historical values ranged between moderate wet, near normal and mild drought. The highest value was in 2002 with a value of 1.1 and the lowest value was in 2001 with a value of -0.83. The period extending from 2018 to 2024 is all near normal. The near normal index values were distributed in the southern and southeastern regions and some parts of the northern region of the governorate, while the rest of the governorate ranged between near normal and near normal.
- For the future period extending from 2025 to 2044, the climate model results showed that the average precipitation amounts will decrease by 30.8% compared to the previous period, and that the lowest average precipitation amounts reached 48.5 mm in 2026, while the highest average precipitation amount did not exceed 118.9 mm in 2030.
- The results calculated from the RDI showed that the years from 2036 to 2044 were all dry years, as the index value was mild drought, except for the year 2043, which was near normal. As for the period from 2025 to 2035, the index value ranged from near normal to near normal to mild drought.

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