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RESEARCH ARTICLE

Bioclimatic Shifts in the Tlemcen Region, Northwestern Algeria

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ABSTRACT

Research aims: This study compares the climatic conditions relevant to forests and matorrals in the Tlemcen region of northwestern Algeria. It examines spatial differences and changes between the historical, intermediate and recent configurations represented in the station summaries.

Design and approach: The study draws on precipitation and temperature summaries for nine reference stations: Tlemcen, Maghnia, Sebdou, Beni Bahdel, Zenata, Beni Saf, Ghazaouet, Nédroma and Fillaoucène. The sources are ANRH and ONM records and the historical compilation of Seltzer (1946). The descriptive comparison considers monthly and seasonal profiles, De Martonne aridity and Emberger climagram positions. Unequal records and incomplete temporal metadata limit comparisons between periods.

Findings: The profiles show low summer rainfall and marked differences between stations. Several recent configurations have lower rainfall or drier bioclimatic positions than their historical counterparts, but changes are not uniform. Temperature profiles also differ between sites and do not support a claim of warming at every station. The available summaries do not establish a regional trend rate or a causal attribution to anthropogenic forcing.

Contribution: The comparison brings together complementary climatic summaries while distinguishing bioclimatic interpretation from direct observation of vegetation change.

Management implications: The results support attention to local climatic conditions and the continuity and quality of station monitoring. Vegetation surveys and land-use observations are needed to assess ecological responses.

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1. Introduction

Temperature and precipitation influence water availability, plant growth and the distribution of vegetation. Mediterranean ecosystems experience a seasonal contrast between wetter, cooler months and a warm, dry summer. Changes in this balance can alter the climatic conditions associated with forests, shrublands and steppe formations.

Bioclimatic indicators summarise different aspects of this seasonal environment. They can help compare stations, but their interpretation depends on the observations, averaging periods and calculation conventions used. A change in an index is evidence about the climatic

conditions represented by that index; it is not a direct measurement of changes in vegetation.

The Tlemcen region includes coastal sectors, the Traras range, the Tlemcen Mountains and inland areas. This varied geography provides a setting for examining differences associated with altitude, maritime influence and continentality. Regional ecological work provides context for interpreting these contrasts (Alcaraz, 1982; Dahmani, 1984).

The study compares climatic summaries from nine reference stations across three configurations. It asks which seasonal features persist, where the summaries indicate drier conditions, and how far these patterns support ecological interpretation. The analysis is descriptive and does not quantify changes in species richness, vegetation cover or ecosystem resilience.

2. Literature review

2.1. *Mediterranean bioclimatic indicators*

Daget (1977) identifies summer dryness as a defining feature of Mediterranean bioclimate and discusses the criteria used to describe it. Bagnouls and Gaussen (1953) relate the dry season to monthly precipitation and temperature. In an ombrothermal diagram, a month is conventionally considered dry when precipitation P, in millimetres, is less than twice mean temperature T, in degrees Celsius. The precipitation and temperature scales must therefore preserve the relationship P = 2T.

Annual aridity and seasonal dryness describe different features. De Martonne's (1926) annual index relates annual precipitation to mean annual temperature, while the Emberger framework combines precipitation and thermal conditions to distinguish Mediterranean bioclimatic settings. Emberger (1936) also discusses the relationship between vegetation belts and climate in North African mountains. None of these classifications alone identifies the cause of a change in vegetation.

2.2. *Regional evidence and ecological interpretation*

Alcaraz (1982) examines vegetation in western Algeria, and Dahmani (1984) studies holm-oak communities in the Tlemcen Mountains. Aimé (1991) investigates the transition between subhumid, semi-arid and arid settings in the Oran Tell. These works provide a regional framework for relating climatic conditions to vegetation, without making a new climatic comparison equivalent to a vegetation survey.

Siba et al. (2024) combine bioclimatic analysis with GIS and Landsat observations of land use in Tlemcen. Their abstract reports a shift towards wetter bioclimatic conditions between 1985-1999 and 2004-2018, alongside forest-area losses and expansion of bare ground between 2000 and 2019. This combination illustrates why land-cover degradation cannot automatically be attributed to climatic drying. Their periods and methods differ from the station summaries considered here.

