Floristic diversity and vegetation dynamics in an arid Mediterranean wetland: the case of Sehb El Masjoune Basin, Central Morocco

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Abstract: The Sehb El Masjoune basin, located in the Oum Er-Rbia watershed (Morocco), is classified as both a Site of Biological and Ecological Interest (SBEI) and a Key Biodiversity Area (KBA). This study presents a phytoecological assessment based on 18 vegetation surveys conducted before and during the site's flooding (November 2020 – June 2021). A total of 70 vascular plant species, representing 29 families, were recorded. Annual therophytes dominate the flora (68%), indicating arid environmental conditions and strong anthropogenic pressures, particularly overgrazing. The chorological analysis of the recorded taxa showed that most of the recorded species belonged to mediterranean (72.8%). The presence of seven endemic and two threatened species highlights the site's ecological value. The analysis of the principal component analysis (PCA) revealed the differentiation of five major plant associations, each reflecting distinct ecological conditions related to substrate type and salinity. The results demonstrate the ecological significance of the basin and emphasize the urgent need for a dedicated conservation and management plan. This study provides a baseline for future biodiversity monitoring and sustainable management efforts in this nationally and internationally important site.

Keywords: plant diversity chorology, phytoecological endemism, endorheic basins, Morocco.

1. Introduction

Wetlands, though covering less than 1% of the Earth's surface, are among the most biologically diverse yet most threatened ecosystems globally (Reddy et al., 2022). Throughout the 20th century, an estimated 69–75% of wetland ecosystems were lost due to extensive anthropogenic alterations, including drainage, infilling, and land conversion (Davidson, 2014; Kundu et al., 2024). In the past two decades, inland wetlands have continued to decline, primarily as a result of agricultural

expansion, urban development, and hydrological modifications. These pressures have led to widespread habitat degradation, loss of biodiversity, and increased vulnerability to invasive species (D'Antonio et al., 2017; Anđelković & Snežana, 2022; Fois et al., 2026).

In North Africa, Morocco hosts one of the region's richest wetland networks, owing to its extensive coastline (~3,500 km), varied topography, and complex hydrographic systems shaped by four major mountain ranges. Despite the vital ecosystem services, they provide including flood regulation, groundwater recharge, and maintaining biodiversity (Ennabili et al., 2021), many Moroccan wetlands are severely degraded or under threat. Recurrent droughts, a defining feature of the Mediterranean climate, and growing anthropogenic pressures have altered species composition, reduced plant diversity, and facilitated the spread of invasive alien species (Hammada, 2007; Mostakim et al., 2019; Chadli et al., 2024).

Among these threatened ecosystems is the Sehb El Masjoune basin, located within the Oum Er-Rbia watershed. Designated in 1994 as a Site of Biological and Ecological Interest (SBEI H31) (BirdLife International, 2020), the site has also been recognized as a Key Biodiversity Area (KBA) under Criterion 1 (Darwall et al., 2014) due to the presence of six trigger species, including two vulnerable vascular plants: *Eryngium variifolium* Cosson and *Cirsium ducellieri* Maire. In addition, the Sehb El Masjoune has been classified by Fennane (2004) as a Plant Important Area (PIA/ZIP). Its ecological importance stems from its unique physical, floristic, and faunal characteristics, making it a priority for conservation action. However, the site currently lacks a formal management framework and remains highly vulnerable to anthropogenic pressures and climate-induced stressors.

Previous botanical surveys of Sehb El Masjoune (Nègre, 1956; Fennane, 2004; Darwall et al., 2014) described its vegetation structure and plant communities' dynamics. Nègre (1956), based on a two-year field study (1952–1953), distinguished several vegetation assemblages: halophilic-hygrophilic and weakly halophilic groups, each characterized by distinct floristic compositions. Dominant species included *Salsola vermiculata*, *Frankenia corymbosa*, *Mesembryanthemum nodiflorum*, *Scirpus maritimus*, *Atriplex halimus*, *Asparagus stipularis*, *Calendula algeriensis*, *Ziziphus lotus*, and *Iris sisyrinchium*. Annual species predominated in most communities, reflecting both the site's aridification and plant adaptations to harsh ecological conditions. Spatial and temporal gradients in soil salinity and moisture were identified as key drivers of vegetation zonation. A vegetation map was produced to document the distribution of these plant communities (Nègre, 1956). Later, Fennane (2004) confirmed the site's botanical value by designating it as a Plant Important Area

(PIA/ZIP), highlighting its unique halophytic assemblages rarely found elsewhere in North Africa. The site also supports a variety of macroinvertebrates and water-dependent bird species (Bird Life International, 2020; Darwall et al., 2014).

Despite this ecological significance, Sehb El Masjoune lacks sufficient current scientific data to inform its conservation and management. In this context, a phytoecological study was deemed necessary to serve as a scientific baseline for future restoration and planning efforts. This study aimed to: (1) assess the floristic diversity of Sehb El Masjoune, with particular attention to endemic and rare species; (2) determine the conservation status of recorded plant taxa and (3) identify and characterize major vegetation communities.

2. Materials and Methods

2.1 Study area

The Sehb El Masjoune is a sub-basin within the Oum Er-Rbiaa watershed. It is geographically located in the central part of the Bahira Plain (central Morocco), between 32°04′–32°09′ N and 7°37′–7°48′ W (Fig. 1), and covering approximately 3,800 ha (Ouzemou et al., 2025) Administratively, the basin falls within the province of Ben Guerir and is entirely encompassed by four rural communes: Ouled Imloul, Lamharra, Ouled Zerrad and Hiadna, the area forms a broad, flat depression extending approximately 17 km in length and 2.5 km in width, oriented from the southwest to the northeast. The topography is generally flat, with slopes ranging from 0.1% to 3% and elevations varying between 401 and 500 m above sea level.

