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FLORISTIC ANALYSIS OF SPONTANEOUS SAHARAN PLANTS: A CASE STUDY OF THE SOUTHERN OASIS REGION OF EL OUED, ALGERIA

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ABSTRACT

Aim of the study

The north-east of Algeria, which comprises an arid Saharan region with a sparse plant ecosystem, was the subject of a phytoecological analysis aimed at inventorying its plant species as well as identifying the factors impacting this random floral succession.

Materials and methods

Four oasis sites in the southern region of El Oued were sampled. Species richness, life forms, chorology, plant cover rate, spatial distribution and similarity were analyzed. The disturbance index of the plant cover was calculated. An evaluation of the effect of soil salinity and pH on halophytic plants was conducted. This study, carried out from 2019 to 2023, involved 80 surveys, and the statistical analysis applied the Xlstat V16 tools.

Results and conclusions

45 species were identified, divided into 37 genera and 19 families. *Poaceae* were the most widespread, followed by *Asteraceae* and *Fabaceae*. Among life forms, therophytes and chamephytes were dominant. Chorologically, Saharo-Sindian species were the most represented, followed by endemic southern Mediterranean and Saharan species. The disturbance index revealed significant degradation of herbaceous species, particularly those associated with the original flora. Numerical analysis, on the one hand, indicated the progressive loss of certain species, probably due to anthropogenic activities such as overgrazing by wandering camel herds, as well as to climate change, and on the other hand, it demonstrated the existence of distinct groups of plant samples, reflecting the impact of environmental factors, where species richness is influenced by signs of degradation due to human activities.

Keywords: degradation, flora, northern Sahara, El-Oued

INTRODUCTION

The plant heritage of the El-Oued region in southern Algeria is facing degradation due to a combination of natural and anthropogenic factors, notably: recurrent drought, aridity, and overgrazing by wandering camel herds. According to Halis et al. (2012), El Oued's flora, characterized by sparse shrubs and grasses, is concentrated at the base of the dunes and is undergoing significant degradation, particularly among the endemic species. Moreover, endemic plants in Algeria and Tunisia are particularly abundant (Sakhraoui et al., 2020). To effectively conserve this unique flora, a thorough understanding of its diversity is crucial (Quézel and Santa, 1962). This requires an in-depth analysis of the floristic composition and ecological factors influencing its distribution. Such an analysis will help assess potential floristic losses and inform

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appropriate conservation programs about this Saharan region, where protection measures are currently lacking (Afokpe et al., 2022). Consequently, this study aims to inventory plant species in the oasis zones of El-Oued, and to analyze the relationship between taxa and their environment (Jinlong et al., 2025). We endeavour to gain insight into biodiversity and spatial distribution patterns (Moualki and Boukrouma, 2021). This assessment will contribute to the development of a warning system for Saharan ecosystems and support the implementation of effective conservation strategies (Manob et al., 2025; Monde et al., 2024).

MATERIALS AND METHODS

Site selection

The survey sites are located in the province of El-Oued, in northeastern Algeria, and south of the Saharan Atlas. Four sites were selected for the study (Fig. 1), with a combined total area of 20,000 hectares. These include: Oued El Alenda site located at 33°11’30.34”N 6°41’8.35”E at an altitude of 102 m above sea level (Fig. 2), Wermes site located at 33°25’33.17”N 6°45’33.17”E, at an altitude of 74 m above sea level (Fig. 3), Debila site located at 33°28’45.25”N 6°55’16.09”E, at an altitude of 70 m above sea level (Fig. 4), and Nakhla site located at 33°17’13.40”N 6°59’49.95”E, at an altitude of 90 m above sea level (Fig. 5). In the studied sites, we carried out 20 surveys at each site. An inventory of the vascular flora of each site was drawn up (Table 1). The general views of the study sites landscapes (Fig. 2, 3, 4, and 5) illustrate the homogeneity of the areas explored and the distribution of all plants.

Climate

To differentiate the El Oued Oasis region climatically, we used the Bagnouls-Gaussen ombrothermic diagram. An analysis of 2020 climate data provided by www.climate-data.org (December 30, 2023) indicates that annual precipitation during the study period recorded