Meddi et al. (2024) examine drought in northern Algeria, while Diaf et al. (2024) use drought indices for the Wadi Lakhdar watershed over 1999-2021. The assessments of the Intergovernmental Panel on Climate Change (IPCC, 2021, 2022) provide a wider context for physical climate change and ecosystem risks. These sources establish the relevance of hydroclimatic assessment; they do not validate the observations or attribution of the present comparison.

3. Materials and methods

3.1. *Study area and stations*

The station set comprises Tlemcen, Maghnia, Sebdou, Beni Bahdel, Zenata, Beni Saf, Ghazaouet, Nédroma and Fillaoucène. It covers inland, mountain, coastal and subcoastal settings. These names identify the locations represented in the comparative material; station identifiers, coordinates and elevations are not available in the accompanying summaries.

3.2. *Climatic sources and temporal coverage*

The historical configuration is attributed to Seltzer's (1946) compilation for 1913-1938. The intermediate and recent configurations are attributed to records from the Agence nationale des ressources hydrauliques (ANRH) and Office national de la météorologie (ONM). The terms historical, intermediate and recent identify the three sets shown in the figures. Exact station-specific dates for the latter two sets are not specified in the available summaries.

Station operation was intermittent in some cases, and the observation periods may differ in length. Differences between their means therefore combine climatic variation with differences in temporal coverage and potentially in data preparation. The comparison does not treat the three configurations as equally sampled climatic normals.

The descriptive assessment uses the monthly and seasonal profiles and the reported bioclimatic diagrams. Individual annual records, missing-data treatments, station-move histories and homogenisation results are not available for independent recalculation. No rate of change per year, significance test or regional weighted average is estimated.

3.3. *Variables and bioclimatic interpretation*

Monthly precipitation profiles describe the timing of water input, and seasonal totals indicate which parts of the year contribute most rainfall. In the seasonal plots, H denotes winter, P spring, E summer and A autumn, following the French labels hiver, printemps, été and automne. A sequence such as HPAE orders those seasons from the largest to the smallest rainfall total. Seasonal ordering alone does not establish climatic continentality.

The De Martonne annual index is $I = P / (T + 10)$, where P is annual precipitation in millimetres and T is mean annual temperature in degrees Celsius (De Martonne, 1926). Lower values indicate greater aridity under this

convention. The comparison uses the plotted station positions rather than a newly calculated index series. The background runoff and irrigation labels in the De Martonne diagram are general interpretive guides, not local hydrological measurements or irrigation recommendations.

The P < 2T criterion provides a conceptual framework for discussing seasonal dryness. Applying it quantitatively requires paired monthly precipitation and mean-temperature values from the same station and period. A complete, consistent matrix is not available here, so the comparison does not estimate a common dry-season duration or precise onset and ending dates.

The Emberger diagram is read using its reported Q2 positions and the winter parameter m, the mean daily minimum temperature of the coldest month. The warm-season parameter M is the mean daily maximum temperature of the hottest month. Neither parameter is the mean annual temperature or an absolute temperature extreme. The quotient values have not been independently recalculated because the station inputs and calculation variant are not documented in full.

4. Results

4.1. *Monthly precipitation*

The rainfall profiles show a summer minimum at all nine stations. Rainfall is concentrated in the cooler part of the year, although the wettest month differs between stations and configurations. This seasonal structure is consistent with the Mediterranean climatic setting described by Daget (1977).

Several recent profiles lie below the historical profile in parts of the wet season. The contrast is clear at stations such as Maghnia and Zenata, while other stations show changes in the timing of rainfall and crossings between the curves. Thus, the figure supports station-specific comparisons rather than a uniform reduction in every month or at every location (Figure 1).

The spatial differences also matter. Mountain and coastal influence can modify precipitation, but the plotted stations do not form a single, consistently ordered rainfall gradient. The profile comparison is not used to infer a measured vegetation response.

