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Assessing Climatic Variability in Data Scare Region of Morocco (UpperLarbaâ Basin): Drought Periods and Exceptional Precipitation Events from 1958 to 2023

Brahim Bougdira
Chouaib Doukkali University, El Jadida, Morocco
Badr Layan
Sadik El Yadari
Sidi Mohamed Ben Abdellah University, Fez, Morocco
Mohamed Ben Abbou
Higher Institute of Nursing Professions and Health Techniques of Fez, Annex Taza, Morocco
Nessraddine Adouk
Chouaib Doukkali University, El Jadida, Morocco
Lahcen Benaabidate
Sidi Mohamed Ben Abdellah University, Fez, Morocco

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Abstract

The southern Mediterranean region is characterized by significant climatic variability, which profoundly affects precipitation patterns, a critical water resource. This region has been experiencing atypical weather events, including extreme precipitation and extended drought periods. The aim of this study is to investigate the climatic variability over data-scarce regions. To attend to this objective, we conducted a comprehensive statistical analysis within the upperLarbaâ basin, as a case study, situated at the edge of the Eastern Rif Mountains. Our research involved a thorough analysis of daily, monthly, and annual precipitation data spanning 65 years, from 1958 to 2023. The homogeneity test revealed a disturbance in the time series from the late 1970s to the early 1980s across all six rainfall stations used. Utilizing the

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Moving Average and Inverse Distance Weighting (IDW) model, we identified variations in rainfall amounts, demonstrating a notable trend from the southwest to the northeast of the basin. Furthermore, correlation analysis between precipitation levels and the North Atlantic Oscillation (NAO) index showed an inverse relationship, particularly evident in the northwestern section of the watershed. The Evapotranspiration Moisture Index (EMI) showed that drought lasted between 33 and 36 years, with one-third of the samples considered normal drought and two cases labeled as severe based on the Standardized Precipitation Index (SPI). Our findings suggest that the Pearson type III distribution is the most appropriate for estimating the return periods of extreme precipitation in Taza, whereas the Gumbel distribution is better suited for Sebt Bouklal. We recorded precipitation levels of 45 mm in Taza and 54 mm in Sebt Bouklal for a 5-year return period. For a 100-year return period, the figures increased to 88 mm in Taza and 95 mm in Sebt Bouklal.

Keywords: UpperLarbaâ basin, climatic variability, extreme precipitation, drought periods

Introduction

The weather of any place refers to the atmospheric variables for a brief period. Climate, however, represents atmospheric conditions for a long period of time and generally refers to the normal or mean course of the weather (Xoplaki, 2002). Additionally, climate is the long-term summation of atmospheric elements and their variations (Raymond et al., 2016). We can expand climate to encompass future expectations spanning several weeks, months, or even years ahead. It should include not only the average values of the climatic elements that prevail at different times but also their extreme ranges, variability, and the frequency of various occurrences. Quadrelli et al. (2001) found that just as one year differs from another, so do decades and centuries, sometimes by a smaller and even more significant amount. Overall, the main climatic elements include precipitation, temperature, humidity, sunshine, wind velocity, and such phenomena as fog, frost, thunder, gale, cloudiness, grass minimum temperature, and soil temperature at various depths (Xoplaki, 2002). Scientists have used various methods to analyze climate features throughout the last century. In such an analysis, scientists usually base the process on monthly observations over a period long enough (usually about 30 years) to ensure more detailed results (Moron and Ward, 1998).

Regional climate variabilities, particularly temperature increases and sudden heavy rainfall, are affecting many natural systems, according to observational evidence (Sebbar et al., 2011). Consequently, analyzing the

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spatial and temporal variability of precipitation, as well as determining the frequency of drought periods and extreme rainfall events, is crucial. These climatic features have direct and indirect implications for water resources. Persistent, stable atmospheric conditions could adversely affect the economy, particularly the agricultural sector. Additionally, excessive precipitation often introduces hydroclimatic risks, potentially leading to losses for individuals and their assets (Sebbar et al., 2011).

Numerous analyses conducted in the Mediterranean region have highlighted a rising trend in the occurrence of climatic droughts, particularly during the winter months (Hoerling et al., 2012). A comprehensive analysis spanning 56 years (1957–2013) has documented the effects of climatic drought on grain production in Spain (Raymond et al., 2016). Furthermore, Barriendos et al. (1999) conducted a study in Catalonia between 1812 and 1824, which identified notable instances of drought affecting the region. In addition, an investigation centered on drought records from Barcelona, spanning 1521–1989, confirmed the occurrence of drought conditions (Barriendos et al., 1998).

Furthermore, the long observation series allowed for the identification of climatic variability, opening extensive possibilities to conduct various methods, which vary depending on the data's quality. Some of these approaches link the general state of atmospheric pressure with other effects occurring in the 500 hectopascal range (Hertig, 2013). For instance, correlating precipitation data from 23 weather stations in Greece during the winter revealed a close relationship between high-pressure systems over Europe and the prevalence of stable weather conditions and drought in the country. Additionally, the study linked the summer air temperatures to atmospheric circulation and sea surface temperatures in the Mediterranean (Xoplaki, 2002).

