

Comprehensive Review of Meteorological Drought in Iraq

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Abstract

Drought is a serious environmental phenomenon characterized by a severe and continuous decrease in rainfall rates and elevated temperatures, which leads to a reduction in soil moisture and serious climatic, environmental, and economic damage. It manifests in various forms, including meteorological, agricultural, and hydrological droughts, each linked to specific causes and effects. Monitoring and assessing drought depend on the use of suitable indicators, which vary in effectiveness depending on regional climatic and geographical conditions. Drought is a recurring problem in Iraq, which is located in arid and semi-arid regions. Continued drought leads to a scarcity of water resources. A review of previous studies shows the existence of research gaps, most notably the lack of comprehensive studies comparing different drought indicators to determine the most appropriate ones for the conditions of Iraq, especially the southern regions, which are characterized by scarcity of rain and high evaporation rates. Therefore, choosing the most appropriate indices is necessary for a more accurate understanding of the drought phenomenon and for developing appropriate strategies for water resource management and adaptation to this recurring event. This situation confirms the urgent need to conduct in-depth studies to address these gaps and provide practical solutions that enhance the sustainability of natural resources in the region.

Keywords:

Drought severity, Semi-arid, Drought index

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1. Introduction

Drought is a complex and prolonged climatic event that affects both the environment and human societies considerably. It is generally defined as a state of water deficiency caused by a sustained reduction in rainfall over an extended period (Lloyd-Hughes, 2014). The consequences of drought, such as reduced water availability and damaged ecosystems, often lead to severe economic losses, particularly in regions that rely on rain-fed agriculture and water-intensive industries (Al-Bazaz and Mahmood Agha, 2023).

Three major factors contribute significantly to the global aggravation and worsening of drought: population density, increased demand for water, and climate change. The continued increase in the global population places increased pressure

on available water resources, exacerbating communities' vulnerability to drought. Increased demand for water — driven by urbanization, agriculture, and industry — further depletes water supplies and reduces resilience during droughts. Climate change alters rainfall patterns and increases the frequency and intensity of extreme weather events, including droughts. These interconnected factors highlight the urgent need to study climate change and its impact on drought (Dierauer and Zhu, 2020).

The American Meteorological Society divides drought into four types based on its stages: (1) meteorological drought, where rainfall is more than 25% below normal levels for a given area; (2) agricultural drought; (3) hydrological drought; and (4) socioeconomic drought (Subramanya, 2017).

Globally, droughts have been exacerbated by climate change, resulting in altered precipitation

patterns and increased evaporation rates. In many regions, such as Iraq, drought has become a recurring environmental issue affecting agricultural productivity, water supply, and economic stability (IPCC, 2013). Iraq's geographic location in an arid and semi-arid zone places it at a heightened risk for drought, particularly in its southern regions, where rainfall is scarce and evaporation is high. Despite the pressing need for drought management strategies, the country continues to experience recurrent droughts that have widespread implications for water resource management and climate adaptation. Several studies have examined drought conditions in Iraq, with a focus on different regions and drought indices. For example, Sulaiman and Younis (2021) assessed the temporal and spatial patterns of drought using the Standardized Precipitation Index (SPI) and the Chinese Z-index (CZI) in Nineveh Governorate. Their findings revealed a pronounced vulnerability to drought, especially during periods of low precipitation. Similarly, Al-Timimi et al. (2012) and Salman et al. (2018) highlighted the critical role of meteorological factors in drought occurrence across Iraq, particularly in the northern and central regions, where precipitation trends are highly variable.

In addition, Mahmood Agha et al. (2025) and Al-Juboori (2023) conducted predictive analyses of drought conditions using traditional and hybrid models. Their studies identified the most effective approaches for forecasting drought severity and duration, offering valuable insight into future drought preparedness—complementing earlier findings regarding spatial and temporal drought behavior in the region.

However, these studies have notable limitations. Most research has focused on specific regions of Iraq, with limited cross-regional comparisons and a lack of comprehensive analysis of the drought indices that are most suitable for Iraq's unique climatic conditions. For instance, while the SPI has been widely used, studies have suggested that other indices such as the CZI and deciles index (DI) might offer more localized insights into drought severity, particularly in Iraq's arid and semi-arid zones (Sulaiman and Younis, 2021; Gaznayee et al., 2022). Moreover, the temporal coverage of these studies is often limited, which may affect the reliability of drought

predictions, especially in light of rapidly changing climate patterns.

International studies, such as those conducted in the USA (Myronidis et al., 2018) and in China (Li and Cai, 2024), provide valuable insights into drought monitoring techniques and indices. However, they often overlook regional variances in drought dynamics, which are crucial for understanding and addressing the unique challenges posed by drought in Iraq. While these studies have contributed to the development of global drought monitoring frameworks, their direct applicability to Iraq is limited due to differences in climate, geography, and socioeconomic conditions.

This review aims to fill the gap in the existing literature by critically evaluating the most relevant drought indices for Iraq with a particular focus on meteorological drought. It will assess the strengths and limitations of various indices, including SPI, CZI, and DI, and their effectiveness in capturing the nuances of drought in Iraq's diverse climatic regions. The findings from this review will provide important insights for policymakers, aiding in the development of more effective and region-specific drought management strategies. Additionally, this review will contribute to the academic discourse on drought monitoring by providing a detailed comparison of indices in the context of Iraq's specific environmental conditions.

The need for effective drought monitoring is especially urgent in Iraq, given its vulnerability to climate change and the intensifying demands on its water resources. Recent climate models indicate that Iraq will experience more frequent and severe droughts in the coming decades, further exacerbating existing water scarcity issues. The agricultural sector, which is highly dependent on rainfall, is particularly at risk; drought leads to reduced crop yields, loss of livestock, and economic instability for rural communities. As such, the development of accurate drought indices tailored to Iraq's specific needs is not only a scientific necessity but also an essential tool for decision-makers. By providing a deeper understanding of drought conditions, this review can help inform better land management, water conservation, and agricultural practices, which are critical for the country's long-term resilience.

In addition to its academic value, this review aims to bridge the gap between research and practice by offering practical solutions to the

drought challenges facing Iraq. It will highlight the most suitable indices for monitoring drought in various regions of Iraq, helping stakeholders, from local farmers to national policymakers, better predict, mitigate, and adapt to drought conditions. Given the escalating water crisis and the rising frequency of drought events in Iraq, the application of the findings from this review is vital to enhance drought preparedness and response strategies. Ultimately, this work will contribute to Iraq's ability to effectively manage its water resources in an increasingly volatile climate.

Table 1: Previous Studies on Drought in Different Regions.

Region	Authors
USA	Myronidis et al., 2018
China	Li and Cai, 2024; Javed et al., 2021
Syria and Jordan	Al-Qinna et al., 2011; Abd-Elhamid et al., 2024
Iran	Morid et al., 2006; Mahmoudi et al., 2019; Sadeghpour and Yavari, 2009
Turkey	Katipoglu, Acar, and Şengül, 2020A; Ozkaya and Zerberg, 2019; Öz et al., 2024; Şener and Davraz, 2024
Iraq	Sulaiman and Younis, 2021; Al-Timimi et al., 2012; Mahmood Agha and Şarlak, 2016; Salman et al., 2018; Yaseen and Awchi, 2024; Kazanchie al., 2024; Yenigun and Ibrahim, 2019; Mahmood Agha and Al-Aqeeli, 2021; Mahmood Agha, 2021; Gaznayee et al., 2022; Yahya et al., 2022; H. Al-Bazaz and A., 2023; Jameel et al., 2023; Hasan et al., 2023; H. J. Al-Bazaz and Mahmood Agha, 2024; Governorate, 1965; Mahmood Agha, 2025; Al-Juboori, 2023.