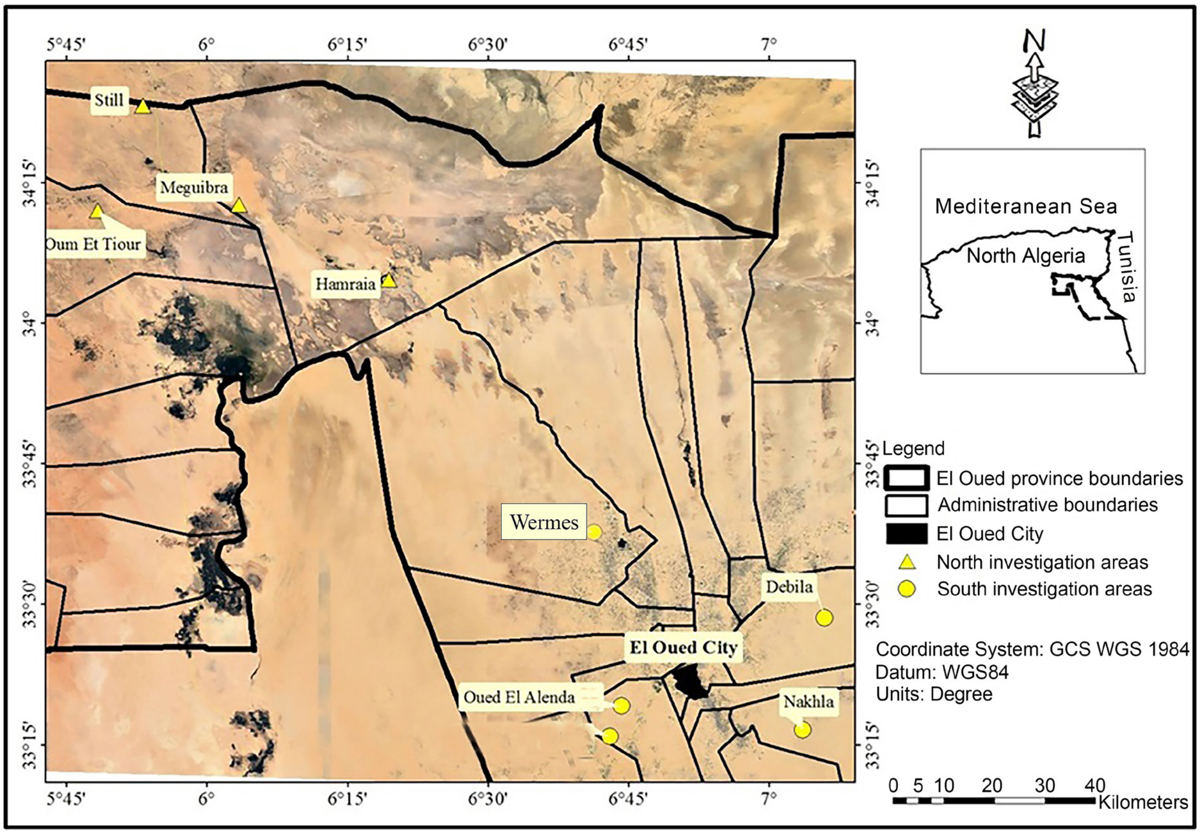

Fig. 1. Study areas around El Oued Oasis (source: Authors’ own elaboration)

an average of 89.21 mm, with a maximum in January (12.3 mm) and a minimum in July (0 mm). The average annual temperature was 25.19°C, with a maximum in July (45.9°C) and a minimum in January (12.7°C).

Soil sampling

Physical analysis

Particle size analysis was carried out by sieving the soil samples through a series of pore meshes of decreasing size: 2 mm, 500 µm, 250 µm, and 50 µm. The fine fraction, consisting of particles smaller than 2 µm, was also collected. Soil moisture was measured gravimetrically by determining the difference in weight before drying (P1) and after drying (P2) the samples in an oven at 105°C for 24 hours. Moisture content was calculated as a percentage, using the following formula:

$$H\% = \frac{P_1 - P_2}{P_1} \cdot 100 \tag{1}$$

Chemical analysis

The soil pH was measured electrometrically, using a pH meter on a soil-water suspension (distilled water) at a ratio of 1:5. Electrical conductivity (EC) was determined at 25°C, using a conductivity meter with a soil/water ratio of 1:5. Total limestone content was measured volumetrically, using the Bernard calcimeter, which involves breaking down calcium carbonates with hydrochloric acid, then measuring the volume of CO_2 released.

Flora sampling

An inventory was carried out by systematic random sampling in spring (March–May) from 2019 to 2023. This approach, based on vegetation physiognomy, involved calculating the minimum area of each site to ensure representative sampling (Merabti et al., 2022). The minimum area, defined as the zone containing nearly all the species in the plant community, was determined using the nested surfaces method (Deghiche Diab et al., 2016). During each inventory, the data concerning the abundance and dominance of each plant species were recorded. For each species recorded during the inventories, we assigned a semi-quantitative index based on the abundance-dominance scale developed by Braun-Blanquet et al. (1952) and then refined by Gillet (2000). This scale comprises the following categories: 5, 4, 3, 2, 1 and +. This methodology has been applied by various authors, such as Hamel et al. (2013), in the context of rare and endemic vascular flora of the Edough peninsula (northeastern Algeria). Inventories were carried out with latitude, longitude, and altitude determined by GPS, and exposure was established using a compass. According to Deghiche Diab et al. (2016), sampling areas varied from 200 to 400 m². A total of 80 inventories were carried out over five years, at a rate of around four inventories per site per year. Plant species were identified using the following references: New Flora of Algeria and the Southern Desert Regions by Quézel and Santa (1962), Flore du Sahara by Ozenda (2004) as well as Synonymic and bibliographic index of North Africa plants by Dobignard and Chatelain (2013). Taxonomic nomenclature is based on the International Plant Names Index Plant (2025) at https://www.ipni.org. Life forms were defined according to Raunkiaer (1934). Reference specimens were deposited at the Laboratory for Biodiversity and Applications of Biotechnology in Agriculture, University of El-Oued, Algeria. The plant community disturbance index (DI) of Gnahoré et al. (2020) was applied to deduce the impact of anthropogenic actions on floristic diversity. This index considers the abundance of two life forms, therophytes and chamaephytes (Loisel and Gamila, 1993). It is calculated as follows:

$$P.I. = \frac{(Number\ of\ chamaephytes + Number\ of\ therophytes)}{Total\ number - f\ species} \times \times 100 \tag{2}$$

Firstly, the Shannon diversity index was calculated for each site over the five study campaigns using the methods by Chytrý et al. (2002) and Gillet (2000). This index provides a mathematical measure of species diversity within a community and is derived from the following formula:

$$H' = -\sum_{i=1}^{n} p_i \, \mathrm{Log}_e p_i \text{ and } p_i = \frac{p_i}{N} \tag{3}$$

where:

- P_i – set of species ranging from 1 to n,
- n_i – number of individuals of each species,
- N – total number of individuals of all species,
- Log_e – logarithm of a number.

Secondly, the Sørensen-Dice similarity index is applied. Similarity, with values ranging from 0 to 1, indicates the links that exist between the group(s). According to Marcon (2024), the similarity index, with values ranging from 0 to 1, denotes the possible and existing links between groups of species; however, according to Hammer and Harper (2001), the similarity index is used to compare plant associations.

RESULTS AND DISCUSSION

These Saharan flora sites were delineated, illustrated, and characterized as follows:

Debila site: Located in the northern part of the study area, this site has a Saharan physiognomy with a diversity of plant species (Fig. 2). It is less affected by human activities, making it a typical potential example for biodiversity protection (Halis et al., 2012).

Nakhla site: Located in the western part of the study region, this site has a dense plant physiognomy and a lower altitude (Fig. 3). It is facing increased anthropic pressure, threatening some species with severe degradation (Akshaya et al., 2020).

Oued El-Alenda site: Characterized by a Saharan physiognomy and difficult human access, this site experiences a harsh climate with cold winters, hot summers and significant temperature variations. Preserving this unique biotope and its wealth of flora is crucial to ensuring its sustainability. Protected areas can play an essential role in maintaining these sites unaltered (Fig. 4).

Wermes site: This site features a desert landscape with very high temperatures, scarce rainfall (less than 50 mm per year) and low biodiversity due to overgrazing and human activities. The soil is poor and dominated by sand dunes, stabilized by psammophilous plants (Fig. 5).

Flora characteristics

This inventory recorded 45 species, belonging to 37 genera and 19 botanical families (Table 1).

