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*Original Research*

# Floristic Characterization of Steppe Grouping of *Lygeum spartum* L. in the Naâma Region (Western Algeria)

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## Abstract

*Lygeum spartum*, a steppe formation in the arid Mediterranean region, can be found in the high Oranian steppe plains of Naâma. A spring 2020 phytoecological study was conducted on a steppe community in the Naâma region of western Algeria. This group occupies vast steppe areas in the high plains of Oran. This study used qualitative and quantitative floristic analysis to examine ecological factors. This study conducted 50 phytoecological surveys to evaluate the formation's floristic composition and ecology. This method allows for the inventory and ecological characterization of natural vegetation in relation to edapho-climatic conditions. The data was analyzed using Factor Correspondence Analysis. The floristic analysis shows less than 20% vegetation cover. Quantitative analysis shows a diverse floristic composition of 47 species from 19 families. The identified plant species mainly belong to the Poaceae and Asteraceae families. Esparto grass accounts for 41% of the floristic composition. The biological spectrum includes therophytes, chamaephytes, and hemicryptophytes. The biogeographical components show 13 taxa with Mediterranean affinity. Floristic data shows three plant subgroups. (i) *Lygeum spartum* and *Caroxylon vermiculatum* dominate these gypso-halophyte steppes. (ii) Psammophytes like *Thymelaea microphylla* dominate these degraded steppes. (iii) Therophytes like *Atractylis caespitosa, Peganum harmala,* and *Plantago albicans* characterize another type of degraded steppe. The esparto group is ecologically versatile due to its climate and soil adaptability. This group is prominent in the South Oranian steppes.

**Keywords:** *Lygeum spartum* L., floristic characterization, steppe grouping, statistical analysis, Naâma

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## Introduction

The Mediterranean steppe is characterized by a relatively low and open vegetation structure, primarily composed of xerophytic plants growing in tufts. This growth pattern often results in sparse vegetation cover with varying degrees of bare soil. It exhibits diverse physiognomies and structures, including herbaceous grasses and woody sub-shrubs. The region is characterized by various types of steppes, including graminaceous, shrubby, crassulescent, succulent, and pulvinate formations, either in pure or mixed compositions [1]. The steppes in North Africa are characterized by their low and expansive nature, primarily consisting of grasses such as *Macrochloa tenacissima, Stipellula parviflora*, and *Lygeum spartum*. These steppes may also contain perennial chamaephytes like *Artemisia herba-alba, Artemisia campestris*, and *Helianthemum hirtum*. These plant communities are further enriched by numerous annual species, often of considerable diversity [2]. The steppe region in Algeria holds a prominent position along the North-South axis. According to Boucherit [3], the region exhibited a significant range of ecological factors, resulting in a diverse landscape. Physiognomic, climatic, and edaphic factors largely determine the dominant characteristics of plant formations in this area. Perennial grassy steppes, including *Macrochloa tenacissima*, *Lygeum spartum*, *Stipagrostis pungens*, and *Stipellula parviflora*, as well as woody chamaephytic steppes characterized by *Artemisia herba-alba* and *Hammada scoparia*, can be observed. Additionally, psammophile or halophile steppes are present, exhibiting spaced tufts with a frequent and often irregular distribution pattern [4-7].

The *Lygeum spartum* grass steppe is a prominent element of the Algerian steppe and is considered the second most prevalent type of steppe, following the *Macrochloa tenacissima* steppe. It is estimated to cover an area of approximately 2 million hectares [8]. The plant thrives in arid and semi-arid bioclimatic zones, specifically on sandy and saline soils [2, 6]. Esparto grass (*Lygeum spartum*) is a resilient and drought-tolerant angiosperm plant, commonly known as "Sparte" in French, "Sennagh" in Arabic, and "Esparto basto" in Spanish. It falls under the class Liliopsida and the family Poaceae and represents the sole species within the Lygeae tribe and the *Lygeum genus* [9, 10]. Steppe rangelands have faced persistent degradation for over three decades, primarily due to the convergence of various natural factors, such as recurrent droughts and climatic aridity, as well as anthropogenic factors, including overgrazing and clearing. This phenomenon, characterized by regressive dynamics, has significant implications for the decline in biological capacity and the disturbance of ecological and socioeconomic equilibria [3, 7, 11-13]. In light of the decline in biological capacity, augmenting the scientific knowledge base about steppe formations is imperative. The primary aim of this study is to investigate the *Lygeum spartum* facies to assess the existing ecological condition of this steppe formation and evaluate its floristic composition using quantitative and qualitative analysis methods such as presence-absence, frequency, and biological types. The study was conducted in the Naâma region.