Geologically, the Sehb El Masjoune area is defined by a subsidence basin that has accumulated sedimentary deposits since the Stephanian period (Frizon et al., 2008). Initially, these deposits consisted of secondary and subsequently tertiary limestone materials. Over time, they became partially overlain by Quaternary lacustrine limestone. The basin floor has since been infilled with abundant silts, primarily transported from the south and to a lesser extent from the north. The prolonged functioning of this basin as a chott (a type of seasonal salt flat) has led to the development of a thick gypsiferous and saline formation (Frizon et al., 2008).

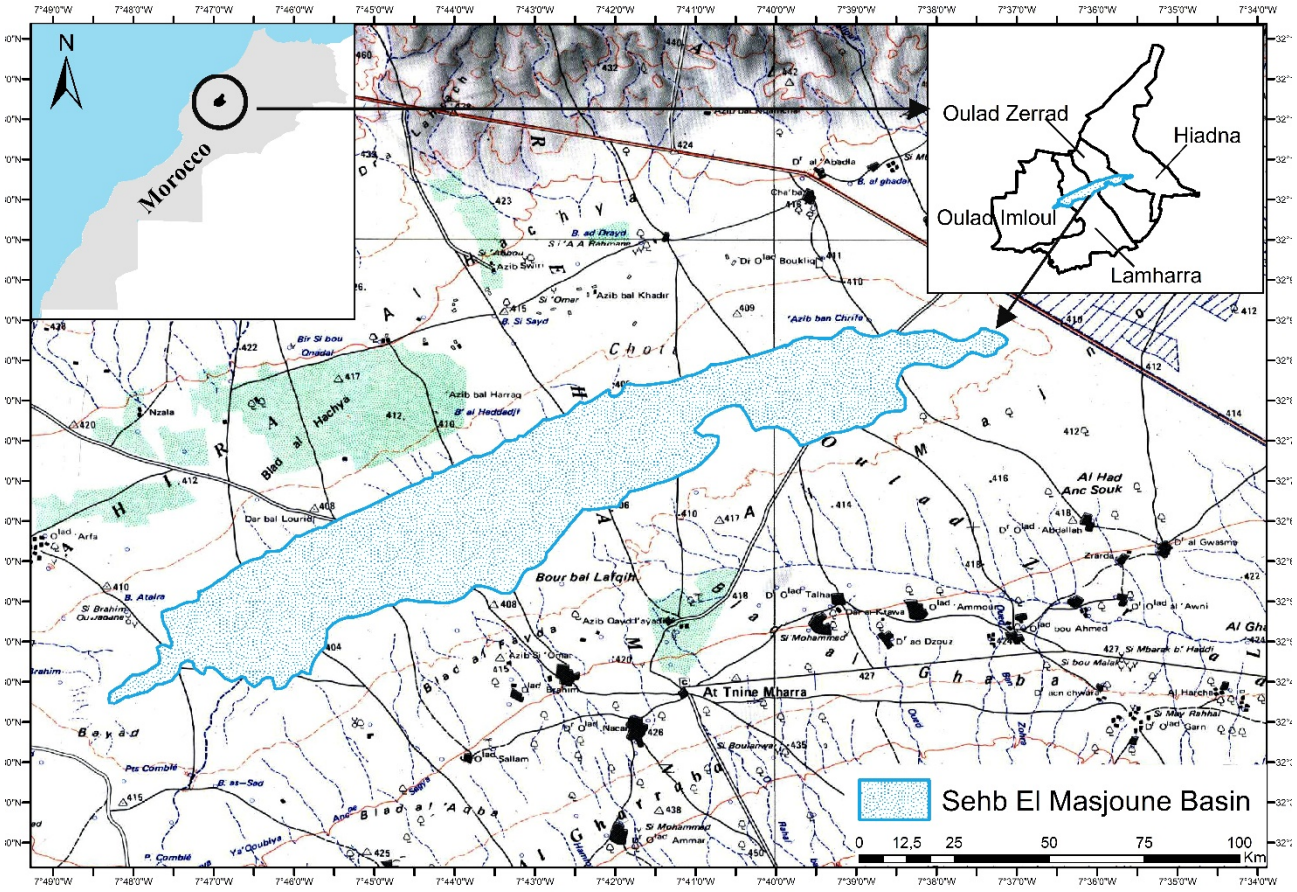

Figure 1. Geographical location of the SBEI Sehb El Masjoune (map extracted from the topographic map of Ben Guerir 1:100,000)

The hydrographic network of the Sehb El Masjoune is poorly developed and limited to ephemeral streams (talwegs) fed by surface runoff from the slopes of the Rhamna and Jbilet massifs. These flows converge toward the endorheic depression of Sehb El Masjoune, which serves as the natural outlet for this temporary drainage system. The Sehb El Masjoune lake also referred to as a sebkha once covered an area of approximately 42 km² in the 1970s. It forms a saline wetland within the Bahira plain and collects surface water from the surrounding highlands, creating a daya (seasonal depression) during the rainy season (Ouzemou et al., 2025).

The Sehb El Masjoune basin is characterized by a semi-arid climate, with low and highly variable annual precipitation (approximately 200 mm), concentrated between October and May, and a prolonged dry season from June to September (El Hasini et al., 2019). Mean monthly temperatures range from 8–18 °C in winter to 18–34 °C in summer. These climatic conditions strongly influence the basin's hydrology and vegetation dynamics. Growing anthropogenic pressure, driven by

population increase and a 60% expansion of irrigated agriculture between 2005 and 2017, has intensified groundwater extraction, increasing hydrological stress and threatening soil quality, plant diversity, and wetland ecosystem stability (Achemrk et al., 2026).

