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Thirteen Centuries of Drought in Tunisia: Historical Reconstruction and Bibliometric Analysis of Indexes in the MENA Context

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Abstract

This paper aims to characterize drought in Tunisia and the MENA region through an approach combining historical reconstruction (700-2023) and bibliometric analysis of monitoring indicators. A multidimensional database was created by cross-referencing the archives of the Directorate General of Water Resources, historical chronicles, and a corpus of more than 5000 articles indexed in Scopus and Web of Science, updated for the MENA region and Tunisia until February 2026. The results reveal an acceleration in the frequency and intensity of dry spells over the last two centuries, with a close link between water crises and socio-political dynamics. Bibliometric analysis confirms the predominance of meteorological indexes, in particular the Standardized Precipitation Index (SPI), to the detriment of hydrological indexes, reflecting a structural bias between diagnostic tools and management needs. For Tunisia, although the SPI is the benchmark due to its simplicity of calculation, no single index effectively characterizes drought across the entire territory due to the diversity of bioclimatic zones. These results call for the development of multi-indicator approaches integrating meteorological, agricultural, and hydrological dimensions to strengthen water resilience in the face of climate change.

Keywords

Drought, Tunisia, MENA Region, Index, Bibliometric Analysis, Historical Reconstruction, Water Resources Management

1. Introduction

Drought is regarded as one of the natural hazards that involve multiple interacting processes and resist simple characterization. It unfolds gradually, without a clear point of onset, progressing over time in a manner often described as a "creeping phenomenon" [1]. Unlike aridity, which reflects a long-term feature of a climate, drought represents a temporary departure from average hydrological conditions [2]. Although research has spanned several decades, no single definition has gained universal acceptance. A survey of the scientific literature identifies over 150 definitions, each shaped by the focus of the discipline (meteorology, agronomy, or hydrology) or by the regional context of the authors [1]. Initial efforts to define drought were based solely on precipitation thresholds.

By the mid-20th century, authors such as [3] had already noted that drought could not be captured by rainfall alone, since it is closely connected to evaporation rates and particular water use needs. Reference [2] supports this view, emphasizing that the difficulty of harmonization arises from the phenomenon itself, which interacts with multiple components of the hydrological cycle and produces delays (time lags) in its effects. This intrinsic complexity prevents reliance on a single, rigid criterion. Consequently, the scientific community has shifted its focus from the pursuit of a single definition to an operational approach based on typology (meteorological, agricultural, hydrological, and socioeconomic), as outlined in [4]. This classification, which has now gained widespread acceptance, facilitates the association of the physical definition of the hazard with its specific sectoral impacts [1] [2].

Meteorological drought is systematically identified as the initial stage of the phenomenon. It is defined by a precipitation deficit relative to a climatological normal over a given period [1] [4]. In conditions where there is an ongoing lack of precipitation, this spread to the root zone is the result. This phenomenon is commonly referred to as agricultural drought. This is characterized by inadequate soil moisture, which limits the ability of plants to meet their physiological needs. This has been shown to result in water stress and reduced crop yields [1]. Hydrological drought refers to the occurrence of negative anomalies in surface water. These include negative deviations in river flows, as well as changes in the levels of lakes and reservoirs. As stated in Reference [2], this type of drought is the result of a propagation process in which the high-frequency meteorological signal is filtered by the characteristics of the watershed. Geology, land use, and natural storage capacity (such as lakes and wetlands) can cause a time lag and attenuation or pooling of drought events [2].

Although traditional classifications have long been used to segment drought according to the compartments of the hydrological cycle, they face a major conceptual limitation: the omission of human dynamics. As a result of human activity, the natural and social cycles which once existed independently have become inseparable.

Therefore, characterizing droughts solely in terms of climatic hazards seems incomplete. Reference [1] considers socio-economic drought by integrating the human dimension, linking physical anomalies to the supply and demand of economic goods. According to reference [5], humans are not merely passive victims of drought; rather, they are key players capable of altering its trajectory, duration and intensity. It is no longer sufficient to analyze fluctuations in climate hazards; we must also analyze the impact of the decisions made in preparation for or in response to them.

In this context of increasing complexity, the Mediterranean region is particularly susceptible to the effects of climate change. In this region, intensified evaporative demand and declining precipitation further increase the vulnerability of societies [6]. Tunisia is particularly affected by changes in its hydrological cycles, marked by an increased frequency and severity of dry spells. This is due to its location on the southern shore of the Mediterranean [7].