2. Study area

Iraq is located in the subtropical latitudes in the Northern Hemisphere, between longitudes (38.45°–48.45°) east of the Greenwich meridian and latitudes (29.5°–37.5°) north of the equator. It is classified within the northern temperate region. The climate of Iraq is divided into two groups: The first is the central and southern regions, characterised by a continental and subtropical climate, which tends to be dry and moderately arid. The second group is the northern region, which is a mountainous area influenced by the Mediterranean climate (Salman et al., 2020). The average annual rainfall is 154 mm across the region, but it is distributed asymmetrically. Rainfall decreases to less than 100 mm in the southern regions, while it exceeds 1200 mm in the northeast of the country (Brouwer and Heibloem, 1986). These numbers are not fixed, as they vary from year to year and from season to season. In

terms of temperatures, during winter, minimum temperatures range from negative values on the slopes of frozen mountains in the northern region to 4 °C–5 °C in the south. In summer, minimum temperatures in the northern regions range from 27 °C to 31 °C, while maximum temperatures may reach 41°C–45 °C. The high temperatures in summer part of Iraq to the risks of drought and the resulting natural disasters (Salman et al., 2017). combination of low rainfall in winter and exposes a large.

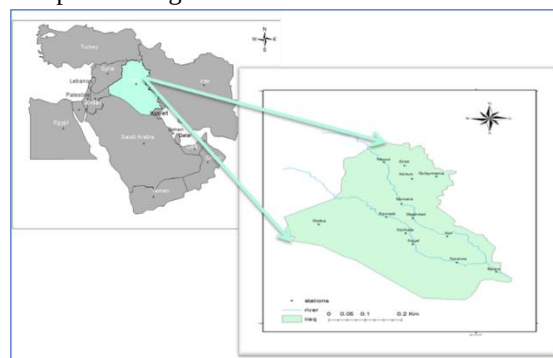


Fig.1: Iraq location in the Middle East.

3. Drought index definitions and categories

Drought indices are essential tools for identifying droughts, assessing their severity and monitoring their evolution over time. Common indices are based on meteorological and hydrological variables. Drought indices are determined by drought triggers, which serve as threshold values for these indices. These triggers distinguish different drought categories and determine when response actions should be initiated or terminated. Drought categories are often classified into severity levels such as mild, moderate, severe, and very severe. Given the complex nature of drought and its dependence on multiple factors such as water supply and demand, hydrological and political boundaries, and antecedent conditions, the indices used should be sensitive to spatial and temporal context. This diversity of definitions has led to the development of more than 150 definitions of drought (Wilhite and Glantz, 1985), which is reflected in the wide variety of indices used to monitor and analyze the phenomenon. Recently, many drought indices have been developed based on the basis of rainfall, temperature, and soil moisture datasets (Mishra and Singh, 2011).

A. Input variables

Different variables are used to predict drought, and these depend on the specific type of drought being predicted or detected. Input variables differ on the basis of the type of drought index applied in the analyses. For example, some drought indices would consider precipitation and temperature values only, while others would utilize a group of climate variables such as precipitation only. Once the relevant variables are identified, the indicators that can be used for drought detection can be determined. In the case of meteorological drought, rainfall is the key factor, and its deficits are commonly used to detect and analyze drought severity.

The aim of this study is to investigate meteorological drought with a particular focus on its analysis using various indices.

When choosing to adopt a particular indicator over another, the purpose of determining the type of drought is taken into account, that is, whether it is for prediction or evaluation. Available data also need to be considered, such as precipitation, temperature, soil moisture, and satellite images, in addition to the geographical area, where the characteristics of drought differ from one region to another (Yihdego et al., 2019). Some studies are intended to study agricultural drought, identify areas exposed to drought, and manage the agricultural plan in proportion to the type and degree of the affected drought. Others are conducted to support water resource management and decision-making with regard to whether water should be stored or released from reservoirs. Studies can also be conducted for civil planning and assessing the risks of drought for a specific area and examining the risks related to and resulting from this phenomenon, and its negative effects on various civil areas to activate emergency plans when necessary (Li et al., 2024).

Most previous research discussed in this paper utilized actual meteorological data recorded by the Iraqi Meteorological and Seismological Organization, the accredited and official source of Iraqi weather and climate data. These data hold accurate details about temperature, precipitation, atmospheric pressure, and relative humidity, which are vital parameters for assessing meteorological drought conditions. These data have been utilized intensively in previous research to identify climate trends in Iraq and study the development of

drought over different periods of time. However, some studies have coverage problems with respect to data for particular areas or discontinuity in data from year to year, which could influence the accuracy of the analysis in certain cases. Most studies conduct tests on the data before its use to ascertain the quality and reliability of the climatic and hydrological data (Mohammed and Scholz, 2023). Testing the data for quality is crucial prior to any study related to climate or water resources. If the data are non-homogeneous, then the stations with unreliable data can be excluded (Mahmood Agha et al., 2017).

B. Drought Indices

1. Deciles Index (DI)

The DI is a method that divides a long-term series of precipitation data into 10 categories or 'deciles' to better assess precipitation anomalies in comparison to normal levels. The values are arranged from lowest to highest, with the first decile representing the lowest 10% of precipitation and the 10th decile representing the highest 10%. The middle values, such as the fifth decile, correspond to normal precipitation conditions. The cases are then classified on the basis of their level of dryness or humidity as outlined in Table 2 to allow for easier comparison with other methods (Tadić et al., 2015).

Table 2: Decile index limits.

	DI	Percentage	Classification
1	Deciles 1-2	Lowest 20%	Much below normal
2	Deciles 3-4	Next lowest 20%	Below normal
3	Deciles 5-6	20% Middle	Near normal
4	Deciles 7-8	Next highest 20%	Above normal
5	Deciles 9-10	Highest 20%	Much above normal

Calculation method

i. Rainfall record data are arranged in ascending order for each time period.

ii. Divide the data into 10 equal groups and calculate percentages using the relationship:

$$D_k = \left(\frac{k \times (N + 1)}{10} \right) \dots \dots \dots (1)$$

Where: D_k is the percentage.

iii. Rainfall bands that correspond to each percentile are identified.

One disadvantage of the decile system is that, within the Australian Drought Monitoring System, it requires a long series of climate records because

it facilitates accurate calculations (Nagarajan, 2009).

2. Standardized Precipitation Index (SPI)

The SPI measures actual rainfall compared with a probability distribution, making it an effective tool for assessing drought across time and different regions. The SPI is calculated on the basis of long-term data and transformed to a normal distribution with mean zero and one standard deviation, where positive values indicate above-average precipitation and negative values indicate lower precipitation. The SPI is increasingly used to assess drought severity in many countries and is sometimes superior to the Palmer Drought Severity Index (PDSI) in some studies (Naresh Kumar et al., 2009).

The SPI is calculated by calculating the gamma probability function for a specific time series of rainfall, where each month is calculated separately, and the gamma distribution is defined by the following formula:

$$g(x) = \frac{1}{\beta^\alpha \Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} \quad \text{for } x > 0 \dots (2)$$

$$\Gamma(\alpha) = \int_0^\infty y^{\alpha-1} e^{-y} dy \dots (3)$$

Where: $\Gamma(\alpha)$: gamma function; (x) : the rain value at which the distribution is to be evaluated; α : the shape parameter of the distribution and has a value greater than one; β : the scale parameter of the distribution and has a value greater than one

$$\alpha = \frac{1}{4A} \left(1 + \sqrt{1 + \frac{4A}{3}}\right) \dots (4)$$

$$\beta = \frac{\bar{x}}{\alpha} \dots (5)$$

$$A = \ln(x) - \frac{\sum \ln(x)}{n_e} \dots (6)$$

Where: n_e : The number of rain coordinates recorded in the rain record.

Substituting the values of α and β , the gamma distribution function becomes as follows:

$$G(x) = \int_0^x g(x) dx = \frac{1}{\beta^\alpha \Gamma(\alpha)} \int_0^x x^{\alpha-1} e^{-x/\beta} dx \dots (7)$$

We assume that the value of $s = x/\beta$ produces a gamma distribution function as follows:

$$G(x) = \frac{1}{\Gamma(\alpha)} \int_0^s s^{\alpha-1} e^{-s} ds \dots (8)$$

Since the values of the gamma function are not defined at zero values and rain records contain zero values, the following function is derived to calculate the cumulative probability of the gamma distribution:

$$H(x) = q + (1 - q)G(x) \dots (9)$$

Where: q : the probability of zero values and it is calculated by dividing the number of zero rain data in the data series (m) by the number of rain coordinates in the rain record (n) ($q=m/n$), and used to deduce the values of the Standard Rainfall Index (SPI) (Iwata et al., 2012).