2.2 Sampling

A phytoecological approach was adopted in this study through-out two years (Spring 2021 to Winter 2023). The methodology involved collecting data on both the physical environment and vegetation within the smallest homogeneous floristic area defined as the minimum sampling surface of 100 m² to ensure the results were representative of the broader study area (Mueller-Dombois and Ellenberg, 1974). This approach allowed for the identification and analysis of distinct floristic groups and the assessment of their relationships with environmental variables, including altitude, substrate type, soil moisture, electrical conductivity, pH, and the degree of anthropogenic disturbance. To comprehensively cover the study area, 18 sampling stations were selected (Tab. 1), at which both ecological parameters and vascular plant species lists were recorded.

Collected specimens of vascular plants were pressed and dried using the herbarium press at the Natural History Museum of Marrakech (NHMM), then identified using three tomes of Practical Flora of Morocco: Manual for the Identification of Vascular Plants (Fennane et al., 1999, 2007, 2014; Hammada et al., 2004) and by comparison with reference specimens housed in the NHMM herbarium. The nomenclature of plant taxa follows the International Plant Names Index (IPNI, https://www.ipni.org/). The rare, threatened, or endemic species of each recorded taxon were identified based on the Catalogue of Rare, Threatened, or Endemic Vascular Plants of Morocco (Fennane and Ibn Tattou, 1998), and the conservation status of each recorded taxon in Morocco was determined according to the Red Book of the Vascular Flora of Morocco (Fennane, 2021).

Table 1. Geographical coordinates, altitude, and substrate type of surveys conducted in the Sehb El Masjoune basin

Site code	Coordinate System (GPS)			Substrate type
	Latitude (Y)	Longitude (X)	Altitude (m)	
1	32° 04.108' N	7° 46.630' W	412	Clay-limestone
2	32° 04.653' N	7° 47.525' W	409	Clay-silt
3	32° 05.222' N	7° 48.111' W	415	Sandy-limestone
4	32° 04.814' N	7° 44.488' W	410	Clay

5	32° 05.663' N	7° 45.759' W	409	Clay
6	32° 06.530' N	7° 45.811' W	415	Silt
7	32° 05.081' N	7° 42.902' W	413	Clay-silt
8	32° 6.027'N	7° 45.172' W	412	Clay-silt
9	32° 7.465'N	7° 44.108' W	408	Silt
10	32° 05.931' N	7° 41.764' W	412	Clay-limestone
11	32° 7.010'N	7° 42.789' W	409	Clay-limestone
12	32° 8.246'N	7° 42.946' W	416	Silt
13	32° 06.975' N	7°39.610' W	415	Clay-limestone
14	32° 08.597' N	7°39.673' W	410	Clay-limestone
15	32° 9.145' N	7° 40.730' W	408	Clay-limestone
16	32° 07.827' N	7°37.640' W	414	Clay-limestone
17	32° 09.007' N	7° 38.839' W	413	Clay-silt
18	32° 08.512' N	7°38.228' W	408	Clay-silt

The cover-abundance of each species within the minimal sampling area was estimated using the Braun-Blanquet scale (1956). The biological types of the recorded species were determined following Raunkiaer's classification (1934), which categorizes plants based on the position of their perennating organs (and thus their growth meristems) during unfavorable seasons (e.g., summer drought or winter cold). These life-form types were assessed in the field and supplemented by consultation of three volumes of Pratical Flora of Morocco (Fennane et al., 1999, 2007, 2014).

The global distribution (chorology) of each species was determined based on data from IPNI (2025), POWO (2025), and APD (2025). The range in the geographical divisions of Morocco are also mentioned using the catalogues for the Identification of Vascular Plants (Fennane et al., 1999, 2007, 2014).

The floristic relevés were manually sorted and analyzed using the tabular method (Mansouri & Miara, 2023), a key step in the synthetic phase of data analysis. First, a raw data table was constructed, where columns represented relevés and rows listed species with their corresponding Braun-Blanquet cover-abundance values. From this, a refined (elaborated) table was produced by arranging species in decreasing order of frequency. Based on this elaborated table, relevés were compared for floristic similarity, allowing for the grouping of those with the most similar species composition.

The final output was a synthetic phytoecological table, grouping relevés of similar floristic composition into distinct plant communities. Each community corresponds to a type of vegetation assemblage composed of species sharing strong ecological affinities. Species within each group were characterized by their frequency and abundance-dominance coefficients, providing a clear representation of the structure and composition of vegetation in the study area.

To further investigate the relationships between species richness and environmental variables, Principal Component Analysis (PCA) was performed using PAST software (Hammer et al., 2001). The explanatory variables included soil temperature, soil pH, substrate type, elevation, and salinity. This multivariate approach is widely used in ecological research to identify patterns of association between environmental gradients and species distribution, thereby highlighting the main factors driving species abundance and spatial variability within the surveyed habitats.

3. Results

3.1 Floristic composition

Based on the 18 phytoecological relevés conducted before and during the water impoundment phase, the Sehb El Masjoune basin exhibits a relatively high floristic richness, with a total of 70 vascular plant species recorded, belonging to 62 genera and 29 families (Fig. 2). The floristic list with the respective attributes is available in Appendix A.

