

INVESTIGATION OF FLORA, SOIL, AND BIODIVERSITY OF ECOSYSTEMS IN ARID EASTERN MOROCCAN RANGELANDS

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Abstract

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Recently, pastoral ecosystem has been strongly studied by naturalists. However, phytoecological research must focus on species richness and enhance these ecosystems. The main objective of this research is to prove that the Moroccan pastoral ecosystem is very rich in terms of soil biodiversity and plant formations. In such areas, some pastoral plants maintain the physicochemical characteristics of soil. The field experiment was based on Braun-Blanquet sampling method with 90 surveys. The vegetation surveys carried out during the spring of the 2014–2018 period showed that there were 30 families, 23 orders, and 99 plant species (47 perennial species and 52 annual or biennial species). Of the 99 species inventoried, 14 species are very rare (RR) (14% of the total flora), six are rare (R), five are suspected rare (R?), three species are extinct or of doubtful presence (?), two are vulnerable (or seem to be), in decline, and could become rare in the short term (V), and one is a suspected very rare taxon (RR?). Investigation of life forms based on Raunkiaer method showed that there were various plants in different life forms. Among them, terophytes (47%) and 2% phanerophytes had the highest and the lowest plant species, respectively. This work led us to discover six species (*Atractylis cancellata*, *Carduus pycnocephalus*, *Scorzonera angustifolia*, *Telephium sphaerospermum*, *Teucrium luteum*, and *Androsace maxima*) and five types of rangeland in eastern Morocco. Chorology results showed a high proportion of Mediterranean biogeographic species in the study area, with a percentage of 35%. North African species followed the Mediterranean, with 14%. Euro-Mediterranean species constituted the major flora in the arid regions and played a significant role in the Mediterranean rangelands with 8%. The percentage of North African and Eurasian species was 6%, followed by North African and Asian species forming 4% of the total species. Eurasian, Paleo temperate, and Mediterranean Asian species had the same percentage (3%). The remains represented a low percentage, but contributed to the diversity and the richness of phytogeographic potential in the rangelands of eastern Morocco.

Key words: biodiversity, plant formations, minerals soil, Eastern Moroccan rangelands

Introduction

The nature and quality of vegetation cover is an important factor for soil conservation because it plays a major role in reducing the erosive impact of precipitation (Turan, Filiz, 2011). Geographic and floristical investigations are the most effective method for managing and protecting the available genetic resources (Vaseghi et al., 2008). There are many life form classifications, but among them, the practical system is Raunkiaer (Denny, 2012). Because of their seasonal rainfall, rangelands in the extratropics and East Africa have a higher productivity than those in the Sahel (Le Houérou, 1984). Arid rangelands occur where the summer rainy season favors the production of woody shrubs mixed with some grasses (Palmer, 2003). Semi-arid rangelands consist of savannahs dominated by acacia trees (Le Houérou, Hoste, 1977).

In contrast to the arid zone, the semi-arid zone is suitable for reseeding rangelands, where only certain species are able to establish themselves (Le Houérou, 1989). Moroccan biodiversity has a particular ecological importance, with more than 24,000 animal and 7000 plant species with an overall endemism rate

of 11% for fauna and more than 20% for vascular plants, a rate almost unequaled in the entire Mediterranean basin (Semee, 2009).

Pastoral biodiversity is the life structure of rangelands. It is the place of microorganism's life, fungi, plants, or animals and the interactions that link them to each other and to the environment in which they live. Pastoralists are part of this environment, and they interact in time and space with other components of biodiversity. This pastoral biodiversity faces several challenges, the main ones being anthropogenic pressure, climate change, overgrazing, fires, illegal and uncontrolled harvesting of wood, tree decimation, parasitic attacks, the application of inappropriate cultural techniques, poaching and extermination of wildlife, and noncompliance with pastoral regulations and legislation.

Grazing can be a sustainable management method for natural rangelands adapted to the objectives of preserving and restoring diversity, which can reconcile ecological and agronomic challenges (Isselstein et al., 2007). Overgrazing impacts vegetation by trampling in high-traffic areas by reducing the height of the vegetation cover (Cole, Bayfield, 1993) and causing partial