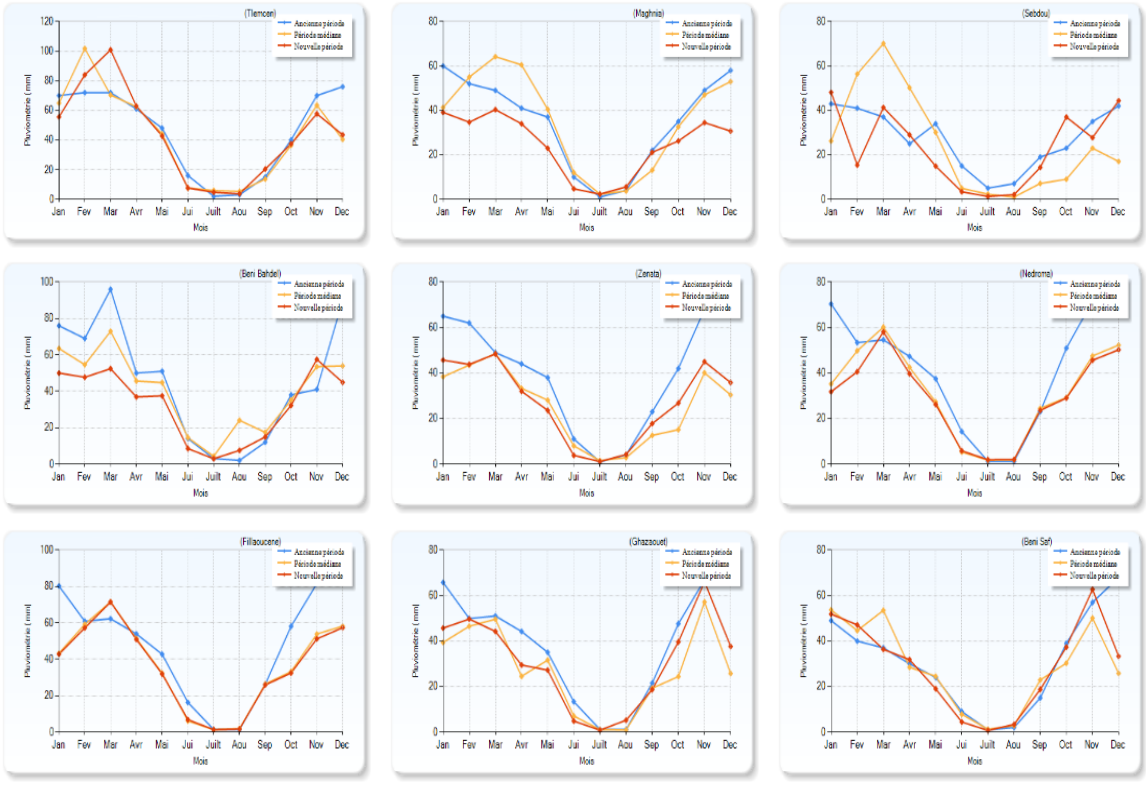


Fig. 1. Monthly precipitation profiles for the three configurations at nine stations

Source: Station summaries attributed to ANRH, ONM and Seltzer (1946). Blue: historical; orange: intermediate; red: recent.

4.2. *Seasonal rainfall distribution*

Winter or spring contributes the largest rainfall total in most station configurations, and summer contributes the smallest. Some profiles switch from winter dominance to spring dominance, as at Tlemcen or Sebdou, while autumn remains important at several coastal stations. The order varies by location and configuration (Figure 2).

This concentration of rainfall outside summer limits water input during the warm season. Ecological consequences depend on soil storage, exposure and vegetation characteristics as well as rainfall totals. The seasonal profiles do not directly measure those processes.

