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Comparative floristic composition and diversity indices in two Algerian steppe regions (Djelfa and Tiaret)

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Abstract. Understanding floristic patterns in Algerian steppe ecosystems is essential for assessing the extent of ongoing ecological degradation. This study provides a comparative floristic analysis of two major steppe regions, Djelfa and Tiaret, based on field surveys conducted during spring campaigns from 2022 to 2024 at 56 sampling stations. A total of 134 taxa belonging to 32 families were identified. *Asteraceae* (26.9%), *Poaceae* (10.5%) and *Fabaceae* (6.7%) form the dominant assemblage, while the biological spectrum is predominantly therophytic (40%), reflecting strong adaptation to arid conditions and increasing ecosystem disturbance. Chorological analysis reveals a dual Mediterranean (32.1%) and Saharan (29.1%) influence, consistent with the biogeographical position of the two regions. Diversity indices show significant structural contrasts: Tiaret exhibits higher and more balanced diversity (H' = 4.51; E = 0.97; 1/D = 80.9), while Djelfa displays reduced floristic stability (H' = 4.39; E = 0.95; 1/D = 66.2) and greater fragmentation. Overall, the results reveal structural indicators of ecological imbalance in Djelfa, suggesting a higher degree of anthropogenic pressure, and underscore the need for ecological restoration and sustainable rangeland management to preserve the biodiversity and functional integrity of Algerian steppe landscapes.

Keywords: floristic diversity; steppic ecosystems; aridity gradient; biodiversity assessment; therophytization; anthropogenic pressure; saharo-sindian element.

Abbreviations: H’ = Shannon-Wiener diversity index; E = Pielou’s evenness index; D = Simpson dominance index; 1/D = Inverse Simpson index; RS = cumulative species occurrences (sum of species recorded across all sampling stations); Th = Therophytes; He = Hemicryptophytes; Ch = Chamaephytes; Ph = Phanerophytes; Ge = Geophytes; Med = Mediterranean; Sah = Saharo-Sindian; Ld = Widely distributed taxa; End N.A. = North African endemics; End Alg-Mar = Algerian-Moroccan endemics; GPS = Global Positioning System; DPI = Dots Per Inch.

1 Introduction

The Algerian steppes represent extensive semi-arid ecosystems, located between the 100 and 400 mm precipitation isohyets on average, although in extreme years certain areas may receive below 100 mm,as an example Naâma 50 mm in 2022–2023 (Boucherit et al., 2024). These environments, covering several million hectares, harbor heterogeneous vegetation dominated by perennial grasses such as *Macrochloa tenacissima* and chamaephytes like *Artemisia herba-alba*. Their floristic composition strongly depends on climatic, edaphic, and topographic gradients, as well as on anthropogenic pressures, which provide essential ecological and socio-economic functions (Slimani & Aidoud, 2018; Haichour et al., 2023; Benamara et al., 2023).

For several decades, the Algerian steppes have experienced accelerated degradation due to the combined effects of recurrent droughts, overgrazing, and climate change, leading to the regression of perennial species in favor of annual species that are more drought-tolerant (Benamara et al., 2023). This evolution is reflected in the floristic predominance of *Asteraceae*, *Poaceae*, and therophytes, indicating progressive adaptation to arid conditions (Guit & Nedjimi, 2019).

In the Tiaret region, the Nador massif presents rich flora with 121 taxa distributed across 38 families, dominated by *Poaceae* and *Asteraceae*. The Shannon-Weaver index (≈ 4.55) indicates significant diversity but is accompanied by a high disturbance index (≈ 63.6%), suggesting the impact of natural and anthropogenic pressures (Benkhettou et al., 2015). Similarly, in Djelfa, the steppe flora studied by Habib et al. (2020) comprised 127 taxa belonging to 33 families, dominated by *Asteraceae* (~29%) and *Poaceae* (~12%), with a high proportion of therophytes (~56%), indicating advanced therophytization.

In this context, the present study aims to compare the floristic composition and structure of plant communities in the steppes of Djelfa and Tiaret, to evaluate their specific richness, and to identify the main indicators of degradation or resilience, with a view to better understanding and sustainable management of these vulnerable steppe environments.

Based on the documented ecological gradients and regional literature, we formulated the following hypotheses: (1) the Djelfa steppe, subjected to higher aridity and anthropogenic pressure, will exhibit lower floristic evenness and higher therophyte dominance than Tiaret; (2) the chorological spectrum will reveal a stronger Saharan influence in Djelfa compared to Tiaret, reflecting the biogeographical transition along the aridity gradient; and (3) diversity indices (Shannon, Pielou, and inverse Simpson) will show significant structural divergence between the two regions, indicating differentiated ecological trajectories.