## Materials and Methods

### Presentation of the Study Area

#### *Study Area*

The study area is in the wilaya of Naâma, part of Algeria's high steppe plains (Fig. 1). It encompasses nearly 3 million hectares. The wilaya of Naâma, like other steppe wilayas with arid ecosystems, is characterized by natural resources, poor and skeletal soils, and several important plant formations based on esparto grass (*Macrochloa tenacissima* (L.) Kunth), esparto (*Lygeum spartum* Loefl. ex L.), Drinn (*Stipagrostis pungens* Desf. De Winter), white mugwort (*Artemisia herba-alba* Asso), and Remth (*Hammada articulata* (Moq.) O.Bolòs & Vigo).

The region of Naâma has a Mediterranean climate with a decreasing bioclimatic gradient from north to south, ranging from semi-arid to lower arid and pre-Saharan. Precipitation is low and irregular, ranging from 190-250 mm/year, with a fairly long dry period of 6-7 months, characterized by low temperatures generally falling below -4°C. Temperature data show cold winters (-0.3ºC<mean daily minimum <2ºC), and very hot summers (32ºC<mean daily maximum <39ºC). This coincides with the meso- and thermo-Mediterranean vegetation belts and explains its belonging to the arid bioclimatic zone [3, 7, 14-16].

The current research was carried out in the steppe plains. Its goal is to use a phytoecological approach to investigate the esparto grass group (*Lygeum spartum*) and its floristic and ecological characterization. The study area is located 10 km west of Naâma (National Road No. 35) in the direction of Ain Benkhelil municipality. At a longitude of 0°31' West and a latitude of 33°18' North, the average elevation is about 1145 m. It should be noted that the study area is not particularly hilly and has only a slight incline.

### Plant Sampling and Data Analysis

The goal of the floristic analysis is to determine the floristic composition and structure of the vegetation and to describe the ecological characteristics of the natural environmental factors of the esparto grass plant group (*Lygeum spartum*). We consulted several works in the steppe space for conducting our work: [2, 3, 17]. Following the vegetation description and inventory, we conducted a floristic inventory and measurements and/or estimates of stationary ecological data using phytoecological surveys. Following systematic sampling,

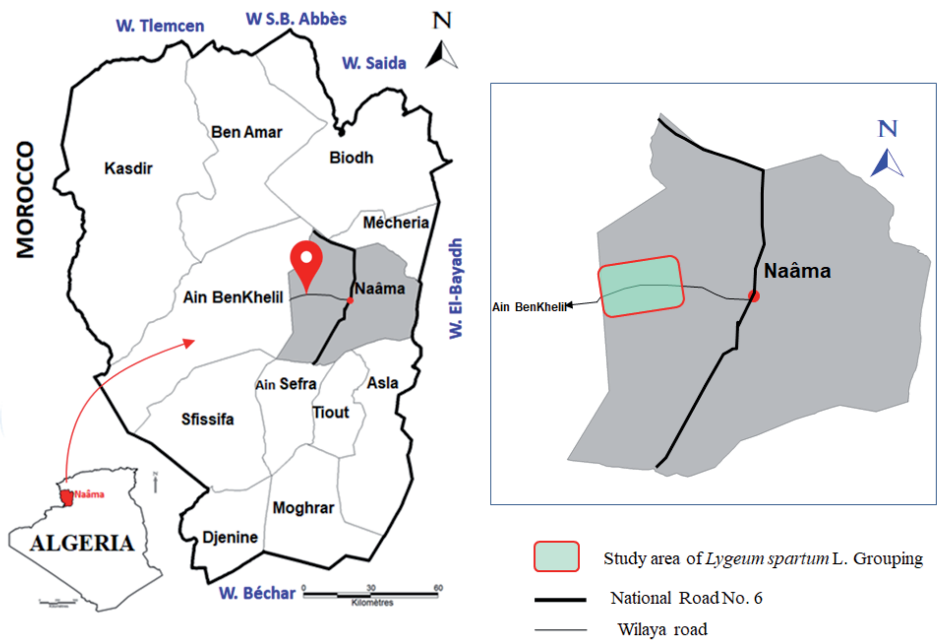


Fig. 1. Geographical location of the study area in the Naâma region.

63 phytoecological surveys were conducted during the vegetation's good phenological period (April to May 2020). We used the minimal area method combined with transects to conduct the phytosociological surveys [18, 19]. The main goal is to create a list of species in a reduced elementary surface and look for new species in increasing surfaces whose area doubles from one to the next. To facilitate the quantitative study, we chose a minimum area of 100 m². The small area allows for identifying all species encountered and creating a floristic list of homogeneous communities [2, 5, 14].

The calculation of biodiversity indicators is based on a quantitative (coverage, floristic composition, and specific richness) and qualitative (presence-absence, frequency, biological types, biogeographical types) analysis of the floristic composition from the steppe grouping of *Lygeum spartum*.

