



Floristic Structure and Ecological Indices of Vascular Flora in the Atteuf Region, Northern Algerian Sahara

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Abstract:

This study presents a computational and ecological assessment of the floristic structure, ecological spectra, and diversity indices of the vascular flora of the Atteuf region in the northern Algerian Sahara. Field surveys were conducted at two stations, and abundance data were compiled for 26 species belonging to 15 botanical families, with a total of 84 individuals. The data were used to establish familial, Raunkiaer biological, and phytogeographic spectra and to compute Shannon-Wiener diversity, maximum diversity, Pielou evenness, and Sorensen similarity indices. The familial spectrum was dominated by Asteraceae and Amaranthaceae, each representing 15.4% of the recorded flora, followed by Poaceae (11.5%). The biological spectrum showed the predominance of hemicryptophytes (38.5%) and chamaephytes (30.8%), with a substantial proportion of therophytes (23.1%), confirming adaptive strategies typical of arid ecosystems. The phytogeographic spectrum was dominated by Saharo-Sindian elements (38.4%), whereas endemic taxa represented 11.5% of the flora. The Shannon-Wiener index reached 4.179 bits, with high Pielou evenness (0.889), indicating a relatively balanced community despite severe water stress. The Sorensen index between stations was 0.323, reflecting moderate floristic similarity and strong spatial heterogeneity. These findings highlight the ecological and conservation value of the Atteuf flora and provide a quantitative baseline for monitoring Saharan plant communities.

1. Introduction

The arid ecosystems of the northern Algerian Sahara constitute valuable model systems for analysing plant biodiversity under conditions of severe water stress. The flora of this region, which is subject to severe climatic constraints, including very low annual precipitation, high potential evapotranspiration, and marked diurnal temperature variation, has developed adaptive strategies that are reflected in specific community structures [1,2].

The Atteuf region provides a suitable framework for analysing floristic composition and vegetation diversity within Saharan environments. Floristic inventory and ecological index calculation allow researchers to characterize taxonomic structure, life-form spectra, phytogeographic affinities, and the spatial organization of plant communities. Such analyses are useful for both biodiversity assessment and ecosystem monitoring in arid zones.

The characterisation of plant communities through Raunkiaer biological spectra is a fundamental approach in phytosociology and plant biogeography. These spectra enable inferences about prevailing bioclimatic conditions and the ecological strategies of the flora [3,4]. Similarly, diversity and similarity indices provide quantitative tools for comparing sampling stations and evaluating community structure [5,6].

The objective of this study was to perform a computational analysis of the vascular flora of Atteuf by: (i) establishing familial, biological, and phytogeographic spectra; (ii) calculating and interpreting ecological indices, including Shannon-Wiener diversity, Pielou evenness, and Sorensen similarity; and (iii) discussing the results in relation to the conservation and management of Saharan ecosystems.

2. Materials and Methods

2.1. Study area

The Atteuf region is located in the northern Algerian Sahara. The climate is of the hot desert type and is characterized by very low annual precipitation, high potential evapotranspiration, and extreme temperatures. According to the floristic framework of Quezel and Santa, the vegetation belongs to the Saharan domain [7].

2.2. Data collection

The floristic inventory was carried out at two sampling stations, denoted R1 and R2. At each station, vascular plant species were identified according to current botanical nomenclature. Abundance data, expressed as the number of individuals per species, were collected for all recorded species. The complete data set included 26 species and 84 individuals.

2.3. Floristic and ecological analyses

The familial spectrum was determined by calculating the relative frequency of each botanical family. The biological spectrum was established by assigning species to Raunkiaer life forms, namely phanerophytes, chamaephytes, hemicryptophytes, cryptophytes, and therophytes, according to the position of renewal buds during the unfavourable season [3,4]. The phytogeographic spectrum was established by classifying species according to their chorological distribution areas [7].

