Natural Hazards
https://doi.org/10.1007/s11069-025-07119-0

ORIGINAL PAPER

Advancing innovative trend analysis for drought trends: incorporating drought classification frequencies for comprehensive insights.

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Received: 23 June 2024 / Accepted: 9 January 2025
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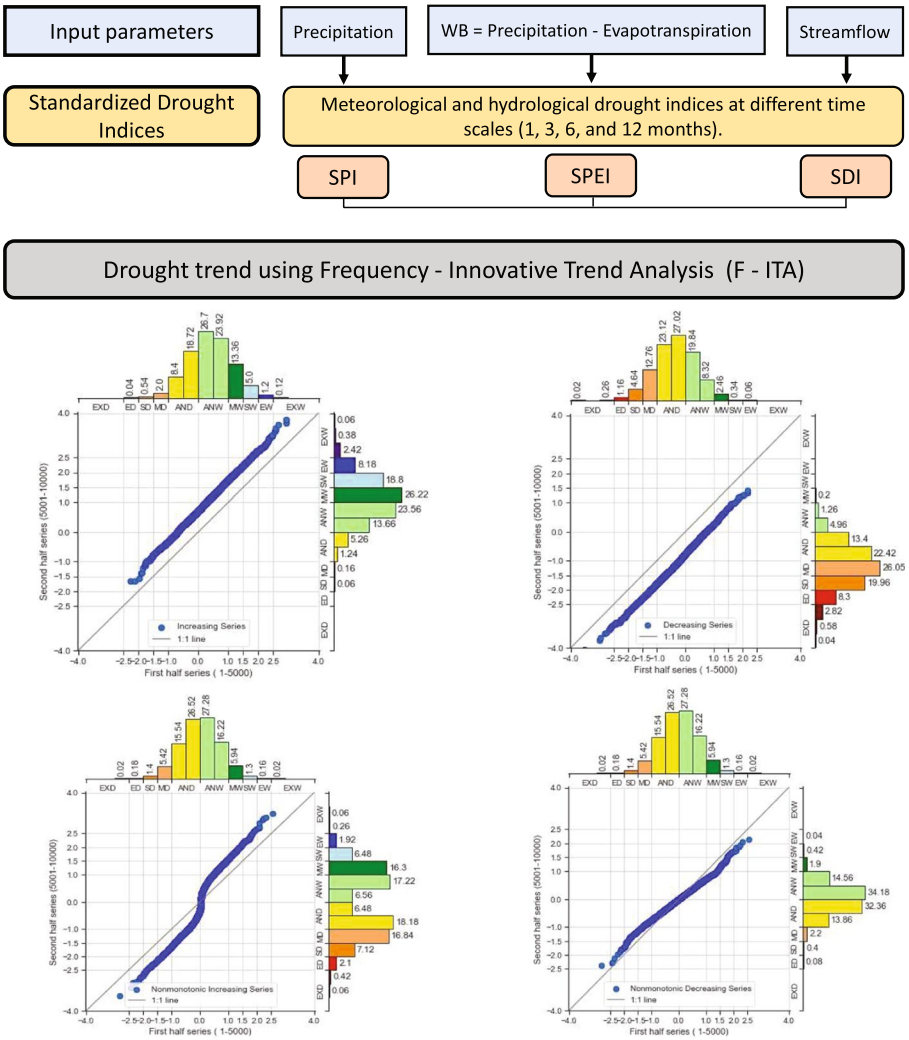
Abstract

As a natural disaster, drought has inverse effects on the agricultural and environmental sectors. Comprehensive drought evaluation is critical for integrated water resources management and drought monitoring. Drought is generally evaluated temporally and spatially without considering its trend, but in recent years, the study of drought trends has become common. However, in drought trend analyses, it is necessary to identify the frequency change of drought classification, along with the sub-trends and their magnitudes, which have been identified in this research with the combined frequency analysis and innovative trend analysis methodologies (F-ITA). Three different drought indices, the standardized precipitation index (SPI), Standardized precipitation evapotranspiration index (SPEI), and streamflow drought index (SDI), were calculated at different time scales at Florya Station, Istanbul, Türkiye, Durham Station in the United Kingdom, and Vargonas (Vargönäs) KRV Station in Sweden. The results showed that F-ITA improved the drought evaluation with a more detailed investigation of meteorological and hydrological drought trends on a microscale rather than stating a decrease or increase trend. There was no trend for SPI-3 and -6 F-ITA; for SPI-12 F-ITA, all drought classifications showed a monotonic increase trend. For example, for SPI-1 and SPEI-1 F-ITA, the abnormally dry classification showed minimal change with frequencies of 35%. The SPEI-12 F-ITA graph showed an increasing trend in all drought classifications. For SPEI-12, the frequency of exceptional drought (extremely dry) events increased from 0.11% (0.66%) to 1.21% (2.3%), while severe and moderate drought frequencies rose significantly from 3.73% to 4.61% and 7.46% to 11.4%, respectively. Finally, monotonic trend increases were noticed in the SDI at all time scales for all classifications.

Extended author information available on the last page of the article

Published online: 17 February 2025

Graphical abstract



Trend conditions and drought frequencies according to F-ITA

Keywords Time series · Drought assessment · Hydrometeorological variables · Standardized precipitation index (SPI) · Standardized precipitation evapotranspiration index (SPEI) · Streamflow drought index (SDI)

1 1. Introduction

Droughts, one of the most complex natural disasters worldwide, have become increasingly important in climate change studies because of their extensive effects, prolonged duration, and high frequency (Alashan 2020a; Mishra and Singh 2010). Climate patterns and

variations drive these drought events and cause severe economic, agricultural, and environmental consequences (Benzater et al. 2019; Abu Arra and Şişman 2024). Also, droughts, characterized by less precipitation, impact water availability and demand, affecting agriculture and industry and resulting in significant financial losses (Caloiero et al. 2018; Şen et al. 2020). According to the literature, the growing frequency and increase of droughts highlight the need for reliable measures to assess and forecast their variations to mitigate possible effects efficiently. (Habibi et al. 2024; Kesgin et al. 2024). These measures are vital for developing strategies to mitigate these impacts and ensure sustainable water resource management (Danandeh Mehr and Vaheddoost 2020; Taylan 2024).

According to Wilhite (2000), drought monitoring consists of four primary types: meteorological, hydrological, agricultural, and socioeconomic droughts. Each type is characterized by distinct variables and indices. Several drought indices have been developed as a first step to calculating drought conditions, including the Standardized Precipitation Index (SPI) (McKee et al. 1993), the Actual Precipitation Index (API) (Şen and Almazroui 2021), the Streamflow Drought Index (SDI) (Nalbantis and Tsakiris 2009), the Reconnaissance Drought Index (RDI) (Tsakiris et al. 2007), and the Standardized Precipitation Evapotranspiration Index (SPEI) (Vicente-Serrano et al. 2010). These indices are considered reliable for evaluating drought locally and globally (Salim et al. 2023; Merabti et al. 2023; Boloorani et al. 2024; Ahmed et al. 2023; Syed et al. 2022). SPI and SPEI are commonly utilized to assess meteorological droughts, while SDI is often used to evaluate hydrological droughts at different time scales. These standardized drought indices apply the principle of probabilistic standardization, converting the original data into unitless metrics that can be compared across different climatic datasets (Abu Arra and Şişman 2024; Raposo et al. 2023). Traditional drought studies in the literature have utilized these indices to evaluate temporal and spatial droughts, including analyzing drought characteristics such as duration, intensity, and frequency (Okkan et al. 2024; Şan et al. 2024).

Increases in the frequency and intensity of extreme climate events, such as droughts, influenced by global precipitation and temperature variations, are observed due to climate change (Haile et al. 2020; Alashan 2020b; Koycegiz and Buyukyildiz 2024). Given this, there is a huge need to study drought trends using classical and innovative methodologies, such as the Innovative Trend Analysis (ITA) method (Şişman and Kizilöz 2021). Assessing the drought trend is crucial for managing and determining the timing and extent of necessary precautions (Güçlü et al. 2020).