Fig. 2. Landscape of Debila site (source: Authors' own elaboration)

Fig. 3. Landscape of Nakhla site (source: Authors' own elaboration)

Fig. 4. Landscape of Oued El-Alenda site (source: Authors' own elaboration)

Fig. 5. Landscape of Wermes site (source: Authors' own elaboration)

Table 1. Species inventoried in the El Oued Oasis region

Families	Species according to IPNI	Geographic type	Life form	Occurrence Index %
Amaranthaceae	*Bassia muricata* (L.) Asch.	Saharan	The.	13
	Cornulaca monacantha Delile	Saharo-Sindian	Cha.	53
	Salsola foetida Vest ex Schult.	Saharo-Sindian	Cha.	20
	Traganum nudatum Delile	Saharo-Sindian	Cha.	38
Asparagaceae	*Albuca amoena* (Batt.) J.C.Manning & Goldblatt	Endemic	Geo.	15
	Drimia noctiflora (Batt. & Trab.) Stearn	Endemic Saharan	Cha.	15
Asteraceae	*Anthemis stiparum* Pomel	Endemic Algero- Moroccan	Hem	15
	Centaurea furfuracea Coss. & Durieu	North African	The.	30
	Ifloga spicata (Forssk.) Sch.Bip.	Saharo-Sindian	The.	25
	Koelpinia linearis Pall.	Mediterrano-Saharo-Irano-Turanian	The.	23
	Picris asplenioides L.	Endemic Algero- Tunisian	The.	13
Boraginaceae	*Echium humile* Desf.	Mediterrano-Saharan	The.	38
	Moltkiopsis ciliata (Forssk.) I.M. Johnst.	Saharo-Sindian	The.	23
Brassicaceae	*Lobularia libyca* Meisn.	South-Mediterranean	The.	35
	Moricandia suffruticosa (Desf.) Coss. & Durieu	Mediterrano-Saharo Sindian	The.	30
Caryophyllaceae	*Herniaria fontanesii* J. Gay	Ibero- Central Mauritanian	Cha.	18
	Polycarpaea repens (Forssk.) Asch. & Schweinf.	Saharo-Sindian	The.	35
	Spergularia diandra (Guss.) Heldr.	Saharo-Sindiano-Irano-Turanian	The.	18
Cistaceae	*Helianthemum lippii* (L.) Dum.Cours.	Mediterrano-Saharan	Cha.	20
Cleomaceae	*Cleome arabica* L.	Saharo-Sindian	The.	38
Cyperaceae	*Cyperus conglomeratus* Rottb.	Tropical-Subtropical	Cha.	18
Ephedraceae	*Ephedra alata* Decne.	Saharo-Sindian	Pha.	63
Fabaceae	*Astragalus crenatus* Schult.	Mediterrano-Saharan	The.	48
	Astragalus gomboeformis Pomel	Endemic North Saharan	Cha.	33
	Astragalus arpilobus Kar. & Kir.	Saharo-Sindian	The.	28
	Calobota saharae (Coss. & Durieu) Boatwr. & B.-E.van Wyk	Endemic Saharan	Pha.	20
	Retama raetam (Forssk.) Webb	Saharo-Sindian	Pha.	43

Table 1. cont.

Families	Species according to IPNI	Geographic type	Life form	Occurrence Index %
Liliaceae	*Asphodelus refractus* Boiss.	Saharan	The.	40
	Asphodelus tenuifolius Cav.	Macaroniso-Mediteranian	Geo.	15
Orobanchaceae	*Cistanche violacea* (Desf.) Hoffmanns. & Link	Endemic North African	The.	10
	Cistanche tubulosa (Schenk) Wight ex Hook.f.	South-Mediterranean	Hem.	15
Plantaginaceae	*Plantago indica* L.	Sub-Mediterranean	The.	18
Poaceae	*Stipagrostis acutiflora* (Trin. & Rupr) De Winter	African-North-Tropical.	Hem.	15
	Stipagrostis obtusa (Delile) Nees	Saharo-Sindian	The.	30
	Cutandia dichotoma (Forssk.) Tr	Mediterranean	Geo.	60
	Cynodon dactylon (L.) Pers.	Thermocosmopolitan	Cha.	28
	Centropodia forskaolii (Vahl) Cope	North and South Saharan.	Hem.	48
	Centropodia fragilis (Guinet & Sauvage) Cope	Endemic Saharan	Hem.	30
	Stipagrostis pungens (Desf.) De Winter	Saharo-South African	Pha.	38
Polygonaceae	*Calligonum azel* Maire	Endemic	Pha.	20
	Calligonum comosum L'Hér.	Saharo-Sindian	The.	15
	Rumex spinosus L.	Mediterranean	Hem.	15
Resedaceae	*Reseda decursiva* Forssk.	South-Mediterranean	The.	10
Zygophyllaceae	*Zygophyllum mayanum* (Schltdl.)	Saharo-Sindian	Hem.	15
	Peganum harmala L.	Irano-Turano-European	The.	40

Explanations:
Life form: Cha.: chamaephyte, **Hem**.: hemicryptophyte, **Pha**.: phanerophyte, **Tea**.: therophyte, **Geo**.: geophyte

Six families account for 60% of the total species present in the vicinity of the El-Oued Oasis. The dominant families are Poaceae (15.55%), Asteraceae (11.11%), Fabaceae (11.11%), Amaranthaceae (8.88%), Caryophyllaceae (6.66%) and Polygonaceae (6.66%). The other families each count between one and two species. These results concur with those of Neffar et al. (2013), who identified *Asteraceae* as the most important family in the Algerian flora, particularly in arid and semi-arid regions. According to the index of occurrence of the different species (Table 1), 9% of species are ubiquitous, with an index of occurrence of between 40% and 50%. However, 5% of species exceed 50%, while 87% of species are less than 40%.