Coverage is the percentage of the ground surface that would be covered if the aerial organs of the species were projected vertically onto the ground [20].

The qualitative characterization of floristic composition is a stage of species enumeration for each biological, systematic, and phytogeographical type, and it was performed on all of the species inventoried.

The processing of floristic data was done by the Minitab software version 16.0. We used a multidimensional CA analysis to visualize the affinities and to highlight the factors that contribute most to the distribution of species in the *Lygeum spartum* steppe group. The CA and HAC analyses correspond to a factorial map of 63 floristic statements and 47 species.

This method of statistical data analysis makes it possible to describe the dependence or correspondence

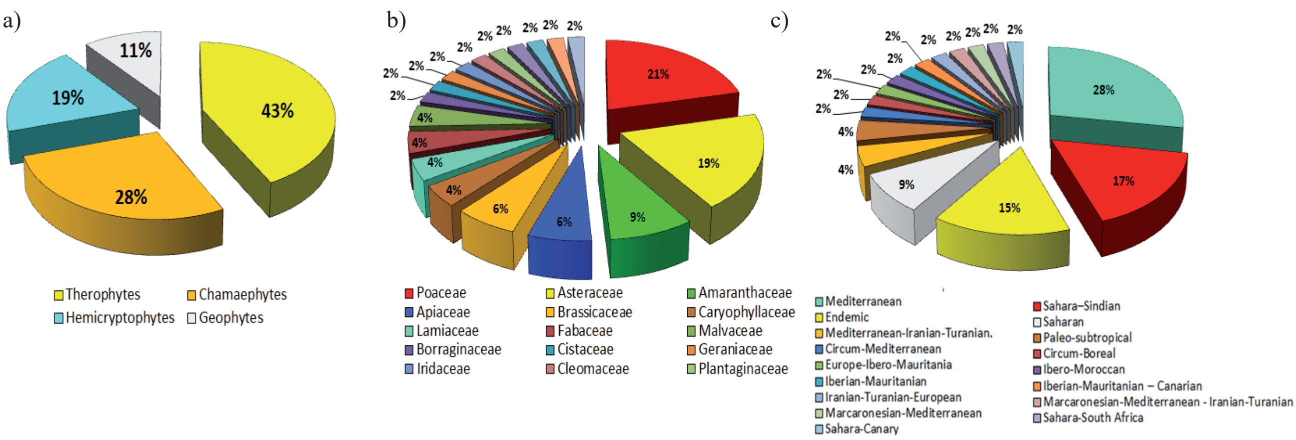


Fig. 2. Quantitative characterization: a) biological, b) systematic, and c) biogeographic.

(contingency links) between variables by providing a factorial representation space common to both variables and individuals [3, 14].

## Results and Discussion

### Floristic Analysis

*Qualitative Aspect*

*Coverage*

The coverage rate is less than 25%, and the *Lygeum spartum* tufts are well-developed, especially in humid areas. According to Benaradj et al. [21, 22] and Guemou et al. [23], this low rate is affected by a variety of factors, including an arid climate, state of degradation, season, psammophytic plant groups, and anthropization (overgrazing, clearing).

*Floristic Richness*

There are 47 companion species in the esparto assemblage. According to Daget and Poissonet [18], the floristic composition of the study group is diverse, with 40 to 50 species, 19 of which are ephemeral (annual) plants. The variation in floristic richness in the arid zone is primarily determined by the number of annual species present in relation to biotope conditions and synergistic action linked to climatic (aridity), edaphic (texture and chemical nature of the soil), and anthropic determinisms [24-26]. Indeed, the study area's arid climate, drought, silting, and desertification have a negative impact on floristic richness [3, 7].

Qualitative aspect of the floristic composition

*Life Forms*

Therophytes have a clear predominance over other forms of life in the global biological spectrum, followed by Chamaephytes (28.26%) and Hemicryptophytes (19.57%). Finally, there are the Geophytes (10.87%). As a result, the biological spectrum is classified as Th>Ch>He>Ge (Table 1 and Fig. 2a)).

Several studies indicate that as environmental aridity increases, the prevalence of therophytes rises [3, 27-30]. This phenomenon, or therophytisation, represents a vital adaptation strategy, allowing flora to withstand harsh arid climatic conditions.

Chamaephytes are the second most adapted to low temperatures and aridity and are better adapted to drought. This adaptation causes the leaf surface to shrink and the root system to grow (*Thymelaea microphylla, Marrubium desertii*). The increase in woody chamaephytes has been observed in Poaceae formations due to overgrazing by sheep and cattle [1, 5, 31]. On the other hand, chamaephytization seems to be closely linked to the anthropogenic degradation of the environment (grazing) with the proliferation of psammophyte species such as *Thymelaea microphylla,* thorny species such as *Echinops spinosissimus* and *Atractylis serratuloides,* and unpalatable species avoided by livestock, namely *Caroxylon vermiculatum* and *Noaea mucronata*.