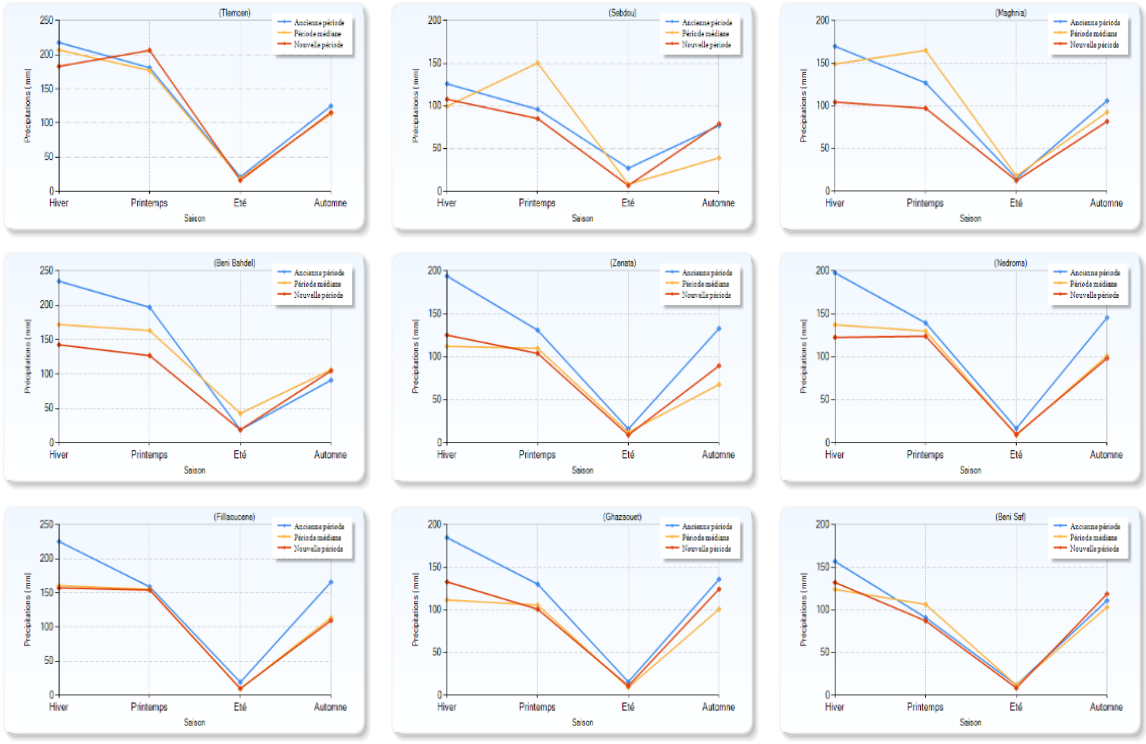


Fig. 2. Seasonal rainfall profiles for the three configurations at nine stations

Source: The same station summaries as Figure 1. Seasons follow the French labels Hiver, Printemps, Été and Automne. Blue: historical; orange: intermediate; red: recent.

4.3. *Temperature profiles*

Temperature affects atmospheric water demand and the timing of biological activity. The monthly profiles generally show a winter minimum and a summer maximum. Mean monthly temperature must be distinguished from m and M, which summarise daily minima and maxima for particular months.