Life forms and chorology

The life forms listed, in descending order of prevalence, are: therophytes (44.44%), chamaephytes (20%), hemicryptophytes (17.78%), phanerophytes (11.11%), and geophytes (6.67%). According to Prochazka et al. (2024), these species thrive in resource-rich environments characterized by sufficient moisture and nutrients. The scarcity of water in the study area and the loose soil structure did not favor phanerophyte or geophyte species known for their perennial character. On account of our study area being warm and geographically located north of the Sahara, we recorded a dominance of the Saharo-Sindian chorological type (13%), followed by the Southern Mediterranean chorological type (4%) (Table 2). These results concur with those reported by

Table 2. Species reproduction rates and their chorology recorded in the vicinity of the El Oued Oasis

Life form	Number of species	Share (%)	Biogeographical type	Number of species	Share (%)
Therophytes	20	44	Saharo-Sindian	21	47
Chamaephytes	9	20	Mediterranean	11	24
Hemicryptophytes	8	18	Endemic	9	20
Phanerophytes	5	11	Africo-Tropical	2	4
Geophytes	3	7	Transition group	1	2
			Cosmopolitan	1	2

Khechekhouche et al. (2020) in their study of the floristic composition of Chott Edhiba in the El Oued region. The distribution of life forms follows the following pattern: Th > Ch > He > Ph > Ge. This pattern reflects the ecological conditions and specific requirements of the species in the study area, notably temperature, water availability, and soil depth. Environmental factors, notably water stress and anthropogenic activities such as harvesting and overgrazing, contribute significantly to habitat degradation. These results concur with those of Khechekhouche et al. (2020), who highlighted the detrimental effects of abiotic factors on plant degradation in arid regions. This reflects a climate-related pioneering phase (El Hafian et al., 2014).

To analyze the chorology results, we chose to group species' chorologies into biogeographic clusters with close affinities, as cited by Abo Hatab et al. (2024), according to which the Saharo-Sindian region is characterized by savannas, semi-deserts, and hot deserts. The Saharo-Sindian type, in our case study, encompasses species including Saharo-Sindian, Saharan, North-South-Saharan, Saharo-South-African, Mediterranean-Saharan-Irano-Turanian, Mediterranean-Saharan-Sindian and Saharo-Sindian-Irano-Turanian species. The Mediterranean type includes Mediterranean, North African, southern Mediterranean, sub-Mediterranean, Mediterranean-Saharan, Macaroneso-Mediterranean and, central Ibero-Mauritanian species. The endemic type includes endemic Saharan and North-Saharan species, endemic Algerian-Moroccan species, endemic Algerian-Tunisian species and endemic North African species. The transition group designates species dependent on the Irano-Turano-European type. The African-tropical type includes tropical-subtropical and African-northern-tropical species. The cosmopolitan type includes a species whose chorology is cosmopolitan (Table 2). If we consider the most dominant biogeographical types (Saharo-Sindian, Mediterranean, and endemic), we observe that the first three account for over 91% of all species (41 out of 45). The less dominant biogeographical types account for only 9%.

Disturbance index (DI)

The disturbance index (DI) quantifies therophytization in an environment based on its species (Gnahoré et al., 2020). This study produced a DI equal to 64.44%, whereas Larbi et al. (2021) calculated a DI of 27% for the Djurdjura cedar forest (northern Algeria). These comparisons highlight the influence of ecological contexts and management practices on DI. In this study, the relatively high DI suggests a high level of degradation of plant formations, with low representation of large perennial species and average representation of all plant formations (Zemmar et al., 2020). Furthermore, consistently high temperatures have eased anthropogenic pressure on vegetation (Marouane et al., 2021). However, climate change and rising temperatures favor species disturbance and increase the risk of index disturbance. According to Skowera et al. (2023), the main cause of the risk of drought is the significant increase in air temperature combined with the absence of any trend in the magnitude of changes in atmospheric precipitation (Zhengrong et al., 2021).

SHANNON-WIENER INDEX

Over the five-year period, application of the Shannon-Weaver index to our samples revealed a decrease in the mean value from 0.415 to 0.365 (Fig. 6), which

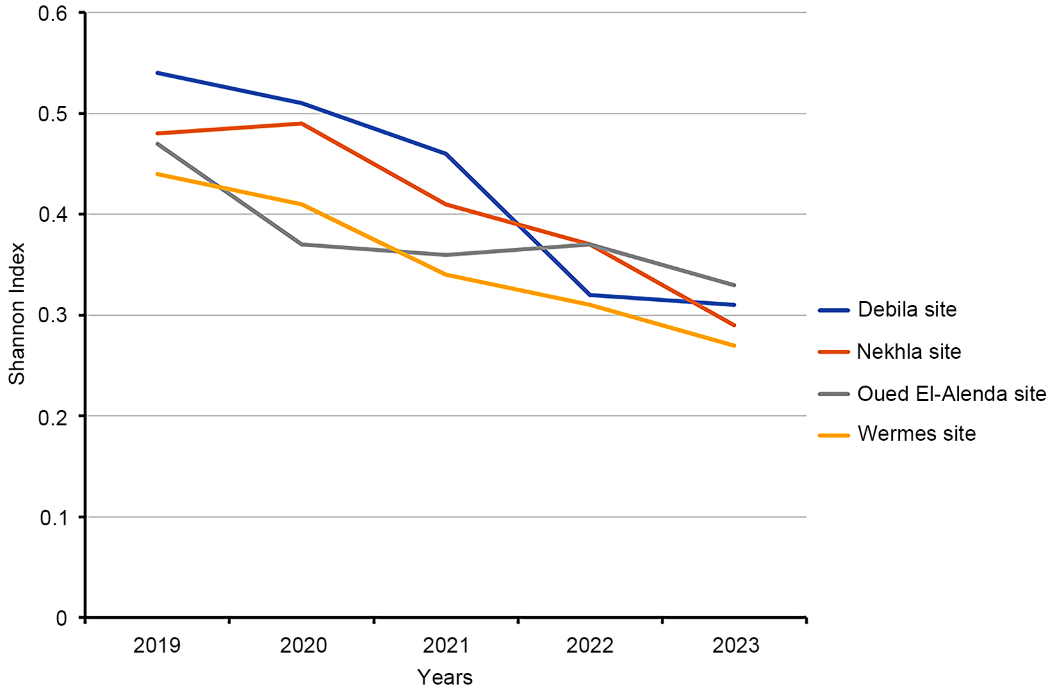

Fig. 6. Shannon-Weaver index of species in the southern region of El Oued Oasis (source: Authors' own elaboration)

indicates a significant decline in species diversity, as reported by Halis et al. (2012). They recorded similar results with species degradation in the El Oued region, reaching 1% of species extinct over 10 years of monitoring.