*Herniaria fontanesii, Plantago albicans, Echium trygorrhizum, Salvia aegyptiaca, Onopordum acaulon*, and geophytes are the least represented. *Lygeum spartum* occurs as a hemi-cryptophyte in matorral undergrowth but as a geophyte in arid steppe in Algeria's high plains and Saharan Atlas [3, 9]. The five geophytes include *Lygeum spartum, Stipellula parviflora, Stipagrostis pungens*, *Stipellula capensis* and *Moraea sisyrinchium*. This poverty in geophytes is generally explained by climate aridification [1, 31, 32]. This finding can be explained by the unfavorable substrate conditions (salinity, insufficient organic matter). This result is linked to climatic factors on the one hand and the impact of humans and their herds on the other [33, 34]. These biological types are a combination of morphological characteristics resulting from the adaptations of species to environmental conditions (edapho-climatic) [2, 14, 35].

*Systematic List*

Table 1 summarizes the results of the floristic composition. The analysis of the overall phytodiversity of the steppe grass group with *Lygeum spartum* resulted

Table 1. List of species of the steppe group with esparto grass (*Lygeum spartum*).

| No. | Species | Family | Life form type | Biogeographic type |
|---|---|---|---|---|
| 1 | *Lygeum spartum* Loefl. ex L. | Poaceae | G | W. Mediterranean |
| 2 | *Caroxylon vermiculatum* (L.) Akhani & Roalson | Amaranthaceae | C | Sah- Mediterranean |
| 3 | *Stipagrostis pungens* (Desf.) De Winter | Poaceae | G | Sahara-South Africa. |
| 4 | *Marrubium deserti* (de Noé) Coss. | Lamiaceae | C | Saharan |
| 5 | *Peganum harmala* L. | Nitrariaceae | T | Iran-Tur-Eur. |
| 6 | *Thymelaea microphylla* Coss. & Durieu ex Meisn. | Thymeleaceae | C | Endemic N.A. |
| 7 | *Atractylis serratuloides* Sieber ex Cass. | Asteraceae | C | Saharan |

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| | | | | |
|---|---|---|---|---|
| 8 | *Echinops spinosissimus ssp. spinosus* Greuter | Asteraceae | T | S. Med. Sah. |
| 9 | *Stipellula parviflora* (Desf.) Röser & Hamasha | Poaceae | G | Mediterranean. |
| 10 | *Stipellula capensis* (Thunb.) Röser & Hamasha | Poaceae | G | Circum-Med. |
| 11 | *Helianthemum lippii* (L.) Dum.Cours. | Cistaceae | C | Med. Sah. |
| 12 | *Herniaria fontanesii* J.Gay | Caryophyllaceae | H | Ibero-Maur-Cen. |
| 13 | *Onopordum acaulon* L. | Asteraceae | T | W Mediterranean |
| 14 | *Cleome amblyocarpa var. glandulosa* (Forssk.) Botsch. | Cleomaceae | T | Sah-Sind. |
| 15 | *Hordeum murinum subsp. leporinum* (Link) Arcang. | Poaceae | T | Circum-bor. |
| 16 | *Plantago albicans* L. | Plantaginaceae | H | Mediterranean |
| 17 | *Avena barbata* Pott ex Link | Poaceae | T | Med.-Iran-Tour. |
| 18 | *Avena sterilis L.* | Poaceae | T | Macar.Med.-Iran-Tour |
| 19 | *Salvia aegyptiaca L.* | Lamiaceae | T | Sah.Sind. |
| 20 | *Launaea nudicaulis* (L.) Hook.f. | Asteraceae | T | Med. Sah.-Sind. |
| 21 | *Schismus barbatus* (Loefl. ex L.) Thell. | Poaceae | T | Macar-Med. |
| 22 | *Morettia canescens* Boiss. | Brassicaceae | T | Sah-Sind |
| 23 | *Astragalus mareoticus* Delile | Fabaceae | H | Sah-Can. |
| 24 | *Atractylis carduus* (Forssk.) C.Chr. | Asteraceae | T | Saharan |
| 25 | *Cutandia dichotoma* (Forssk.) Trab. | Poaceae | T | Mediterranean. |
| 26 | *Bromus fasciculatus* C.Presl | Poaceae | T | Paleo-sub-trop. |
| 27 | *Malva aegyptia* L. | Malvaceae | H | Sah.-Sind. Mediterranean |
| 28 | *Noaea mucronata* (Forssk.) Asch. & Schweinf. | Amaranthaceae | C | Med.-Iran-Tour. |
| 29 | *Echium trygorrhizum* Pomel | Boraginaceae | H | End. Saharan |
| 30 | *Anacyclus monanthos subsp. cyrtolepidioides* (Pomel) Humphries | Asteraceae | T | Endemic N.A. |
| 31 | *Atractylis caespitosa* Desf. | Asteraceae | H | Ibero.-Maur. |
| 32 | *Moraea sisyrinchium* (L.) Ker Gawl. | Iridaceae | G | Paleo-subtropical. |
| 33 | *Ziziphus lotus* (L.) Lam. | Rhamnaceae | P | Mediterranean. |
| 34 | *Reichardia tingitana* (L.) Roth | Asteraceae | T | Ibero.-Mar. |
| 35 | *Pallenis hierichuntica* (Michon) Greuter | Rosaceae | T | Sah- Sindian. |
| 36 | *Erodium microphyllum* Pomel | Geraniaceae | H | Endemic |
| 37 | *Anabasis oropediorum* Maire | Amaranthaceae | C | Sah- Sindian. |
| 38 | *Deverra triradiata subsp. intermedia* (L.Chevall.) Pfisterer & Podlech | Apiaceae | T | Endemic N.A. |
| 39 | *Malva parviflora* L. | Malvaceae | T | Mediterranean |
| 40 | *Centaurea calcitrapa* L. | Asteraceae | T | Euro-Mediterranean |
| 41 | *Teucrium campanulatum* L. | Apiaceae | T | W. Mediterranean |
| 42 | *Medicago laciniata* (L.) Mill | Fabaceae | H | Med. Sah. Sindian |
| 43 | *Launaea capitata* (Spreng.) Dandy | Asteraceae | H | Sah. Mediterranean |
| 44 | *Ferula longipes* Coss. ex Bonnet & Maury | Apiaceae | T | Endemic N.A. |
| 45 | *Ononis natrix* L. | Fabaceae | T | Mediterranean |
| 46 | *Eruca vesicaria* (L.) Cav. | Brassicaceae | T | Mediterranean |
| 47 | *Bassia muricata* (L.) Asch | Amaranthaceae | T | Saharan |