The cumulative probability values of the gamma distribution are transformed into a normal distribution as a random variable using the following equations:

$$SPI = -\left(s - \frac{2.515517 + 0.802853s + 0.010328s^2}{1 + 1.432788s + 0.189269s^2 + 0.001308s^3}\right)$$

$$\text{For } 0 < H(x) \leq 0.5 \dots (10)$$

$$SPI = -\left(s - \frac{2.515517 + 0.802853s + 0.010328s^2}{1 + 1.432788s + 0.189269s^2 + 0.001308s^3}\right)$$

$$\text{For } 0 < H(x) < 1 \dots (11)$$

Where:

$$s = \sqrt{\ln\left(\frac{1}{(H(x))^2}\right)} \quad \text{for } 0 < H(x) \leq 0.5 \dots (12)$$

$$s = \sqrt{\ln\left(\frac{1}{(1-H(x))^2}\right)} \quad \text{for } 0.5 < H(x) < 1 \dots (13)$$

It is classified as shown in Table 3 (Asadi Zarch et al., 2015)

Table 3: SPI, CZI, MCZI, ZSI, and RDI index limits.

SPI, CZI, MCZI, RDI, and ZSI	Classification
2 or more	Extremely wet
1.5-1.99	Very wet
1.49-1	Moderately wet
-0.99 to 0.99	Near normal
-1 to -1.49	Moderately dry
-1.5 to -1.99	Severely dry
and less than -2	Extremely dry

disadvantage of the SPI is that drought is evaluated based on total rainfall only, neglecting other parameters such as humidity, radiation, and soil conditions (Labudová et al., 2015). In addition, the SPI schedule takes into account only rainfall and cannot explain the role of global warming in changes in drought (Tayfur, 2021)

3. Z-Score index (ZSI)

ZSI is an analogue of CZI, but with fewer requirements than the latter in terms of inputs, and is presented in the following format:

$$ZSI = \frac{P - \bar{P}}{SD} \times 100 \dots (14)$$

Where: $\bar{P}$: Average monthly rainfall (mm);

P : Rainfall in a particular month (mm); SD :

Standard deviation for any measurement period.

The equation is called standardization or normalization. The Z score indicates the number of standard deviations the rainfall value is above or below the mean. This index is not the same as the SPI because it does not require adjusting the data to fit a gamma or Pearson type III distribution (Katipoglu et al., 2020). Drought is classified based on the ZSI results as shown in Table 3 (Mahmoudi et al., 2019).

4. China Z-index

The National Climate Center of China developed the CZI as an improvement to the SPI (Wu et al., 2001). The CZI is a composite climatic drought index based on climatological precipitation data and the Pearson type III distribution.

The following is the basic equation for CZI:

$$CZI = \frac{6}{c_s} \left(\frac{c_s}{2} \phi + 1 \right)^{1/3} - \frac{6}{c_s} + \frac{c_s}{6} \dots \dots (15)$$

Where: c_s : deviation coefficient; ϕ : uniform variable.

The c_s and ϕ equations are calculated as follows:

$$c_s = \frac{\sum_{i=1}^n (p_i - p)^3}{ns^3} \dots \dots (16)$$

$$\phi = \frac{p_i - p}{s} \dots \dots (17)$$

Where: s is the average sample variance; n is the total number of months.

Table 3 determines the drought state.

5. Modified China Z-Index (MCZI)

The modified CZI (MCZI) is a tool used to evaluate the level of drought in a specific area. This indicator is based on measurements of rainfall, temperature, and humidity, and aims to determine the extent of dryness or humidity in each environment. The MCZI calculates deviations from normal climatic conditions, which helps identify drought periods and estimate their impact on agriculture and water resources. These data are used in planning and resource management, especially in areas affected by climate change. The MCZI is calculated in the same way as the CZI except that instead of the mean, the median is used in calculating this indicator (Sulaiman and Younis, 2021).

6. Percent of normal precipitation index (PNPI)

The percent of normal precipitation index was first developed by Ndlovu and Demlie (2020). This indicator measures the ratio of actual

precipitation to the normal rate and is expressed as a percentage. The % normal index is effectively used to raise awareness about drought conditions at local and seasonal levels, and is expressed in the following formula:

$$PNI = \frac{P_i}{P} \times 10 \dots \dots \dots (18)$$

Where: PNI: Percentage of Natural Precipitation Index; P_i : Actual rainfall; P : Rainfall rate. Table 4 is used to classify drought (Asrari et al., 2011).

Table 4: PNPI index limits.

PNPI	Classification
More than 120	Humid
80 to 120	Normal
70 to 80	Light drought
55 to 70	Moderately drought
40 to 55	Severely drought

7. Bhalme and Mooley Drought Index (BMDI)

This index was invented by Bhalme and Mooley in 1980. It calculates the percentage deviation of monthly or annual rainfall compared to its normal mean. This index is similar to the Palmer index, as it considers the influence of precipitation from the previous month in its calculations, making it a redundant index (Eslamian et al., 2017).

Calculation method:

- i- Calculating the average ($\bar{x}$) and standard deviation (s) of the monthly precipitation data during the study period.
- ii- Calculating the monthly humidity index (MI), the percentage deviation of monthly rainfall from its long-term average.
- iii- Determining the minimum values of monthly humidity during the study period and finding their cumulative value.
- iv-Fitting linear regression on the highest value of monthly cumulative humidity using the least squares technique.

The classification is done according to Dunkel (2015) Table 5.

Table 5: BMDI Index limits.

BMDI	Classification
-0.99 to 0.99	Near to normal
-1 to -1.99	Weak drought
-2 to -2.99	Moderate drought Severe
Less than or equal to -3	Severe drought

8. Reconnaissance Drought Index (RDI)

The Reconnaissance Drought Index (RDI) is used to detect drought on the basis of potential evaporation and transpiration (PET) values and

rainfall data, where the maximum and minimum temperature values are used to calculate PET. These are referred to as the initial values of the RDI (Oksal and Beden, 2024), and the calculation is done using the equations:

$$a_k^{(i)} = \frac{\sum_{j=1}^k P_{ij}}{\sum_{j=1}^k PET_{ij}} \dots\dots\dots (19)$$

Where: P_{ij} and PET_{ij} are i by hydrological year respectively; j : of the year are the rainfall and PET values for the month; n is the total number of years of available data.

The second natural RDI is calculated every year using equation (19), where the arithmetic average of the values calculated for n years is known.

$$RDI_n^{(i)} = \frac{a_k^i}{\bar{a}_k} - 1 \dots\dots\dots (20)$$

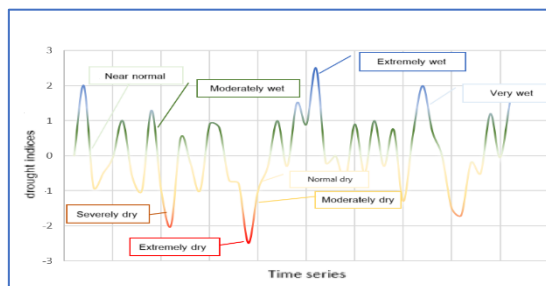


Fig. 2: Drought classification scheme.

In calculating the standard RDI, an equation similar to the index equation (SPI) is used.

$$RDI_{st(k)}^{(i)} = \frac{y_k - \bar{y}_k}{\bar{\sigma}_k} \dots\dots\dots (21)$$

Where: $\bar{y}_k$ and $\bar{\sigma}_k$ express the average and standard deviation, respectively.

This index is classified based on Table 3.