The Shannon-Wiener diversity index (H') was calculated as:

$$H' = -\sum p_i \log_2 (p_i) \quad (1)$$

where $p_i = n_i/N$ is the proportion of individuals belonging to species i , n_i is the abundance of species i , and N is the total abundance. The logarithm to base 2 was used, and diversity was expressed in bits [8,9]. Maximum diversity (H_{max}), Pielou evenness (E), and the Sorensen similarity index (IS) were calculated as follows [6,10,11]:

$$H_{max} = \log_2 (S) \quad (2)$$

$$E = H'/H_{max} \quad (3)$$

$$IS = 2C / (A + B) \quad (4)$$

where S is species richness, C is the number of species common to the two stations, and A and B are the numbers of species recorded at stations R1 and R2, respectively.

2.4. Statistical processing

The ecological indices were computed from the abundance matrix using standard numerical procedures. Graphical representations of the familial, biological, and phytogeographic spectra were produced to support interpretation of the floristic structure.

3. Results

3.1. Floristic composition

The inventory recorded 26 vascular plant species distributed across 15 botanical families (Table 1). The most species-rich families were Asteraceae and Amaranthaceae, with four species each (15.4%), followed by Poaceae, with three species (11.5%). Brassicaceae, Plantaginaceae, and Solanaceae each included two species (7.7%). The remaining families were represented by one species each (3.8%), indicating a relatively diversified taxonomic structure.

Table 1. Distribution of families in the Atteuf flora ($N = 26$ species).

Family	Number of species	Relative frequency (%)
Asteraceae	4	15.4
Amaranthaceae	4	15.4
Poaceae	3	11.5
Brassicaceae	2	7.7
Plantaginaceae	2	7.7
Solanaceae	2	7.7
Cucurbitaceae	1	3.8
Zygophyllaceae	1	3.8
Euphorbiaceae	1	3.8
Convolvulaceae	1	3.8
Fabaceae	1	3.8
Apocynaceae	1	3.8
Plumbaginaceae	1	3.8
Rutaceae	1	3.8
Tamaricaceae	1	3.8

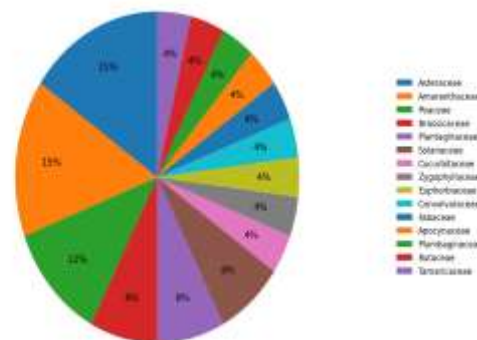


Figure 1. Familial spectrum of the Atteuf flora ($N = 26$ species).

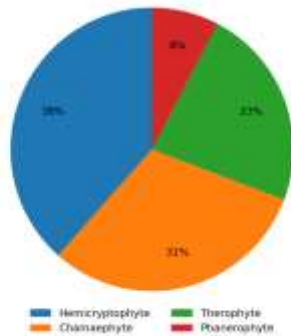
3.2. Biological spectrum

The Raunkiaer biological spectrum (Table 2) was dominated by hemicryptophytes, with 10 species (38.5%), and chamaephytes, with 8 species (30.8%). Therophytes represented 6 species (23.1%), whereas phanerophytes accounted for only 2 species (7.7%). No cryptophytes were recorded.

This biological structure differs from the normal Raunkiaer spectrum, mainly through the overrepresentation of chamaephytes and therophytes and the underrepresentation of phanerophytes. Such a pattern is consistent with the dominance of drought-resistant and drought-avoiding life forms in arid and Mediterranean floras [2,4].

Table 2. Raunkiaer biological spectrum of the Atteuf flora.

Life form	Number of species	Relative frequency (%)
Hemicytrophite	10	38.5
Chamaephyte	8	30.8
Therophyte	6	23.1
Phanerophyte	2	7.7

**Figure 2.** Biological spectrum of the Atteuf flora (N = 26 species).

3.3. Phytogeographic spectrum

The phytogeographic spectrum (Table 3) showed a marked predominance of Saharo-Sindian elements, with 10 species (38.4%), confirming the affiliation of the Atteuf flora with the Saharan phytogeographic domain. Cosmopolitan and Mediterranean elements each represented four species (15.4%), whereas pluriregional elements accounted for two species (7.7%).