The Wermes site appears to be the most degraded, with 0.27 for the year 2023, compared with 0.54 for the Debila site in 2019 (Fig. 6). This trend is probably linked to the decline in the number of endemic species, some of which are currently threatened. Several factors may contribute to this loss: human impact on the environment, notably habitat disturbance through over-exploitation of resources such as overgrazing by camel herds, has led to vegetation loss and soil erosion. The soil degradation is mainly caused by the accumulation of sand and salts, which negatively affects soil fertility and hinders plant growth. Climate change, characterized by decreasing rainfall and rising average monthly temperatures, is causing water shortages and creating unfavorable conditions for plant survival. Taken together, all these factors contribute to a less diverse and more vulnerable ecosystem in the southern region of the El Oued Oasis.

Species groups

Analysis of similarities is used to compare plant associations (Medjber Teguig, 2014). It reveals relationships between species groups (Marcon, 2024). High similarity values suggest a common floristic composition or ecological conditions (Walter and Jean-Michel, 2006). The similarity of species in the areas surrounding the El Oued Oasis has enabled us to identify two main groups (Fig. 7), likely to share a similar floristic composition or ecological characteristics.

Species group (1), shown in Figure 7, is a large heterogeneous group located in a low-lying area subject to overgrazing. The analysis of similarities, which considers species variation as an ecological indicator cited by Novaković-Vuković et al. (2019), reveals the heterogeneity of these herbaceous samples, reflecting strong anthropogenic pressure and spatial variation. In addition, this area experiences very low precipitation (less than 89 mm · year^{-1}) and cold winters.

This group includes psammophilous species that inhabits coarse sandy areas, such as *Stipagrostis pun-*

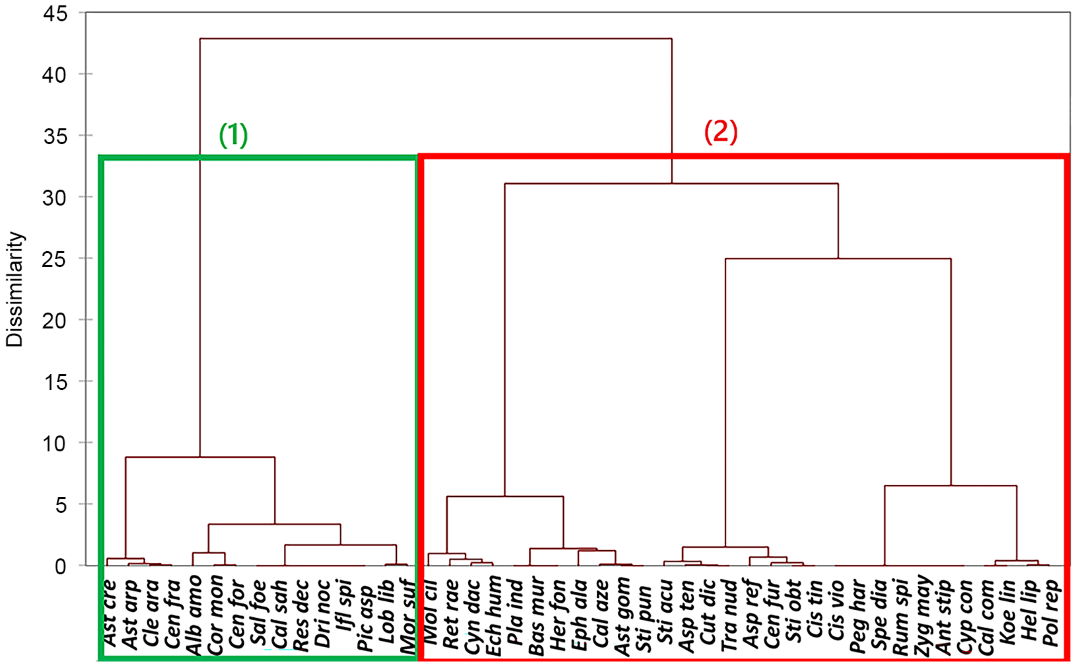

Fig. 7. Species similarity in the El Oued Oasis (source: Authors' own elaboration)

gens, cited by Chehma and Huguenin (2017) in the Algerian northern Sahara, *Retama raetam*, reported by Ward et al. (1993) as a plant typical of sandy habitats in the Negev desert in the Middle East, and finally, *Bassia muricata*, known to grow in sandy habitats in northern Egypt (Abd-El Gawad et al., 2020). The sites studied in the El Oued oases include the Al Alenda site (south-western area) and the Debila site (north-eastern area); by contrast, the Wermes site (north-western area) has sparse, degraded vegetation. The second group of species (group 2 in Fig. 7) concerns the Nakhla site, located to the south-east of the study area, containing species favoring fine sand, sandbanks and dunes such as: *Calabota saharae* found at the foot of the dunes and sandy pile cited by Benmerzoug (2022), *Centropodia fragilis* which is a common perennial herb on Nabkhas as cited by Elmefregy and El-Sheikh (2020), and *Cleome arabica* an annual herb, abundant in sandy environments (Ladhari et al., 2020). We note that this site belongs to a particular anthropogenic perimeter with intensive agricultural activity: the Ghout, which is a natural hydro-agrarian system (Khebizi et al., 2023). These areas can be considered as depressions that often serve as collection points for materials transported by wind and water stagnation (Belkhodja et al., 2021). In general, vegetation in the oasis areas of El Oued is characterized by low diversity and low density, composed of spontaneous plants adapted to the edaphic and climatic conditions of the region. These plants generally exhibit rapid growth, small size, and specialized adaptations (Halis et al., 2019).

Effect of environmental factors on vegetation

Principal component analysis (PCA) of plants and their environments in the El Oued Oasis explains 72.12% of the variability in the data (Fig. 8). It illustrates and highlights the distribution of plant species in the studied areas, as well as the environmental variables represented by soil properties, pH, electrical conductivity and silt content, where four groups are identified (Fig. 8).

In the biplot above, we deconstructed and presented the various correlations between the four sites, edaphic types and plant groupings, according to their ecological affinities and needs (Fig. 8).