However, despite the multitude of previous studies, an overview of drought in Tunisia would provide a more comprehensive understanding of the challenges that need to be addressed in order to cope with it. It is therefore essential to have a thorough understanding of the hazard, based on two methodological pillars. On the one hand, a long-term historical perspective. In contrast, the most commonly used drought indexes are identified, with the corresponding typology and characterization limitations noted.

The primary objective of this paper is to provide a comprehensive characterization of drought in Tunisia and its correlation with the broader MENA region. The specific objectives are as follows: 1) To gain an understanding of the history of drought in Tunisia; 2) To identify the main drought indices worldwide and in Tunisia; 3) To characterize drought in Tunisia using the indexes cited in the bibliography.

2. Data and Method

The methodology adopted in this paper is based on the reconstruction of a multidimensional database combining centuries-old archives and modern bibliometric analysis (**Figure 1**). The initial phase of this process involves a historical reconstruction of drought in Tunisia over an extended period. By cross-referencing the archives of the Directorate General for Water Resources (DGRE) with the detailed social chronicles in the reference work [8], significant events since the year 700 [9] have been identified.

Following the methodological framework of [8] and [9], drought events were identified based on documented socio-environmental impacts, with cross-validation against DGRE instrumental data when available. Within this protocol, frequency corresponds to the count of distinct events per temporal window, while intensity is inferred qualitatively from the severity of recorded impacts (e.g., famine extent, price spikes, migration), with source discrepancies and duplicates reconciled according to the criteria detailed in these references. This approach enables us to look beyond the statistical analysis of rainfall and identify droughts by examining their impact on Tunisian society over the centuries.

The second part of the study is based on an exhaustive inventory of global and

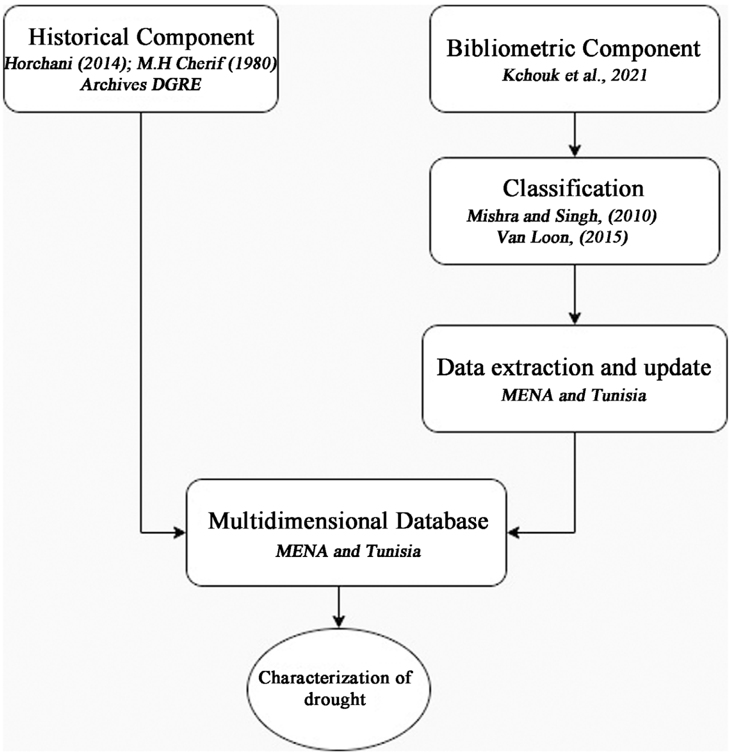

Figure 1. Methodological framework.

regional literature, processed using the RStudio environment. The *Bibliometrix* package [10] was used to extract and update data specific to Tunisia from a corpus of more than 5000 research articles published between 1980 and 2020 and indexed in the Scopus and Web of Science databases [11]. The update process concentrated on geographical occurrences and practices involving the use of drought indices in Tunisia and the MENA region.

The bibliometric protocol followed the methodology established in [11] [12], using the *Bibliometrix* package [10]. Search strings combined drought-related keywords (e.g., "drought", "dry spell", "water scarcity") with geographical terms for the MENA region (list provided in Supplementary Material), queried in title/abstract/keyword fields of Scopus and Web of Science. Screening, de-duplication, and index classification procedures are detailed in these references.

The drought indexes detected in the database were classified into three physical categories: meteorological (e. g., SPI, SPEI)[1], agricultural/soil moisture (e. g., NDVI, VCI)[1] and hydrological (e. g. reservoir levels, flow anomalies).