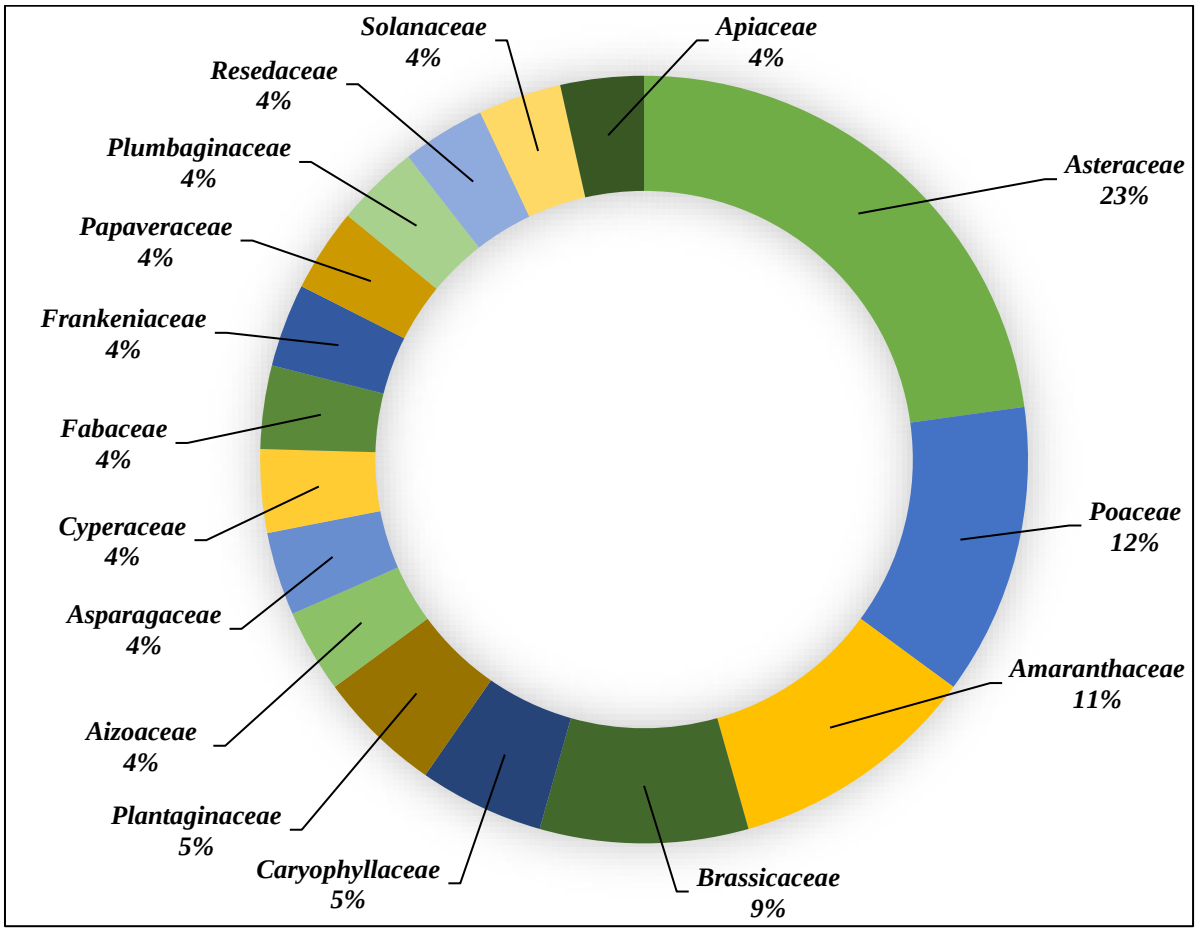

Figure 2. Percentage of species within each family in the Sehb El Masjoune basin

The most species-rich families are (Fig. 2): *Asteraceae* (13 species, 23%), *Poaceae* (7 species, 12%), *Amaranthaceae* (6 species, 11%), *Brassicaceae* (5 species, 9%), *Caryophyllaceae* and *Plantaginaceae* with (3 species, 5% each). Ten families are represented by two species each: *Aizoaceae, Asparagaceae, Cyperaceae, Fabaceae, Frankeniaceae, Papaveraceae, Plumbaginaceae, Resedaceae, Solanaceae, Umbelliferae.* The remaining 13 families are each represented by a single species: *Apocynaceae, Asphodelaceae, Convolvulaceae, Crassulaceae, Cucurbitaceae, Geraniaceae, Iridaceae, Lythraceae, Malvaceae, Polygonaceae, Rhamnaceae, Verbenaceae, Nitrariaceae.*

In addition, the study area is home to 11 halophyte species belonging to seven plant families (Tab. 2). Two of these, *Cressa cretica* L. and *Aeluropus littoralis* (Gouan) Parl., are classified as strict halophytes according to Hammada et al. (2004), indicating a high degree of specialization for saline habitats. These species have specific morphological and physiological adaptations that enable them to tolerate high substrate salinity. The *Amaranthaceae* and *Poaceae* families are the most represented

within the study site, with three species each, while the *Convolvulaceae, Cyperaceae, Frankeniaceae, Plantaginaceae,* and *Plumbaginaceae* each have one halophyte species.

Table 2. Halophilic species recorded in the Sehb El Masjoune basin according to Hammada *et al.* (2004) [With: * = Strict halophytes]

Families	**Species**
Amaranthaceae	*Beta macrocarpa* Guss.
	Caroxylon vermiculatum (L.) Akhani & Roalson
	Suaeda vera J. F. Gmelin
Convolvulaceae	*Cressa cretica* L.*
Cyperaceae	*Bolboschoenus maritimus* (L.) Palla
Frankeniaceae	*Frankenia laevis* L.
Plantaginaceae	*Plantago coronopus* L.
Plumbaginaceae	*Limonium ornatum* (Ball) O. Kuntze. E
Poaceae	*Aeluropus littoralis* (Gouan) Parl.*
	Hordeum marinum Hud
	Sphenopus divaricatus (Gouan) Rchb.

3.2 Endemism and threatened taxa

The flora of Sehb El Masjoune also includes nine plant species endemics to Morocco, including two species classified as rare: *Cirsium ducellieri* Maire and *Diplotaxis assurgens* (Delile) Thell. Other notable endemic taxa namely: *Diplotaxis tenuisiliqua* Delile; *Diplotaxis virgata* (Cav.) DC; *Limonium ornatum* (Ball) O. Kuntze; *Linaria bipartita* (Vent.) Willd; *Eryngium variifolium* Cosson; *Psychine stylosa* Desf; and *Spergularia purpurea* (Pers.) G. Don fil. I. This level of endemism and rarity, representing 11.47% of the recorded flora, highlights the site's high conservation value and justifies its designation as a Site of Biological and Ecological Interest (SBEI) and a Key Biodiversity Area (KBA) (Darwall et al., 2014).