in the identification of 47 taxa from 19 families and 41 genera.

These systematic analyses reveal a more nuanced diversity in the study area's families and genera. Two families dominate the floristic esparto grass composition (*Lygeum spartum*) in the study area. The Poaceae family is the most numerous, with 10 species (21%), followed by the Asteraceae family with 9 species (19%). These two families alone account for 40% of all species. This dominance is justified because they are cosmopolitan families that are well-known all over the world. They are also better adapted to changes in environmental conditions and anthropogenic pressures (overgrazing) in these environments (Fig. 2b)).

The high proportion of Poaceae in the study area can be explained by the fact that these taxa have a high possibility of tillering and a faster regrowth rate after the herds have passed. It is followed by tri-specific families (3 species), such as Apiaceae, Brassicaceae, Fabaceae, and Amaranthaceae, as well as di-specific families (2 species), such as Caryophyllaceae, Lamiaceae, and Malvaceae. Boraginaceae, Cleomaceae, Cistaceae, Geraniaceae, Iridaceae, Plantaginaceae, Rhamnaceae, Rosaceae, Thymeleaceae, and Zygophyllaceae, on the other hand, are represented by a single species. The families present in the floristic composition have changed dramatically, with a significant decrease in Fabaceae (a single species), resulting in a decrease in the pastoral quality of the rangelands [2, 21, 36].

### *Biogeographic Plan*

*Lygeum spartum*'s biogeographical affinity is described as a West Mediterranean species by Quézel and Santa (1962, 1963). It is typical of the high steppe plains' vegetation. The phytogeographical spectrum of the listed species (Table 1) reveals a notable dominance of Mediterranean taxa, with 13 species accounting for 28.26% of the total floristic composition. *Stipellula parviflora, Plantago albicans, Ziziphus lotus, Cutandia dichotoma, Ononis natrix*, and *Malva parviflora* are a few examples. This confirms the floristic uniqueness and characteristics of our study area's North African steppes. The presence of Saharo-Sindian species (17.39%) in the floristic composition would most likely reflect the climate aridification [37, 38]. Thus, endemic species are represented by 7 species (15.22%), the majority of which are North African, 3 Saharan species (5.88%), Med-Iran-Tour (4.35%), and Paleo-subtropical (4.35%) (Fig. 2c)).

The other biogeographical components (multi-regional elements) are represented by a single species (Circum-Mediterranean, Circum-boreal, Euro-Mediterranean, Ibero-Moroccan, Ibero-Mauritanian, Ibero-Mauretanian-Canarian, Iranian-Touranian-European, Macaronesian-Mediterranean-Irano-Touranian, Macaronesian-Mediterranean, Sahara-South Africa and Sahara-Canarian).