9. Percent of Normal by Mean

The percent of normal by mean (PN) index is an effective and simple tool for drought assessment and is preferred for its ease of calculation and ability to accurately describe drought conditions. The statistical construction of this index has been criticized for inconsistency in two aspects (Morid et al., 2006). Firstly, because no statistical transformation is used for the log rainfall distribution, the difference between the mean value and the median value can undermine its accuracy. Secondly, as a result of the different distribution of seasons and regions, this indicator cannot be used to compare drought across seasons and regions. Therefore, this method lacks the required robustness, according to the index using the following equation:

$$PN(\%) = \frac{P-X}{X} \times 100 \dots\dots\dots (22)$$

Where:

P : the amount of observed rainfall (mm)

x : the average rainfall for a given period (mm).

The results are classified as shown in Table 6.

Table 6: PN index limits.

PN	Classification
More than 110	wet
80 to 110	normal
55 to 80	Moderately dry
40 to 50	Very dry
Less than 40	Extremely dry

10. Drought theory

All drought indices allow the identification of dry and wet periods within a specific time scale for any location where rainfall and temperature data are recorded. Positive values indicate an increase in the amount of rain compared with the general average, which means wet years, while negative values indicate a decrease in the amount of rain compared with the general average, which indicates dry years (Majid Kalyana and Awchi, 2015). Fig. 2 shows the classification of drought based on dependence on drought indicators according to the classification by Tsakiris et al. (2007).

Yevjevich (1969) proposed the theory of continuous events or the theory of runs, which is considered an important tool for studying and analyzing drought statistical properties. This theory depends on the principle of continuity of observed values -for example, positive values- so that the previous or next value is of a different type,

for example, negative values (Al-Mohseen, 2009). The periods and occurrences of drought are typically derived from historical records by using non-parametric methods. However, such methods are often limited in scope and may lack sufficient reliability for accurately characterizing drought behavior. A more consistent and comprehensive approach is required to overcome these limitations. Therefore, this theory has been adopted to provide a more systematic representation of drought characteristics.

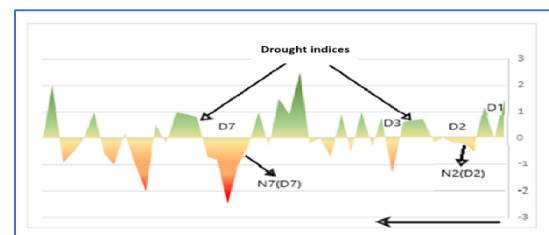


Fig. 3: Drought Indices: Duration, Intensity and Frequency Calculations.

Many indices can be inferred from drought, periods and duration of its occurrence, and by relying on clear inputs such as the total rain and monthly temperatures only. From these indices, the value of dehydration sustainability (drought duration D_i) shown in Fig. 2 can be inferred. Drought values can be calculated by using Equation (22). In addition to calculating the drought intensity by calculating the amount of rain deficiency from normal rates and using Equation (23) (Awchi et al, 2017), the percentage of dry frequency can be calculated (relative frequencies) by dividing the number of years of dehydration by the number of overall years (Mahmood Agha et al., 2017).

$$M_j = \sum_{i=1}^t |\bar{x} - x_i| \dots \dots \dots (23)$$

Where:

M_j : Total drought value (mm); $\bar{x}$: Rain rate for the data series; x_i : Rain value at time i ; t : Number of periods of rain deficit during the dry period.

$$I_j = \frac{M_j}{D_j} \dots \dots \dots (24)$$

Where: D_j : Drought Sustainability (Year);

I_j : Drought Intensity (mm/year).

4. Previous studies

Given the complexity of drought as a phenomenon and the diversity of its wide-ranging impacts across various sectors, numerous studies have aimed to develop indices for assessing drought characteristics and comparing its patterns across different environmental settings. However, variations in climatic and hydrological characteristics from one region to another make it challenging to adopt a single, universally applicable index. Accordingly, this review seeks to provide a comprehensive overview of the relevant research efforts. It begins by examining studies that focus on the comparison of drought indicators, followed by a review of global studies, regional research with an emphasis on the Middle East, and studies that specifically address drought conditions in Iraq.

A. Comparing the indicators of climate drought

Many studies have compared drought indicators in different regions of the world. For example, in Iran, the performance of seven indicators (DI, PN, SPI, CZI, MCZI, EDI) was

monitored for 32 years. The results showed that the SPI and CZI indicators operate symmetrically but are slow in responding to determine the beginning of drought. Moreover, the DI responds greatly to precipitation events but for only one year, with a contrast in time and space. SPI and EDI are able to determine the beginning of drought and in temporal and spatial contrast consistently, thus being recommended for studying the drought properties in the region (Morid et al., 2006). Similarly, another study conducted in Iran used six indicators of meteorological drought (PN, SPI, CZI, MCZI, Z-Score, and the drought index of Idu Marton) in six climatic zones to assess the spatial and temporal dynamics of drought. The results showed that the Z-Score, CZI, and MCZI indices are effective alternatives to SPI, especially when long-term time series are limited, or when the use of SPI is complicated, with their effectiveness depending on the duration of drought and climatic conditions (Shahabfar and Eitzinger, 2013). Several studies have been conducted to assess drought indicators and their effectiveness across various regions. For example, in Oregon, USA, drought indicators were evaluated using rainfall, temperature, and evaporation data from 88 climate stations. The Pearson's correlation coefficient between the indices showed that the Z3 aridity index exhibited the strongest correlation ($r > 0.65$) with streamflow variables (Myronidis et al., 2018). In Iran, drought indicators such as SPI, PN, ZSI, Di, CZI, EDI and MCZI were compared across 41 stations for the 1985–2013 period. The results indicated that ZSI, SPI and CZI showed similar characteristics in terms of assessing drought conditions, whereas Di and PN exhibited different behaviors. Moreover, the MCZI index was less effective in drought monitoring, with SPI and EDI emerging as the most reliable indicators in that region (Mahmoudi et al., 2019). In Turkey, a study of the Euphrates basin's drought from 1966–2017 compared various indices, including SPI, ZSI, RAI, SPEI, and RDI, and found that the indices based on the SPI, Z-score index (ZSI), and others such as RDI and SPEI exhibited similar patterns. However, RDI and SPEI, which depend more on temperature data, are more effective than SPI and ZSI in detecting drought conditions, especially when considering the role of evaporation and water consumption (Katipoglu et al., 2020). The phenomenon of drought in the Mekera Basin in northern Algeria was studied using eight rain

indices (SPI, RDI, RAI, ZSI, CZI, MCZI, PNI, DI), where the results showed strong correlations between most indices ($r > 0.68$) with the superiority of DI and Z-Score in monitoring drought events, which support the importance of integrating indices to improve the spatial and temporal assessment of drought (Elhoussaoui et al., 2021).

These studies evidently show that while different drought indices can provide valuable insights, their effectiveness varies depending on regional conditions and the specific characteristics of the area under study. The comparison of multiple drought indices highlights the importance of selecting the most suitable indicators for each region. Furthermore, it underscores the need for further research to refine these indicators for more accurate drought monitoring and prediction, especially in areas with complex climatic conditions.

In Iraq, Sulaiman and Younis (2021) evaluated the performance of three drought indices (SPI, DI and CZI) based on observational data from meteorological stations in the Nineveh region (Mosul, Tel Afar and Sinjar) for the period 1981–2018. The results revealed that the DI demonstrated the highest correlation coefficient, indicating its superior suitability for drought assessment in the region due to its ability to capture local variations in precipitation and moisture levels. Also, a study was conducted in Salah al-Din Governorate in Iraq for the period (1990-2021) to estimate the climatic drought indicators (SPI, RDI, PNI, RAI, ZSI, and Papa) and study their relationship to desertification and land degradation using rainfall, temperature, humidity, and evapotranspiration data. The results showed that severe droughts occurred during 1990-1993 and 1998-2000, and the drought continued during 2020-2021 compared to wet years between 2015-2018. It also showed that there are strong correlations between SPI and the rest of the indicators ($r > 0.97$, R^2 reaches 0.99 with RDI), which indicate a high agreement between these indicators in the assessment of drought in the region (Khalaf and Hummadi, 2023). In comparison, research in China analyzed indicators such as geophysical and hydrological indices (GEVI, HI, K, PA) and found that SPI, SPEI, and the PDSI provided the most reliable drought assessments across different time scales, particularly when considering rainfall and temperature variability (Li and Cai, 2024).