In this counting protocol, a single article could contribute to multiple index totals if it utilized several indicators. Synonymous terms and acronyms were grouped under canonical names during the keyword cleaning process in *Bibliometrix* [10].

Thus, A database has been constructed to cover the MENA region, with a particular focus on Tunisia. This database incorporates various types of drought and

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[1] Table 1 in Section 3 Results and Discussion presents the complete list of drought indicators.

related indexes. It is important to note that anthropogenic drought is not treated here as a separate category. As stated in the literature, human influence (e.g. pumping, reservoir management) is considered inseparable from responses in the water cycle [2]. As it is not possible to isolate a pure human signal without data on a theoretical "natural world" [13], we consider that anthropogenic impacts are intrinsically captured by hydrological and agronomic indices.

3. Results and Discussions

3.1. Main Drought Indexes Used in the Literature

Table 1 presents a bibliometric summary of drought indexes. This systematic inventory lists the following for each indicator: (i) the acronym and full name; (ii) the open-source packages available for calculation (R, Python); (iii) the seminal reference introducing the method; and (iv) the number of publications that have used it. This structure makes it possible to objectively assess the methodological practices of the international scientific community and identify de facto standards as well as persistent gaps.

Table 1. Inventory and bibliometric occurrence of drought indices.

Acronym	Full Name	Package (open source)	Seminal Reference	Number of publication
Meteorological Drought				
SPI	Standardised Precipitation Index	SPEI (R), climate-indices (Py), spei	[14]	1855
PDSI	Palmer Drought Severity Index	scPDSI (R), climate-indices (Py)	[15]	880
SPEI	Standardised Precip. Evap. Index	scPDSI (R), climate-indices (Py)	[16]	784
RAI	Rainfall Anomaly Index	Precintcon (R)	[19]	248
AI	Aridity Index	CGIAR-CSI (Global Aridity)	[20]	187
KBDI	Keetch-Byram Drought Index	ClimInd (R), kbdi-ffdi (Py)	[21]	55
Z-index	Palmer Z-index	scPDSI (R), climate-indices (Py)	[15]	21
PNP	Percent of Normal Precipitation	climate-indices (Py)	[22]	19
Deciles	Precipitation Deciles	ClimInd (R), climate-indices (Py)	[23]	9
Agronomic Drought				
NDVI	Normalized Diff. Vegetation Index	terra (R), phenofit (R)	[17]	1311
LAI	Leaf Area Index	Lunar (R), ProSAIL(Py)	[24]	588
EVI	Enhanced Vegetation Index	MODISTools, vegIndexCalc (R)	[25]	204
VCI	Vegetation Condition Index	spatialEco (R)	[26]	185
VHI	Vegetation Health Index	spatialEco (R)	[26]	104
SMA	Soil Moisture Anomaly	snotelr, SPEI (R)*	[27] [28]	78
ESI	Evaporative Stress Index	NASA	[29]	41
SWDI	Soil Water Deficit Index	CropWaterBalance (R)	[30]	25

Continued

ETDI	Evapotranspiration Deficit Index	SPEI (R), Evapotranspiration, PyET	[31]	21
CMI	Crop Moister Index	scPDSI (R)*, climate-indices (Py)	[32]	20
SMDI	Standardised Moisture Soil Index	SPEI (R)*	[31]	10
CWSI	Crop Water Stress Index	water (R), PySEBAL(Py)	[33]	3
Hydrological Drought				
SDI	Streamflow Drought Index	hydroTSM (R), SPEI (R)*, climate-indices (Py)	[18]	114
SRI	Standardised Runoff Index	SCI (R), SPEI (R)*, climate-indices (Py)	[34]	75
SSFI	Standardised Streamflow Index	SCI (R), SPEI (R)*, climate-indices (Py)	[35]	59
Reservoir	Reservoir Storage/Level Index	reservoir (R), SCI (R)*	[36]	31
PHDI	Palmer Hydrological Drought Index	scPDSI (R)*, climate-indices (Py)	[15]	27
SWLI	Standardised Water-Level Index	SCI (R), SPEI (R), climate-indices (Py)	[37] [38]	13
GRI	Groundwater Resources Index	SPEI(R)*	[39]	3
SSI	Streamflow Anomaly	SPEI (R), climate-indices (Py)	[40]	3
SGI	Standardised Groundwater Index	SCI (R)*	[41]	2

Cross-reference with the dataset of Kchouk *et al.*, (2021); Updated Database (MENA and Tunisia) February 2026.