Alternative methodologies employed statistical analysis to develop experimental models. These techniques remain a core strategy for identifying both drought and exceptional precipitation phases. Such studies considered the variability of precipitation as a principal climatic element in estimating drought periods. Certain indicators aim to establish the thresholds necessary for distinguishing between wet and dry periods (McKee et al., 1993). In this context, the focus has been on assessing the correlations among different factors that affect weather patterns. Numerous studies have underscored the connection between diminishing precipitation levels and the rising drought incidence, which particularly intensifies during the summer and autumn in the central and western areas of the Mediterranean basin (Hertig, 2013).

The southwestern coastline, akin to other Mediterranean areas, showcases notable fluctuations in precipitation, lying between the temperate zone to the north and the tropical zone to the south. This region experiences

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hot, arid summers, while the coastal regions benefit from a more temperate climate. In winter, high-pressure systems shift toward the Canary Islands, allowing polar cold fronts to advance and introduce precipitation and humidity, impacting numerous southwestern Mediterranean nations. Taibi and Meddi (2013) conducted research in Algeria that revealed significant variability in precipitation from 1940 to 2004, highlighting an initial increase in rainfall during the early 1940s and a sustained decline that continued until the beginning of the current century. In Tunisia, studies have demonstrated that drought is a persistent issue, often lasting for two to three consecutive years or even longer (Benzarti, 2001).

Morocco, like other nations along the southern Mediterranean coastline, is witnessing a rise in the duration of drought periods. Geological, geomorphological, and historical evidence suggests that Morocco ranks among the region's most vulnerable to drought and climate fluctuations (Sebbar et al., 2011). The country's geographical location renders it particularly susceptible to the effects of high-pressure systems originating from the Azores and the Sahara, alongside the intrusion of dry tropical air masses (Elkbichi et al., 2024). Additionally, the incidence of drought has significantly escalated in the last ten years, adversely affecting water resources and inflicting damage on the economy, especially within the agricultural sector (Ouchouia and Chaouki, 2022).

On the other hand, exceptional precipitation denotes a significant amount of rainfall occurring within a short timeframe. This type of precipitation has immediate effects on water dynamics, often resulting in a notable increase in streamflow that exceeds normal levels, thereby posing potential flood risks (Habibi, 2012; Qadem, 2019). Local populations of Taza's region frequently witness such occurrences downstream of the Larbaâ River and its tributaries, crossing several urban and rural centers (Layan et al., 2024a).

This study attempts to identify climatic variability in data-scarce regions. It specifically focuses on semi-arid regions of northeastern Morocco, where irregular rainfall patterns and sparse meteorological monitoring networks exacerbate the difficulties of measuring the weather elements. This article aims to apply a unique method to investigate the climatic variability over the UpperLarbaâ basin. It explores the temporal and spatial variability of precipitations and droughts in relation to atmospheric pressure systems, specifically by analyzing the differential effects of the Azores High and the Icelandic Low. The study also clarifies the connection between positive phases of the North Atlantic Oscillation index and the occurrence of stable weather conditions and drought. Due to the limited data, we will rely on free online resources, which have provided 65 years' worth of monthly observations to investigate drought frequency and its severity. Furthermore, we will analyze

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daily data spanning 40 years to identify significant precipitation events. We will conduct a statistical analysis to assess correlations and return periods associated with these exceptional precipitation events. We will also use standard indicators to distinguish between dry and wet periods while applying the Inverse Distance Weighting (IDW) model for spatial analysis.

Study area

The study focuses on the UpperLarbaâ basin in northeastern Morocco, characterized by a semi-arid climate and strategically located in the pre-Rif mountains (Figure 1). The catchment encompasses an area of approximately 284 km², accounting for 9.64% of the Inaouen basin (Layan et al., 2024a) (Figure 1). We selected this area due to its notable climatic variability, making it a perfect case study for conducting statistical analysis to investigate the methods' accuracy. We delineated the watershed's boundaries using two topographic maps at the scale of 1:50,000, specifically Ain Boukellal and Bab el Mrouj. The region is characterized by a semi-arid climate and regularly experiences sporadic and unpredictable rainfall, often manifesting as brief, intense storms with substantial precipitation. Overgrazing and unsustainable forest utilization have led to significant degradation of the vegetation cover, exacerbating water erosion (Tribak, 2020). Impermeable rock types, like marls and marl-limestones, make it harder for water to soak in, which leads to more surface runoff (Layan et al., 2024b). The northern mountain peaks feature conglomerate formations and resilient sandstone (Tribak, 2020). Geomorphologically, the watershed predominantly exhibits hilly landforms, a consequence of severe erosion affecting vulnerable lithologies and unprotected soils. The Larbaâ Wadi is characterized by a torrential hydrological regime, marked by sudden and intense flooding during the fall and winter months, alongside prolonged low-flow conditions lasting several months (Layan et al., 2024a). The Sebt Bouklal Rural Center sits along the Larbaâ River, approximately 17 kilometers northeast of Taza City. The community's developments occupy the floodplain of the Larbaâ Wadi, adjacent to Road 29, which serves as the national route connecting nearby towns and villages. Such anthropogenic activities disrupt natural flow during flood events (Layan et al., 2024a). Unfortunately, the decision-making processes have overlooked the hydrological characteristics of the drainage basin.

Materials and methods

Materials

In this study, we primarily based the work on daily, monthly, and annual rainfall data from six stations located within and around the UpperLarbaâ basin (Table 1). The daily observations spanning a 40-year

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period from 1981 to 2020 were obtained from the NASA Langley Research Center (LaRC). While the monthly and annual meteorological information was sourced from publicly available platforms like the University of California's TerraClimate database (Hegewisch, 2023; Abatzoglou, 2018), which maintains a comprehensive 65-year record from 1958 to 2023.