2 Study Area

The study was conducted in two regions located in southwestern Algeria: Djelfa and Tiaret (Figure 1).

They belong to the vast Algerian steppe belt between the 100 and 400 mm annual precipitation isohyets on average (Boucherit et al., 2024). They are characterized by a semi-arid to arid climate, marked by high interannual precipitation variability, cold winters, and hot, dry summers.

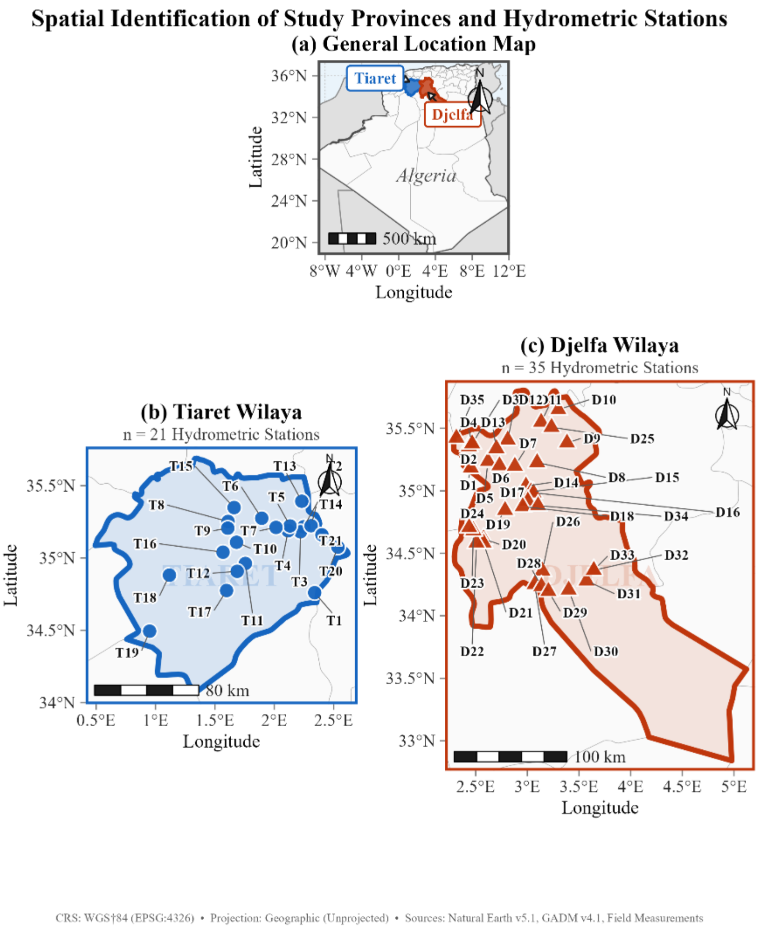

Figure 1. Spatial identification of study provinces and hydrometric stations: (a) Tiaret Wilaya (n = 21 sampling stations), (b) general location map of Algeria, (c) Djelfa Wilaya (n = 35 sampling stations). Coordinate Reference System: WGS 84 (EPSG:4326). Sources: Natural Earth (v5.1), GADM (v4.1), field measurements.

3 Materials and Methods

3.1 Field Sampling and Data Collection

Sampling was carried out during spring campaigns from 2022 to 2024. Fifty-six observation stations were selected across both study regions using a stratified sampling method (Gounot, 1969).

Each station is represented by three phytosociological samples on homogeneous 100 m² **plots, chosen to reflect local floristic composition faithfully. Sampling was conducted according to the classic Braun-Blanquet method (1951**)

Geographic coordinates of each station were recorded using a portable GPS device and are presented in Table 1.

Taxonomic identification of species was performed using the floras of Quézel & Santa (1962-1963) , Chehma(2006), and Dobignard & Chatelain (2010-2013).

Table 1. Geographic coordinates of sampling stations in Djelfa and Tiaret.