This inventory reveals marked heterogeneity in the use of indexes, with a clear predominance of meteorological indices designed to quantify climate drivers, to the detriment of indices measuring hydrological or agronomic impacts. The Standardized Precipitation Index (SPI), as proposed by [14], is widely recognized as the absolute methodological standard, with 1843 publications representing nearly one-third of the analyzed corpus. This dominance can be explained by its simplicity: The model's simplicity in terms of its input data, i.e., rainfall, as well as the simplicity of its calculation and the availability of open-source packages (SPEI in R, climate-indices in Python), have also contributed to its widespread use.

The PDSI [15] and SPEI [16] indices continue to be significant, with 875 and 780 occurrences, respectively. While the PDSI is outdated, it remains a historical reference that incorporates a simplified water balance (rainfall, temperature, and soil retention capacity). The most recent SPEI represents a significant advancement by incorporating evaporative demand (ETP), making it more sensitive to global warming. These two indices reflect the growing importance attached to the thermal dimension in the characterization of contemporary droughts.

With regard to agricultural drought, remote sensing has transformed monitoring practices. The NDVI (Normalized Difference Vegetation Index, [17]) has been cited in a total of 1308 publications, making it the preferred proxy for assessing large-scale vegetation water stress. Its success is based on free and continuous access to satellite data (NOAA-AVHRR, MODIS, Landsat) since the 1980s. Derived indices (EVI, VCI, VHI) complement this arsenal with 204, 185, and 104 occurrences, respectively, offering improved atmospheric corrections and temporal normalizations.

However, a methodological imbalance emerges when examining hydrological indexes. The Streamflow Drought Index (SDI, [18]), a critical tool for surface water resource management, has only been documented in 114 publications, which is significantly lower than the number of publications for the SPI. Despite the strategic importance of aquifers as a last-resort resource during crises, there is limited research on groundwater-specific indices (SGI: 2 publications; GRI: 3 publications). Similarly, storage indexes (Reservoir Level Index: 31 publications) are underrepresented, despite their direct operational variable status for decision support.

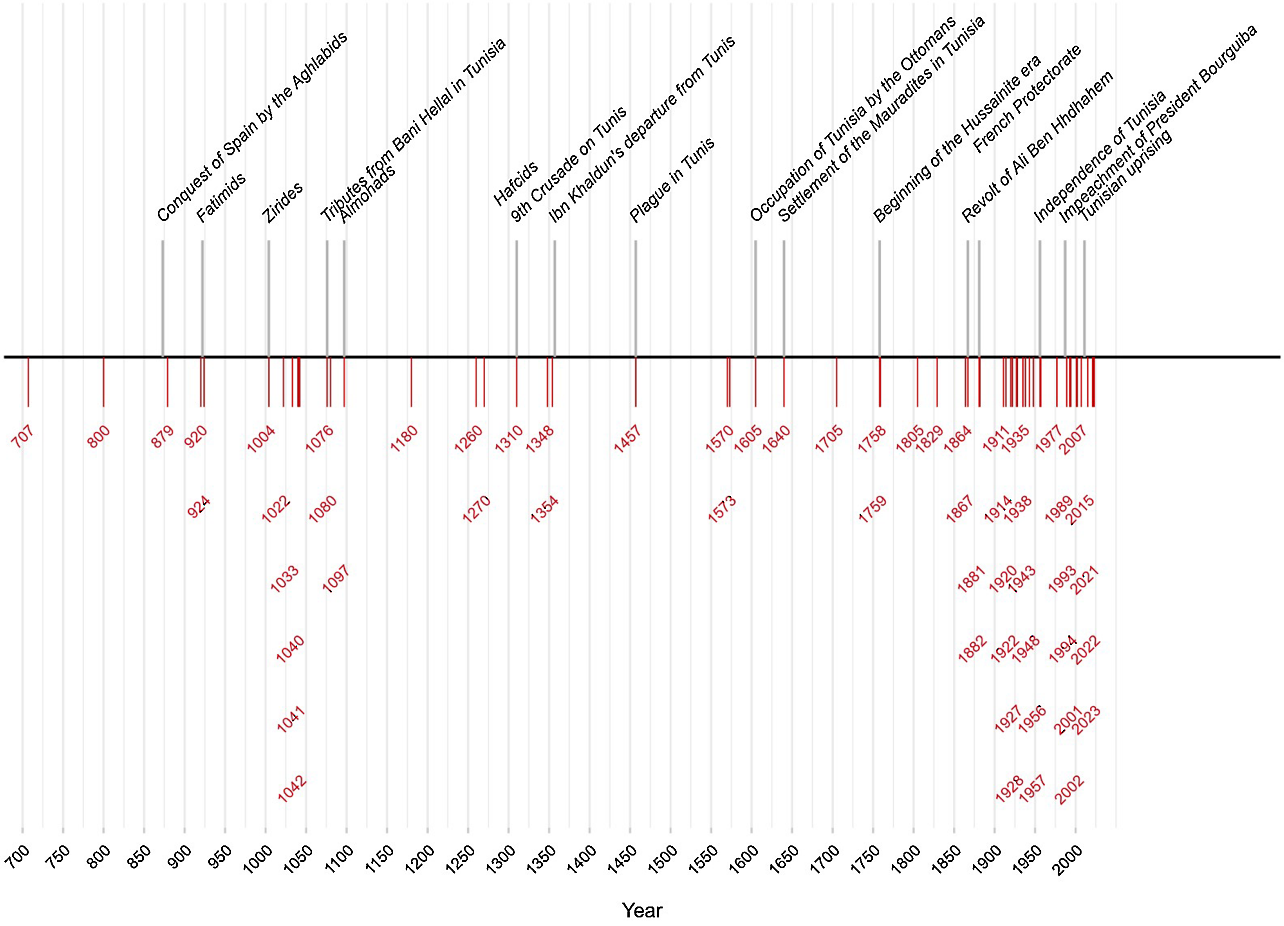
This overview reveals a structural bias in scientific literature: research overwhelmingly favors easily accessible and standardized forcing indexes (e.g., rainfall, temperature, vegetation) at the expense of impact indexes (e.g., flow rates, groundwater levels, stocks), which are nevertheless more relevant for crisis management.