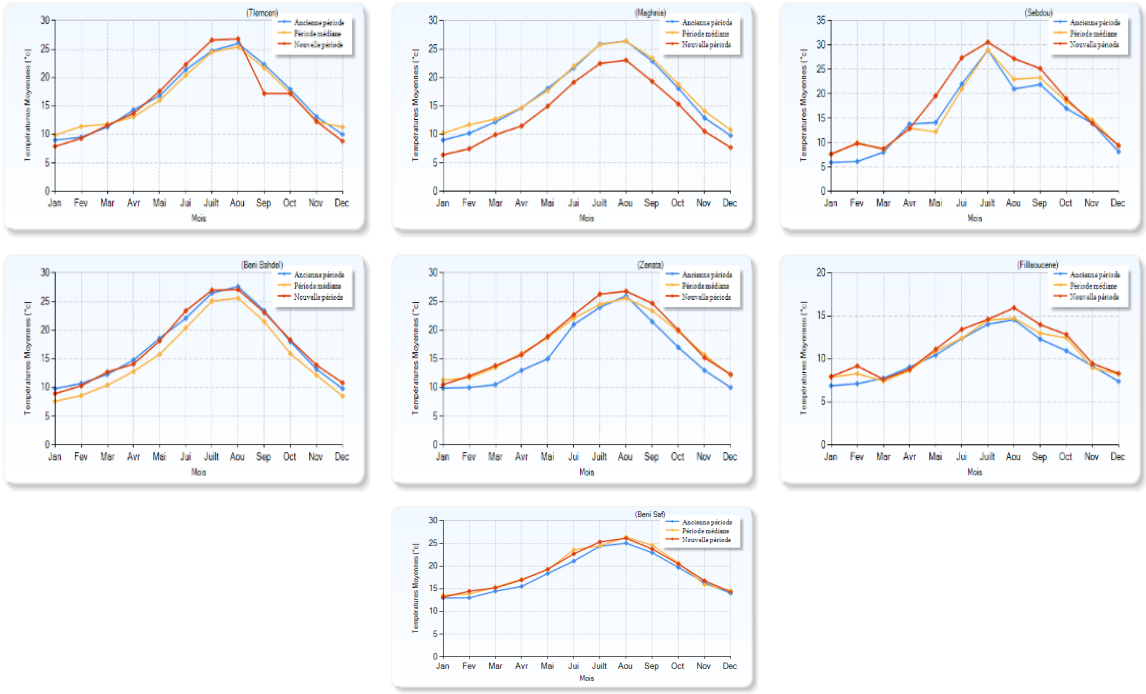


Fig. 3. Monthly mean temperature profiles for seven stations

Source: The same station summaries as Figure 1. The monthly profiles for Nédroma and Ghazaouet are excluded from this comparison. Blue: historical; orange: intermediate; red: recent.

The profiles do not show the same change at every station. The recent configuration is warmer in parts of the year at Tlemcen and Zenata, whereas the Maghnia profile is cooler than the earlier profiles in many months. Comparisons should therefore retain both the direction and the seasonal pattern of change (Figure 3).

The Nédroma and Ghazaouet monthly-temperature profiles contain isolated peaks that cannot be evaluated without the underlying observations. These two profiles are excluded from the descriptive monthly-temperature comparison. Their exclusion does not establish that the observations are erroneous and limits the coverage of Figure 3 to seven stations.

Within the Emberger framework, winter conditions depend on m rather than the lowest point on a mean-temperature curve. A diurnal temperature range, a difference between monthly means and the annual amplitude M - m are also distinct measures. They are not interchangeable indicators of dryness.

Across the retained profiles, the cooler months occur in winter and the warmest part of the year falls in summer. The differences between configurations are descriptive features of the station summaries and do not establish a statistically significant warming trend.

The coincidence of warm weather and low rainfall provides the basis for the combined bioclimatic interpretation. Temperature or rainfall alone cannot establish the duration or intensity of plant water stress.

5. Discussion

5.1. *Reading the combined indicators*

The rainfall and temperature profiles describe complementary aspects of the climatic environment. Annual aridity, seasonal dryness and Emberger classification summarise these observations in different ways. Agreement between them can help identify a pattern, but the indicators share input variables and should not be treated as independent statistical confirmations.

Regional ecological literature links vegetation distributions with climatic and site conditions (Alcaraz, 1982; Dahmani, 1984; Djebaili, 1984). These relationships support an interpretation of possible moisture constraints. The present study does not test the performance or expansion of any plant species.

5.2. *De Martonne aridity*

The De Martonne diagram places stations at different positions within the annual precipitation-temperature space. Several recent positions move towards lower aridity-index classes relative to their historical positions, while differences between the intermediate and recent configurations vary among stations (Figure 4). This indicates spatially uneven changes in the represented climatic balance.