Additionally, the North Atlantic Oscillation index (NAO) was considered in our case study. This index is defined by differential pressure between a high-pressure system located in Lisbon and a low-pressure system over Iceland (Delannoy, 1988). In periods when the NAO index is positive, the Azores high-pressure system surpasses the typical winter average, resulting in increased dryness. Conversely, during negative phases of the NAO index, the low-pressure system over Iceland weakens, which allows the Icelandic low to intensify and the Azores high to recede (Sebbar et al., 2011; Filahi et al., 2015; Zamrane, 2016). These atmospheric conditions often promote the influx of disturbances from temperate regions into northern and northwestern Morocco, potentially leading to extreme precipitation events that can trigger significant flooding (Hanchane, 2017).

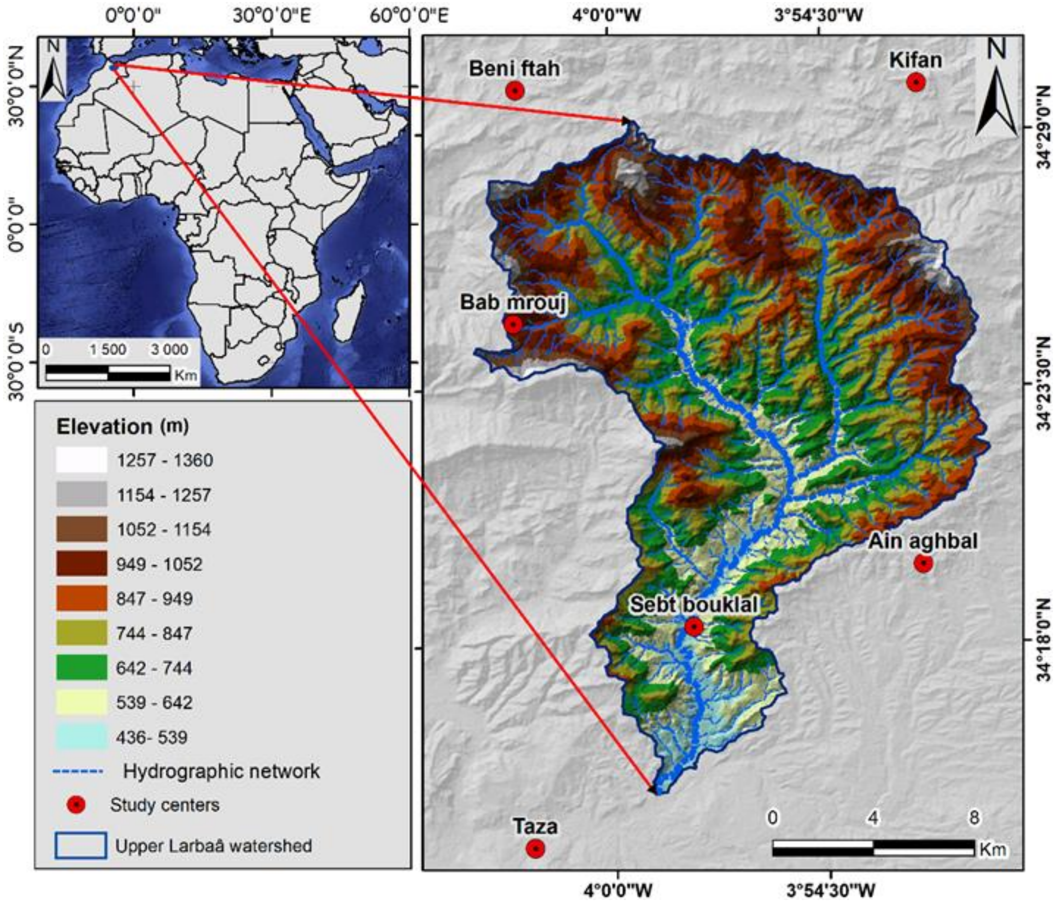

Figure 1. Study area (northeastern Morocco, UpperLarbaâ watershed)

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Methods

To assess the data's continuity, we implemented a homogeneity test to determine whether the sample series is homogeneous or exhibits discontinuities (Lubés et al., 1994 and 1998). Such tests were applied using various methods to measure homogeneity across 166 climate observation centers in the northwest region of Morocco (Sebbar et al., 2011). In our case, we processed these tests using the ones found by Pettitt (1979) and Buishand (1984).