One of the most popular and well-known trend methods is the innovative trend analysis (ITA). This method, first introduced by Şen (2012), is particularly effective in analyzing non-stationary time series data, which is common in drought studies due to the variable nature of climate-related phenomena. ITA's graphical representation makes it easier to observe potential changes in the median and other percentiles of time series data, providing a clear presentation of increasing or decreasing trends in drought (Şen 2012; Güçlü 2020). The ITA approach has increasingly been utilized as a powerful tool in drought analysis, offering a robust way to identify and visualize trends in different types of drought analysis, such as the studies by (Yeşilköy and Şaylan 2022; Gumus et al. 2023; Achite et al. 2023; Berhail and Katipoğlu 2023; Niazkar et al. 2024; Robleh et al. 2024; Kartal and Emiroglu 2024; Ozocak et al. 2024; Simsek et al. 2024; Kesgin et al. 2024; Tuğrul and Hinis 2024; Caloiero 2018; Elouissi 2021; Phuong et al. 2022). However, after thoroughly evaluating these articles and other articles that used classical trend methods for drought trend study, it is evident that determining the trend direction and slope is insufficient. For example, Yeşilköy and Şaylan (2022) determined the drought trend for the Northwestern part of Türkiye using SPEI and the self-calibrated

Palmer Drought Severity Index (sc-PDSI). Their study showed that the drought would increase in the study area. Achite et al. (2023) applied the ITA method to the SPI and Standardized Runoff Index (SRI) values at different time scales in the Wadi Ouahrane basin in Algeria, and their study showed various trend directions within the used stations. Also, Tuğrul and Hinis (2024) evaluated the trend using classical and innovative methods. They used ITA for SPI and SDI in Apa dam in Türkiye, and they considered the drought classification in their analysis without considering its frequencies. Considering the literature review done for the articles conducted for drought trend studies, there is a gap in evaluating the drought trend, which is insufficient by determining the direction and slope of this trend without considering the drought classification and the frequency of each classification.

Despite ITA's strengths, it has some limitations, particularly its current analysis of drought events, classifications, and frequencies. ITA does not integrate the frequency of various drought classifications into its analysis, which is crucial for a more comprehensive understanding of drought impacts under different climate conditions. The importance of incorporating the frequency and percentage of each drought classification (e.g., mild, moderate, severe, and extreme) in drought analysis cannot be neglected. Analyzing the frequency of each drought classification helps understand the distribution of different drought intensities over time (Wang et al. 2019). For instance, Abu Arra et al. (2024a) demonstrated that evaluating the critical drought could significantly improve water resource plans by indicating the most common drought conditions to be addressed. Also, Abu Arra et al. (2024b) introduced the Frequency—Innovative Trend Analysis (F-ITA) methodology. However, a thorough evaluation indicated that more enhancement, improvement, and discussion are necessary to understand the advantages and implications of F-ITA better. The original article introduced the F-ITA without sufficient explanation and discussion. Subsequently, this research enhances the F-ITA in different aspects. These improvements include adding more frequencies with drought sub-classifications (10 classifications), extending the discussion to include the implications and limitations, improving F-ITA visualization, one of the most important advantages in ITA methodologies, and including the used code.

Recognizing the importance of analyzing both drought frequency and drought classification sub-trends, this research aims to apply the frequency analysis and Innovative Trend Analysis (ITA) method. This research applies the Frequency-Innovative Trend Analysis (F-ITA) method, which integrates the frequency of each drought classification into both halves of the time series. This integration allows for a microscale examination of drought sub-trends, offering a nuanced analysis of how different drought severities and frequencies change over time. The main novelty of this article lies in its comprehensive analysis and discussion of F-ITA, including adding more classifications and frequencies and generalizing it for any drought classification in the literature, discussing its advantages, limitations, and future implications, improving its visualization, and enhancing its utility across various applications. To achieve the main objectives of this research, F-ITA is applied in three different climate locations and at different time periods. In Florya Station, Istanbul, Türkiye (1953–2020) using SPI method. At Durham Station in the United Kingdom, from 1868 to 2020, both the SPI and the SPEI were used. Lastly, the method was applied to Vargones KRV Station in Sweden (1807–2022) for SDI, helping to understand hydrological drought trends. These applications present the F-ITA method's robustness and adaptability for analyzing drought trends under diverse climatic conditions, enhancing water resources management tools and preparation.

2 2. Materials and methodologies

The methodology section of this research begins with standardized drought indices, including the SPI and SPEI, which are used to assess meteorological droughts based on precipitation and the water balance, respectively. Following this, the SDI is calculated to evaluate hydrological drought, focusing on streamflow data. After that, a specific drought classification is selected, detailing the frequency of occurrence for each drought classification to provide a detailed and comprehensive drought evaluation. Then, the well-known ITA method is applied. The final part of the methodology integrates frequency analysis, drought classification, and ITA to obtain the frequency ITA (F-ITA) method. Figure 1 shows the methodological approach that used in this research.

2.1 Standardized precipitation index (SPI)

The SPI, introduced by McKee et al. (1993), calculates meteorological drought over different time scales, such as 1, 6, 9, and 12 months, using only precipitation records. Firstly, the raw monthly precipitation data is fitted to a suitable probability density function (PDF). This involves conducting goodness-of-fit assessments such as the Kolmogorov–Smirnov and Chi-Square tests to ensure the chosen PDF accurately represents the precipitation data for the selected timescales. Following this, the probabilities derived from the monthly precipitation are probabilistically normalized to conform to a standard normal PDF characterized by a zero mean and a unit standard deviation. The Gamma PDF is widely recognized as the most appropriate PDF for calculating the SPI in many research studies (Wang et al. 2019).

The Gamma distribution's PDF is defined as:

$$g(x) = \frac{1}{\beta^{\alpha} T(\alpha)} X^{\alpha-1} e^{\frac{-x}{\beta}} for\, x > 0 \tag{1}$$

where α is the shape parameter and β is the scale parameter, x is the monthly precipitation. T(α) is the Gamma function. The shape and scale parameters are derived using Thom's approximation method:

$$\alpha = \frac{1}{4A}\left(1 + \sqrt{1 + \frac{4A}{3}}\right) \tag{2}$$

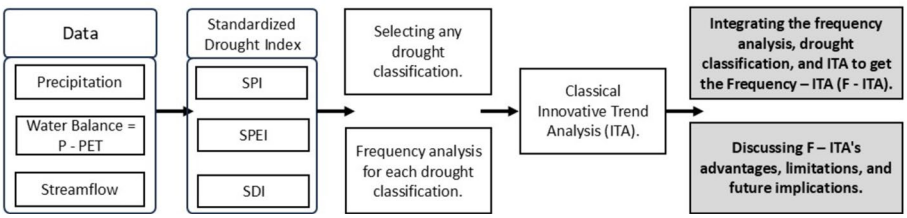


Fig. 1 The methodological approach of this research

$$\beta = \frac{\overline{X}}{\alpha} \tag{3}$$

$$A = \ln\left(\overline{X}\right) - \frac{\sum \ln(X)}{n} \tag{4}$$

where $\overline{X}$ represents the mean precipitation; n is the total number of data points; X is the precipitation for the current period.

2.2 Standardized precipitation evapotranspiration index (SPEI)

Vicente-Serrano et al. (2010) developed the SPEI, which builds upon the SPI methodology by including potential evapotranspiration (PET) data in its calculations. SPEI essentially utilizes the difference between precipitation and PET data (Water Balance—WB), fitting this data to a suitable PDF. After verifying the fit with Chi-Square and Kolmogorov–Smirnov tests, probabilities are calculated from the water balance records for various timescales and then probabilistically standardized to a standard normal PDF. Further details on the SPEI methodology are explained in the original paper (Vicente-Serrano et al. 2010).

2.3 Streamflow drought index (SDI)

The SDI was developed to evaluate hydrological droughts by analyzing streamflow data (Nalbantis and Tsakiris 2009). Like the SPI, the SDI is applied over various time scales to assess drought effects on streamflow. The core principle of the SDI is to measure deviations in streamflow against historical data, a critical aspect of effective water resource management (Vicente-Serrano et al. 2012). The calculation of the SDI begins by identifying the most fitting PDF for the streamflow data. In contrast to the Gamma used for SPI and the Log-Logistic often used for SPEI, the SDI generally utilizes the Pearson Type III distribution (Vicente-Serrano et al. 2012). Selecting an appropriate PDF for the SDI, similar to other standardized drought indices, involves rigorous goodness-of-fit testing, such as the Kolmogorov–Smirnov and Chi-Square tests, to ensure the data's fit (Stephens 1970). This verification is essential to confirm that the SDI precisely represents true streamflow behaviors. After establishing the suitable PDF, the streamflow data are probabilistically standardized to a normal distribution with a zero mean and unit standard deviation.