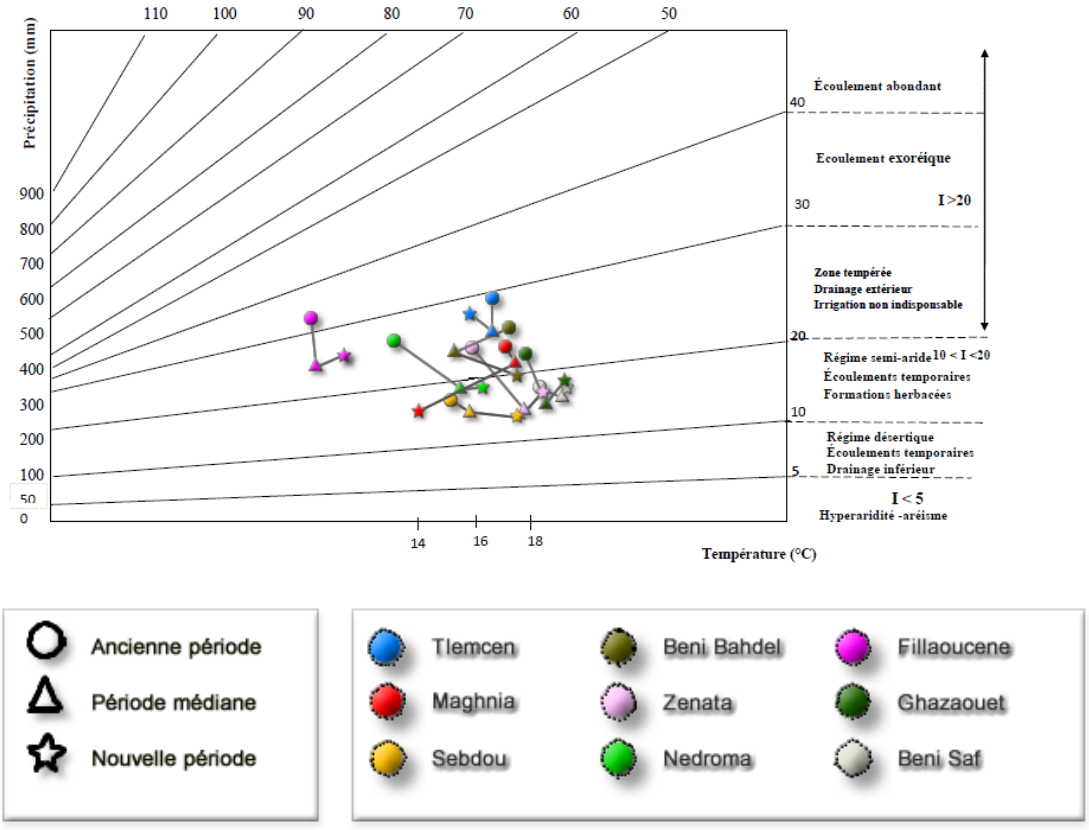


Fig. 4. De Martonne diagram for the three station configurations

Source: Reported station positions in the De Martonne diagram. The legend identifies stations and the historical, intermediate and recent configurations.

The plotted positions provide an annual summary. They do not describe rainfall intensity, soil-water storage or the occurrence of individual drought events. The descriptive pattern should therefore be considered alongside seasonal information, and the background categories should not be used as direct evidence of runoff or irrigation requirements.

5.3. *Seasonal moisture limitation*

The rainfall and retained temperature profiles indicate low rainfall during the warm season. This coincidence is consistent with the Mediterranean pattern of seasonal moisture limitation, but it does not directly measure soil moisture or plant water stress.

Variation in the timing of rainfall also makes late spring and autumn relevant to local water availability. The comparison does not assign a precise dry-season length to individual stations because a consistent set of paired monthly inputs is not available.

The ecological consequences depend on rooting depth, soils and access to stored water. These factors are not measured by the climatic summaries.

Possible effects on forest or matorral dynamics remain ecological interpretations. No new vegetation plots, floristic inventory or satellite vegetation index were analysed for this comparison.

5.4. *Emberger bioclimatic positions*

Figure 5 combines the reported Q2 positions with m to distinguish moisture conditions and winter thermal variants. The diagram includes semi-arid, subhumid and humid positions, and several recent configurations occupy drier positions than their historical counterparts. The pattern differs between stations.