Table 1. Rainfall stations used for statistical analysis. **Max**: Maximum of annual Precipitation (mm); **Min**: minimum of annual precipitation (mm); **Av. Prec**: Average of annual Precipitation (mm); **St. Div**: Standard deviation (mm)

Station	Latitude	Longitude	Min	Max	Av.prec	St.Div
Kifan	34°31'15''N	3°51'15''W	274	887	501	125
Sebt Bouklal	34°18'45''N	3°58'45''W	293	1058	581	151
Taza	34°13'45''N	4°01'15''W	307	1154	625	166
Bab mrouj	34°23'45''N	4°03'45''W	282	975	536	137
Ain aghbal	34°18'45''N	3°51'15''W	275	937	519	134
Beni ftah	34°28'45''N	4°01'15''W	278	952	532	134

Additionally, we employ the Inverse Distance Weighting (IDW) model to evaluate the spatial variability of precipitation over the designated period. This method (IDW) allows interpolations to estimate unknown values at specific locations based on known values from surrounding points (Matheron 1965; Tabios et al. 1985; Phillips et al., 1992; Lebel et al., 1996; Hutchinson 1998; Taesombat et al., 2009; Brou 2005; Valent et al., 2015). The underlying assumption is that points closer to the target location have a greater influence on the estimated value than points farther away. The IDW formula is as follows:

$$Z(x) = \frac{\sum_{i=1}^{N} \quad Z(x_i) * \left(\frac{1}{d(x,x_i)^p}\right)}{\sum_{i=1}^{N} \quad \left(\frac{1}{d(x,x_i)^p}\right)}$$

Where: Z (ϰ): *The value we want to estimate at the unknown location ϰ;* ***N:*** *Number of known nearby points ;* ***Z (ϰi):*** *Known values at neighboring locations* ***ϰi*** *(The points containing known data) ;* ***d (ϰi , ϰ)****: The distance between the unknown location* ***ϰ*** *and the known locations* ***ϰi*** *;* ***p :*** *The power or exponent that determines how much distance affects the weighting The higher the p-value, the less influence distant points have.*

Furthermore, the study attempted to pinpoint occurrences of climatic drought by utilizing a range of indicators, including the Evapotranspiration Moisture Index (EM) index to differentiate between dry and wet years and the

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(SPI) index to evaluate drought severity. The EM index allows measuring how much annual precipitation is different from its historical average (Ndong et al. 1995; Servat et al. 1998; Le Barbe et al. 2002; Lawin, 2007; Sebbar et al., 2011). Negative index values signify years of reduced rainfall, while positive values denote wetter years. While the deviation from the average highlights both dry and wet years, the SPI index allowed us to assess the severity of climatic drought. This index is defined as the result of the deviation from the average divided by the standard deviation. According to this index, the values range from -0.99 for mild drought, -1.00 to -1.49 for moderate drought, -1.50 to -1.99 for severe drought, and approximately -2.00 for extreme drought (McKee et al. 1993; Sebbar 2013; Daki et al. 2016).

Finally, we conduct additional analysis of the daily precipitation. Due to data limitations, we restrict this examination to two locations: the rural commune of Sebt Bouklal and the city of Taza (Table 2), where we have access to daily observations spanning a 40-year period from 1981 to 2020. We obtained the data from the NASA Langley Research Center (LaRC). The focus of this analysis is to identify exceptional precipitation events that could result in recurrent flooding, particularly in the Sebt Bouklal area, located downstream of the Larbaâ River. To do this, we looked at the results from different statistical models, such as the Generalized Extreme Value (GEV) distribution, log-normal distribution, Gumbel distribution, and Pearson Type III distribution. The goal was to ascertain the most appropriate model for estimating the return periods of exceptional precipitation, which range from 5 to 100 years (Bobée et al. 1991; El Adlouni et al., 2014).

Table 2. Stations used to identify exceptional precipitation. Max: Maximum Precipitation (mm); Date: the date which corresponds to the maximum value

Station	latitude	Longitude	Max	Date
Taza	34°13’45’’N	4°01’15’’W	80,18	30-11-2010
Sebt Bouklal	34°18’45’’N	3°58’45’’W	104,35	30-11-2010

Results

Break periods

The results indicated the presence of interruptions in the sampling series for all stations. Specifically, the Kifan, Bab Mrouj, and Bni Ftah centers recorded a breakup in 1978, the Taza center in 1979, and both Sebt Bouklal and Ain Aghbal in 1980 (Table 3). These interruptions suggested a lack of consistency in the observed series, with varying averages recorded at each station. During the first period, rainfall exceeded 700 mm at the Taza center and 600 mm at four other centers, while the Kifane center recorded 596 mm. In contrast, the second period saw a decrease in precipitation, with amounts not exceeding 500 mm except at the Taza and Sebt Bouklal centers.

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Table 3. Break periods and precipitation variation

Stations	First Average		Second Average		Precipitation rate (%)
	Period	Precipitation (mm)	Period	Precipitation (mm)	
Kifan	1958-1978	596	1979-2023	459	13
Sebte boukklal	1958-1980	685	1981-2023	527	13
Taza	1958-1979	746	1980-2023	568	14
Bab mrouj	1958-1978	634	1979-2023	493	13
Ain aghbal	1958-1980	616	1981-2023	469	14
Beni ftah	1958-1978	628	1979-2023	489	12

Spatial variability of precipitation

The results clearly show significant changes in precipitation levels throughout the entire region of the UpperLarbaâ Basin. We observe higher precipitation in the southwest section compared to the northeast. Furthermore, the biannual spatial variability of rain demonstrates a general trend of decreasing values, apart from a notable increase between the years 2000 and 2010 (Figure 2). Indeed, at the beginning of the 1960s, the entire basin recorded an average precipitation of over 600 mm. The amount of rainfall gradually declined until the early 2000s, when it fell below 500 mm in vast regions of the basin. Between 2000 and 2010, there was a resurgence in precipitation levels, surpassing 600 mm. On the other hand, over the past decade, precipitation has once again decreased below 500 mm, except for the centers of Sebt Bouklal and Taza (Figure 2).