Despite their low participation, they contribute to the diversity and richness of the region's plant genetic potential. This group is less diversified biogeographically because it is very anthropized (overgrazing and cultivation) and thus threatened by the silting plague affecting the entire steppe region of Naâma. These results would probably confirm an evolution of biogeographic types under the influence of climate change and ecological conditions that cause the dissemination of plant species by anemochory and zoochory [39]. This analysis appears to present a disproportion between the dominant phytogeographical elements (Mediterranean and Endemic) and the other phytogeographical types. The biogeographical affinities of the species identified confirm the arid nature of the environment [14, 40].

### *Floristic Data Processing*

Table 2 displays the eigenvalues of the correlation coefficient matrix, the percentage of explained variance, and the cumulative variance by axes. We limited our interpretation to the first three factorial axes, which absorb more than 49.94% of the information. This variation in information allowed us to identify the major ecological factors influencing the diversification of the floristic composition characteristic of the groups with *Lygeum spartum*. The inertia rates of the three axes are 20.86%, 16.51%, and 12.56%, respectively. The cloud's structure is relatively good along the first two axes.

On the floristic and physiognomic plans, the ascending hierarchical classification separates three distinct classes (Fig. 3).

– Class 1: This class is dominated by the presence of the study species, *Lygeum spartum*. It determines the physiognomy of the landscape (95% of floristic records) due to its high frequency and abundance coefficient. Esparto grass (*Lygeum spartum*) is a grass that is both a xerophyte and a gypsophyte. It is mostly found in open areas (Fig. 3) and becomes invasive on gypsum marls [41]. It can occasionally be found between the esparto steppes and croplands in an intermediate dynamic stage. *Moraea sisyrinchium* appears to have given way to *Lygeum spartum* due to environmental degradation and silting [5, 42].

On the edaphic level, esparto develops on sandy surface horizon soils with wind contributions, a low rate of organic matter, and the presence of a significant rate of limestone ($CaCO_3$) at very shallow depths [43, 44]. This species (*Lygeum spartum*) becomes very abundant and replaces the esparto facies when the calcareous crust becomes slightly saline.

Table 2. Eigenvalues and percentages of inertia.

| Factor axis | F1 | F2 | F3 |
|---|---|---|---|
| Own values | 0.5363 | 0.4244 | 0.3230 |
| Inertia rate (%) | 20.8641 | 16.5107 | 12.5666 |
| Total in (%) | 20.8641 | 37.3748 | 49.9414 |

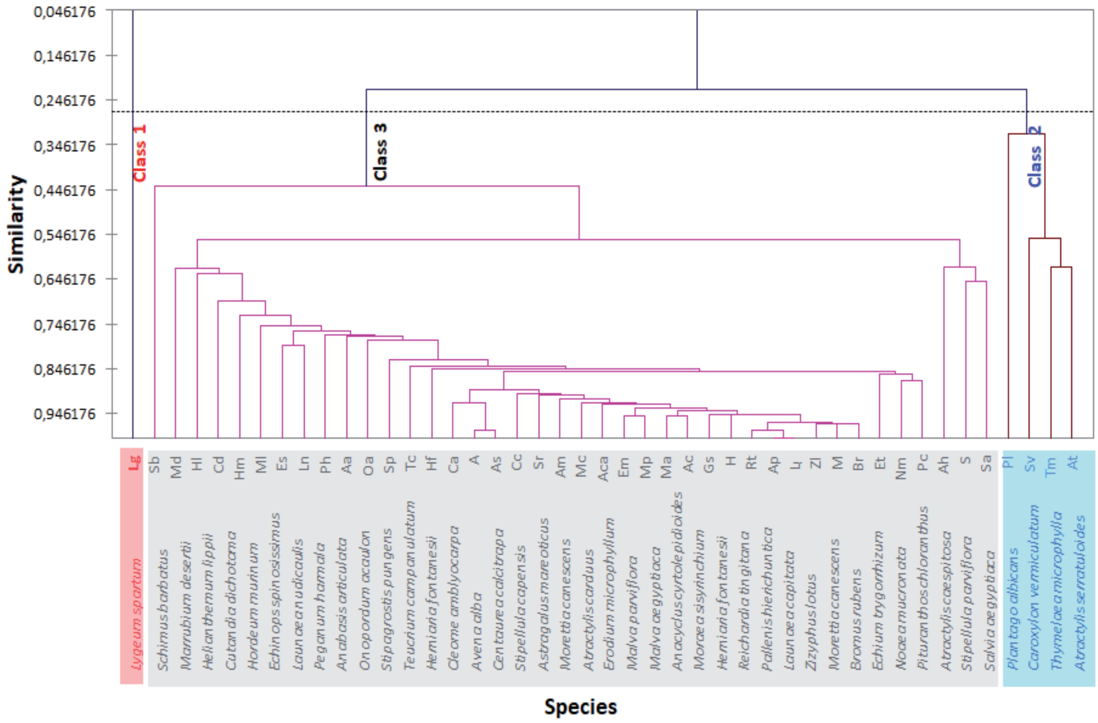


Fig. 3. Dendrogram of the hierarchical classification (HAC) of the floristic composition of esparto grass (*Lygeum spartum*).