While these findings provide useful insights into drought monitoring, this research highlights a critical gap in understanding the best indices for Iraq, especially considering the region's unique climatic conditions. This review aims to address this gap by evaluating the suitability of different drought indices, such as SPI, DI and CZI, for Iraq. In conclusion, while indices such as SPI and CZI are useful in other regions, Iraq's complex climate necessitates further exploration to select the most accurate and region-specific drought indicators. The results of this review will contribute to better-informed decisions regarding drought preparedness and water resource management in Iraq, and it will offer essential guidance for policymakers seeking effective drought mitigation strategies in the face of climate change.

B. Studies related to meteorological drought in the Middle East

Over the years, drought has been considered a clear problem that threatens the world in general and the Middle East in particular. Hence, researchers in the Middle East have been studying drought characteristics. In Jordan, a study of drought characteristics was presented using the SPI in addition to the NDVI, revealing the repetition of drought in uneven periods and showing that the intensity increased over time (Al-Qinna et al., 2011). A study in Sistan and Baluchistan Province in Iran, which was obtained using the Markov series, showed that drought might exceed 70% in the central regions of the country (Sadeghpour and Yavari, 2009). Drought in Syria was evaluated using remote sensing data and the SPI. Findings showed that severe drought events were recorded in 1990, 2014, and 2016, with 2016 having the highest severity of drought (Abd-Elhamid et al., 2024). In Turkey, a comprehensive study was conducted on the basis of data from 219 stations distributed in the region using SPI, SPEI, and RDI. The results of the study confirmed that the region has been subjected to moderate drought (Öz et al., 2024). Another study was conducted in Turkey using data from three stations over 57 years from 1965 to 2022 on the basis of SPI, RAI, CZI, and ZSI. The RAI gave the highest value to drought (−4.5) and proved the existence of an increased link between indices over a one-year time scale and the occurrence of drought (Şener and Davraz, 2024).

A study in East Asia showed that the responses of soil moisture and hydrological drought to meteorological drought differ spatially and temporally, showing a weak correlation between soil moisture and meteorological drought in the north of the region in the short term (1-6 months) versus stronger correlations in the south in the long term (9-24 months). Hydrological droughts have also shown a strong and persistent correlation with atmospheric droughts across all durations, with delays of up to 8-10 months in the north compared to rapid responses in the South (Mtupili et al., 2025).

A review of the literature on drought in many regions of the world, in general, and in the Middle East region in particular, with the exception of Iraq, showed that the regions in general had been exposed to droughts in different return periods. Each study specialized in different indicators, obtained results for a specific region, and recommended the use of appropriate evidence according to the hydrological conditions to which the region is exposed and the nature of its rain distribution.

C. Studies on climate drought in Iraq

Iraq is one of the areas that is most affected by drought. The effects of drought, along with the increasing problems of water shortage, have given rise to the urgent need to study drought and its effects, and to analyze the consequences of this catastrophic phenomenon. From this point of view, many researchers have written about drought and applied analysis methods using several indices.

A study was presented to detect drought in Iraq using GIS and remote sensing based on the SPI and the anomaly of the Normalized Difference Vegetation Index (NDVI). The final drought maps showed that 14.4%, 61.6%, 23.2%, and 0.8% of the study area were classified as slight, moderate, severe, and very severe drought, respectively. The results also indicated that the northwestern region of Iraq is more prone to drought (Al-Timimi et al., 2012). Drought has also been studied throughout Iraq to detect temporal and spatial changes using RDI, showing that the year 2008 was the worst year of drought over all parts of Iraq (Mahmood Agha and Şarlak, 2016). Man Kendall studied drought in Iran, finding a decrease in the annual number of rainy days and confirming the increase in drought period (Salman et al., 2018). In addition, the state of drought throughout Iraq was discussed

through the SPI and the theory of flow to analyze the characteristics of atmospheric drought, its quantity, severity, and rain deficit. The northern region was the most prone to drought, and the Iraq region was subjected to varying periods of drought that affected 45% of the study area (Yaseen and Awchi, 2024). In Iraq, research has been conducted to evaluate the performance of the CZI, MCZI, and SPI on a time scale of 1, 3, 6, 9, and 12 months, relying on rain data for the 1980–2021 period for five meteorological stations. The results showed an interconnection and high similarity between the results of the indices with the increase in time ranges. The SPI is more sensitive to detecting the beginning of drought and has more severe characteristics than other indices, while the MCZI identifies moisture earlier than the other two can. Moreover, SPI and CZI have been observed to be good indicators for describing drought in the Iraq region (Kazanchi et al. 2024).

We conclude from the above findings that the Iraq region has generally been exposed to periods of severe drought, which sometimes reached critical levels. Moreover, northern Iraq is the most affected by high drought levels. Specialized studies have been conducted to analyze drought in northern Iraq in particular. One study analyzed drought properties in terms of its duration and intensity using the SPI for different time scales (1, 3, 6, 9, 12 months). The results showed that the year 2008 was the driest year during the study period (Yenigun and Ibrahim, 2019). Also, the effect of the Arctic Oscillation Index (AOI) on drought indicators in northern Iraq was studied using the SPEI for 3, 6, and 12 months. The SPEI and the AOI showed a higher correlation in the 12-month time scale than in the 3- and 6-month time scales for all regions (Mahmood Agha and Al-Aqeeli, 2021). Scientists have also studied droughts by using the CZI for a one-month time scale in Nineveh Governorate for Mosul, Sinjar, and Tal Afar stations. All stations experienced dry periods during the month of March (Mahmood Agha, 2021). Recently, a study on drought and forecasting in the Kurdistan Region of Iraq used the RDI for the 1973–2020 period to detect the beginning and end of drought, as well as to predict future drought by using two types of artificial neural networks. The findings show that the driest years were 1998–1999 for the Amadi, Erbil, and Sulaymaniyah stations and 2007–2008 for the rest of the nine stations (Gaznayee et al., 2022).

In this study, we aim to analyze climatic drought in Iraq by using multiple drought indices, building on previous research that explored the effectiveness of various drought indices in the region. Numerous studies have evaluated the performance of drought indices in different regions of Iraq, but these have been limited to a few commonly used indices, focusing on various aspects such as rainfall, effective runoff, and temperature variability. For example, one study developed a multivariate drought index that combines rainfall and effective flow data for northeastern Iraq. Another study focused on climate change impacts in northern Iraq (Erbil, Dohuk, Sulaymaniyah, Mosul and Kirkuk) using the SPI for the 1980–2020 period. The study concluded that all regions experienced drought, as indicated by values below (-1) , indicating deficits in soil moisture, groundwater, and water bodies (Jameel et al., 2023).

Further research in northern Iraq utilized rainfall variables and effective flow to model a drought index through the coupling method. The Frank function was the best choice for modelling the cumulative distribution function, and the proposed binary index showed a strong match with SPI and SRI, demonstrating its applicability (Hasan et al., 2023). In Nineveh Governorate, drought was assessed using SPI and CZI, revealing a clear decrease in rainfall levels and a noticeable increase in temperatures, with the Tel Abta station experiencing the highest frequency of drought events (Al-Bazaz and Mahmood Agha, 2024). A separate analysis in Sulaymaniyah, northern Iraq, assessed drought using SPI, SPEI, and RDI for different time intervals (3, 6, 9, and 12 months). The Darbandikhan station had the highest drought frequency, with significant drought observed at the Sulaymaniyah and Dokan stations (Governorate, 1965; Haveen M. Rasheed, 2024). A study based on rainfall data (1980–2021) for five stations in Iraq indicated the evaluation of the SPI and ZSI indicators on time scales of 1–12 months, where it was found that the correlation between them is weak in short periods and increases in long periods (9–12 months), especially in the northern regions. SPI showed a higher ability for early detection of drought with sharper and longer periods, while ZSI was more suitable for moisture analysis over the 12 months (Kazanchi and Awchi, 2025).