These results highlight the close relationship between plant communities and soil properties in this arid environment. Debila group is characterized by

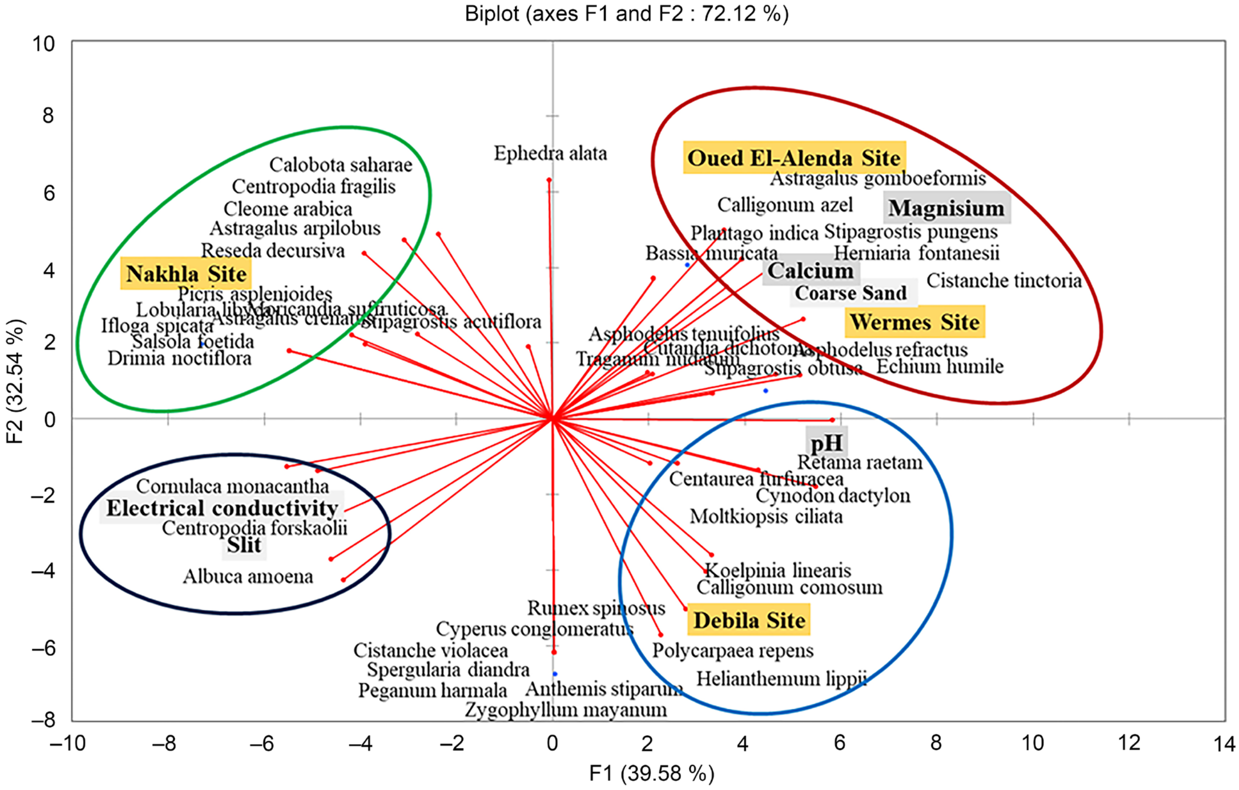

Fig. 8. Biplot of El Oued Oasis soil's parameters and species (with the sites marked in yellow, and the edaphic factors, in gray) (source: Authors' own elaboration)

a preference for low pH soils, unlike the Nakhla group (Fig. 8). Nakhla group has a higher pH (Fig. 8). Oued El Alenda and Wermes groups are negatively correlated with high electrical conductivity and silty soils, with the presence of halophytic plants. This group shows a preference for silt-rich soils (Fig. 8).

The similarity and correlation between groups of oasis species from the four sites in the southern region of El Oued – as shown in Figure 8 – presents two large, opposing, and negatively correlated groups, which are the group of plants on the right of the biplot, and which make up the sites of Oued El Alenda, Wermes and Debil, versus the group of plants from Nakhla, which is located on the left of the biplot (Fig. 8).

CONCLUSIONS

The inventory of vascular flora growing in four sites within the El Oued region (north-east Algeria) comprises 80 inventories (20 per site). It identified 45 species, dominated by the *Poaceae* family, followed by *Asteraceae* and *Fabaceae*. Therophytes were the most dominant life form. Chorologically, Saharo-Sindian, Mediterranean and endemic elements were dominant, reflecting the aridity of the areas studied and their high temperatures. The average disturbance index (DI) revealed a high level of degradation. The study showed that there are two large groups of plants in the southern region of El Oued which are negatively correlated, the first group is composed of the sites of Oued El-Alenda, Wermes and Debila; and the second group of plants is that of Nakhla. However, the loss of plant cover, combined with climate change and farming practices, is contributing to the loss of biodiversity. To preserve this natural heritage, integrated conservation programs are essential. These programs should include, on the one hand, protective measures such as the implementation of dissuasive laws to prevent the over-exploitation of natural resources, and on the other hand, community commitments such as the extension of awareness-raising programs for local communities on the preservation of these environments.

REFERENCES

Abd-ElGawad, A., El Gendy, A., El-Amier, Y., Gaara, A., Omer, E., Al-Rowaily, S., . . . Elshamy, A. (2020). Essential oil of *Bassia muricata*: Chemical characterization, antioxidant activity, and allelopathic effect on the weed *Chenopodium murale*. Saudi Journal of Biological Sciences, 27(7), 1900−1906. https://doi.org/10.1016/j.sjbs.2020.04.018

Abo Hatab, A.S., Al-Sodany, Y.M., Shaltout, K.H., Haroun, S.A., El-Khalafy, M.M. (2024). Saharo-Sindian endemic flora of Egypt: critical checklist, floristic analysis, habitats, and phytogeographic distribution. Phytotaxa, 647(2), 121–143. https://doi.org/10.11646/phytotaxa.647.2.1

Afokpe, P.M.K., Phiri, A.T., Lamore, A.A., Toure, H.M.A.C., Traore, R., Kipkogei, O. (2022). Progress in climate change adaptation and mitigation actions in sub-Saharan Africa farming systems. Cahiers d’Agricultures 31(4). https://doi.org/10.1051/cagri/2021037

Akshaya, K.V., Prangya, R.R., Eunseok, L., Puspendu, B., Jaeho, B., Rao, Y.S., . . . Yu, C. (2020). Biodiversity and sustainability. In: R. Surampalli, T. Zhang, M.K. Goyal, S. Brar, R. Tyagi (ed.), Sustainability: Fundamentals and Applications, USA Wiley, 255−275.