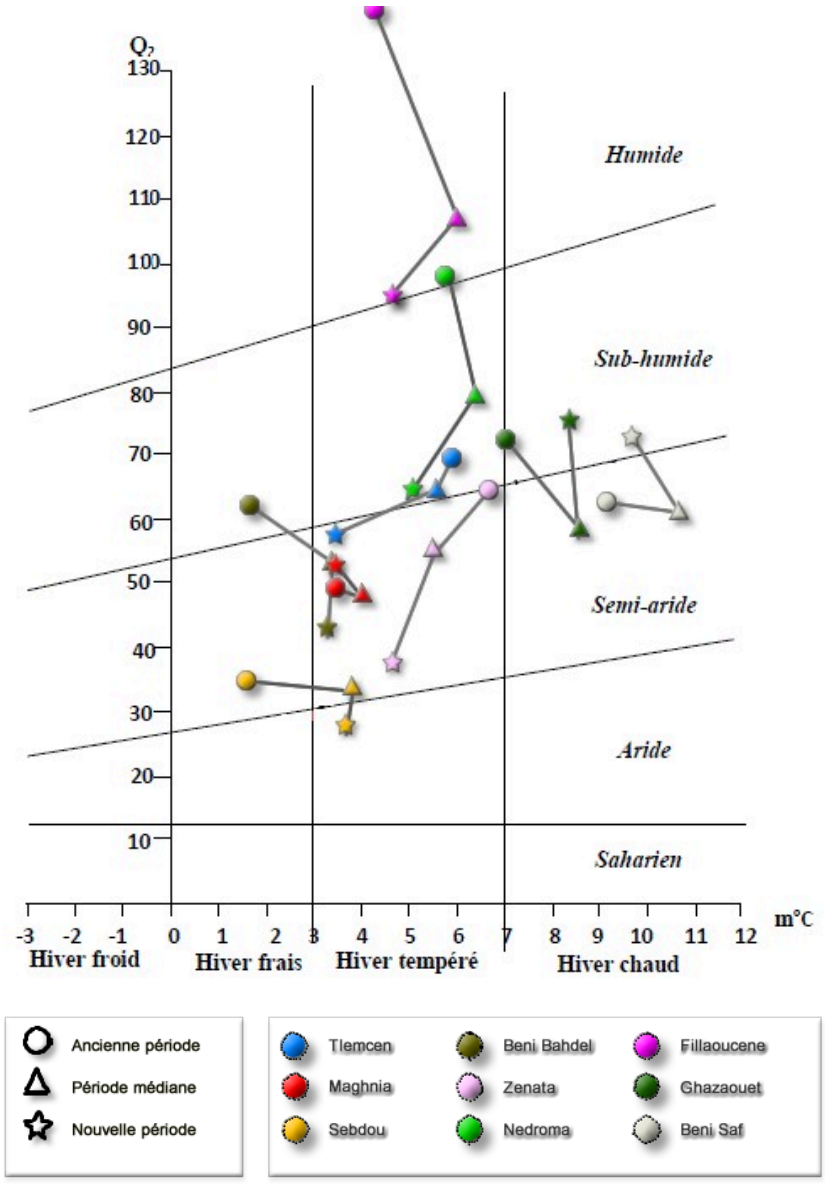


Fig. 5. Reported Emberger Q2 climagram positions of the reference stations

Source: Reported station positions in the Emberger diagram. Circle: historical; triangle: intermediate; star: recent.

The station trajectories do not support classifying the entire region in one moisture class or one winter variant. A fall in Q2 indicates a change within the chosen classification, while a change in m concerns the winter thermal component. These two dimensions should be read separately.

Some Traras stations retain relatively wet positions, particularly Fillaoucène, while several inland stations occupy semi-arid or transitional positions. Coastal influence does not produce the same classification at every station, and climatic classifications do not by themselves measure vegetation condition.

The figure provides a descriptive synthesis of the station summaries. Without complete dates, input values and quality-control records, it cannot establish a rate of climatic change, the statistical significance of a displacement or its attribution to anthropogenic forcing.

5.5. *Integrated interpretation and comparison with regional studies*

The clearest common feature is summer dryness, accompanied by differences in precipitation and thermal conditions between locations. Several configurations are consistent with increased climatic moisture limitation, but temperature changes and movements between the later configurations are not uniform. This supports a local interpretation rather than a single regional trajectory.