According to the Red Book of Vascular Flora of Morocco (Fennane, 2021), the 70 species listed in Sehb El Masjoune are classified into six conservation status categories (Tab. 3). The majority of species (64, or 91.43%) are classified as least concern (LC). Two species (2.86%) are listed as near threatened (NT), while two others are classified as not applicable (NA) and data deficient (DD), each representing 1.43% of the total flora. In addition, two species are classified as threatened: *Cirsium ducellieri*, listed as critically endangered (CR), and *Diplotaxis assurgens*, assessed as vulnerable

(VU). These results highlight the importance of targeted conservation measures for the most threatened taxa within this ecosystem.

Table 3. Number of species by category and their percentages recorded in the flora of Sehb El Masjoune (SBEI). [CR: Critically endangered; DD: Data Deficient; LC: Least Concern NA: Not applicable; NT: Near Threatened; VU: Vulnerable]

Conservation status category	Number of species	%
LC	64	91,43
NT	2	2,86
NA	1	1,43
VU	1	1,43
CR	1	1,43
DD	1	1,43

3.3 Life form

Raunkiaer's classification (1934) indicates that the biological spectrum of the recorded flora is characteristic of arid bioclimatic zones, with a marked dominance of therophytes, which account for 47 species (representing 67%). Chamaephytes are the second most represented group with 10 species (14.29%), followed by hemicryptophytes with 7 species (10%), geophytes with 4 species (5.71%), and phanerophytes represented with only 2 species (2.85%) (Fig. 3). This distribution reflects significant ecological instability within the SBEI, mainly resulting from intense anthropogenic pressures, particularly overgrazing and excessive groundwater extraction for agricultural purposes.

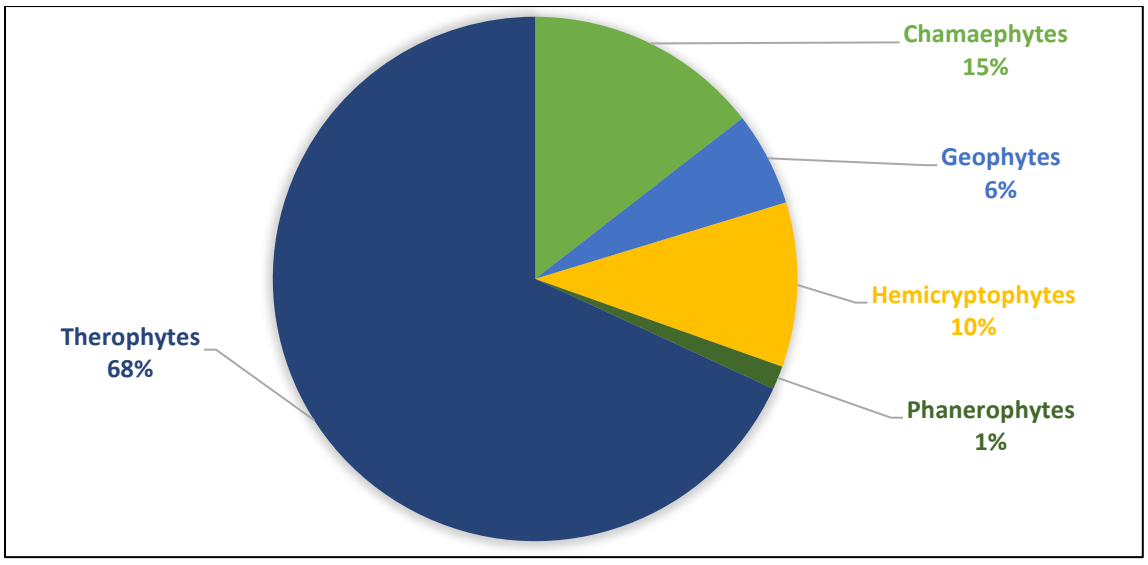

Figure 3. Biological spectrum of plant species inventoried at the Sehb El Masjoune basin

3.4 Chorology

Chorological analysis of the flora recorded in the study area reveals a clear predominance of multiregional taxa, which account for 39 species (55.71%). Next come bi-regional taxa, which comprise 22 species (31.43%), while mono-regional taxa represent only 9 species (12.85%) (Tab. 4). Among the mono-regional elements, North African species are the most represented, constituting 11.43% of the total flora. Within the multiregional group, the most frequent chorotypes are Macaronesian-Mediterranean and Iranian-Turanian, each contributing 8.57%, followed by the Macaronesian-Mediterranean-Eurasian type at 4.29%. The most common bi-regional element is the Mediterranean-Arabic chorotype, which represents 7.14% of the total species recorded in the Sehb El Masjoune basin.

Table 4. Chorology variation of plant species inventoried at the Sehb El Masjoune basin. [N-Af: North African ; WE-Me: Western–Eastern Mediterranean ; W-Me: Western Mediterranean ; At: Atlantic ; Ma: Macaronesian ; Af: African ; Ind: Indo ; Trop: Tropical ; As: Asiatic ; Ar: Arabian ; Euras: Eurasiatic ; S: Saharan ; Mo: Moroccan ; IP: Iberian Peninsula ; Le: Levantine ; NS Am-temp: North to South American temperate ; Temp: Temperate ; Sub-Tr: Subtropical ; Aus: Australian ; Eur: European ; Ca: Caucasian ; Saf: Southern African ; Ir-Tur: Irano-Turanian ; Sa: Sahelian ; P: Pakistani ; W-Eur: West European ; W-As: West Asian ; Si: Sindien ; NW-Eur: North West European ; Cas: Central Asiatic].