In addition, many recent studies have addressed the topic of hydrological drought

forecasting using various indicators and traditional or hybrid models, focusing on analyzing the characteristics of drought in terms of intensity, duration, and frequency. For example, Mahmood Agha et al. (2025) presented a study that examined the drought characteristics of the upper Zab River using the standard discharge index (SSI) on the 6- and 12-month scales, and applied traditional forecasting models such as the ARIMA model and two exponential smoothing models, where the ARIMA model proved its efficiency in representing the temporal behavior of drought with high accuracy amounting to 92.4% (R^2) at the 6-month scale. In another study, Al-Juboori (2023) developed a hybrid model using KNN and K-means techniques to predict drought based on the SDI index, and the model achieved a performance 85% higher than the traditional model.

Although these studies focused on hydrological drought, the similarity in the methodology of analysis and forecasting is directly relevant to the topic of climatic drought, since the same models and indicators can be used to analyze the characteristics of meteorological drought with higher accuracy. The adoption of advanced statistical methods such as ARIMA can contribute to the construction of an effective forecasting system that enhances the capacity of Hydroplanning and Climate Adaptation in dry and semi-dry environments.

While previous studies explored drought indices in Iraq, a comprehensive and integrated approach to evaluate meteorological drought across different regions, incorporating multiple drought indices, is still needed. This study aims to fill this gap by analyzing meteorological drought in Iraq using a combination of established indices, which will provide a more comprehensive understanding of drought patterns and their implications.

This review found that the studies that included northern Iraq were extensive and were conducted using many indices such as SPI, SPEI, CZI, and MCZI. Overall, the results show that the region suffers from drought and that the northern region is the most exposed part to drought on varying time scales.

5. Conclusions and Recommendations

A review of the previous literature related to the Middle East, especially Iraq, shows that the

region suffers from successive droughts ranging from light to very severe. Together, these studies demonstrate the occurrence of drought, but most lack data for northern Iraq.

This gap is the absence of a comprehensive study that can determine the most appropriate and most accurate indices for drought measurement, taking into account the conditions of the region, especially the distribution of rain and other climatic factors that affect it. Although most studies indicated that the length of the time chain used for drought analysis is equal to or more than 30 years, the validity of the use of indicators based on shorter time chains is worth investigating. This approach is of particular importance in dry and semi-dry areas such as northern Iraq, where rains are rare and evaporation rates are high, thereby making these areas more vulnerable to repeating droughts. Moreover, the literature still lacks a comprehensive analysis that compares different indicators to determine their suitability for the conditions of northern Iraq. Clear recommendations on the selection of the most appropriate index are also lacking, which can provide an accurate and comprehensive picture of the drought phenomenon in this region. Some studies, such as that of Sulaiman and Younis (2021), suggest that the DI is effective in northern Iraq. These findings are geographically limited. Therefore, this review underscores the need for a comprehensive nationwide study to identify the most suitable drought index for Iraq as a whole. Bridging this research gap is an important step towards a better understanding of this phenomenon and effective adaptation measures.

Table 7: Summary of studies conducted in Iraq.

Meteorological drought indices	Reference
SPI, NDVI	Al-Timimi 2012
RDI	Mahmood Agha and Şarlak 2016
MK	Salman et al. 2018
SPI	Yenigun and Ibrahim 2019
SPI, CZI, Deciles	Sulaiman and Younis 2021
SPEI	Mahmood Agha and Al-Aqeeli 2021
CZI	Mahmood Agha 2021
RDI	Gaznayee et al. 2022
SPI	Jameel et al. 2023
SPI, RDI, PNI, RAI, ZSI, Papa	Khalaf and Hummadi, 2023
SPI, SPEI, RDI	Haveen M.Rasheed 2024
SPI	Yaseen and Awchi 2024
CZI, MCZI, SPI	Kazanchi And Taymoor Awchi 2024
ZSI, SPI	Kazanchi And Taymoor Awchi 2025

6. Conflict of Interest

The authors declare that they have no conflict of interest.

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8. Author Contributions

Sura Basim Idrees Al-Kalo: Conceived and prepared the manuscript; conducted the literature search and collected the relevant references; wrote and organized the manuscript; and prepared the manuscript for submission.

Omar Miqdad Abdul-Ghani Agha: Proposed the research topic and contributed to defining the research methodology; reviewed and evaluated the results; critically reviewed the discussion section; and provided scientific guidance, comments, and suggestions throughout the preparation and revision of the manuscript.

Both authors reviewed and approved the final version of the manuscript.

9. References

- Abd-Elhamid, H.F., Zeleňáková, M., Soľáková, T., Saleh, O.K. and El-Dakak, A.M., 2024. Monitoring flood and drought risks in arid and semi-arid regions using remote sensing data and standardized precipitation index: A case study of Syria. *Journal of Flood Risk Management*, 17(1), e12961. <https://doi.org/10.1111/jfr3.12961>
- Al-Bazaz, H. and Mahmood Agha, O.M.A.M., 2023. A Study of the Homogeneity of Climatic Data for Rain, Temperature and Humidity for Nineveh Governorate. *Al-Rafidain Engineering Journal (AREJ)*, 28(2), pp. 173–185. <https://doi.org/10.33899/rengj.2023.137763.1225>
- Al-Bazaz, H. J. and Mahmood Agha, O.M.A., 2024. Climate change and the behaviour of meteorological drought and its impact on wheat yield. *Engineering and Applied Science Research*, 51(2), pp. 248–258. <https://doi.org/10.14456/easr.2024.24>
- Al-Juboori, A.M., 2023. Prediction of Hydrological Drought in Semi-arid Regions Using a Novel Hybrid Model. *Water Resources Management*, 37(9), pp. 3657–3669. <https://doi.org/10.1007/S11269-023-03520-1/METRICS>
- Al-Qinna, M.I., Hammouri, N.A., Obeidat, M.M. and Ahmad, F.Y., 2011. Drought analysis in Jordan under current and future climates. *Climatic Change*, 106(3), pp. 421–440. <https://doi.org/10.1007/S10584-010-9954-Y/METRICS>
- Al-Mohseen, K.A., 2010. Frequency Analysis of Hydrologic Drought (Case Study). *Al-Rafidain*