Wilaya	**Station Code**	**Coordinates (°N, °E)**	**Altitude (m)**
Djelfa	D01-D35	34.19–35.65, 2.21–3.64	683–1251
Tiaret	T01-T21	34.49–35.39, 0.95–2.53	789–1296

3.2 Data Analysis Methods

To evaluate the structure and diversity of plant groupings, ecological indices were calculated according to standard formulas described by **Shannon & Weaver (1949), Simpson (1949), and Pielou (1966)**, as follows:

The **Shannon index** (H'), calculated according to the formula:

$$H' = -\sum_{i=1}^{S} p_i ln(p_i)$$

measures species richness and distribution; it varies from 0 to ln(S), with diversity considered low for $H' < 1$, moderate for $1 \leq H' \leq 3$, and high above 3.

- **Pielou's evenness** (E), expressed as:

$$E = \frac{H'}{\ln(S)}$$

provides information on the homogeneity of species distribution; it ranges from 0 to 1, indicating unequal distribution when $E < 0.5$, a moderate distribution between 0.5 and 0.8, and a very homogeneous distribution when $E > 0.8$.

- The **Simpson index** (D), defined by:

$$D = \sum_{i=1}^{S} \frac{n_{i(n_i-1)}}{N(N-1)}$$

evaluates specific dominance; low values of D (or high values of $1/D$) reflect significant diversity, while values close to 1 indicate marked dominance.

4 Results

4.1 Floristic Composition and Family Dominance

Following the floristic inventory conducted across the entire study area (regions of Tiaret and Djelfa), we identified **134 taxa**, distributed across **32** botanical families. This species richness is well-positioned within the Southern Algerian steppe.

Analysis of floristic composition reveals family heterogeneity. The most represented families that give this steppe its characteristic appearance are: *Asteraceae* (36 taxa, or 26.87%), *Poaceae* (14 taxa, or 10.45%), and *Fabaceae* (9 taxa, or 6.71%). These three families alone represent more than 44% of the total richness.

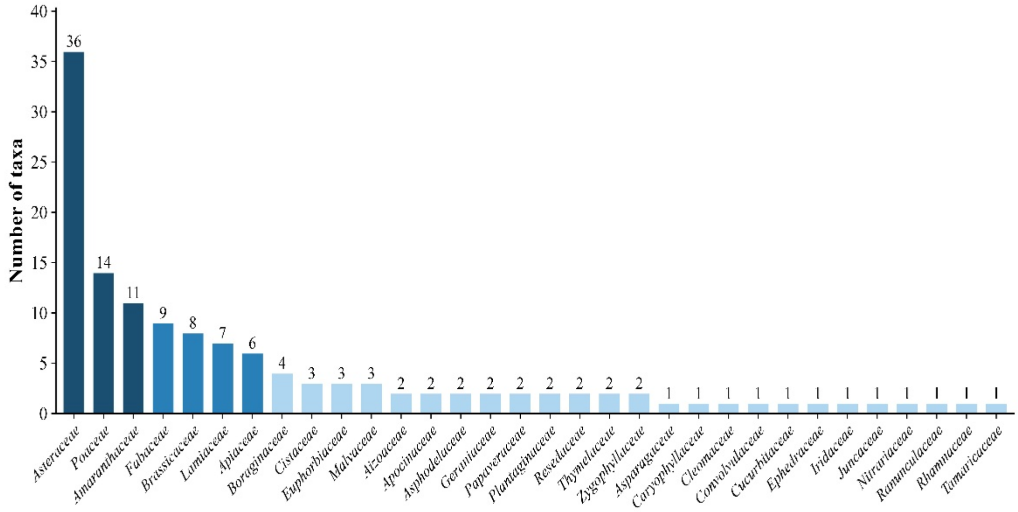

Figure 2. Distribution of floristic families by number of taxa.

4.1.1 Biological Types

Analysis of the biological spectrum according to **Raunkiaer's (1934)** system reveals flora dominated by short-cycle species and protective forms. The overall spectrum of the entire study area (Tiaret and Djelfa) is dominated by Therophytes (Th), with 54 taxa, followed by Hemicryptophytes (He), with 38 taxa, then Chamaephytes (Ch), with 27 taxa. Phanerophytes (Ph) (10 taxa) and Geophytes (Ge) (5 taxa) are weakly represented.