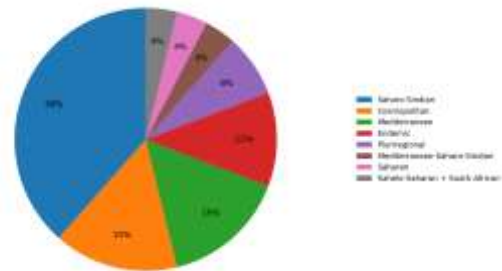
The endemic component included three species (11.5%). This proportion indicates the conservation and biogeographic value of the region, particularly because endemic taxa in arid environments may be vulnerable to climatic and anthropogenic pressures.

3.4. Diversity and evenness indices

The Shannon-Wiener diversity index reached $H' = 4.179$ bits for a species richness of $S = 26$ and a total abundance of $N = 84$ individuals. The theoretical maximum diversity was $H_{max} = 4.700$ bits, and Pielou evenness was $E = 0.889$ (Table 4).

Table 3. Phytogeographic spectrum of the Atteuf flora.

Phytogeographic type	Number of species	Relative frequency (%)
Saharo-Sindian	10	38.4
Cosmopolitan	4	15.4
Mediterranean	4	15.4
Endemic	3	11.5
Pluriregional	2	7.7
Saharan	1	3.8
Mediterranean-Saharo-Sindian	1	3.8
Sahelo-Saharan + South African	1	3.8

**Figure 3.** Phytogeographic spectrum of the Atteuf flora (N = 26 species).

This Shannon-Wiener value is high for an arid ecosystem. Previous work in desert and arid ecosystems has reported lower or spatially variable diversity values, indicating that local habitat heterogeneity may strongly influence the distribution of plant diversity [12,13]. The high Pielou evenness suggests that individuals were relatively evenly distributed among species and that diversity was not driven only by the presence of many rare species [14].

3.5. Floristic similarity

The Sorensen index between the two sampling stations was $IS = 0.323$, based on 16 species recorded at R1, 15 species recorded at R2, and 5 species common to both stations. This value indicates moderate similarity and notable floristic dissimilarity between the two sites.

Table 4. Ecological indices calculated for the Atteuf flora.

Index	Formula / Value	Interpretation
Specific richness (S)	$S = 26$	Total number of recorded species
Total abundance (N)	$N = 84$	Total number of individuals
Shannon-Wiener diversity (H')	$H' = 4.179$ bits	High species diversity for an arid ecosystem
Maximum diversity (H_{max})	$H_{max} = \log_2 (26) = 4.700$ bits	Theoretical maximum diversity under equiprobability
Pielou evenness (E)	$E = 0.889$	Very high evenness
Sørensen index (IS)	$IS = 2 \times 5 / (16 + 15) = 0.323$	Moderate similarity between stations R1 and R2

Summary of ecological indices
Flora of the Atteuf region, Algeria (N = 26 species, 2 surveys)

Index	Symbol	Value	Interpretation
ALPHA DIVERSITY			
Species richness	S	26	Total number of species
Total abundance	N	84	Total number of individuals
Shannon-Wiener	H'	4.179	High diversity for an arid ecosystem
Maximum diversity	Hmax	4.700	Theoretical maximum diversity
Pielou evenness	E	0.889	Very even distribution
Simpson index	D	0.073	Low dominance
BETA SIMILARITY			
Sørensen	IS	0.323	Moderate similarity between stations
Jaccard	J	0.193	Low species community overlap
INTER-STATION CORRELATION			
Pearson	r	0.000	No linear correlation
Spearman	ρ	-0.217	No monotonic association
Kendall	τ	-0.190	No ordinal association
Regression R ²	R ²	0.000	0% variance explained

Figure 4. Summary of calculated ecological indices for the Atteuf flora.