Benaradj et al. [9, 45] indicated that the *Lygeum spartum* steppe develops on accumulation glacis or in depressions, on deep soils with a sandy-loamy and/or sandy texture, corresponding mainly to Sierozems formed from sandy accumulations on xeric calcimagnesic soils, with a shallow calcareous crust and a silty-sandy texture.

– Class 2: *Caroxylon vermiculatum*, *Thymelaea microphylla, Atractylis serratuloides*, and *Plantago albicans* are the four most common species in the Class 2 group. These companion species are found in more than half of floristic surveys. However, the species that make up the floristic composition of this formation are thought to be drought-tolerant xerophytes. They are degradation indicator species because they are toxic or thorny and are disliked by animals [46]. This abundance of unpalatable species (low fodder value) that are ignored by herds, such as *Atractylis serratuloides* and *Caroxylon vermiculatum*, indicates significant degradation caused by overgrazing [47, 48]. The presence of psammophytic species of mediocre pastoral quality, such as *Thymelaea microphylla*, corresponds to degraded vegetation in a sandy environment with wind inputs [9, 49].

– Class 3: This class is characterized by the following highly diverse floristic composition (*Stipagrostis pungens, Stipellula capensis, Bromus rubens, Cutandia dichotoma, Avena sterilis, Echinops spinosissimus, Anabasis articulata, Launaea capitata, Launaea nudicaulis, Helianthemum lippii,* etc.).

As a result, the floristic composition is quite diverse, faithfully reflecting seasonal variations through a succession of different biological types (therophytes, chamaephytes, geophytes). The vegetation distribution reflects all of the conditions that exist there, and the ecological significance of the presence of an indicator plant species varies greatly with the importance of its requirements [6, 37, 50]. It appears that the distribution of some *Lygeum spartum* companion species is primarily determined by edaphic conditions, as well as physical and chemical factors [7, 51]. The establishment of psammophyte species (*Thymelaea microphylla* and *Stipagrostis pungens*) is facilitated by surface silting or the accumulation of wind-blown sand deposits. In other cases, less palatable species such as *Noaea mucronata, Atractylis serratuloides*, and *Caroxylon vermiculatum* can replace these facies [2, 52].

We observe that the positive side of the factorial axis (F1) includes the following species: *Stipagrostis pungens*, *Stipellula capensis*, *Morettia canescens*, *Malva parviflora*, *Onopordum acaulon*, *Atractylis serratuloides*, *Thymelaea microphylla,* and *Echium trygorrhizum*. As a result, this axis represents a decreasing silting gradient. Furthermore, the superficial silting of biotopes favors their enrichment in psammophile species, which can serve as a link. The presence of species associated with the steppe formation with *Lygeum spartum*, such as *Asteriscus pygmaeus*, *Moraea sisyrinchium*, *Pallenis hierichuntica,* and *Anabasis articulata*, constitutes the negative side of the 1/2 axis. This axis represents the beginning of steppization and an increasing gypsophila gradient.

The study of the ecological structure of the *Lygeum spartum* group in the Naâma steppe region reveals that species groups are differentiated. This classification is based on a climatic and aridity gradient, an edaphic gradient associated with a decrease in the soil physical,