2.4 Drought classification

Drought classification plays a crucial role in drought studies, as it helps determine the severity of drought events, which are key to understanding their impacts on ecosystems. Precise classification and frequency or probability provide a structured way to assess droughts' risk and potential effects, facilitating better water resource management and planning. Various drought classifications are available, such as the one proposed by McKee et al. (1993). McKee et al. (1993) classified drought into eight categories, as detailed in Table 1, where negative values signify drought events and positive values indicate wet events. Furthermore, an additional extreme category is introduced to comprehensively analyze the drought classifications and frequencies, expanding the maximum drought and wet

Table 1 Drought classifications based on McKee et al. (1993)

Drought index_DI	Classification	Frequency (%)
$2.50 \leq DI$	Exceptional wet (EXW)	0.62
$2.00 \leq DI < 2.50$	Extreme wet (EW)	1.69
$1.50 \leq DI < 2.00$	Severe wet (SW)	4.42
$1.00 \leq DI < 1.50$	Moderate wet (MW)	9.22
$0.00 \leq DI < 1.00$	Abnormally wet (ANW)	34.05
$-1.00 \leq DI < 0.00$	Abnormally dry (AND)	34.05
$-1.50 \leq DI <$-1.00	Moderate drought (MD)	9.22
$-2.00 \leq DI <$ -1.50	Severe drought (SD)	4.42
$-2.50 \leq DI <$ -2.00	Extreme drought (ED)	1.69
$-2.50 > DI$	Exceptional drought (EXD)	0.62

classifications to −2.5 and 2.5. This new classification, termed exceptional drought and exceptional wet, applies to events with values less than −2.5 and more than 2.5 for dry and wet conditions, respectively. This new classification differs from the classification used in the original article of F-ITA, enabling a more comprehensive understanding of drought frequencies. The definition and characteristics of these events vary according to the drought definition used, as indicated in (Abu Arra and Şişman 2023). The frequencies play a pivotal role in understanding and classifying droughts. This probabilistic approach allows for a standardized classification across different regions and climates, making it easier to compare drought conditions. Table 1 below summarizes the drought classification according to the SPI theory developed by McKee et al. (1993).

2.5 Frequency analysis

Based on the drought classification explained in the previous sub-section, each frequency classification's frequency analysis involves calculating the presence of a particular drought classification over the whole period. Equation 5 shows the frequency analysis. Frequency analysis quantifies how often different drought classifications, such as abnormally dry, moderate drought, severe drought, and extreme drought, occur within the period. Dealing with drought as a percentage using frequency analysis indicates the intensity and persistence of different drought classifications. This is a crucial and very important step for evaluating drought patterns, severities, and classifications.

$$\text{Frequency} = \frac{\text{Number of months in each classification}}{\text{Total number of months}} \times 100\%. \tag{5}$$

2.6 Frequency—innovative trend analysis (F-ITA)

2.6.1 Concept and background of ITA

For several decades, trend detection studies in hydrometeorological series have been widely utilized in the literature. The ITA approach, particularly popular recently (Şen 2012), provides significant benefits by visually identifying monotonic and nonmonotonic trends. Its widespread use and popularity among researchers are due to its simplicity and efficiency.

Unlike other trend methods, such as Mann–Kendall, Spearman, and Mann–Whitney, the ITA offers more detailed information about changes in different series segments. Moreover, without any assumptions, the ITA method can reveal five distinct trend types, as seen in Fig. 2.

ITA involves dividing the time series data into two equal parts: the first half representing the "earlier" period and the second half representing the "later" period. The values from the two halves are then plotted against each other on a scatter plot. The distribution and pattern of the points on this plot indicate the presence and direction of trends. For instance, an increasing trend is displayed when the points lie above the 1:1 line, while a decreasing trend is suggested when the points lie below the 1:1 line. For drought trend analysis, an increasing trend is indicated when points lie below the 1:1 line, while a decreasing trend is suggested when points lie above the 1:1 line.

2.6.2 F-ITA by adding drought classification frequencies

While the ITA method effectively identifies trends, it can be further applied by incorporating the frequency of drought classifications, resulting in the Frequency Innovative Trend Analysis (F-ITA) (Abu Arra et al. 2024b). This enhancement involves adding an additional

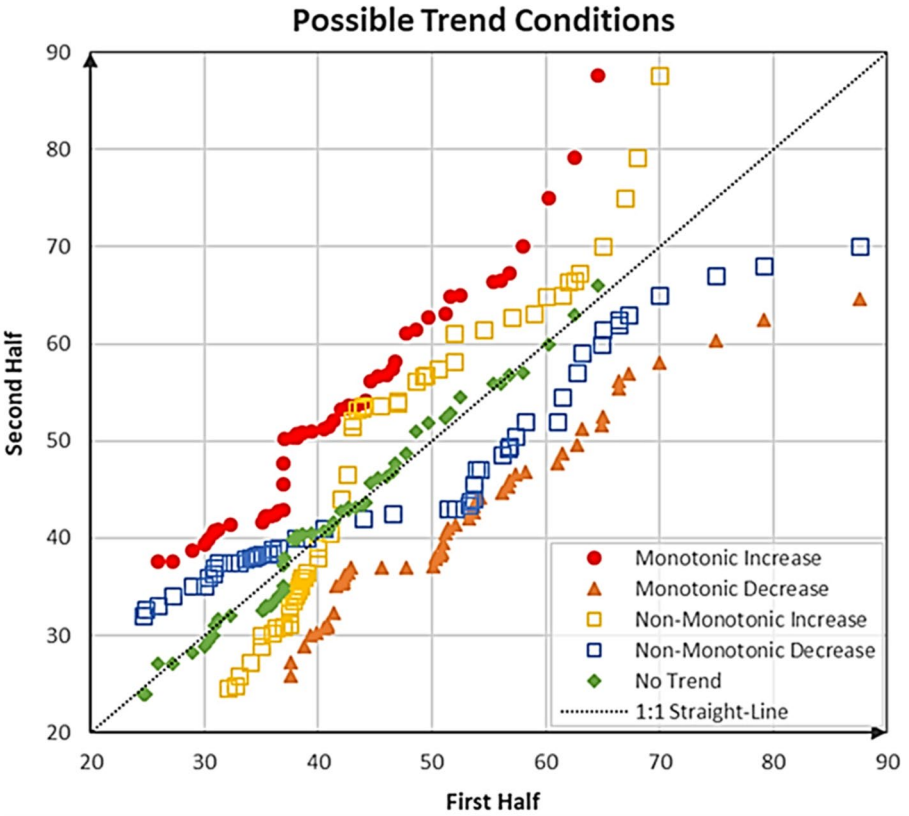


Fig. 2 Trend conditions according to the ITA method (Dabanlı et al. 2016)

dimension to the ITA graph, representing the frequency of each drought classification. Drought classifications can include categories such as "normal," "moderate drought," "severe drought," and "extreme drought" based on specific thresholds of drought indices.

In the F-ITA method, the frequency of each drought classification within the earlier and later periods is calculated and displayed on the ITA scatter plot. This provides a more comprehensive understanding of drought trends by showing the trend direction and indicating changes in the frequency of different drought classifications over time. For instance, an increasing frequency of severe and extreme droughts would be visually apparent on the F-ITA graph, offering valuable insights into the evolving drought patterns. Figure 3 shows the template of F-ITA graphs with the trend conditions and drought frequencies.

2.6.3 Applicability to any drought index and classification

One of the key advantages of the F-ITA method is its versatility and applicability. It can be applied to any drought index, such as SPI and SPEI, among others. Additionally, the method is adaptable to any drought classification. This flexibility ensures that the F-ITA

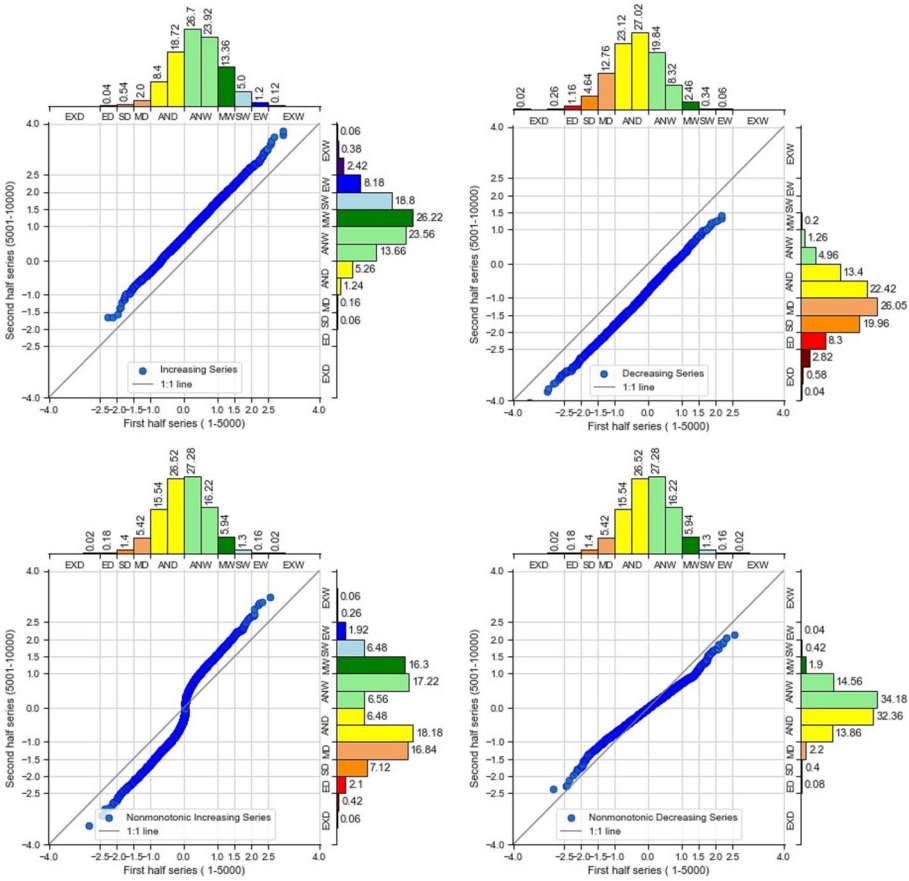


Fig. 3 Trend conditions and drought frequencies according to F-ITA

method can be utilized in various contexts and for different purposes, making it a valuable tool for comprehensive drought trend analysis.