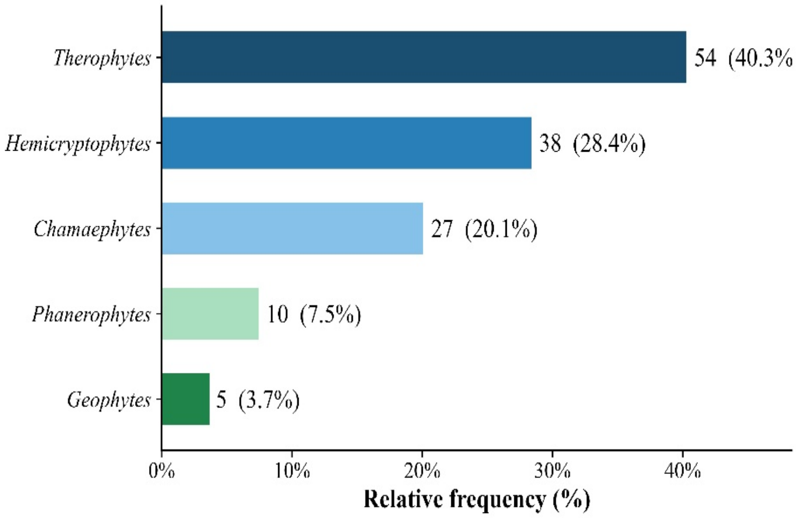

Figure 3. Biological spectrum of the study area.

4.1.2 Chorological Types

Analysis of the chorological spectrum of the flora inventoried in both wilayas (Tiaret and Djelfa) reveals dual biogeographic influence. The Mediterranean (Med) element dominates the entire study area, with 43 taxa (32.09%).

The geographic position of our area, in transition between the Tell and the Sahara, is reflected in the strong presence of the Saharo-Sindian (Sah) element, which ranks second with 39 taxa (29.10%).

Endemism is represented by 14 taxa in total (10.45%), distributed between North African endemic species (End N.A.) (11 taxa) and Algerian-Moroccan endemics (End Alg-Mar) (3 taxa).

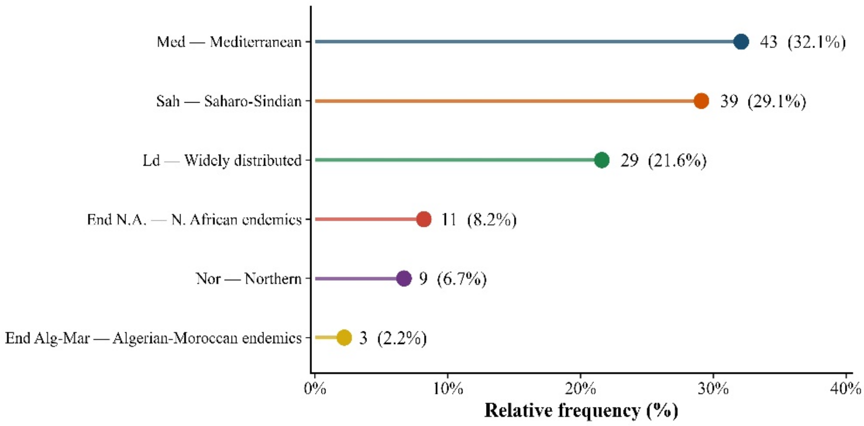

Figure 4. Chorological types of identified taxa.

4.2 Diversity Indices

4.2.1 Diversity Indices and Floristic Balance (Alpha Diversity)

Analysis of Alpha Diversity, synthesized in the table above and illustrated by the Box Plot (Figure), reveals a generally high level of diversity, but is marked by significant divergence between the two wilayas. The Shannon-Wiener diversity index averages 4.515 bits for Tiaret and 4.398 bits for Djelfa. However, comparison between wilayas is revealing, particularly via Pielou's evenness index;

Tiaret stations display relatively high and stable evenness (E = 0.97), conversely, Djelfa presents slightly lower evenness (E = 0.95). Most importantly, the greater dispersion of values in Djelfa's Box Plot indicates fluctuation and the strong dominance of a few opportunistic species (Therophytes).

The most revealing index of structural difference is the Inverse Simpson index. This index, which measures the effective number of species, reaches 80.9 in Tiaret, compared to 66.2 in Djelfa. This significant difference attests to better species equipartition in Tiaret.

Pielou's evenness index reinforces this conclusion: Tiaret stations display high and stable evenness (E = 0.97), while Djelfa shows slightly lower evenness (E = 0.95) and greater dispersion in the Box Plot. Low evenness and the drop in the inverse Simpson index in Djelfa are the most conclusive indicators of strong dominance of a few opportunistic species (annual Therophytes), to the detriment of rarer or perennial species.

A Kruskal-Wallis test on per-station species richness showed no statistically significant difference between the two regions ($H = 1.81$, $p = 0.18$), confirming that observed divergences in Shannon and Simpson indices reflect structural rather than purely numerical differences.