Chorology	**Species Number**
Monoregional	
N-Af	8
WE-Me	1
Total	**9**
Biregional	
At, W-Me	1
Ma, Af-Ind-Trop	2
Ma, Ind-As	2
Ma, Me	1
Me, Ar	5
Me, As	1
Me, Euras	1
Me, N-Af	1
Me, S	1
Me, S-Ar	1
Mo, IP	1
N-Af, Le	1
NS Am-temp, Trop	1

Temp, Sub-Trop	2
Trop, Sub-Trop	1
Total	**22**
Multiregional	
Euras, N-Af, Ar, Aus	1
Ma, Euras, Af-Trop	1
Ma, Me, Euras, Af-Trop	1
Ma, Euras, Ar	1
Ma, Eur, Me	1
Ma, Eur, Me, Cc, SAf	1
Ma, Eur, Me, Af-Ind-Trop	1
Ma, Eur, Me, Ar	1
Ma, Me, Ir-Tur, Ar, SAf	1
Ma, Me, Af-Ind-Trop	1
Ma, Me, Ar	1
Ma, Me, Euras	3
Ma, Me, Ir-Tur	6
Ma, Me, Ir-Tur, S	1

Ma, Me, Ir-Tur, Af-Ar	1
Ma, Me, Ir-Tur, Af-Ind-Trop	1
Ma, Me, Ir-Tur, S-Sa	1
Ma, Me, S-Ar	1
Ma, S Eur, N-Af, Ir-Tur	1
Ma, W-Me, S	1
Me, Af-Eura, Ir-Tur	1
Me, Af–Ir-Tur, Ind-P	1
Me, CAs–Ind	1
Me, Euras, At	1
Me, Ir-Tur, Af-Ind-Trop	1
Me, Ir-Tur, Af-Trop	1
Me, Ir-Tur, Ar	1
Me, W-As, Ind	2
Me, W-Eur, Ir-Tur	1
Me, Ir-Tur, Ar-Si	1
Me, At, NW-Eur	1
Total	**39**

3.5 Geogrpahical distribution in Morocco

The distribution of the 70 plant taxa recorded in the Sehb El Masjoune basin across Morocco's phytogeographical divisions offers valuable insights into their ecological range, spatial distribution, and regional status (Tab. 5). Species richness varies notably among the regions, with the Middle Atlantic Morocco (Mam) division recording the highest number of taxa (65 species), likely due to its geographical proximity to the study area. This is followed by the Rif (R) with 61 species, North Atlantic Morocco (Man) with 60 species, and the Mediterranean Littoral (LM) and Eastern Plateau (Op) with 58 and 55 species, respectively. The High Atlas (HA) harbors 53 species, while Saharan Morocco (Ms) and the Anti-Atlas (AA) support 49 and 48 species. Lower numbers are recorded in the Middle Atlas (MA) (42 species) and the Eastern Moroccan Mountains (Om) (37 species), with the Saharan Atlas (As) showing the least floristic similarity, comprising only 28 taxa. These patterns reflect the strong influence of geographical proximity and ecological continuity on the distribution of plant species across Morocco's phytogeographic regions.

Table 5. Distribution of the flora of Sehb El Masjoune Basin according to the phytogeographical divisions of Morocco. [AA: Anti-Atlas. HA: High Atlas. MA: Middle Atlas. Mam: Middle Atlantic Morocco. Man: North Atlantic Morocco. R: Rif. Om: Eastern Moroccan Mountains. Op: Eastern Plateau. LM: Littoral Mediterranean. Ms: Saharan Morocco. As: Saharan Atlas].

Geographic division	**Species Number**
Biregional	
MA Man	1
HA Mam	1
AA HA	1
HA Mam	1
Total	**4**
Tri-regional	
Man LM R	1
HA Mam Man	1
Total	**2**
Multiregional	
AA HA MA Mam Man R	1
AA HA Mam Man Op Om LM R	1
As AA HA MA Mam Man Op Om LM R	1
HA MA Mam Man Op R	1
HA MA Mam Man Op LM R	1
HA MA Mam Man Op Om LM R	1
MA Mam Man Op LM R	1
MA Mam Man Op Om LM R	1
Mam Op LM R	1
Mam Man LM R	1
Mam Man Op LM R	2
Ms AA HA MA Mam Man LM R	1
Ms AA HA MA Mam Man Op LM R	1
Ms AA HA MA Mam Man Op Om LM R	3
Ms AA Mam Man R	1
Ms AA Mam Man LM R	1
Ms AA HA Mam LM	1
Ms AA HA Mam LM R	1
Ms AA HA Mam Man Op LM R	1
Ms AA HA Mam Man Op Om LM R	2
Ms AA HA Mam Man R	1
Ms AA HA Mam Man Op R	1
Ms AA MA Mam Man Op LM R	1
Ms As HA Mam Op	1
Ms As Mam Op LM R	1
Ms As HA Mam Op LM R	1
Ms As AA Mam Man Op LM R	1
Ms As AA HA Mam Op Om LM R	1
Ms As AA HA Mam Man Op Om LM R.	1
Ms HA Mam Man Op LM R	1
Ms HA MA Mam Man Op Om LM R	1
Ms MA Mam Man LM R	1
Ms Mam Man Op LM R	2
All of Morocco except As	2
All of Morocco except As, Ms	1
All of Morocco	21
Non-Saharan Morocco	2
Total	**64**

3.6 Vegetation communities

The analysis of the principal component analysis (PCA) revealed the differentiation of five distinct plant community groups within the Sehb El Masjoune SBEI (Fig. 4). The distribution and relative abundance of vegetation assemblages were mainly structured along two principal axes, which together explained 90.425% ($p < 0.05$) of the total variability in the analyzed dataset. The first PCA axis, accounting for 77.94% of the total variance, showed a strong correlation with salinity, indicating that this factor constitutes the main environmental gradient governing vegetation distribution across the study area. The second axis, explaining 12.48% of the total variability, was primarily associated with specific richness and environmental humidity, reflecting the influence of local moisture conditions on floristic composition. These ecological gradients enabled the discrimination of five plant community types, each defined by its spatial distribution, floristic diversity, and ecological characteristics.. These communities are associated with *Aeluropus litoralis*, *Frankenia corymbosa*, *Suaeda fruticosa*, *Salsola vermiculata*, and *Atriplex halimus*, as outlined below:

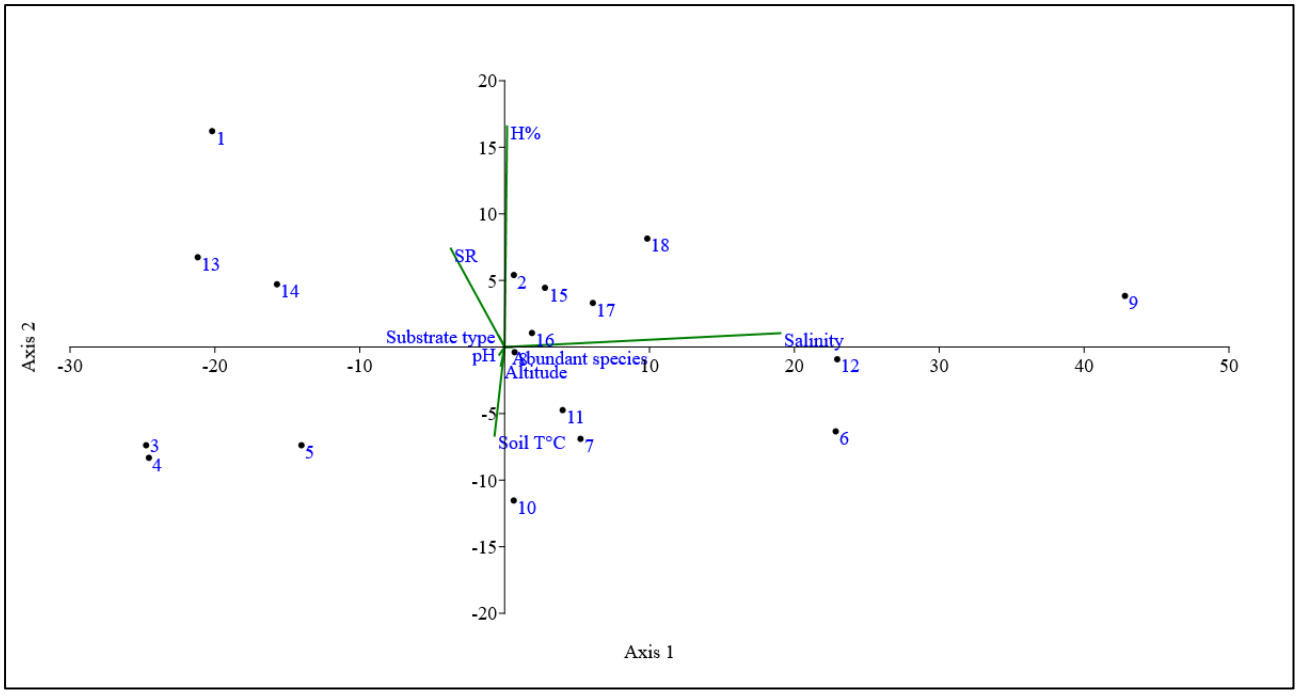

Figure 4. Ordination plots of PCA illustrating the relationship between environmental factors and prospected surveys. (Abbreviations: SR: Specific richness; H%: Relative humidity).

The *Aeluropus litoralis* community: was identified in Stations (S): S6, S9, and S12 mainly located in clay-silt depressions subject to seasonal waterlogging. This formation is characterized by the lowest floristic richness recorded in the study area and shows a negative correlation with salinity (r=-0.54;

$p<0.05$). This low-diversity halophytic association is dominated by *Aeluropus litoralis*, which thrives under moderate to high salinity and periodic submersion. Other key species include *Beta macrocarpa*, *Mesembryanthemum nodiflorum*, and the Moroccan endemic *Cirsium ducellieri*. While primarily composed of strict halophytes, several annuals tolerant to moderate salinity emerge during late spring.

The *Suaeda fruticosa* community was recorded in stations S2, S4, S8, S13 and S14, constitutes the most widespread community in the SBEI, covering over two-thirds of the area, this association occurs on calcareous and clay soils. It is characterized by moderate to high floristic richness, dominated by *Suaeda fruticosa* and *Mesembryanthemum nodiflorum* forming dense seasonal mats. Vegetation cover ranges from 30% to 75%, with annuals reaching 5–20 cm and chamaephytes up to 40 cm of height.

The *Frankenia corymbosa* community was found in three stations This heterogeneous community, found in the northern and central basin, features a visually distinct three-layered structure: sparse shrubs (*Frankenia corymbosa*), a patchy lichen layer, and a dense herbaceous cover. The light-colored, gypsum-rich sandy soils reflect high solar radiation. Associated species include *Spergularia diandra* and *Anabasis syriaca.*

The *Salsola vermiculata* community was distinguished in stations S1, S5, S11, and S17restricted to the northern section, this species-rich community (25 species) occurs on calcareous and silt-rich substrates with lower salinity. Dominant taxa include *Salsola vermiculata, Frankenia corymbosa,* and the Moroccan endemics *Eryngium variifolium* and *Linaria bipartita*. It supports a floristically diverse assemblage despite its limited spatial extent.

The *Atriplex halimus – Ziziphus lotus* community corresponding to the remaining surveyed stations confined to silty, cultivated soils with low salinity, this community comprises species adapted to disturbed agricultural habitats. Dominant taxa include *Atriplex halimus*, *Ziziphus lotus*, *Diplotaxis assurgens*, and *Phalaris minor*. According to Nègre (1956), the substrate is richer in clay and silt than that of the *Salsola* community, influencing species composition and structure.