3 Study area and application

This research uses three stations representing different climatic regions and contributes to various data sets for meteorological and hydrological drought trend evaluation. These stations are located in Türkiye, the United Kingdom (UK), and Sweden, providing a comprehensive overview of climatic variability over different periods (70–214 years). Florya station is at 40.97°N latitude and 28.78°E longitude in Istanbul, Türkiye. This station has been utilized for the SPI calculation from 1953 to 2020. The area faces a moderate climate with an average annual precipitation of 645.4 mm and a standard deviation of 44.04 mm. The data from Florya station offers valuable insights into the precipitation patterns and trends over nearly 70 years. The second station, Durham station, UK, provides a valuable dataset for calculating the SPI and the SPEI (Burt and Burt 2022).

The precipitation and temperature data spans from 1868 to 2021, making it one of the longest continuous records available. The station records an average annual precipitation of 652.5 mm with a standard deviation of 31.74 mm. Also, the monthly temperature data, averaging 8.59 °C with a standard deviation of 4.46 °C, is crucial for comprehensive climate analysis. The average monthly temperature data was used to calculate the potential evapotranspiration. This extensive dataset is instrumental in understanding long-term climatic trends and the impact of precipitation and temperature variations on drought conditions. The third station is Vargones KRV station in Sweden, a hydrological station with an extensive record of annual streamflow data from 1807 to 2022. This station has been used to calculate the SDI. The average annual streamflow recorded is 535 m^3/s with a standard deviation of 161.26 m^3/s. The long-term dataset, spanning over two centuries, provides an unparalleled opportunity to study hydrological patterns and trends in streamflow, offering insights into the impacts of climatic changes on water resources. The selection of these three stations, representing different geographical and climatic regions, allows for a comprehensive study of meteorological and hydrological drought indices. This diverse and extensive dataset is essential for developing robust climate models and improving the accuracy of drought trends and water resource management. Table 2 summarizes the climatic characteristics of the stations used in this research.

Table 2 Climatic characteristics of the annual total precipitation, temperature, and streamflow of the used stations in this research

Station	Latitude	Longitude	Variable	Average	Standard Deviation	Period
Florya station	40.97 (N)	28.78 (E)	Annual precipitation (mm)	645.4	44.04	1953–2020
Durham station	54.77 (N)	1.59 (W)	Annual precipitation (mm)	652.5	31.74	1868–2021
			Monthly Temperature (°C)	8.59	4.46	1868–2021
Vargones KRV station	58.36 (N)	12.37 (E)	Annual streamflow (m^3/s)	535.0	161.26	1807–2022

4 Results

Below, F-ITA application graphs have been presented, in which the SPI, SPEI, and SDI drought index trends of the three stations have been evaluated for 1-, 3-, 6- and 12 month timescales, and the frequencies of each drought classification have been interpreted. The calculations started with preparing precipitation, water balance, and stream flow data sets for four specified timescales. Afterward, the most appropriate cumulative distribution functions (CDF) for each data set prepared for every timescale were determined. In identifying the appropriate CDF, the parameters of each distribution function have been calculated using the Kolmogorov–Smirnov test. Finally, the cumulative probability values of each data set were determined, and the standardized SPI, SPEI, and SDI index values corresponding to the relevant cumulative probability values were calculated using probabilistic standardization. While precipitation and stream flow data measured directly at the mentioned stations were used in SPI and SDI calculations, the Thornthwaite method (Thornthwaite 1948) was used in the monthly potential evapotranspiration calculation required to compute the water balance data used in SPEI calculation. Finally, the detailed trend and frequency graphs below have been prepared using the calculated drought index values and F-ITA methodology.

4.1 F-ITA for florya station using SPI

The trends of the calculated SPI-1, SPI-3, SPI-6, and SPI-12 drought index values were examined based on the precipitation data sets observed at the Istanbul Florya meteorology station between 1953 and 2020, except SPI 12 and partially SPI 1; it was understood that there was no trend for SPI 3 and SPI6. Initially, for SPI-1 F-ITA chart given below (Fig. 4), the trend for exceptional drought (EXD) and extreme drought (ED) events was increased. Accordingly, the frequencies of these events varied slightly over time. While the frequency of EXD events in the 1953–1986 period was 0.49%/0.74%/1.47% in the drought classification ranges as -4 _-3.5/-3.5_-3/-3_-2.5 respectively, it was 0.98%/1.23%/0.98% in the 1987–2020 period. For ED drought classification, the trend decreased; accordingly, the ED event frequencies occurring in both periods decreased from 3.19 to 1.96%. There was an decreasing trend for SPI-1 values less than −2, as seen in Fig. 4. For the severe drought (SD), moderate drought (MD), and abnormal drought (AND) classifications given in the F-ITA graph, it is deduced that there was no trend between 1953 and 2020. Therefore, the frequencies in these drought classifications have not changed significantly in the relevant period. The frequencies of SD, MD, and AND events that have been calculated in the years 1953–1986 (1987–2020) are 3.92%(4.17%), 8.09%(8.33%), and 32.5% (32.6%), respectively.

When a detailed evaluation is made for five different drought classifications by taking into account the Florya SPI-3 and SPI-6 F-ITA graphs, it is seen that there was no trend except for the SPI-6 EXD and ED classifications. For SPI-6 F-ITA graph, the EXD and ED drought classifications intervals where the SPI-6 < -2, the scatters are slightly above the 1:1 line, and therefore, the drought trend is slightly decreasing. Considering the frequency of drought classifications in the analysis period, the frequency of EXD events for 1953–1986 was 0.74%, while no drought events were encountered in this classification in the 1987–2020 period. This relationship between decreasing trend and decreasing the frequency of the corresponding classification is rational, and it can be said that the decreasing trend is quantified at 0.74%. For ED classification, while the frequency of occurrence was

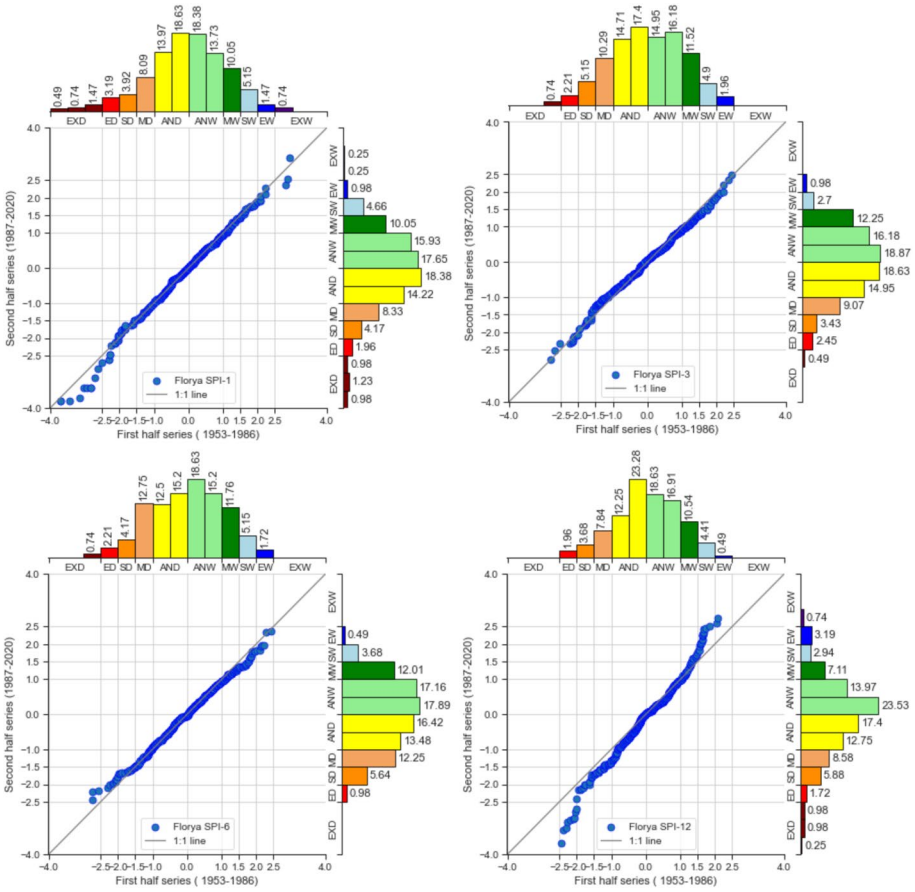


Fig. 4 F-ITA for SPI at 1, 3, 6, and 12 month time scales for Florya meteorology station between 1953 and 2020

2.21% in the first period, with a decreasing trend in the drought in the second period, the frequency of ED classification decreased to 0.98%.