3.2. Historical Overview of Drought in Tunisia

Figure 2 illustrates the chronology of drought episodes documented in Tunisia over a span of more than thirteen centuries.

An analysis of this historical series reveals a heterogeneous temporal distribution of events, with increasing density over the centuries. The following three distinct periods can be identified: The drought patterns exhibited three distinct periods. The first period, spanning from 700 to 1500, was marked by sporadic documentation of events. The second period, from 1500 to 1850, witnessed a noticeable decline in drought frequency, which could be attributed to a lack of documentation. The third period, from 1850 to 2023, exhibited a notable surge in drought episodes. This heightened awareness of droughts, in terms of both duration and frequency, can be partly attributed to the increased accessibility of relevant documentation. Nevertheless, the recent period (1850-2023), and more specifically the early 20th century, stands out for its exceptionally high density of events (n = 20). While this trend is consistent with the era of industrialization and the associated rise in greenhouse gas concentrations [42], we acknowledge that improved archival coverage may also contribute to this apparent acceleration. Thus, the link between post-1850 drought frequency and anthropogenic climate change is presented here as a plausible hypothesis, pending formal attribution analysis that disentangles documentation bias from climatic signals. This finding aligns with observations indicating an acceleration of climate hazards in the Mediterranean region ([6] [7]), particularly in Tunisia.

Additionally, the intersection of climatic events and historical milestones, such as dynasties, occupations, and independence, offers novel perspectives for examining the interplay between natural hazards and socio-political dynamics. This approach aligns with the recommendations outlined in [5] and [43], which underscores the necessity to incorporate the human dimension into the study of



Ameur Horchani, (2014)
Mohamed Hedi Cherif, (1980)
General Directorate of Water Resources (DGRE)

Figure 2. Historical drought in Tunisia.

droughts. The authors assert that "*humans are not merely passive victims but actors capable of altering the trajectory of the phenomenon*".

The historical database contains numerous records that support this complex interaction:

- It has been observed that periods of prolonged drought often coincide with episodes of famine and political instability. For instance, the significant increase in dry events in the 11th century (1022, 1033, 1040, 1041, 1042, 1080, 1097) occurred before or coincided with the invasion of the Banu Hilal (tributes recorded in 1076), a major tribal migration that had a considerable impact on the demographic and social structure of *Ifriqiya*[2]. This correlation suggests that climatic stresses may have acted as triggers or amplifiers of migratory movements and conflicts over resources.
- Subsistence crises have also been linked to epidemics. The drought of 1457 coincided with the plague in Tunis, illustrating the phenomenon of syndemic, whereby climatic hazards weaken populations through famine and malnutri-

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[2] Ancestral name of Tunisia.

tion, thereby exacerbating their vulnerability to infectious diseases.