The observed dissimilarity may be related to micro-environmental heterogeneity, including variation in soil texture, local topography, and water availability. It may also reflect the mosaic structure of Saharan vegetation and differences in disturbance history, such as grazing or trampling.

4. Discussion

4.1. Familial and biological structure

The predominance of Asteraceae and Amaranthaceae in the familial spectrum is consistent with observations from arid Saharan environments. These families include species that are well adapted to xeric conditions and may tolerate drought, high irradiance, and salinity [1]. The biological spectrum, dominated by hemicryptophytes and chamaephytes, reflects adaptation to intense water stress. Hemicryptophytes benefit from renewal buds located at the soil surface, where they are relatively protected from dehydration and thermal extremes. Chamaephytes are often small perennial plants that reduce exposure to drought and may maintain persistent organs close to the ground [2,3]. The proportion of therophytes (23.1%) indicates the importance of annual species that complete their life cycle during favourable periods. Although therophytes are characteristic of arid environments, their moderate proportion in this flora suggests that the Atteuf region retains a degree of vegetation permanence compared with more hyper-arid systems [4].

4.2. Phytogeographic affinities

The dominance of Saharo-Sindian elements confirms the Saharan phytogeographic affiliation of the flora [7]. The presence of Mediterranean and cosmopolitan

elements also indicates adjacent biogeographic influences and the capacity of some species to colonize a wide range of ecological conditions.

The endemic taxa recorded in the inventory represent an important component of the regional plant heritage. Their conservation is especially relevant in the context of climate change, habitat disturbance, and increasing anthropogenic pressure on Saharan ecosystems.

4.3. Diversity and evenness

The high Shannon-Wiener index and Pielou evenness reveal a plant community that is both relatively diverse and balanced in terms of abundance distribution. This configuration is notable in an arid ecosystem, where strong dominance by a limited number of highly adapted xerophilous species might be expected.

Several factors may explain this pattern. First, local microhabitats such as wadis, regs, and hamadas may promote coexistence by providing distinct ecological niches. Second, moderate disturbance can maintain communities in intermediate successional states that favour coexistence. Third, biotic interactions, including competition and facilitation, may reduce the dominance of individual species.

The balanced abundance structure suggested by Pielou evenness may contribute to community resilience. In ecological theory, higher diversity and more even distributions are often associated with greater stability in the face of environmental fluctuations [15,16].

4.4. Inter-station similarity

The low-to-moderate Sørensen similarity between stations underlines the heterogeneous spatial structuring of Saharan vegetation. This heterogeneity is a characteristic feature of arid ecosystems, where the distribution of water and nutrients is patchy and

vegetation is organized in discontinuous mosaics [17,18].

This spatial heterogeneity should be considered when designing conservation strategies. Sampling and monitoring programmes based on a single station may underestimate regional floristic variability and may fail to detect localized populations of endemic or rare taxa.

5. Conclusion

The computational analysis of the vascular flora of the Atteuf region revealed a plant community structured according to the typical patterns of Saharan ecosystems. Familial, biological, and phytogeographic spectra were consistent with expectations for an arid environment in the northern Sahara. The predominance of hemicryptophytes and chamaephytes, together with the substantial presence of therophytes, reflects the adaptation of the flora to xeric constraints.

The diversity indices, particularly $H' = 4.179$ bits and $E = 0.889$, indicate a relatively diverse and well-balanced community despite severe water stress. The Sorensen index ($IS = 0.323$) shows that the two stations share only part of their flora, highlighting the importance of spatial heterogeneity in Saharan vegetation.

The presence of endemic taxa gives the Atteuf region significant conservation value and supports the need for locally adapted management measures. Future research should include temporal monitoring of floristic diversity, functional trait analysis, and assessment of anthropogenic impacts on vegetation community structure.

Author Statements:

- **Ethical approval:** No ethical committee approval was required for this floristic inventory because the study did not involve human participants or animal experimentation.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
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- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author.

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