The SPI-6 F-ITA graph (Fig. 4) shows no significant change in trends and frequencies of SD, MD, and AND events. Likewise, while there was no trend in the abnormal wet (ANW) and moderate wet (MW) classifications, the frequencies of these classifications have not changed much. For severe wet (SW) and extreme wet (EW), it is understood that the trend was slightly decreasing, and accordingly, the frequencies of these classifications changed slightly. As a result, the frequencies of SW and EW classifications in Florya station between 1987 and 2020 decreased from 5.15%(SW) to 1.72%(EW) in the first period to 3.68%(SW)-0.49%(EW) in the second period, depending on the decreasing in the trend. As for the SPI 3 F-ITA graph, there was no trend for the drought and wet classifications. For these classifications, it is seen that there was no significant change between 1953 and 2020. Relatively small differences were observed across several drought or wet classifications. The frequencies of EXD classification for SPI-3 at Florya station were below 1% in both periods. While the frequencies of ED, SD, and MD events were 2.21%–5.15%–10.29%, respectively, in the first half period, they were calculated as 2.45%–3.43%–9.07%,

respectively, in the second period. For AND and ANW classifications, there was no trend, which are the most occurring classifications in the dry and wet periods, and judging by the change in their frequencies, the frequency of these classifications increased slightly in the second period.

For SPI-12 F-ITA graph at Florya station, the trend for all drought classifications (SPI-12 < 0) was generally a monotonic increase. With the advantage of ITA methodology and F-ITA graphs, trends for each drought classification have been examined in detail. For example, while there were no drought events in the EXD classification (0%) between 1953 and 1986, as seen from the F-ITA graphs (Fig. 4), the frequency of EXD classification due to a significant increasing drought trend in 1987–2020 was 2.23%.

This is one of the most significant results of F-ITA graphs. For SPI-12 F-ITA graph, drought trends for ED, SD, and MD showed monotonic increases. For the AND classification, the trend was a non-monotonic increase. Considering the changes in the frequency of drought classifications due to these increasing trends, there was almost no change in the frequency of these drought classifications in both periods. While the frequency of all drought classifications was 49.01% for 1953–1986, this rate was 48.54% in 1987–2020 with a small difference. However, the most important difference was seen in the AND classification, which is close to the wet classification due to the increase in drought trend. For the -0.5 < SPI-12 < 0 drought classification, the frequency, 23.28% in 1953–1986, decreased to 17.4% in 1987–2020. Finally, the frequencies of EXD-ED-SD and MD classifications for the years 1953–1986 and 1987–2020 were respectively calculated as 0% (2.21%)-1.96% (1.72%)-3.68% (5.88%) and 7.84% (8.58%).

4.2 F-ITA for durham station using SPI and SPEI

The 1-month timescale meteorological drought evaluation results at Durham station using the SPI-1 and SPEI-1 F-ITA graphs indicated that both indices showed varying trends for different drought classifications. The SPI-1 F-ITA graph exhibited a slightly decreasing drought trend for ED and EXD classifications and no trend for SD, MD, AND, ANW, MW, and SW classifications. For the EXD classification, the frequency decreased from 0.88% in the first period to 0.66% in the second period. The frequencies of drought classifications remained relatively stable between the two periods analyzed. For example, the SD and MD frequencies fluctuated slightly but without significant trends. The AND classification showed minimal change, with frequencies of approximately 33% in both periods.

In contrast, the SPEI-1 F-ITA graph demonstrated a slightly increasing drought trend in the frequency of drought events, particularly in the SD and MD classifications. The frequency of SD events increased from 4.5% in the first period to 5.05% in the second period, while MD frequencies rose from 8 to 10.1%. These changes suggested that short-term drought events, as indicated by SPEI-1, have become slightly more frequent over the years. The EXD and AND classifications in the SPEI-1 F-ITA graph remained relatively stable, with EXD frequencies at 0.55–0.77% and AND frequencies at 30.84–30.93% across both periods, indicating a notable increase in moderate to severe drought conditions over time.

For the 3 month timescale drought evaluation of Durham station, according to the SPI-3 and SPEI-3 F-ITA graphs, ITA graphic results for the drought and wet classifications have been summed up without considering the sub-classification intervals. When evaluated, no significant trend existed for the SPI wet and drought classifications. While no significant trend existed in the SPEI wet classification, a somewhat monotonic increasing drought trend emerged in the drought classification. On the other hand,

for trends and frequency changes, starting from drought classifications with the F-ITA methodology, taking each drought classification as a reference, it was seen that there was no trend (no significant drought increase) in SPI-3 (SPEI-3) EXD events. Accordingly, while the frequency of drought events in this classification for SPI-3 was calculated as 0.66% and unchanged in both periods, according to SPEI-3, the frequency of EXD events increased from 0 to 0.33%. If a comparison is performed between these two indices used in drought monitoring, SPI analysis indicated that EXD classification has been much more frequently in the region than in SPEI. When ED, SD, MD, and AND drought classifications were analyzed for SPI-3, respectively, the F-ITA graph showed no trend in these four drought classifications, while the frequencies in the analysis period supported these findings. The frequencies of ED, SD, MD, and AND classifications in the periods 1870–1945 and (1946–2021) were also 1.43% (1.64%)–4.39% (4.61%)–10.75% (10.64%) and 33.99% (31.36%). In terms of drought assessment, there was little change.

According to the SPEI-3 F-ITA analysis results, the monotonic increase drought trend in drought events continued among ED, SD, and MD. At the same time, there was no significant trend regarding AND classification. Depending on the trend of each drought classification, it was seen that in the first (and second) period for ED, SD, and MD classifications, respectively, 0.66% (2.41%)-4.39% (6.14%)-10.86% (11.29%), It appeared that there has been change. On the other hand, the frequency of AND classification did not change much at 30.15% in the first period and 28.95% in the second period. If the trends and frequencies in each classification defined for wet classification are interpreted, there was no significant trend in all classifications. In contrast, the frequency of AND classification has decreased slightly for the second period, depending on the increasing drought trend in drought events in 1946–2021. Also, the frequencies of EXW, EW, SW, MW, and ANW classifications for the years 1870–1945 and 1946–2021 are respectively 0.55% (0.66%)-1.32% (1.32%)-3.95% (4.93%)-9.65% (9.98%), and 38.48% (33.99%).

For SPI-6 and SPEI-6 F-ITA graphs (Figs. 5 and 6), there was no trend for wet classification for both SPI-6 and SPEI-6 ≥ 0. For drought classifications where SPI-6 and SPEI-6 < 0, the trends changed between increasing drought trend and no trend. SPEI-6 F-ITA deduced that the trends indicated different results according to drought classifications: increasing and no trend. For wet classifications, the frequency of EXW classification for SPI-6 increased significantly between 1946 and 2021 (0.99%) compared to 1870–1945 (0.11%). According to the same analysis, while the frequency of EW events decreased slightly from 1.75% to 1.21% in the second period, the frequencies of SW, MW, and ANW classifications respectively increased slightly from 5.15% (6.47%) to 7.13% (8.66%) and 34.1% (34.54%) compared to the first period (in the second period). SPEI-6 F-ITA graph for wet classification showed that for the first (and second) period, the frequency of EXW classification was calculated as 0.55% (0.66%), and there was no significant change in frequency between 1870 and 2021. While the frequency of EW classifications was 0.88% in 1870–1945, it increased to 1.86% in the 1946–2021 period. Depending on the increasing trend in this classification, there was an increase of over one hundred percent in the frequency of the classifications. The frequencies of SW and MW classifications were calculated as 4.61% (3.95%) and 10.42% (10.09%) for the first (and second) periods, respectively, and it is understood that the frequencies of these classifications decreased slightly in the second period. For the ANW classification, the frequency, which was 36.73% in the first period, decreased to 33.33% in the second period. Considering the SPI-6 and SPEI-6 index results as a reference, it was seen that there was no significant difference between the results given by both methods.