- The period of French protectorate (from 1881) saw an increase in recorded droughts (1867, 1881, 1882, 1911, 1914, 1920, 1927, 1928, 1935, 1943). This period also saw profound changes in agricultural structures and local revolts *(Ali Ben Ghedhahem*'s revolt in 1864-1867), regional famines, and successive waves of rural exodus. The accumulation of climatic stresses in this context of colonial domination likely contributed to the exacerbation of social tensions and resistance movements.
- Finally, despite the development of water infrastructure, the contemporary period is marked by persistent droughts. Recent events (2015, 2021, 2022, 2023) have occurred against a backdrop of major political tensions (the 2011 uprising, the 2021-2023 institutional crisis), reminding us that vulnerability to drought remains a key socio-political issue for post-revolutionary Tunisia.

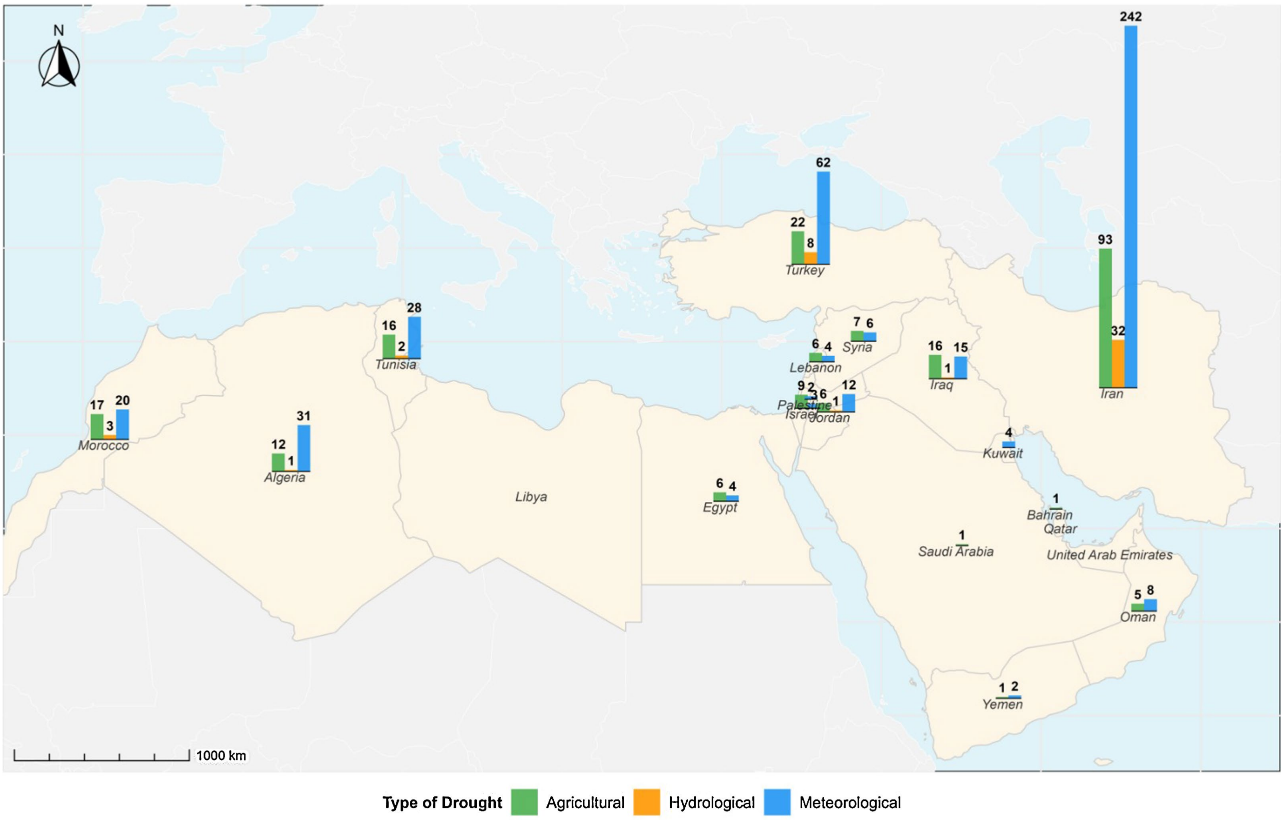
It is important to note that these associations represent historically plausible links based on chronological correlations and documentary evidence, rather than statistically demonstrated causal effects. These observations underscore the complexity of drought assessment and highlight the need for nuanced climate indexes that can accurately capture its multifaceted nature. It is part of a coupled human-environment system in which rainfall deficits interact with governance structures, demographic dynamics, and geopolitical contexts. As discussed in [1], "the socio-economic dimension of drought emerges from the interplay between physical anomalies and societies' response capacities, making this hazard an intrinsically interdisciplinary subject of study".