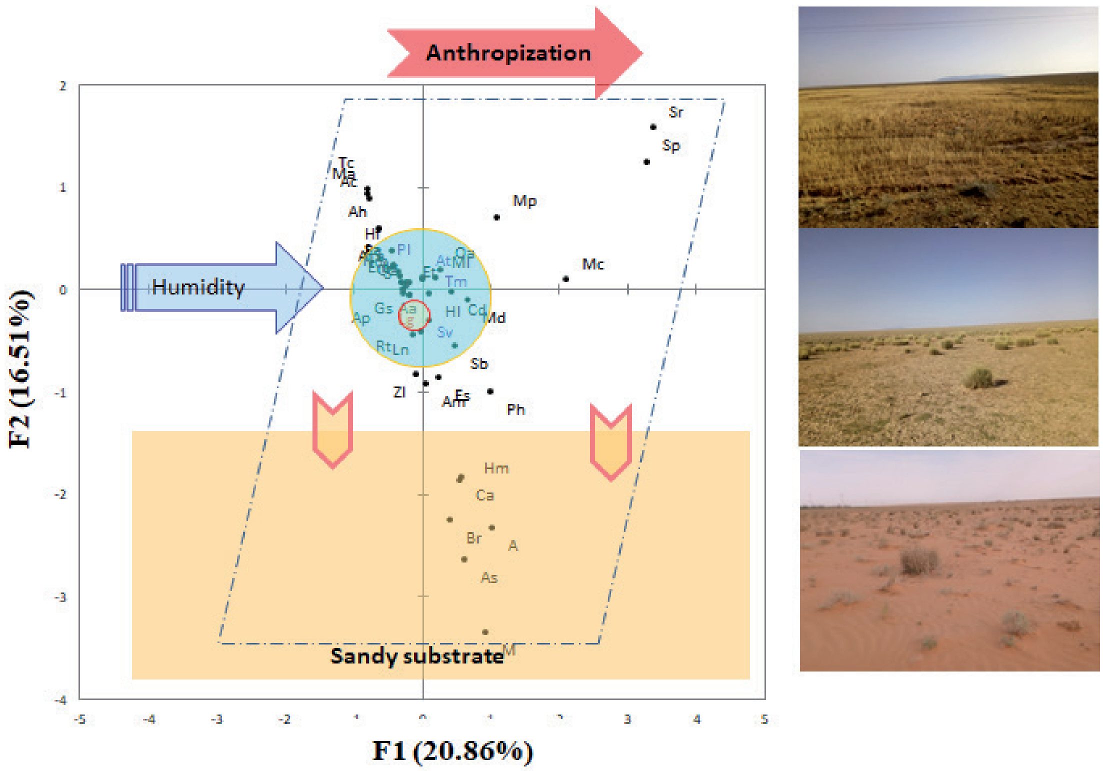


Fig. 4. Projection of various species on the factorial axes (F1/F2).

water, and nutrient potential, and an anthropogenic gradient [2, 53, 54]. This study found that the synergistic action of aridity and anthropic action resulted in significant changes at the vegetation level; these two factors appear to support most of the factorial axes (F1, F2, and F3) (Fig. 4).

The floristic data analysis revealed a regressive dynamic of the vegetation of the *Lygeum spartum* steppe grouping. This has led to a significant change in the accompanying composition and a reduction in plant cover, ranging from species characteristic of *Lygeum spartum* steppes to other indicators of degradation based on *Stipagrostis pungens, Thymelaea microphylla, Atractylis serratuloides, Caroxylon vermiculatum,* and *Peganum harmala*. In addition, it depends on the local climate, where surface silting is very noticeable in the study sites [3, 4, 49]. Pastoral pressure and harsh climatic conditions explain the steppe populations' regressive dynamic with *Lygeum spartum*. Overgrazing significantly impacts vegetation qualitatively and quantitatively. This overgrazing must have played a role in the decline of esparto grass, but the drought's impact would have been far more significant [5, 37, 55-57].

Thus, despite its adaptability, *Lygeum spartum* is not particularly resistant to severe droughts [5, 25]. *Lygeum spartum* regression can have serious consequences for the ecological and socioeconomic balance of the entire ecosystem after soil degradation and the destruction of the steppe plant community, resulting in long-term desertification, which is the most advanced stage of degradation [58-60]. The dynamics of vegetation in these areas have revealed that the process of degradation and conversion of pastoral land through cultivation (excessive clearing, plowing, and cultivation practices) results in a decrease in pasture area and a change in their floristic composition [2, 6, 21, 39, 55].

## Conclusions

The steppe of *Lygeum spartum* has great agropastoral, socioeconomic, and ecological value in the high steppe plains of Naâma. *Lygeum spartum* can significantly extend in arid steppe environments due to its ecological plasticity, which allows for good adaptation. The phytoecological analysis of the steppe group with *Lygeum spartum* is based on the ecological characterization and floristic diversity of the vegetation. We inventoried 47 species, divided into 19 families and 41 genera. The bioclimatic environment of the Mediterranean is represented by therophytes (41%), chamaephytes (28%), hemicryptophytes (19%), and geophytes (11%). The Poaceae and Asteraceae families are well-represented (40% of total richness). The Mediterranean element predominates from a biogeographical perspective (55%). The CA analysis of the 63 readings supported by the HAC reveals the presence of three steppe facies: a) *Lygeum spartum* facies, b) *Caroxylon vermiculatum, Thymelaea microphylla, Atractylis serratuloides*, and c) *Stipagrostis pungens* facies, which correspond to vegetation degradation in a sandy environment with wind deposits. Good knowledge of the particularities of the *Lygeum spartum* group and ecological requirements (biological, climatic, floristic, and edaphic aspects) is required for any biodiversity conservation action.

## Conflict of Interest

The authors declare no conflict of interest.

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