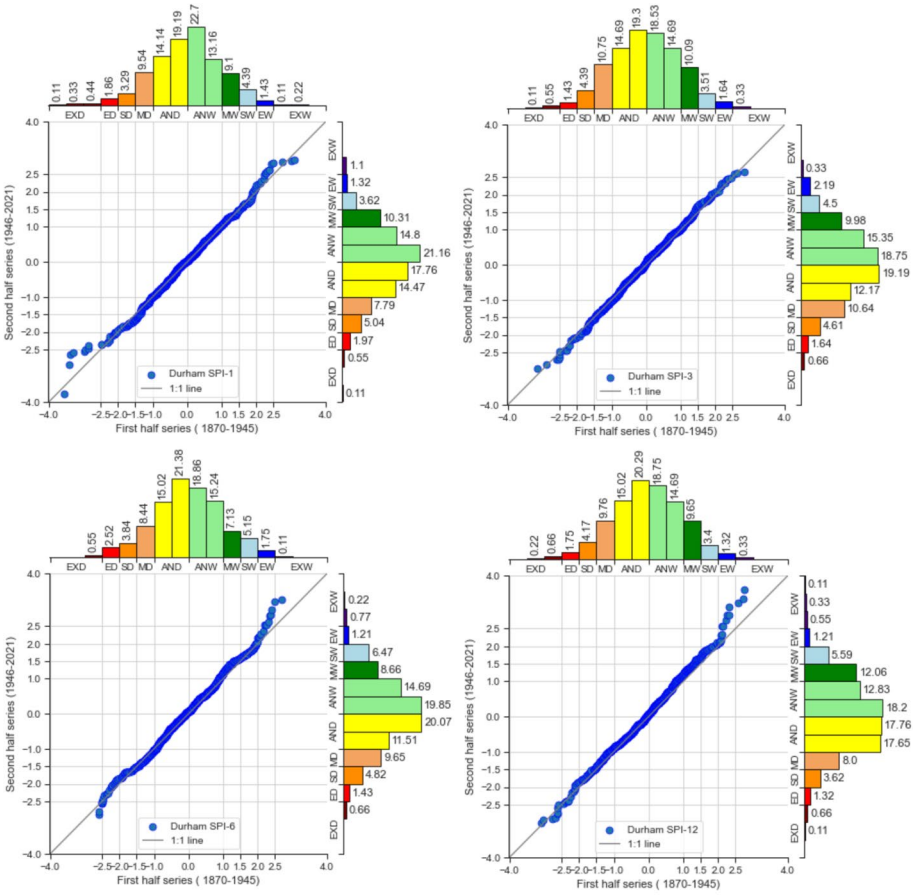


Fig. 5 F-ITA for SPI at 1, 3, 6, and 12 month time scales for Durham meteorology station between 1870 and 2021

For the SPI-6 (Fig. 5), the drought trend was slightly increased in this EXD classification, and the frequency increased from 0.55 to 0.66%. On the other hand, according to SPEI-6, the frequency was rarely encountered in this classification (0.11%) in the years 1870–1945, and due to a slight drought trend increase seen in the years 1946–2021, the frequency of EXD classification increased slightly, and increased to 0.22%. For the SPI-6 F-ITA graph at ED classification (Fig. 5), with the decreasing drought trend in this classification, the frequency in the first half period decreased from 2.52 to 1.43% in the second period. According to F-ITA SPEI-6 (Fig. 6), the frequencies increased from 0.44 to 2.85% after the monotonic decreasing trend in the index values in the ED drought classification. For SD, MD, and AND drought classifications and according to the SPI-6 F-ITA graph (Fig. 5), each drought classification had no significant trend. However, since there was no clear trend in drought classifications, the total frequencies of SD, MD, and AND classifications decreased from 3.84% + 8.44% + 15.02% + 21.38% = 48.68% in 1870–1945 to 4.82% + 9.65% + 11.51% + 20.07% = 46.05% in 1946–2021.

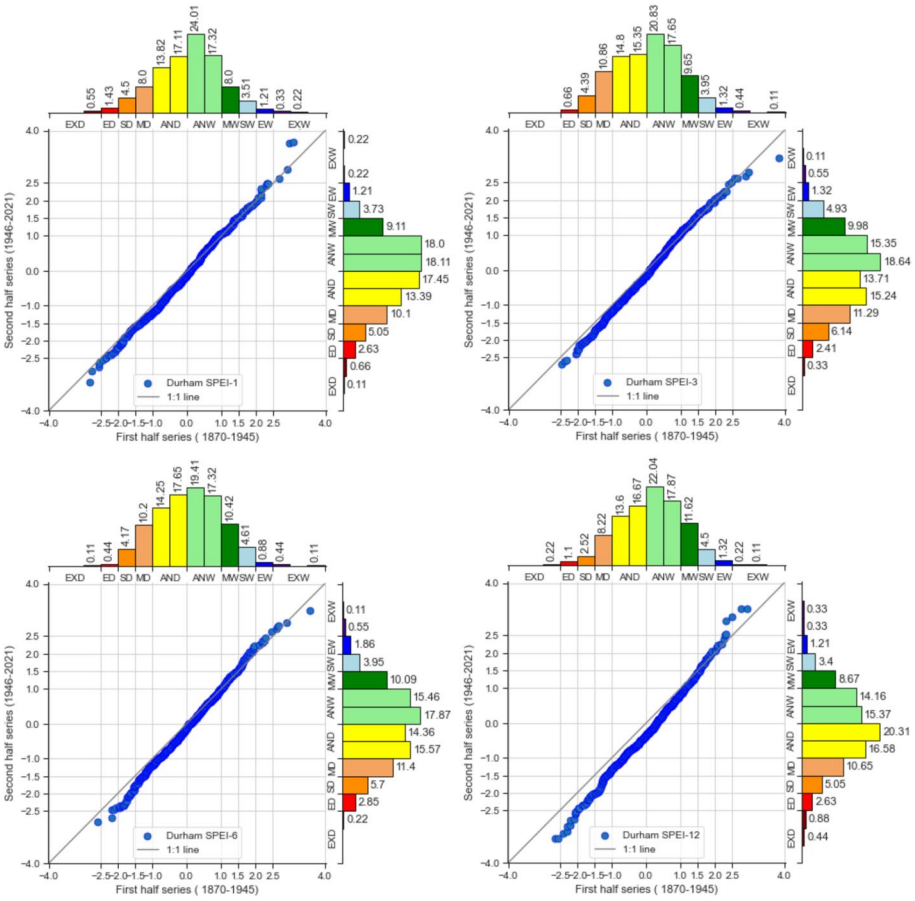


Fig. 6 F-ITA for SPEI at 1, 3, 6, and 12 month time scales for Durham meteorology station between 1870 and 2021

For the 12 month timescale drought evaluation at Durham station, the SPI-12 and SPEI-12 F-ITA graphs revealed different insights. The SPI-12 F-ITA graph indicated no significant trends in most drought classifications, with EXD, SD, and MD frequencies remaining stable over the analyzed periods. For instance, the frequency of EXD events for SPI-12 remained at 0.77–0.88% in both periods, while ED and SD frequencies showed minimal variation. The frequencies for ED (SD) decreased from 1.75 5% (4.17%) in the first period to 1.32% (3.65) in the second period. Moreover, the frequency of abnormally dry (AND) conditions showed stable variation, increasing from 35.31% in the first period to 35.41% in the second period.

On the other hand, the SPEI-12 F-ITA graph exhibited an increasing drought trend in the frequency of all dry and wet events, highlighting that long-term drought conditions have become more pronounced over time. The frequency of EXD (ED) events increased from 0.22% (1.1%) to 1.32% (2.63%), while SD and MD frequencies rose significantly from 2.52% to 5.05% and 8.22% to 10.65%, respectively. The AND classification frequency also showed a notable drought increase from 30.27% to 36.89%, reflecting the shift

towards more severe drought conditions. This increasing drought trend in SPEI-12 further emphasized the growing impact of long-term droughts on the region, reflecting changes in precipitation and evapotranspiration patterns. These findings suggest that SPEI-12 is more sensitive to capturing the frequency and severity of long-term drought events than SPI-12, providing critical insights into the evolving drought dynamics at Durham station.