Table 2. Diversity indices of the two study regions. *RS = cumulative species occurrences (sum of species recorded across all sampling stations per region); unique taxa: Tiaret = 105, Djelfa = 103, combined total = 134.

Index (Unit)	**Tiaret zone**	**Djelfa zone**
Shannon H' (bits)	4.515	4.398
Pielou E	0.97	0.95
Cumulative Species Occurrences (RS)*	201	294
$1 - D$(Simpson)	0.988	0.985
$1/D$(Simpson)	80.9	66.2

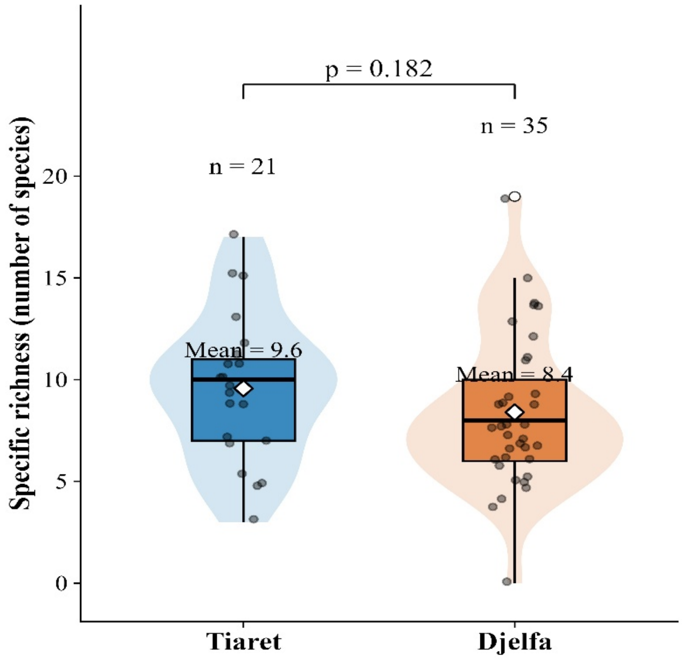

Figure 5. Boxplots of specific richness in both study regions.

5 Discussion

A total of 134 taxa, belonging to 32 families, were recorded in both regions. Korichi (2016) had recorded 66 taxa in Djelfa, Benalia et al. (2018) had identified 84, and even the more comprehensive studies by Maamri (2016) and Rahmoune (2018) had reached only 129 and 126 taxa, respectively. The surplus we recorded compared to Habib et al. (2020), who counted 127 taxa, is directly attributable to the bi-regional approach; 105 taxa are specific to Tiaret, 103 to Djelfa, and the overlap between the two lists remains partial; despite their geographical proximity and climatic similarity, their floras are not interchangeable and retain distinct identities. On the other hand, Habib et al. (2020) reported comparable species richness within the Djelfa steppes, confirming the high internal variability of this region.

The value obtained in this study remains slightly higher than those reported in previous studies, which can be explained by the inclusion of sampling stations from both Tiaret and Djelfa, thereby introducing more varied ecological conditions. This heterogeneity is reflected in partially distinct floristic assemblages across the floristic stages of the steppe regions (Aidoud, 1984).

The dominance of the *Asteraceae, Poaceae*, and *Fabaceae* families is consistent with findings reported from Algerian steppes (Habib et al., 2020; Nouar et al., 2021; Benkhettou et al., 2022). This floristic structure mainly reflects the ability of these families to persist under steppe conditions characterized by drought and high thermal amplitudes (Ozenda, 1977; Kazi-Tani et al., 2010). At the local scale, the high abundance of *Asteraceae* in the degraded stations of Djelfa appears to be associated with vegetation opening under grazing pressure and the regression of perennial species, a phenomenon already reported in disturbed steppe areas of central Algeria (Djaballah & Chehma, 2008).

The chorological spectrum pattern observed in both regions reflects their transitional location between the Tell Atlas and the pre-Saharan zone, characterized by the coexistence of Mediterranean and Saharo-Sindian elements. The analysis revealed that the Saharo-Sindian element accounts for 29.1% of the total floristic inventory, ranking second, whereas Habib et al. reported it in fourth position with only 13% in the Djelfa region. This discrepancy appears to be primarily related to differences in methodology, particularly the southward extension of our sampling network, which includes more arid stations where Saharan taxa become more frequent than Mediterranean ones. These observations align with studies reporting the progression of desertification in northern Algeria (Boucherit et al., 2024; Benamara et al., 2023), and suggest that future chorological inventories conducted under conditions of climate change and increasing thermal amplitude will likely confirm the northward expansion of Saharan elements.