Belkhodja, N., Sari-Ali, A., Benabadji, N. (2021). Floristic diversity of Tamaricaceae of the northern region of western Algeria: dynamic and biological aspects. Algerian Journal of Environmental Science and Technology, 7(4), 2183–2189.

Benmerzoug, A. (2022). Therapeutic valorization of *Ononis angustissima* and *Genista saharae:* Biological activities (Ph.D. Dissertation). Ferhat Abbas University, Setif, Algeria.

Braun-Blanquet, J., Roussine, N., Nègre, R., Emberger, L. (1952). Les Groupements végétaux de la France méditerranéenne. Centre national de la recherche scientifique. Carte des groupements végétaux: Macabert frères.

Chehma, A., Huguenin, J. (2017). Le ‘Drinn’, Stipagrostis pungens. Caractéristiques floristiques et modes d’usage. Revue des BioRessources (Université Kasdi Merbah-Ouargla, Algérie), 7(1), 59−66.

Chytrý, M., Tichý, L., Holt, J., Botta-Dukát, Z. (2002). Determination of diagnostic species with statistical fidelity measures. Journal of Vegetation Science, 13(1), 79−90. https://doi.org/10.1111/j.1654-1103.2002.tb02025.x

Deghiche Diab, N., Deghiche, L., Kachai, S. (2016). Importance of spontaneous plants of steppe arid regions Ouled Djellel Biskra (Algeria). International Journal of Botany Studies, 1(3), 3−7.

Dobignard, A., Chatelain, C. (2013). Index synonymique de la flore d’Afrique du Nord: vol. 3: Dicotyledoneae: Balsaminaceae-Euphorbiaceae (C.J.B.G, Genève, ed. vol. 1, 2, 3, 4, 5): Editions des Conservatoire et Jardin botaniques.

El Hafian, M., Benlandini, N., Elyacoubi, H., Zidane, L., Rochdi, A. (2014). Étude floristique et ethnobotanique des plantes médicinales utilisées au niveau de la préfecture d’Agadir-Ida-Outanane (Maroc). Journal of Applied Biosciences, 81(1), 7198−7213. https://doi.org/10.4314/jab.v81i1.8

Elmefregy, M., El-Sheikh, M.A. (2020). Ecological status of sand binder plant white saxaul (Haloxylon persicum) at the managed area of Al-Qassim, Saudi Arabia: plant associations and population structure. Applied Ecology and Environmental Research, 18(2), 2781−2794. https://doi.org/10.15666/aeer/1802_27812794

Gillet, F. (2000). La phytosociologie synusiale intégrée: Guide méthodologique (Polycopie ed.). Neuchatel, France: Laboratoire d’écologie végétale et de phytosociologie, Institut Botanique, Université de Neuchatel.

Gnahoré, É., Koné, M., Soro, Y., N’guessan, Y.J., Bakayoko, A. (2020). Effets de l’anthropisation sur la diversité floristique à la périphérie du Parc National du Banco, Abidjan, Côte d’Ivoire. Afrique Science, 16(4), 167−180.

Halis, Y., Benhaddya, M.L., Khellou, M., Hadjoudj, M., Benhania, A. (2019). Floristic diversity of Saharan wetlands in the region of Oued Righ, northeastern Sahara of Algeria. International Journal of Biological and Agricultural Research, 1(1), 008−014.

Halis, Y., Benhaddya Mohammed, L., Bensaha, H., Mayouf, R., Lahcini, A., Belhamra, M. (2012). Diversity of halophyte desert vegetation of the different saline habitats in the valley of Oued Righ, Low Sahara Basin, Algeria. Research Journal of Environmental and Earth Sciences, 4(3), 308−315.

Hamel, T., Seridi, R., Belair, G., Slimani, A., Babali, B. (2013). Flore vasculaire rare et endemique de la peninsule de l’Edough (Nord-Est Algerien). Revue des Sciences et de la Technologie, 26(1), 65−74.

Jinlong, C., Pengju, Z., Isaac, D.A. (2025). Plant Diversity and Interspecific Interactions in Desert-Oasis Transition Zones: Insights from the Badain Jilin Desert. Sustainability, 17(3). https://doi.org/10.3390/su17031259

Khebizi, H., Benlaoukli, B., Chaouche, M., Chacha, B. (2023). The Ghout of El Oued in Algeria: A patrimony and a natural hydro-agrarian alarm system to advance. Larhyss Journal, 20(3), 7−24.

Khechekhouche, E.-A., Alia, Z., Khezzani, B., Guehef, Z.H. (2020). Study of the floristic composition of a wetland (chott Edhiba) in the Souf region (Northern Sahara, Algeria). International Journal of Sciences and Research, 76(3), 221−233. https://doi.org/10.21506/j.ponte.2020.3.16

Ladhari, A., Andolfi, A., Della Greca, M. (2020). Physiological and Oxidative Stress Responses of Lettuce to Cleomside A: A Thiohydroximate, as a New Allelochemical from Cleome arabica L. Molecules, 25(19), 1−18. https://doi.org/10.3390/molecules25194461

Larbi, R., Meddour, O.S., Bouxin, G., Meddour, R. (2021). Diversité floristique et phytogéographique de la cédraie du massif forestier d'Ait Ouabane (versant nord-oriental du parc national du Djurdjura, Algérie). Lejeunia, Revue de Botanique, 204(1), 1−15. https://doi.org/10.25518/0457-4184.2384

Loisel, R., Gamila, H. (1993). Traduction des effets du débroussaillement sur les écosystèmes forestiers et pré-forestiers par un indice de perturbation. Annales de la Société des Sciences Naturelles et d'Archéologie de Toulon et du Var, 45(2), 123−132.

Manob, D., Arijit, D., Suman, S. (2025). Development of a comprehensive framework for wetland ecosystem assessment and management. Geoscience Frontiers, 16(3). https://doi.org/10.1016/j.gsf.2025.102036

Marcon, E. (2024). Biodiversity measurements. Paris, France, Hal-AgroParisTech.

Marouane, A., Chenchouni, H., Belarouci, M.E.H., Bradai, L., Bouallala, M.H. (2021). Diversity of psammophyte communities on sand dunes and sandy soils of the northern Sahara desert. Journal of King Saud University, Science, 33(8), 101656−101656. https://doi.org/10.1016/j.jksus.2021.101656

Medjber Teguig, T. (2014). Etude de la composition floristique de la region du souf (Sahara septentrional Algerien). Algerian Journal of Arid Environment, 4(1), 53−59.