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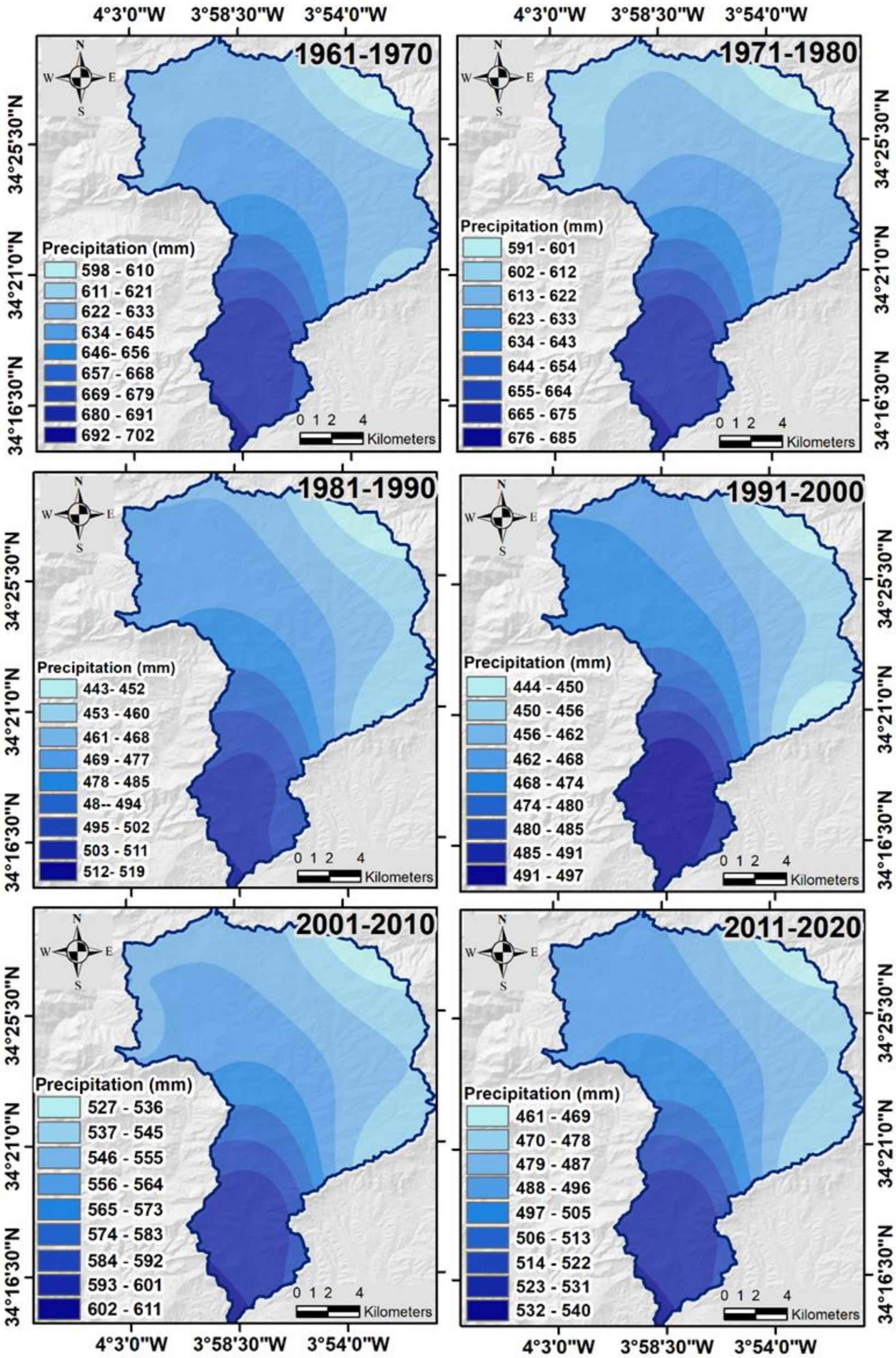

Figure 2. Spatial variability of precipitation within the UpperLarbaâ basin.
(Based on data sourced from TerraClimate on August 10, 2024)

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Correlation between Precipitation and the North Atlantic Oscillation (NAO)

In our case study, we assessed the correlation through simple linear regression, followed by an evaluation of the correlation's strength using the available data. Based on Pearson's Bravais table, we found that when the theoretical threshold for the observed series falls between 0.2320 and 0.2502, all the examined stations have inversely exceeded this threshold (Table 4). So, our results show that there is a strong link between the amount of rain in the UpperLarbaâ Basin and the North Atlantic Oscillation Index. The northwest of the basin, particularly the Bab Mrouj and Beni Ftah regions, experiences more impact than the rest (Figure 3). This matter pertains to the retreat of the Azores High and the subsequent impact of the cold polar front, which carries air masses saturated with moisture from the Atlantic Ocean.

Table 4. Correlation analysis between rainfalls and the Atlantic oscillation index.