4.3 F-ITA for vargoens Krv station using SDI

Considering the monthly average stream flow data measured regularly for 214 years between 1809 and 2022 at the Vargoens Krv River observation hydrology station, the drought trends and drought frequencies of the region were investigated with the help of calculated SDI for 1–3-6 and 12 month timescales. Regarding hydrological drought, the trends and frequencies of different drought and wet classifications during the period have been evaluated in detail using F-ITA graphs. As a result of the analysis, non monotonic increases were generally evident according to the time series of drought and wet classifications. First, for the F-ITA SDI-1 graph (Fig. 7), it was understood that the SDI index

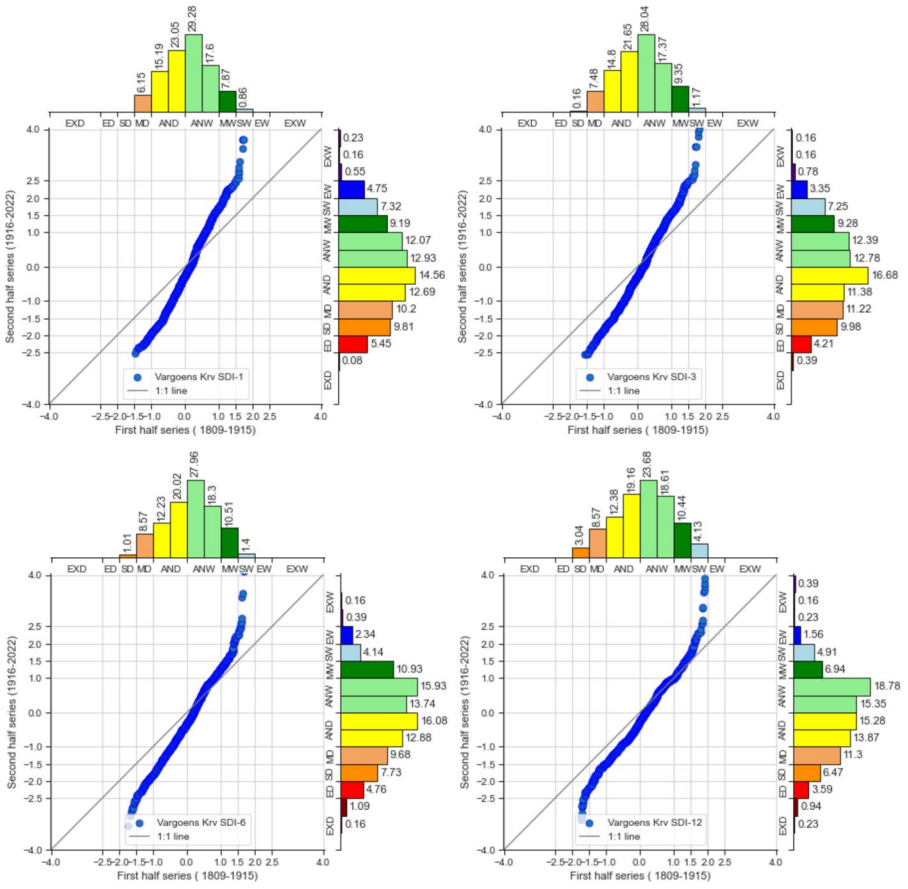


Fig. 7 F-ITA for SDI at 1, 3, 6, and 12 month time scales for Vargoens Krv river between 1809 and 2022

values and non monotonic trends calculated for the wet and drought significantly increased the trend. Accordingly, the frequency of occurrence of each classification except AND and ANW events has clearly increased. While there were no events in EXD, ED, and SD classifications between 1809 and 1915, the frequency of events in these classifications in 1916–2022 was calculated as 0.08%, 5.45%, and 9.81%, respectively. Due to the non monotonic increase trend in drought classifications, the frequencies of events in the ED, SD, and MD classifications increased significantly in the twentieth century. Similarly, there has been a significant increase in the frequency of wet classifications recently. While EW and EXW events were not encountered between 1809 and 1915, the frequency of these classifications in the 1916–2022 period was calculated as 4.75% and 0.94%, respectively. While a small number of 0.86% frequency occurred in the SW classification in the first 107-year period, the incidence of frequencies in this classification increased significantly in the second 107 years, reaching 7.32%.

For the SDI-3 F-ITA graph (Fig. 7), non monotonic increasing trends were quite evident for the drought and wet classifications. According to the time series of SDI calculated using flow data between 1809 and 1915, it was understood that drought and wet events in this period were distributed in MD, AND, ANW, and MW classifications with a frequency of approximately 99%. On the other hand, ED, EXD, EW, and EXW events never occurred during this period. It can be said that 1916–2022 were quite dry and wet, depending on the trend of increased drought and wet events, compared to the nineteenth century and the first years of the twentieth century. For the SDI-3 F-ITA graph, the non monotonic trend increase in each classification was clearly noticed. Therefore, significant differences stand out when the frequencies of dry and wet classifications in 1916–2022 and 1809–1915 are compared. In the 1916–2022 period, EXD 0.39% and ED 4.21% were encountered, which did not appear in the first period, while the frequencies of SD and MD events were also 9.98% (0.16%) and 11.22% (7.48%) in this second period, compared to the years (1809–1915). Similar changes in frequencies were also valid for wet classifications. While EXW (1.10%) and EW (3.35%) classifications were not seen in the first period and were encountered in the second period, the frequency of SW classification increased significantly from 1.17 to 7.25%. However, there was a trend increase in the MW classification. Also, it was understood that the number of events in both periods was close to each other, with frequencies of 9.35% and 9.28%. Finally, due to non monotonic trends and frequency increases in the EXD, ED, SD, MD, EXW, EW, and SW classifications, the frequencies of events in the AND and ANW classifications in the 1916–2022 period have decreased significantly.

For the SDI-6 F-ITA graph (Fig. 7), the averages and variances of drought and wet classifications increased significantly in 1916–2022 compared to 1809–1915. The most obvious and striking example was the ANW events between 1809 and 1915. The frequency of the wet classification occurring most frequently in this period was $27.96\% + 18.3\% = 46.16\%$ (Fig. 7). As can be noticed in the F-ITA graph between 1916 and 2022, depending on the increase and decrease in the index values, the frequency of the ANW classification decreased to $13.74\% + 15.93\% = 29.67\%$. These changes in the mean and variance of the calculated index values significantly increased the frequencies of EXD, ED, SD, and EXW, EW, and SW events in 1906–2022, respectively, compared to 1809–1915. While EXD, ED, EXW, and EW classifications were not observed in the first period, which mostly coincided with the nineteenth century with the significant non monotonic trend increase in the dry and wet periods, these events occurred in the second period in the 20th and partly at the beginning of the twenty-first century. The frequencies were EXD 1.25%, ED 4.76%, EXW 0.55%, and EW 2.34%. As for SD and SW classifications, it was clear that their frequency

increased significantly in the years 1916–2022 compared to 1809–1915. For severe dry and wet classifications, while the frequency of SD classifications was 1.01% and SW was 1.4% in the first 107 years, it increased to SD 7.73% and SW 4.14% in the second 107 years.

Finally, for the SDI-12 F-ITA graph, it was noticed that the results were close to the other 3 timescales, and therefore, there can be similarities with the comments made. When the SDI-12 F-ITA graph was compared to the SDI-1, SDI-3, and SDI-6 graphs (Fig. 7), one of the most important differences was that the data scatter was relatively closer to the 1:1 line. This indicated that the variance change was lower for the dataset. Therefore, unlike other timescales, it was seen that for this timescale, the non monotonic trend increase occurred at relatively lower levels. Thus, the frequencies of each classification in the drought and wet classifications were represented in a broader range. Unlike the other three SDI F-ITA graphs, SD 3.04% (6.47%) and SW 4.13% significantly increased the frequency of classifications in the first (and second) period. Similar to the other three timescales, EXD, ED, EXW, and EW events were not encountered in the first period. When it comes to the 1916–2022 period, with the non monotonic increasing trend in drought and wet classifications, the extreme events and their frequency in this period were calculated as EXD 1.17%, ED 3.59%, EXW 0.78%, and EW 1.56%. According to the SDI F-ITA results, by using four different timescales to monitor the drought events and identify their trends and frequency changes over these periods, there have been significant non monotonic trend increases in drought and wet events in recent years. Extremely dry and wet events, not seen in the nineteenth century and the beginning of the twentieth century, have been frequently encountered from 1916 until today.

5 Discussion

Compared to classical methods, the ITA method effectively detects both monotonic and non-monotonic trends in time series. Additionally, the ITA can visually display trends on a square graph. However, the method does not provide frequency distributions of the first and second half series or show the changes between these two sub-series distributions. Monotonic trends shift the distribution of the first sub-series to the right (increasing) or left (decreasing), while non-monotonic trends distort the distribution shapes.

With climate change and drought, the stationarity of hydrometeorological series has been questioned by many researchers (Alashan 2018; Bayazit 2015; Lins and Cohn 2011; Rehan and Hall 2014; Alashan et al. 2024). Non-monotonic increasing trends can lead to multimodal or double-peaked distributions, wheras non-monotonic decreasing trends increase the skewness of the distribution (Fig. 3). In this figure, the main graph represents the ITA, and two margin graphs illustrate innovations of the new frequency innovative trend analysis (F-ITA). Abu Arra et al. (2024a, b) introduced the F-ITA method to enhance the visual capability of ITA method by adding the frequency values of sub-series to the ITA graph. These frequency values of the sub-series categories, such as exceptional drought, extremum drought, severe drought, etc., allow researchers to investigate the non-stationarity of hydrometeorological series. However, the subject required further discussion and improvement, particularly in terms of classification, visualization, and the code used for the analysis. Additionally, the limitations and future implications of the method were thoroughly addressed in this article to provide a comprehensive understanding.