- Engineering Journal, 18(6), <https://doi.org/10.33899/rengj.2010.35187>
- Al-Timimi, Y.K., George, L.E. and Al-Jiboori, M.H., 2012. Drought Risk Assessment In Iraq Using Remote Sensing And GIS Techniques. *Iraqi Journal of Science*, 53(4), pp. 1078–1082.
- Asadi Zarch, M.A., Sivakumar, B. and Sharma, A., 2015. Droughts in a warming climate: A global assessment of Standardized precipitation index (SPI) and Reconnaissance drought index (RDI). *Journal of Hydrology*, 526(July), pp. 183–195. <https://doi.org/10.1016/j.jhydrol.2014.09.071>
- Asrari, E., Masoudi, M. and Afrough, E., 2011. Analyzing Spatial and Temporal Pattern of Humid, Normal and Drought Years Using Percent of Normal Precipitation Index (PnPI) in Fars Province, Iran. *Journal of Applied Sciences in Environmental Sanitation*, 6(3), pp. 299–308.
- Awchi, T.A. and Kalyana, M.M., 2017. Meteorological drought analysis in northern Iraq using SPI and GIS. *Sustainable Water Resources Management*, 3(4), pp. 451–463. <https://doi.org/10.1007/S40899-017-0111-X>
- Brouwer, C. and Heibloem, M., 1986. *Irrigation Water Needs: Irrigation Water Management. Training Manual No. 3*, <http://www.fao.org/3/u3160e/u3160e04.htm#2.1.1>
- Dierauer, J.R. and Zhu, C., 2020. Drought in the Twenty-First Century in a Water-Rich Region: Modeling Study of the Wabash River Watershed, USA. *Water* 2020, Vol. 12, 181 P., <https://doi.org/10.3390/W12010181>
- Dunkel, Z., 2015. Categorisation of Drought Indices Used in Agricultural Meteorology. November.
- Elhoussaoui, A., Zaagane, M. and Benaabidate, L., 2021. Comparison of various drought indices for assessing drought status of the Northern Mekerra watershed, Northwest of Algeria. *Arabian Journal of Geos*, 14(10). <https://doi.org/10.1007/S12517-021-07269-Y>
- Eslamian, S., Ostad-Ali-Askari, K., Singh, V.P., Dalezios, N.R., Ghane, M., Yihdego, Y., and Matouq, M., 2017. A Review of Drought Indices. *International Journal of Constructive Research in Civil Engineering (IJCRCE)*, 3, pp. 48–66. <https://doi.org/10.20431/2454-8693.0304005>
- Gaznayee, H.A.A., Al-Quraishi, A.M.F., Mahdi, K., Messina, J.P., Zaki, S.H., Razvanchy, H.A.S., Hakzi, K., Huebner, L., Ababakr, S.H., Riksen, M., and Ritsema, C., 2022. Drought Severity and Frequency Analysis Aided by Spectral and Meteorological Indices in the Kurdistan Region of Iraq. *Water* 2022, Vol. 14, 3024 P., 14(19), 3024. <https://doi.org/10.3390/W14193024>
- Governorate, S., 1965. *Journal of Engineering Physics. International Journal of Heat and Mass Transfer*, 8(7), 1052. [https://doi.org/10.1016/0017-9310\(65\)90089-x](https://doi.org/10.1016/0017-9310(65)90089-x)
- Hasan, I.F., Kamal, N.H.M., Awchi, T.A. and Abdullah, R., 2023. Drought Assessment Using Two-Variate Modelling. *IOP Conference Series: Earth and Environmental Science*, 1222(1). <https://doi.org/10.1088/1755-1315/1222/1/012022>
- IPCC, 2013. *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge: Cambridge University Press.
- Iwata, T., Nishiyama, N., Nagano, K., Izumi, N., Tsukioka, T., Chung, K., Hanada, S., Inoue, K., Kaji, M. and Suehiro, S., 2012. Preoperative serum value of sialyl Lewis X predicts pathological nodal extension and survival in patients with surgically treated small cell lung cancer. *Journal of Surgical Oncology*, 105(8), pp. 818–824. <https://doi.org/10.1002/jso.23002>
- Jameel, M., Hameed, S., Shemal, K., Al-Ansari, N. and Abed, S.A., 2023. Spatial and Temporal Assessment of Drought in the Northern Prone of Iraq Using Standardized Precipitation Index. *Engineering*. <https://doi.org/10.4236/eng.2023.1510047>
- Katipoglu, O.M., Acar, R. and Şengül, S., 2020. Comparison of meteorological indices for drought monitoring and evaluating: A case study from the Euphrates Basin, Turkey. *Journal of Water and Climate Change*, 11(1S), pp. 29–43. <https://doi.org/10.2166/wcc.2020.171>
- Kazanchi, S.R. and Awchi, T.A., 2024. Meteorological Drought Analysis Using Multiple Indices for Selected Stations in Iraq. *Tikrit Journal of Engineering Sciences*, 31(2), pp. 91–105. <https://doi.org/10.25130/tjes.31.2.9>
- Kazanchi, S.R. and Awchi, T.A., 2025. Evaluation of SPI and ZSI, Meteorological Drought Indices on Different Time Scales in Iraq. *AIP Conference Proceedings*, 3211(1). <https://doi.org/10.1063/5.0257186/3346170>
- Khalaf, A.A. and Hummadi, A.H., 2023. Time Series Analysis of Drought Indices for Monitoring Desertification and Land Degradation. *Iraqi National Journal of Earth Science*, 23(2), pp. 189–202. <https://doi.org/10.33899/earth.2023.139660.1068>
- Li, L. and Cai, H., 2024. A comparative study of various drought indices at different timescales and over different record lengths in the arid area of northwest China. *Environmental Science and Pollution Research*, 31(17), pp. 25096–25113. <https://doi.org/10.1007/S11356-024-32803-2>
- Li, H., Guo, J., Yan, D., Wang, H. and Jiang, X., 2024. Hydrological Drought Risk Assessment and Its Spatial Transmission Based on the Three-Dimensional Copula Function in the Yellow River Basin. <https://doi.org/10.3390/w16131873>
- Labudová, L.Í.V.I.A., Turňa, M.A.R.O.Š. and Nejedlík, P.A.V.O.L., 2015, September. Drought monitoring in Slovakia. In *Towards Climatic Services. International scientific conference*.
- Mahmood Agha, O.M. A., Ahmed, K.A., and Naser, A.I., 2025. Hydrological drought characteristics prediction using traditional models for the Great Zab River in Iraq. *Theoretical and Applied Climatology*, 156(5), pp. 1–15. <https://doi.org/10.1007/S00704-025-05515-X>