Coefficient	Kifan	Sebt Bouklal	Taza	Bab mrouj	Ain aghbal	Beni ftah
R	-0,36	-0,38	-0,38	**-0,39**	**-0,36**	**-0,39**
R^2	0,13	0,14	**0,15**	**0,15**	**0,13**	**0,15**

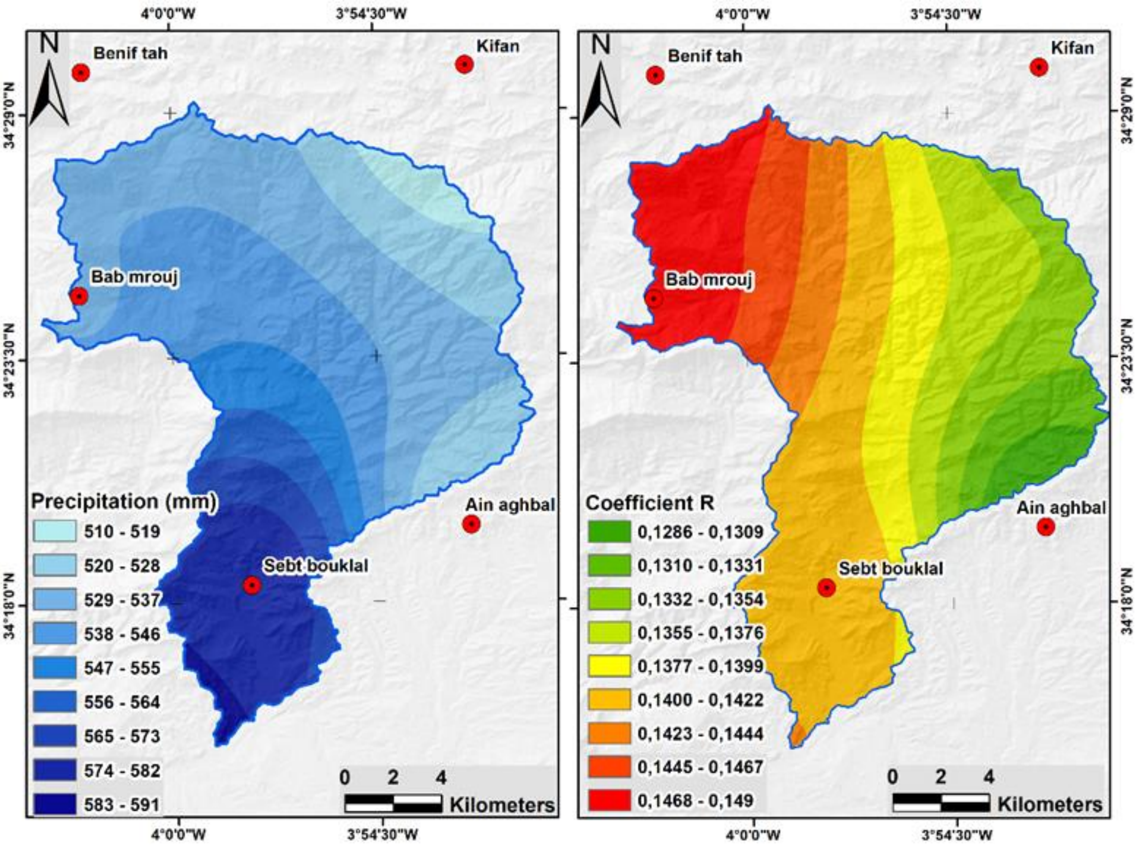

Figure 3. Notable correlation between precipitation and the North Atlantic Oscillation (NAO) index (Based on data sourced from TerraClimate on August 10, 2024)

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Assessing drought periods

The findings suggest that dry years are marginally more common than wet years. For instance, in the Kifane region, there have been 36 dry years out of a total of 65 years, whereas both Bab Mrouj and Beni Ftah recorded 33 dry years each (Figure 4). This information highlights the arid climatic conditions that prevail in most of the UpperLarbaâ Basin.

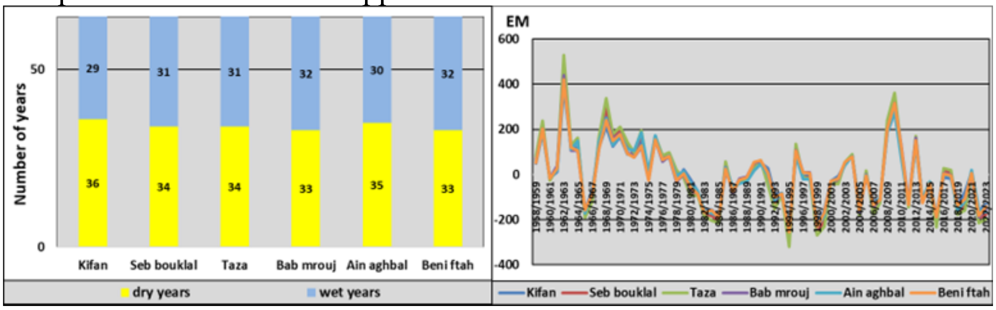

Figure 4. Dry and wet years using the deviation from the average

The results indicate that all the stations experienced a normal drought for more than 20 years out of a total of 65 years, accounting for approximately one-third of the observed series period (Figure 5). Furthermore, about one-sixth of this period consisted of relatively dry years, while severe drought occurred during two specific seasons: the first in the 1994/1995 season and the second in the 1998/1999 season. We recorded no instances of exceptional drought (Figure 5).