3.3. Drought Indexes in the MENA Region and Tunisia

Figure 3 emphasizes the significant heterogeneity in the application of drought indexes across the MENA region, reflecting both methodological and structural disparities between the countries in question. A clear predominance of meteorological indices can be observed across the entire basin, confirming the global bibliometric trends identified by [10] and [11]. As [6] notes, this emphasis on meteorological drivers facilitates international standardization, but it can also obscure the intricate processes underlying drought propagation to agricultural and hydrological domains.

Regarding agricultural drought, the map demonstrates cases a notable yet inconsistent presence of indexes derived from remote sensing, particularly NDVI. This dynamic is particularly evident in countries with relatively developed research capabilities or a high dependence on rain-fed agriculture, such as Morocco, Tunisia, and Egypt. The increasing use of these spatial indices addresses the need for large-scale monitoring of vegetation water stress, as evidenced by the research conducted by [7] in Tunisia.

However, despite the strategic role of surface water and groundwater for water security in the region, the hydrological indexes of direct impact related to these appear marginal or even absent. This methodological imbalance corroborates the



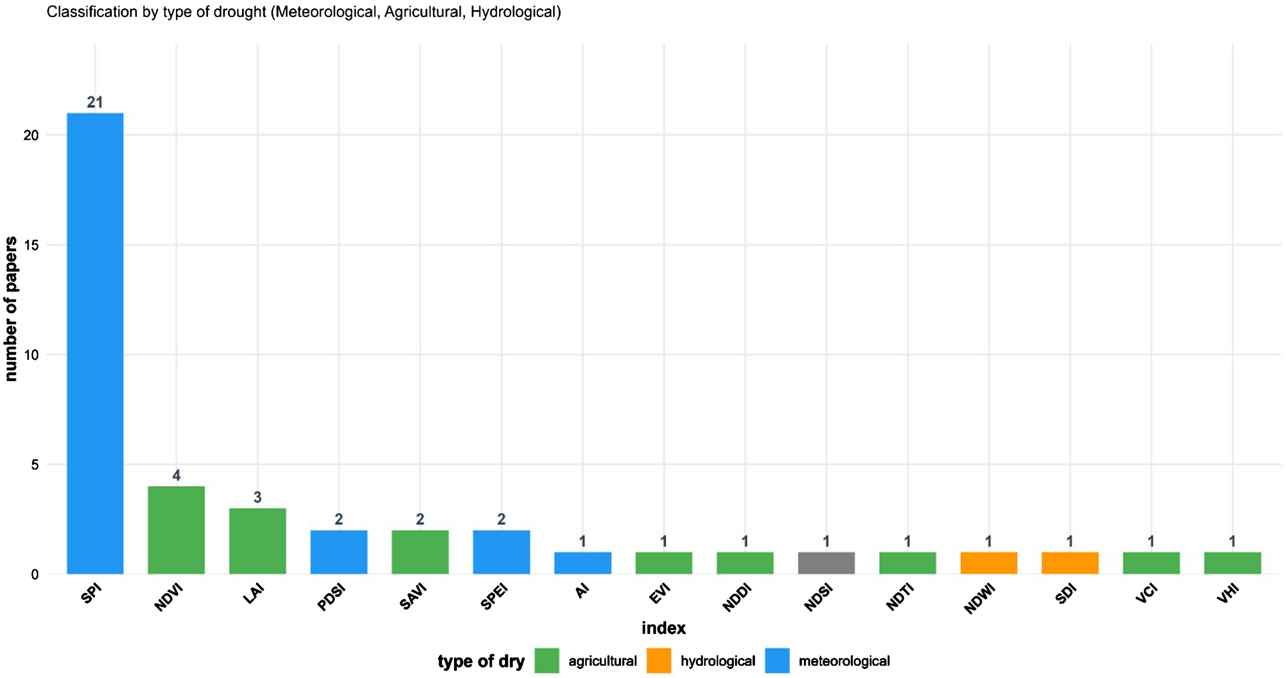
Source: Kchouk (2021) updated February 2026

Figure 3. Bibliometric mapping of indexes related to types of droughts: case of the Middle East and North Africa region (1980-2026).

observations of [44], which point to gaps in hydrological monitoring networks and a lack of reliable flow data in the MENA region. This deficiency results in a structural mismatch between the available diagnostic tools and the actual needs of managers, who require information on water stocks rather than just deficits in rainfall.