Merabti, K., Rebbas, K., Ait Hammou, M. (2022). Inventory of epiphytic lichens in the cedars of Ouanougha and Maadid (Mounts of Hodna, Algeria). Journal of EcoAgriTourism, 18(2), 11−24.

Monde, R., Wayne, T., Abel, R. (2024). The Integration of Land Restoration and Biodiversity Conservation Practices in Sustainable Food Systems of Africa: A Systematic Review. Sustainability, 16(8951). https://doi.org/10.3390/su16208951

Moualki, N., Boukrouma, N. (2021). The influence of environmental factors on the distribution and composition of plant species in Oued Charef dam, northeast of Algeria. Biodiversitas, 22(1), 346−353. https://doi.org/10.13057/biodiv/d220142

Neffar, S., Chenchouni, H., Si Bachir, A. (2013). Floristic composition and analysis of spontaneous vegetation of Sabkha Djendli in North-east Algeria. Plant Biosystems, 150(3), 396−403. https://doi.org/10.1080/11263504.2013.810181

Novaković-Vuković, M., Eremija, S., Lučić, A., Hadrović, S., Solomun, M.K., Blagojević, V., Košanin, O. (2019). Floristic composition of black pine forests on serpentinite in the territory of Serbia and Bosnia and Herzegovina (B&H). Applied Ecology and Environmental Research, 17(2), 4999−5010. https://doi.org/10.15666/aeer/1702_49995010

Ozenda, P. (2004). Flore et végétation du Sahara (3rd ed.). Paris, France, CNRS.

Prochazka, L.S., Alcantara, S., Rando, J.G., Vasconcelos, T., Pizzardo, R.C., Nogueira, A. (2024). Resource availability and disturbance frequency shape evolution of plant life forms in Neotropical habitats. New Phytologist, 242(2), 760−773. https://doi.org/10.1111/nph.19601

Quézel, P., Santa, S. (1962). Nouvelle flore de l'Algérie et des régions désertiques méridionales, 2nd ed., Paris.

Raunkiaer, C. (1934). The Life Forms of Plants and Statistical Plant Geography. Oxford University Press, London.

Sakhraoui, N., Boussouak, R., Metallaoui, S., Chefrour, A., Hadef, A. (2020). La flore endémique du Nord-Est algérien face à la menace des espèces envahissantes. Acta Botanica Malacitana, 45. https://doi.org/10.24310/abm.v45i0.6138

Skowera, B., Baranowska, A., Pokrývková, J. (2023). Variability of thermal and precipitation conditions in the area north-eastern Lublin region in the aspect of atmospheric drought risk in the period from 1971 to 2020. Acta Scientiarum Polonorum, Formatio Circumiectus, 22(4). https://doi.org/10.15576/ASP.FC/2023.22.4.15

Walter, J.M.N. (2006). Méthodes d'étude de la végétation. Méthode du relevé floristique, Deuxième partie: Université Louis Pasteur Strasbourg, France.

Ward, D., Olsvig-Whittaker, L., Lawes, M. (1993). Vegetation-environment relationships in a Negev Desert erosion cirque. Journal of Vegetation Science, 4(1), 83–94. https://doi.org/10.2307/3235735

Zemmar, N., M'hammedi Bouzina, M., Ababou, A., Belhacini, F., Hadidi, D. (2020). Analysis of the floristic diversity in a southern Mediterranean ecosystem. Case of Bissa forest, Chlef (Algeria). Botanica Complutensis, 44, 19‒28. https://doi.org/10.5209/bocm.64447

Zhengrong, D., Mingxia, N., Ya, T., Sobota, M., Jianxin, X. (2021). Impact of Climate Change and Human Activities On the Sustainable Development of Xinjiang Aksu Oasis (China). Acta Scientiarum Polonorum, Formatio Circumiectus, 20(2), 3‒18. https://doi.org/10.15576/asp.Fc/2021.20.2.3

IPNI. International Plant Names Index. Royal Botanic Gardens (UK), Harvard University Herbaria & Libraries (USA) and Australian National Botanic Gardens (Australia). http://www.ipni.org

ANALIZA FLORYSTYCZNA LOSOWO WYBRANYCH ROŚLIN SAHARYJSKICH: STUDIUM PRZYPADKU POŁUDNIOWEGO REGIONU OAZOWEGO EL OUED W ALGIERII

ABSTRAKT

Cel badania

Północno-wschodnia Algieria, obejmująca suchy region Sahary z rzadkim ekosystemem roślinnym, była przedmiotem analizy fitoekologicznej w celu inwentaryzacji gatunków roślin i czynników wpływających na losową sukcesję roślin. Pobrano próbki z czterech stanowisk oazowych w południowym regionie El Oued.

Materiały i metody

Przeprowadzono analizę bogactwa gatunków, form życia, chorologii, stopnia pokrycia roślinnością, rozmieszczenia przestrzennego i podobieństwa. Dokonano oceny wskaźnika zaburzeń pokrycia roślinnością, a także wpływu zasolenia gleby i pH na rośliny halofityczne. Badanie to, przeprowadzone w latach 2019–2023, obejmowało 80 badań. Analizę statystyczną wykonano przy użyciu Xlstat V16.

Wyniki i wnioski

Zidentyfikowano 45 gatunków, podzielonych na 37 rodzajów i 19 rodzin. Najbardziej rozpowszechnione były trawy (Poaceae), a następnie astrowate (Asteraceae) i bobowate (Fabaceae). Wśród form życia dominowały terofity i chamefity. Pod względem chorologicznym najliczniej reprezentowane były gatunki saharo-sindyjskie, a następnie endemiczne gatunki południowego regionu Morza Śródziemnego i Sahary. Wskaźnik zaburzeń ujawnił znaczną degradację gatunków zielnych, szczególnie tych związanych z pierwotną florą. Analiza numeryczna wykazała, z jednej strony, postępującą utratę niektórych gatunków, prawdopodobnie z powodu działalności antropogenicznej, takiej jak nadmierny wypas przez wędrujące stada wielbłądów, a także zmiany klimatu, z drugiej strony zaś ujawniła odrębne grupy próbek roślin odzwierciedlające wpływ czynników środowiskowych, a także oznaki degradacji z powodu działalności człowieka.

Słowa kluczowe: degradacja, flora, północna Sahara, El-Oued