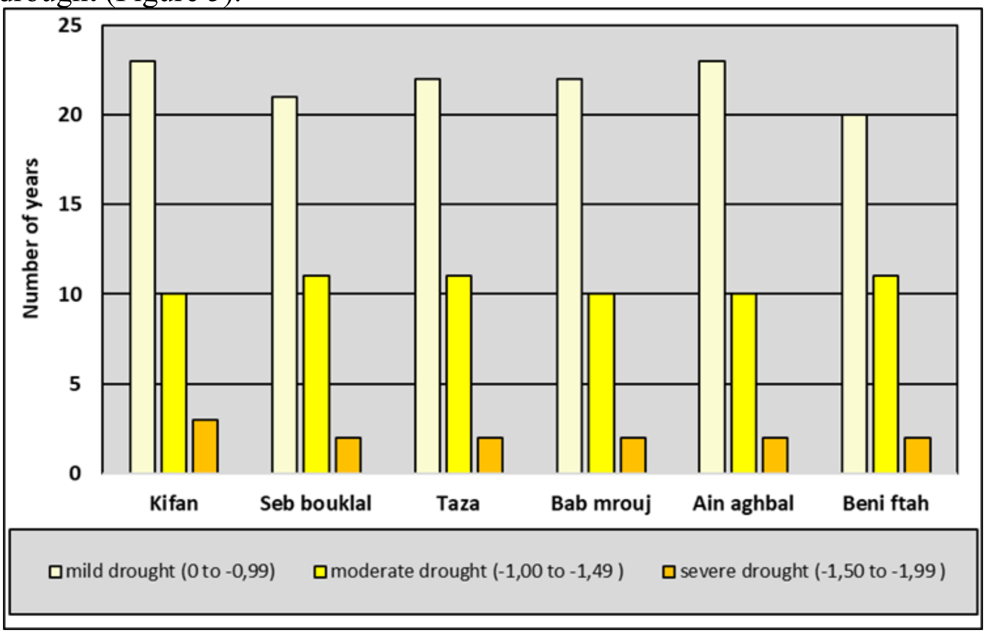

Figure 5. Drought severity over the stations studied

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Assessing exceptional precipitation

To identify the extreme incidents of precipitation, we primarily utilized maximum daily precipitation data from the Taza and Sebt Bouklal stations, covering a period of over 40 years. The monthly analyses, illustrated in Figure 6, indicated that November experiences the highest frequency of heavy rainfall, followed closely by February and January. This pattern suggests that extreme precipitation events are predominantly associated with the winter season, consistent with the climatic characteristics of the Mediterranean region (Figure 6).

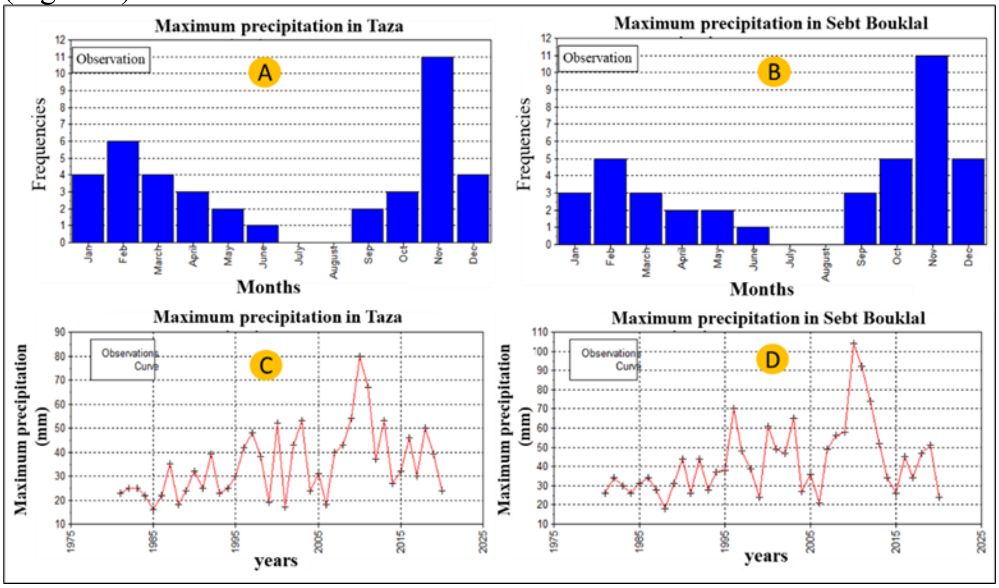

Figure 6. A and B illustrate the monthly distribution of maximum precipitation, C and D highlight the biannual distribution of maximum precipitation

An evaluation utilizing multiple tests provided results that differ from one to another. The Wald-Wolfowitz test showed that the data used are independent at a 1% confidence level, and the Kendall test indicated a clear trend of decreasing maximum daily rainfall. On the other hand, the Pearson Type III distribution works best for predicting return periods at the Taza station, while the Gumbel distribution is the best fit for the Sebt Bouklal center (Table 5 and Figure 7). From the results, we also noted that the Taza station has a possibility to receive a quantity of rain exceeding 45 mm every 5 years, greater than 65 mm for a 20-year period, and approximately 88 mm for a return period of 100 years. Conversely, for the Sebt Bouklal station, the return periods recorded were 54 mm for a 5-year period, 73 mm for a 20-year period, and over 95 mm for a 100-year return period (Table 6 and Figure 7).

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Table 5. Results of different distribution laws used.