The F-ITA method is applied to Florya and Durham meteorology stations, as well as the Vargoens Krv streamflow station, covering different climates and locations. The SDI at the

Vargoens Krv station exhibits non-monotonic increasing trends, resulting in drought and wet increasing. As shown in Fig. 7, the second half series of the SDI-6 indices demonstrates a multimodal distribution, whereas the second halves of the other SDI indices have larger standard deviations compared to the first sub-series distributions, although they retain a single peak modal value.

Outliers can impact the results of the ITA method by distorting the visual representation of trends and patterns. These extreme values can exaggerate or mask the actual trends, leading to potentially misleading interpretations of the data. For instance, while a decrease is observed in the Durham SPEI-6 exceptional wet (EXW) indices for the first and second half series, an actual increase is present. The frequency of the exceptional wet indexes increased from 0.55% (0.44 + 0.11) in the 1870–1945 period to 0.66% (0.55 + 0.11) in the 1946–2021 period. The F-ITA method proves useful for robust evaluations of time series with outliers. Similarly, in the Florya SPI-1 series, there is a notable increase in exceptional wet indexes from 0.33% (0.11 + 0.22) to 1.1%, although it may appear as a decrease. This highlights the importance of using the F-ITA method for accurate analysis. Also, the drought classification proposed by McKee et al. (1993) has been expanded to cover more classifications, such as abnormally dry/wet and exceptional drought/wet, providing a more in-depth and microscale framework for the drought evaluation. Any drought classification can be integrated with the F-ITA methodology. The version of F-ITA in (Abu Arra et al. 2024a, b) utilizes frequency values of sub-series categories as numbers on auxiliary axes in a square plot with two margin axes. This mathematical representation of frequency values diminishes the visual clarity of the ITA method. Histogram bars play a crucial role in stationarity analyses. The integration of histogram bars into the F-ITA approach enhances visual efficacy and offers an assessment of the dataset's stationarity.

F-ITA improved the classical drought trends by allowing the capture of how drought trends of different classifications and severities occur rather than determining the classical trend direction (Ozocak et al. 2024; Phuong et al. 2022). For example, Ozocak et al. (2024) applied the ITA method to detect trends (no trend, increasing trend, and decreasing trend) in 12 month SPI using significance levels, rather than utilizing the method's high visual advantage for different locations over Türkiye. In our research and as seen in the SPI-12 F-ITA graph for Florya station, the region experienced a constant trend, but there is an increase in the EXD drought events (from 0 to 2.21%). These extreme drought trends have adverse effects on water resources and agricultural sectors. Hence, F-ITA provides a further step in terms of drought trends. Also, regarding risk assessment, frequencies play a key role in determining the risk level of each drought trend. For example, in the Durham station and based SPEI-3 F-ITA graph (000), the EXD increased from 0 to 0.33%, and for SPEI-12 F-ITA graph (Fig. 6), it increased from 0.22 to 1.32%. Both cases have an increasing trend, but the risk level is different.

Based on our best knowledge and after carefully reviewing the existing literature, no research has been conducted on Durham station considering the trend of SPI and SPEI using the ITA method. The Durham station is the third-longest continuous climate series in the UK. Its records provide us with a long period of data, from 1868 until 2021 (about 150 years) (Burt and Burt 2022), providing more reliable data for SPI and SPEI calculations. The results showed an increasing trend in SPEI-12, further emphasizing the growing impact of long-term droughts on the region, reflecting changes in precipitation and evapotranspiration patterns providing critical insights into the evolving drought dynamics at Durham station.

Numerous studies have used the ITA method for drought trend evaluation. For example, Achite et al. (2023) estimated the drought trend in north Algeria based on SPI, Standardized Runoff Index (SRI), and ITA. They indicated that the drought trend results are important for the agricultural sector, which is the main sector in this area. Additionally, an increase in drought in the first decade of 2000 has been detected. However, considering the essential role of

agriculture, the physical differences between plants, and the effect of drought classification and frequencies, there is a need to incorporate the F-ITA to comprehensively analyze and evaluate the impact of drought in the agricultural sector.

One of F-ITA methodology's most essential advancements is its power comparison process between different drought indices, such as SPI and SPEI. Berhali and Katipoğlu (2023) compared these two indices over the Wadi Mekerra basin in northwest Algeria using various methods, including the ITA method. Their results showed a significant level of agreement between them. However, given the importance of drought classification and its frequency in drought trend evaluation, a more detailed comparison and assessment can be conducted using F-ITA, leading to a more comprehensive evaluation and assessment of drought trends. Furthermore, our research suggests that SPEI-12 is more sensitive to capturing the frequency and severity of long-term drought events than SPI-12.

Yeşilköy and Şaylan (2022) evaluated the drought in the northwestern region of Türkiye, where agricultural activities are intensively carried out, by taking the SPEI as a reference for the years 1971–2018, 2019–2050, and 2051–2099. In their study, the authors interpreted drought events and trends for the future according to RCP 4.5 and RCP 8.5 scenarios, and it was generally stated that drought events would increase in the region in the future. In addition, the frequency of drought was calculated according to both scenarios for the period 2051–2099, and drought occurrence was found to be in the range of 20–46% (average = 38%) according to RCP 4.5, while it was in the range of 42 to 51% (average = 47%) according to RCP 8.5. As can be seen from the results obtained, drought trends have been evaluated in general terms. As a result, the authors have expressed that the infrastructure of water resources should be planned and managed, and action plans should be implemented for water harvesting. To sustain the agricultural productivity of the region to solve the problems encountered and experienced, drought trend evaluation for upcoming research of the region should be made more comprehensively rather than in general terms, and the trends in each drought classification and their frequencies should be revealed and evaluated. F-ITA addresses all these deficiencies.

Tuğrul and Hiniş (2024) investigated the trends in SPI and SDI drought indices in their research in terms of helping decision-makers in estimating and managing the future values of water resources, dam management, and energy production. As a result of the study, it is stated that an increasing trend was observed in all months according to the statistical evaluation for SPI-12 and SDI-12, lacking the necessary details for making plans and decisions. When the graphics are examined, it is seen that although the trend direction in each drought classification is determined separately, the changes in the frequencies of the drought classes are not revealed. Therefore, the most critical dam management and energy production parameters cannot be interpreted. In summary, F-ITA improves the drought trend analysis and allows for a more detailed and microscale explanation of drought events and characteristics.

6 Conclusion

In brief, this research emphasizes the importance of analyzing drought frequency and classification using the F-ITA method. This method integrates the frequency of each drought classification into both halves of the time series, enabling a microscale evaluation of drought trends and providing a comprehensive analysis of how different drought severities change over time. The method's effectiveness and applicability were explored in three diverse climate locations for both meteorological and hydrological droughts:

Florya Station, Istanbul, Türkiye; Durham Station, United Kingdom; and Vargönäs KRV Station, Sweden. The key findings are summarized as follows:

- Incorporating the frequencies and drought classification improved the evaluation of drought trends beyond only finding increases or decreases, facilitating a microscale analysis of meteorological and hydrological drought trends.
- The F-ITA method effectively detects both monotonic and non-monotonic trends in time series with drought frequencies.
- Exceptional wet and dry categories were added to the drought classification introduced by McKee et al. (1993) to comprehensively and more accurately evaluate the extreme wet and dry events.
- There was no trend for SPI-3 and -6 F-ITA at Florya station; for SPI-12 F-ITA, all drought classifications showed a monotonic increase trend.
- The drought trend results for SPI and SPEI at Durham station were slightly different because each depended on different input parameters.
- For Durham station, the F-ITA SPI-12 graph indicated no significant trends in most drought classifications, with EXD, SD, and MD frequencies remaining stable over two periods. Furthermore, the frequency of abnormally dry (AND) conditions exhibited consistent change, increasing from 35.31% in the first half to 35.41% in the subsequent half.
- Non-monotonic trend increases were determined in SDI at all time scales in Vargoens Krv station for drought and wet classifications.
- In the SDI-1 F-ITA graph, there were no EXD, ED, or SD events recorded from 1809 to 1915, but the frequencies of these events from 1916 to 2022 were determined to be 0.08%, 5.45% and 9.81%, respectively.

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s11069-025-07119-0) contains supplementary material, which is available to authorized users.

Acknowledgements The authors would like to acknowledge that this paper is submitted in partial fulfilment of the requirements for PhD degree at Yildiz Technical University. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author contributions Ahmad Abu Arra: conceptualization, Methodology, Formal analysis, Visualization, Writing—original draft, Writing—review & editing. Sadık Alashan: conceptualization, Methodology, Formal analysis, Visualization, Supervision, Writing—original draft, Writing—review & editing. Eyüp Şişman: data curation, Conceptualization, Methodology, Supervision, Writing—original draft, Writing—review & editing.

Funding Open access funding provided by the Scientific and Technological Research Council of Türkiye (TÜBİTAK). No funding.

Data availability The data are available from the corresponding author upon reasonable request.

Declarations

Conflict of interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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