Restoration planning should consider these spatial differences together with soil conditions, land use and existing vegetation. A broad bioclimatic category can guide site assessment, but it is insufficient on its own to select species or predict restoration success.

The comparison with Siba et al. (2024) requires particular care. Their bioclimatic results indicate improved rainfall conditions between 1985-1999 and 2004-2018 even though their satellite analysis identifies forest loss between 2000 and 2019. The climatic periods, sampling and methods are different from those considered here. Their findings therefore support distinguishing land-use pressures from climatic signals, rather than treating every regional study as evidence of the same drying trend.

Meddi et al. (2024) and Diaf et al. (2024) provide regional drought context using approaches that differ from a comparison of bioclimatic summaries. Their findings cannot be substituted for missing station records in the present study.

For management, climatic information is most useful when combined with hydrological records and observations of vegetation and land use. This combination would help assess whether a climatic contrast corresponds to a change in ecological conditions.

The photographs in Figure 6 illustrate matorral landscapes in the study region. They do not constitute a dated before-and-after comparison or quantify a change in cover, species composition or ecosystem resilience.

A shift towards drier climatic conditions may reduce the suitability of some sites for moisture-demanding vegetation. Establishing that response requires field or remote-sensing observations and consideration of disturbance and land management. The climatic comparison alone cannot demonstrate an expansion of xerophytic formations or a loss of forest.



Fig. 6. Matorral landscapes in the Tlemcen region

Photographs: BARKA Fatiha.

6. Limitations and management implications

6.1. *Limits of the evidence*

The records differ in duration and include gaps in station operation. Exact intermediate and recent dates, station identifiers and complete quality-control procedures are not documented in the available summaries. These limitations prevent independent reproduction of the full station-by-period comparison. The exclusion of two temperature profiles further limits the thermal assessment. The retained figures are descriptive summaries, and their underlying observations have not been independently validated. Bioclimatic indices based on averages also do not resolve heatwaves or short drought events.

6.2. *Monitoring and ecosystem management*

The comparison identifies a need for continuity in station monitoring and for attention to differences between

coastal, mountain and inland sites. Climatic summaries can inform drought surveillance and the initial assessment of restoration sites, but they do not replace local hydrological, soil or vegetation evidence. The study does not quantify fire risk or assess marine ecosystems.

6.3. *Further research*

Further work could assemble station identifiers, coordinates, elevations and complete observation dates, then apply a documented procedure for missing data, station changes and homogenisation. Comparable time windows and annual records would allow formal trend analysis. Vegetation inventories, permanent plots and satellite observations would then support direct tests of ecological responses and separation of climatic and land-use effects.

7. Conclusion

The station summaries show substantial spatial variation in the Tlemcen region and a persistent Mediterranean summer rainfall minimum. Several recent profiles and bioclimatic positions are consistent with greater moisture limitation relative to historical conditions, while the direction and size of differences vary among stations.

The temperature profiles do not establish uniform warming, and the Emberger diagram includes more than one moisture class and winter variant. The available summaries support a descriptive comparison rather than a regional trend estimate or a causal attribution.

Ecological implications should be assessed against observations of vegetation, soils and land use. The present comparison does not measure a change in forest cover, biodiversity, productivity or resilience.

Maintaining long-term climatic records and combining them with standardised ecological observations would provide a stronger basis for assessing local vulnerability and planning restoration. The temporal and data-quality limits of the present summaries remain relevant to any management use.

Declarations

Author Contributions. Both authors contributed to the study concept, interpretation of the findings, and writing and revision of the manuscript.

Funding. The study received no external funding.

Conflicts of Interest. The authors declare no conflicts of interest.

Ethics Approval and Informed Consent. Not applicable.

Data Availability Statement. The climatic data were obtained from ANRH and ONM records and from the historical compilation of Seltzer (1946). Data are available from the corresponding author on reasonable request, subject to data-access requirements.

Declaration of Generative AI Use. The authors declare that the scientific content of this article was not produced using generative artificial intelligence.

Acknowledgements. The authors have no acknowledgments to declare.

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