Stations	GEV Law	Log normal	Gumbel	Pearson type III
Taza	2,80	4,40	4,40	**2,40**
Sebt Bouklal	5,60	4,80	**4,40**	6,00

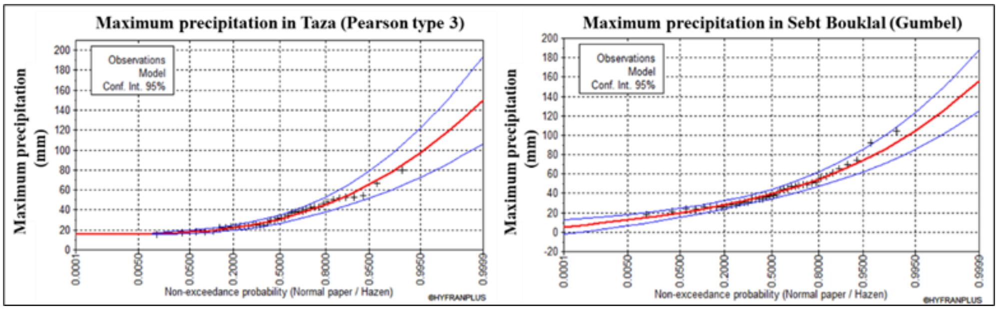

Figure 7. Maximum daily rainfall adjustments by Gumbel and Pearson type 3 distributions over Taza city and Sebt Bouklal rural center

Table 6. Maximum daily rainfall for different return periods ranging from 5 years to 100 years.

Stations	5	10	20	50	100
Taza (mm)	45,3	55,6	65,5	78,4	88,00
Sebt Bouklal (mm)	54,3	64,2	73,8	86,1	95,3

Discussion

Upon examining the findings, we observed that the UpperLarbaâ Basin region has undergone substantial spatio-temporal variations in precipitation levels. During the late 1970s and early 1980s, there was a significant disruption that led to an average reduction in precipitation of approximately 100 mm (Figure 2). These alterations were associated with the overall climatic conditions along the southern Mediterranean coast (Xoplaki et al., 2004), situated between the temperate north and the tropical south, which in turn affects the positioning of the Azores. The presence of the Azores plays a crucial role in sustaining consistent weather patterns, ultimately resulting in climatic drought. This phenomenon is evident in the local deviations from the EM average, assessed over a period of 35 years within a 65-year timeframe. Additionally, one-third of the data analyzed demonstrated normal drought conditions, while around 10% experienced relative drought (Figure 4). All involved research centers only recorded severe drought episodes during two specific seasons: 1994/1995 and 1998/1999 (Figure 5).

Furthermore, several rainfall statistical studies conducted in the northwestern part of Morocco have highlighted the relationship between precipitation and the NAO index (Knippertz et al., 2003; Sebbar et al., 2011). Simple linear regression analysis further confirmed this relationship locally, demonstrating an inverse correlation between the two. The negative phase of the NAO index helps bring the polar disturbances laden with moisture from

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the Atlantic Ocean, whereas the positive phase obstructs these weather processes, leading to the prevalence of drought conditions. (Filahi et al., 2015). Such influences typically have a positive effect on the northern regions of the country (Khomsi 2014; Hanchane, 2017), as well as the northwestern parts of the UpperLarbaâ Basin (Figure 3).

In discussing the spatial distribution of rainfall, a significant gradient is evident from the southwest to the northeast of the UpperLarbaâ Basin. The analysis using a moving average identifies three distinct periods: the first, spanning from 1960 to 2000, shows a general decline in rainfall across most areas of the basin. Following a period from 2000 to 2010, there was a marked increase in rainfall, but this trend has reverted to a decrease over the past decade (Figure 2). Furthermore, a pronounced spatial gradient from the northwest to the southwest of the basin suggests a relationship between rainfall patterns and the North Atlantic Oscillation index (Figure 3).

In general, the analysis of climatic variability necessitates a minimum observation period of 30 years (OMM, 1969). In this study, we utilized a dataset covering 60 years for annual and monthly observations, while daily data spans 40 years. These durations were sufficient for conducting comprehensive climatic assessments. Our results were consistent with other studies made in various regions along the southwestern Mediterranean coast. Although disruptions in the dataset caused major problems with our methodology, the outcomes were promising, enabling us to identify climatic phenomena such as biannual variability and periods of drought. Also, looking at daily data helped us find extreme rainfall events that might have caused flooding, especially in the lower area near Sebt Bouklal and Taza city (Layan et al., 2024a).

Conclusion

The implemented methodology demonstrated its efficacy in identifying climatic variability, making it a valuable instrument for detecting drought periods. The study suggests this method to enhance water management efforts and explore alternative supply options to mitigate drought periods, including support for desalination initiatives. While the study enabled us to estimate maximum precipitation under various return periods, there remains a pressing need for more comprehensive research to convert rainfall data into flow measurements and assess its effects on communities and infrastructure. Using hydrologic-hydraulic modeling could be a helpful way to mimic how the river behaves and look at possible flood situations. Our future research will focus on this proposed method to accurately identify flood risks in the Taza region.

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Author contribution: All authors participated in reviewing and approving the final version of the manuscript. B. Bougdira played a key role in the study stages, methodology, and drafting of the manuscript, while B. Layan, M. Ben Abbou, S. El yadari, and L. Benaabidate provided supervision, as well as reviewing and interpreting the results.

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Conflict of Interest: The authors reported no conflict of interest.

Data Availability: All data are included in the content of the paper.

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