Figure 4 emphasizes the methodological heterogeneity in the application of drought indexes in Tunisia. In accordance with global bibliometric trends identified by [12] and **Table 1**, there is a clear predominance of meteorological indices, particularly the Standardized Precipitation Index (SPI), which is the benchmark tool in Tunisian literature. This preference can be explained by several factors: The simplicity of calculating the SPI is advantageous because it requires only rainfall series. Furthermore, the availability and accessibility of precipitation data is beneficial. Finally, the World Meteorological Organization's recognition of this index as the standard for monitoring meteorological droughts [45] is a significant asset.

However, recent literature reveals the emergence of indices incorporating the thermal dimension (SPEI) and remote sensing (NDVI, VCI), reflecting a growing awareness of evaporative demand and plant stress in the Mediterranean context. Despite this diversity, current monitoring has limitations, notably a lag between meteorological indices (SPI, SPEI) and actual impacts on water security. The



Source : Kchouk et al. (2021)
updated February 2026

Figure 4. Drought indexes used in Tunisia (1980-2026).

development of hybrid indexes, which combine climate forcings and management variables (such as reservoir levels and withdrawals), is still limited by the accessibility of hydrological data (flows and piezometry).

Although the SPI is the benchmark tool due to its simplicity and the availability of rainfall data, recent studies highlight that no single index can effectively characterize drought across the entire territory. This discrepancy can be attributed to the diverse bioclimatic zones of Tunisia, which result in varied responses to rainfall deficits. Reference [7] Demonstrates that the SPI performs better in the humid northern forest region, while the PDSI, which incorporates the thermal dimension, is more suitable for the semi-arid central steppe. In the southeast, [46] recommend a multi-scale approach (SPI-3 to SPI-72) to capture both seasonal agricultural droughts and multi-year structural sequences. More recently, [47] underscored the significance of remote sensing indices (NDWI, NDTI) for monitoring strategic reservoirs such as Sidi Salem, where the contraction of water surfaces (−47.6% between 1985 and 2025) cannot be fully explained by rainfall deficits alone. These results underscore the necessity for a diversified monitoring strategy, integrating meteorological, agricultural, and hydrological indexes according to bioclimatic zones and water utilization

4. Conclusions

This study characterized drought in Tunisia and the MENA region using a methodological approach combining long-term historical analysis and a bibliometric review of monitoring indexes. The results achieved align with the three specific objectives established, offering potential avenues for water resource management in the context of climate change. The historical reconstruction of drought episodes in Tunisia (700-2023) reveals an acceleration in the frequency and intensity of dry events over the last two centuries, with an exceptional density at the beginning of the 20th century (n = 20). This trend corroborates the observations of [6] concerning the increased exposure of the Mediterranean region to climate hazards. Beyond the physical dimension, the analysis highlights a close link between water crises and socio-political dynamics, confirming that drought acts as a multiplier of threats to the stability of societies [5] and [43].

Bibliometric analysis reveals a structural bias in scientific output, with research predominantly focusing on forcing indexes (SPI: 1,843 publications; PDSI: 875; SPEI: 780) that are readily accessible and standardized, while neglecting impact indexes (flows, groundwater levels, stocks) that are more pertinent for crisis management. This imbalance is also observed in the MENA region, where hydrological indexes remain marginal. In Tunisia, SPI is the benchmark tool due to its simplicity and the availability of rainfall data. However, it has its limitations, and there is a trend towards indexes that capture the effects of climate change, such as SPEI. Additionally, a single index is not sufficient to effectively characterize drought across the entire territory due to the diversity of bioclimatic zones.

The bibliometric update is focused on the period 2020-2026, but it is important to note that its findings are dependent on the indexing of articles in the Scopus and Web of Science databases. This may underestimate regional output published in local journals. Additionally, the absence of continuous hydrological data (such as flow rates and piezometry) hinders the operational validation of the identified impact indexes.

Future research should focus on: 1) Developing composite indices adapted to the Tunisian context, incorporating regional bioclimatic variability; 2) Improving hydrological monitoring networks to enable the calculation of operational indexes (SDI, SGI, reservoir levels); and 3) explicitly integrating the socio-economic dimension into early warning systems, in accordance with the recommendations of [5] on drought in the Anthropocene.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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