4. Discussion

The floristic and phytoecological analysis of the Sehb El Masjoune basin reveals a particularly high level of biodiversity, especially for a wetland ecosystem located in an arid bioclimatic zone. A total of 70 vascular plant species have been recorded, including seven endemic taxa and two rare taxa,

highlighting the ecological importance of the site and justifying its classification as both a Site of Biological and Ecological Interest (SBEI) and a Key Biodiversity Area (KBA). The biological spectrum is dominated by therophytes (67%), reflecting the arid environmental conditions of the region and significant anthropogenic pressures, particularly overgrazing and land use change. This trend is consistent with findings from other Mediterranean and semi-arid regions, where biological spectra are often biased toward annual species due to seasonality and human disturbance (Mostakim et al., 2022). Similar results were reported by Zine et al. (2021) on the rehabilitated phosphate waste cover of the Kettara mine, High Atlas of Morocco, where 39 vascular plant species belonging to 19 families were inventoried and therophytes constituted the dominant life form. The authors attributed this predominance to adaptation to arid and semi-arid climates, where annual species complete their life cycle rapidly and produce abundant wind-dispersed or protected seeds capable of remaining dormant until favorable rainfall conditions occur. Such reproductive strategies enable rapid colonization of unstable substrates and constitute an effective adaptation to prolonged drought and unpredictable precipitation regimes. Compared with the M'Goun Geopark (Outourakhte et al., 2025), where therophytes represent only 36.24% of the flora and hemicryptophytes account for 35.32%, the markedly higher proportion of therophytes in the Sehb El Masjoune basin indicates a more disturbed and environmentally constrained ecosystem. In contrast, the greater representation of perennial life forms in the M'Goun Geopark reflects the higher habitat heterogeneity and comparatively better conservation status of its mountainous landscapes. Therefore, the predominance of therophytes in the Sehb El Masjoune wetland not only represents an adaptive response to water scarcity and climatic unpredictability but also constitutes a reliable ecological indicator of habitat degradation and increasing ecosystem vulnerability under combined natural and anthropogenic pressures.

In addition, this study highlights the impact of soil salinity and anthropogenic activities on vegetation structure and floristic diversity. Species richness tends to decrease in areas with higher salinity levels and in areas influenced by intensive agricultural practices. These results are consistent with the findings of Mostakim et al. (2020), further reinforcing the role of environmental stressors in the composition of plant communities in arid wetland ecosystems.

The distribution of the 70 taxa in the Sehb El Masjoune basin shows marked variation in floral richness according to Morocco's phytogeographical divisions. The greatest diversity observed in regions close to the study site highlights the influence of geographical proximity and ecological conditions on the distribution of plant species. The chorological study reveals a clear predominance of multiregional taxa, reflecting the influence of several biogeographical regions and the area’s status as

an ecological transition zone. This pattern is common in the arid and semi-arid environments of North Africa, where widely distributed species dominate due to their adaptation to climatic constraints, followed by biregional taxa, confirming the region's mixed biogeographical affinity. The Mediterranean-Arabian chorotype, which is the most prevalent, is characteristic of steppe and pre-Saharan ecosystems subject to severe aridity and, more marginally, by monoregional taxa, Monoregional taxa remain few in number, indicating a low degree of biogeographical specialisation. The North African elements, although few in number, nevertheless demonstrate a certain degree of floristic distinctiveness. This chorological structure reflects the diversity of the biogeographical affinities of the local flora and highlights the dominant influence of Mediterranean and Macaronesian elements in the floristic composition of the Sehb El Masjoune basin.

Phytosociological analysis of the Sehb El Masjoune basin identified five distinct plant associations, each reflecting specific ecological conditions and anthropogenic influences. The *Aeluropus litoralis* association, characterized by low species diversity and a preference for clay-loam substrates, is typical of seasonally flooded saline depressions. Large areas of the basin are dominated by *Suaeda fruticosa* and *Frankenia corymbosa*, the latter distinguished by its stratified plant structure and affinity for gypsum-rich soils. Although limited in area, the *Salsola vermiculata* community has a high floristic richness and includes two Moroccan endemic species, highlighting its importance for conservation. The *Atriplex halimus-Ziziphus lotus* association is associated with loamy soils influenced by cultivation, clearly reflecting the impact of land use on community composition. Taken together, these associations illustrate distinct ecological differentiation shaped by substrate type, salinity gradients, hydrological regimes, and human activity, and they form coherent plant units that contribute to the overall structure and functioning of the wetland ecosystem.

Comparison with previous classifications confirms the presence of five plant associations previously described by Nègre (1956), although the *Bolboschoenus maritimus* association, typically found in highly saturated areas, is notably absent, probably due to altered hydrological conditions. Furthermore, the proliferation of opportunistic and ruderal species such as *Peganum harmala* L., *Solanum nigrum* L., *Chenopodiastrum murale* (L.) S. Fuentes, Uotila & Borsch, and *Xanthium spinosum* within several communities is evidence of ongoing ecological degradation. This invasion threatens the floristic integrity and abundance of native species in the SBEI, highlighting the urgency of habitat conservation and restoration measures.

5. Conclusion

This study demonstrates that the Sehb El Masjoune basin is a heterogeneous mosaic of microhabitats that are home to a wide variety of plant communities, including several rare, endemic, or endangered taxa. The coexistence of halophytes tolerant to high salinity, gypsophytes adapted to gypsum-rich substrates, and ruderal species indicative of anthropogenic disturbances reflects a dynamic and ecologically complex system. This diversity is shaped by the interaction of natural factors, such as soil composition, salinity gradients, and seasonal hydrological fluctuations, as well as by ongoing human pressures, including overgrazing and agricultural encroachment. Despite its high conservation value, the site remains unprotected and is increasingly threatened by overgrazing, agricultural expansion, and habitat degradation. The floristic and phytoecological data presented here provide a valuable baseline for long-term monitoring and emphasize the urgent need to establish effective conservation and management strategies, including habitat restoration and legal protection, to safeguard the biodiversity and ecological integrity of this unique arid wetland.

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