- Mahmood Agha, O.M.A., and Al-Aqeeli, Y.H., 2021. Analysis of the Standardized Precipitation Evapotranspiration Index over Iraq and its relationship with the Arctic Oscillation Index. *Hydrological Sciences Journal*, 66(2), pp. 278–288. <https://doi.org/10.1080/02626667.2020.1854765>
- Mahmood Agha, O.A. M. and Şarlak, N., 2017. Analysis of Meteorological Drought in Iraq Using the Reconnaissance Drought Index (RDI). *International Journal of Advanced Research*, 5(3), pp. 473–479. <http://dx.doi.org/10.21474/IJAR01/3535>
- Mahmood Agha, O.M.A.M., 2021. Investigating the Meteorological Drought Using CZI in Nineveh Governorate, Iraq. *Tikrit Journal of Engineering Sciences*, 28(4), pp. 14–24. <https://doi.org/10.25130/tjes.28.4.02>
- Mahmood Agha, O.M.A. M., Bağcı, S.Ç., and Şarlak, N., 2017. Homogeneity Analysis of Precipitation Series in North Iraq. *IOSR Journal of Applied Geology and Geophysics*, 05(03), pp. 57–63. <https://doi.org/10.9790/0990-0503025763>
- Mahmood Agha, O.M.A.M., and Şarlak, N., 2016. Spatial and temporal patterns of climate variables in Iraq. *Arabian Journal of Geosciences*, 9(4). <https://doi.org/10.1007/s12517-016-2324-y>
- Mahmoudi, P., Rigi, A. and Miri Kamak, M., 2019. A comparative study of precipitation-based drought indices with the aim of selecting the best index for drought monitoring in Iran. *Theoretical and Applied Climatology*, 137(3–4), pp. 3123–3138. <https://doi.org/10.1007/s00704-019-02778-z>
- Majid Kalyana, M. and A. Awchi, T., 2015. Investigating the Meteorological Drought in Northern Iraq Using Deciles Method. *Al-Rafidain Engineering Journal (AREJ)*, 23(3), pp. 12–21. <https://doi.org/10.33899/rengj.2015.101539>
- Mishra, A.K. and Singh, V.P., 2011. Drought modeling - A review. *Journal of Hydrology*, 403(1–2), pp. 157–175. <https://doi.org/10.1016/j.jhydrol.2011.03.049>
- Mohammed, R. and Scholz, M., 2023. Quality Control and Homogeneity Analysis of Precipitation Time Series in the Climatic Region of Iraq. *Atmosphere*, 14(2), pp. 1–12. <https://doi.org/10.3390/atmos14020197>
- Morid, S., Smakhtin, V. and Moghaddasi, M., 2006. Comparison of seven meteorological indices for drought monitoring in Iran. *International Journal of Climatology*, 26(7), pp. 971–985. <https://doi.org/10.1002/joc.1264>
- Mtupili, M., Wang, R., Gu, L. and Yin, J., 2025. Delayed Response of Soil Moisture and Hydrological Droughts to Meteorological Drought Over East Asia. *International Journal of Climatology*, 45(9), e8883. <https://doi.org/10.1002/JOC.8883>
- Myronidis, D., Fotakis, D., Ioannou, K. and Sgouropoulou, K., 2018. Comparison of ten notable meteorological drought indices on tracking the effect of drought on streamflow. *Hydrological Sciences Journal*, 63(15–16), pp. 2005–2019. <https://doi.org/10.1080/02626667.2018.1554285>
- Nagarajan, R., 2009. Drought Indices. *Drought Assessment*, pp. 160–204. https://doi.org/10.1007/978-90-481-2500-5_5
- Naresh Kumar, M., Murthy, C.S., Sesha Sai, M.V.R. and Roy, P.S., 2009. On the use of Standardized Precipitation Index (SPI) for drought intensity assessment. *Meteorological Applications*, 16(3), pp. 381–389. <https://doi.org/10.1002/MET.136>
- Ndlovu, M.S. and Demlie, M., 2020. Assessment of meteorological drought and wet conditions using two drought indices across KwaZulu-Natal Province, South Africa. *Atmosphere*, 11(6), 623 P. <http://dx.doi.org/10.3390/atmos11060623>
- Oksal, N.G.S. and Beden, N., 2024. Drought analysis based on SPI and RDI drought indices in the Burdur Basin. *Turkish Journal of Engineering*, 8(1), pp. 127–138. <https://doi.org/10.31127/tuje.1326875>
- Öz, F.Y., Özalkan, E. and Tatlı, H., 2024. Comparative analysis of SPI, SPEI, and RDI indices for assessing spatio-temporal variation of drought in Türkiye. In *Earth Science Informatics*. Springer Berlin Heidelberg. <https://doi.org/10.1007/s12145-024-01401-8>
- Salman, S.A., Shahid, S., Afan, H.A., Shiru, M.S., Al-Ansari, N. and Yaseen, Z.M., 2020. Changes in climatic water availability and crop water demand for Iraq region. *Sustainability (Switzerland)*, 12(8), pp. 14–27. <https://doi.org/10.3390/SU12083437>
- Salman, S.A., Shahid, S., Ismail, T., Chung, E.S. and Al-Abadi, A.M., 2017. Long-term trends in daily temperature extremes in Iraq. *Atmospheric Research*, 198, pp. 97–107. <https://doi.org/10.1016/J.ATMOSRES.2017.08.011>
- Salman, S.A., Shahid, S., Ismail, T., Rahman, N. bin A., Wang, X. and Chung, E.S., 2018. Unidirectional trends in daily rainfall extremes of Iraq. *ThApC*, 134(3–4), 1165–1177. <https://doi.org/10.1007/S00704-017-2336-X>
- Şener, E. and Davraz, A., 2024. Comparison of drought indices in the analysis of temporal and spatial changes of climatic drought events: a case study in the Egirdir Lake basin (Isparta/Turkey). In *Natural Hazards (Vol. 120, Issue 14)*. Springer Netherlands. <https://doi.org/10.1007/s11069-024-06711-0>
- Shahabfar, A. and Eitzinger, J., 2013. Spatio-temporal analysis of droughts in semi-arid regions by using meteorological drought indices. *Atmosphere*, 4(2), pp. 94–112. <https://doi.org/10.3390/atmos4020094>
- Subramanya, K., 2017. *Engineering Hydrology*. book <https://idr.l3.nitk.ac.in/jspui/handle/123456789/14285>
- Sulaiman, Z.A. and Younis, A.M., 2021. Comparison of different drought indices in Nineveh. 1–5. *Proceedings of Academica Sera International Conference*, Istanbul, Turkey, 20th – 21st April, 2021
- Tadić, L., Dadić, T. and Bosak, M., 2015. Usporedba različitih metoda za ocjenu suše na području kontinentalne Hrvatske. *Gradjevinar*, 67(1), pp. 11–22. <https://doi.org/10.14256/JCE.1088.2014>

Tayfur, G., 2021. Discrepancy precipitation index for monitoring meteorological drought. *Journal of Hydrology*, 597, 126174.
<https://doi.org/10.1016/J.JHYDROL.2021.126174>

Tsakiris, G., Pangalou, D. and Vangelis, H., 2007. Regional drought assessment based on the Reconnaissance Drought Index (RDI). *Water Resources Management*, 21(5), pp. 821–833.
<https://doi.org/10.1007/S11269-006-9105-4>

Wilhite, D.A. and Glantz, M.H., 1985. Glantz, 1987. Understanding the Drought Phenomenon: The Role of Definitions, 10(3), pp. 111–120.
<http://digitalcommons.unl.edu/droughtfacpub%0AWilHITE>

Wu, H., Hayes, M.J., Weiss, A. and Hu, Q., 2001. An evolution of the standardized precipitation index, the China-Z index and the statistical Z-score. *International Journal of Climatology*, 21(6), pp. 745–758.
<https://doi.org/10.1002/joc.658>

Yahya, B.M., Seker, D.Z. and Ahmed, K.A., 2022. Drought Monitoring Based on Predicted SPI Using Fuzzy Controller System. *Iraqi National Journal of Earth Science*, 22(2), pp. 140–152.
<https://doi.org/10.33899/earth.2022.176633>

Yaseen M. Ismael and Taymoor A. Awchi, 2024. IOP Conf. Ser.: Earth Environ. Sci. 1374012063
<https://doi.org/10.1088/1755-1315/1374/1/012063>

Yenigun, K. and Ibrahim, W.A., 2019. Investigation of drought in the northern Iraq region. *Meteorological Applications*, 26(3), pp. 490–499.
<https://doi.org/10.1002/MET.1778>

Yevjevich, V., 1969. An objective approach to definitions and investigations of continental hydrologic droughts. *Journal of Hydrology*, 7(3), 353.
[https://doi.org/10.1016/0022-1694\(69\)90110-3](https://doi.org/10.1016/0022-1694(69)90110-3)

Yihdego, Y., Vaheddoost, B. and Al-Weshah, R.A., 2019. Drought indices and indicators revisited. *Arabian Journal of Geosciences*, 12(3), pp. 1–12.
<https://doi.org/10.1007/S12517-019-4237-Z>



مراجعة شاملة للجفاف المناخي في العراق



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الملخص:

الجفاف هو ظاهرة بيئية خطيرة تتميز بانخفاض حاد ومستمر في معدلات هطول الأمطار وارتفاع درجات الحرارة، مما يؤدي إلى انخفاض رطوبة التربة وحدوث أضرار مناخية وبيئية واقتصادية جسيمة. ويتجلى الجفاف بأشكال متعددة، تشمل الجفاف المناخي والزراعي والهيدرولوجي، حيث يرتبط كل نوع بأسباب وآثار محددة. تعتمد مراقبة الجفاف وتقييمه على استخدام مؤشرات مناسبة تختلف في فعاليتها تبعاً للظروف المناخية والجغرافية لكل منطقة. ويُعد الجفاف مشكلة متكررة في العراق، الذي يقع ضمن المناطق الجافة وشبه الجافة، حيث يؤدي استمرار الجفاف المناخي إلى ندرة الموارد المائية. وقد أظهرت مراجعة الدراسات السابقة وجود فجوات بحثية، أبرزها غياب الدراسات الشاملة التي تقارن بين مؤشرات الجفاف المختلفة لتحديد الأنسب منها لظروف العراق، لا سيما المناطق الجنوبية التي تتميز بندرة الأمطار وارتفاع معدلات التبخر. لذا فإن اختيار المؤشرات الأكثر ملاءمة يُعد خطوة ضرورية لفهم أدق لظاهرة الجفاف ووضع استراتيجيات مناسبة لإدارة الموارد المائية والتكيف مع هذا الحدث المتكرر. وتؤكد هذه الحالة على الحاجة الملحة لإجراء دراسات معمقة لمعالجة هذه الفجوات وتقديم حلول عملية تعزز استدامة الموارد الطبيعية في المنطقة.

الكلمات المفتاحية:

شدة الجفاف، شبه جاف، دليل الجفاف

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