The biological spectrum of the studied regions is characterized by a high proportion of therophytes (40.3%), reflecting the disturbed state of the steppe rangelands. Although this value is lower than those reported by Habib et al. (2020) and Rabehi et al. (2025) in the Djelfa region, it remains high despite the inclusion of stations in Tiaret where perennial chamaephytes are relatively better preserved. In Djelfa, the dominance of therophytes appears to be associated with the combined effects of drought, overgrazing, and the gradual opening of the vegetation cover, as already reported in several alfa and Artemisia steppes in the region (Slimani & Aidoud, 2018; Djaballah & Chehma, 2008). The decline of chamaephytes notably *Artemisia campestris, Arthrophytum scoparium*, and *Artemisia herba-alba* reflects a modification in the functioning of steppe rangelands, as these species play an important role in soil stabilization and the limitation of wind erosion (Benabadji & Bouazza, 2002; Haichour et al., 2023). The high values of evenness and the inverse Simpson's index observed in Tiaret reflect a more homogeneous distribution of species within plant communities, in contrast to Djelfa, where a few opportunistic taxa appear to dominate the floristic composition.

This decline favors the establishment of short-cycle annual species, better adapted to disturbed environments and repeated drought episodes. The low rate of endemism (10.45%) and the relatively high proportion of widely distributed taxa (21.64%) thus reflect a trend toward floristic homogenization in the studied steppes (Quézel & Médail, 2003; Miara et al., 2016), with a more pronounced therophytization in the steppe sectors of Djelfa (Nouar et al., 2020). The Shannon's index values in Tiaret (4.51) and Djelfa (4.39) are sufficiently close to indicate that both regions support comparable species richness with a relatively balanced distribution (Benkhettou et al., 2015). However, the more pronounced difference in the inverse Simpson's index (80.9 versus 66.2) reveals that dominance of certain species is more pronounced in Djelfa, reducing community evenness despite similar species richness (Kadi-Hanifi, 2003; Miara et al., 2016).

This pattern can be explained by local bioclimatic and anthropogenic conditions. Djelfa, situated in a transitional zone between the Tell and the High Plateaus, experiences stronger drought stress and more pronounced seasonality than Tiaret. Within this context, therophytes annual species that complete their life cycle within a few weeks following the scarce winter rainfall rapidly colonize available spaces in an uneven manner, generating density peaks for certain species at the expense of others. Perennial species, which require greater water and soil stability, are therefore underrepresented. This is consistent with observations from Algerian steppes, where the proportion of therophytes increases with aridity (Habib et al., 2020; Rabehi et al., 2025). Additionally, grazing areas in Djelfa are more exposed to pastoral pressure and a reduction in perennial vegetation cover (Slimani & Aidoud, 2018; Djaballah & Chehma, 2008), while certain stations in Tiaret associated with the Nador Massif exhibit environmental heterogeneity including topographic diversity and less degraded soils that promotes a more balanced distribution of species (Benkhettou et al., 2015).

The Kruskal-Wallis test (H=1.81; p=0.18) confirms that this difference is not related to the number of species; the stations do not differ significantly in terms of raw species richness. Consequently, the variation lies in how individuals are distributed among these species it is the community structure that diverges, rather than its floristic inventory. This finding aligns with studies conducted in other Algerian steppes, where similar aridity gradients produce the same type of community restructuring without a net loss of biodiversity (Miara et al., 2016; Benkhettou et al., 2022).

Conclusion

This study compares the floristic structure of the steppes of Djelfa and Tiaret. The two regions exhibit similar levels of species richness, but their structure differs markedly. In Tiaret, the structure appears more balanced as reflected in the evenness and inverse Simpson's index likely due to the diversity of local conditions, particularly in the areas of the Nador Massif. In Djelfa, a more uneven structure and a stronger dominance of annual species prevail, driven by the combined effects of drought stress and pastoral pressure.

Above all, the results shows a general trend toward vegetation simplification, more pronounced in certain areas of Djelfa, reflected in a relative decline in perennial species and an increase in opportunistic species. Communities dominated by *Macrochloa tenacissima* and *Artemisia* *herba-alba* remain the most sensitive to the observed changes and warrant special attention in areas that are still functional.

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