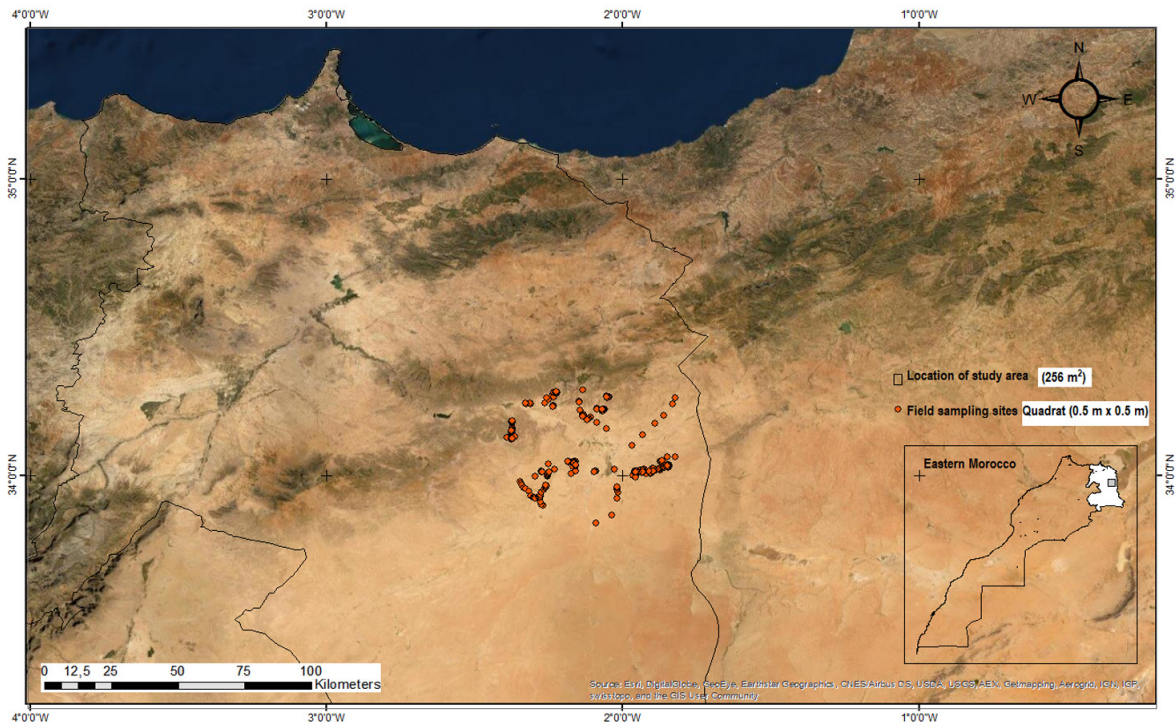


Fig. 1. Location of field sampling sites and vegetation surveys in Eastern Moroccan rangelands (year 2014).

or total destruction of plant species (Crawley, 1997). Trampling favors the creation of bare ground areas and the development of small vegetation species, since there is less competition for light, space, and nutrients (Bullock et al., 2001).

A terrestrial ecosystem characterized by bare soil is very favorable for uncompetitive plant species that rapidly colonize this ecosystem, either from the seed bank (Silvertown et al., 1999) or by the vegetative extension of clonal species (Bonis et al., 2005).

On the other hand, herbivores promote seed dispersal (Marriott et al., 2004) when seeds are transported in the animal's fleece (Fischer, Stöcklin, 1997) or when seeds, after passing through the animal's digestive tract, are found in its feces (Malo, Suarez, 1995). These processes can promote the spread of plant species and the genetic diversification of terrestrial ecosystems. The creation of heterogeneity is among the factors frequently mentioned to explain the impact of grazing on the floristic composition and diversity of plant communities (Sebastià et al., 2008).

Overall, important areas in the rangelands of eastern Morocco remain virtually unexplored. Eastern Morocco is characterized by low and irregular annual rainfall in the order of 194 mm, with a minimum of 77 mm and a maximum of 299 mm recorded during 1998 and 2009, respectively. The average temperature is 15.5 °C; August is the hottest month of the year and January the coldest.

This study concerns a census of the plant species in these terrestrial ecosystems. The study area is located in the commune of Beni Mathar in the east of Moroccan highlands. Almost all of the rangelands in the east of Morocco are linked to the province of Jerada (Hachmi et al., 2015, 2018; Zbiri et al., 2019a). They are limited to the north and east by the horst chain and the borders between Morocco and Algeria, respectively. In the

south, they are limited by the province of Figuig. The potential evapotranspiration is 1153 mm/year. Soil texture is sandy-loamy, with low organic matter content and vulnerability to water and wind erosion (Hachmi et al., 2015; Zbiri et al., 2019a). Recently, Zbiri et al. (2022a) reported that high correlations were found for sparse and moderate correlations for shrub rangeland. The anomalies maps showed a very good similarity between remotely sensed soil moisture and normalized difference vegetation index (NDVI). The results revealed that the bottom-up precipitation from advanced scatterometer (SM2RAIN-ASCAT) and the NDVI product could accurately predict drought events in arid and semi-arid rangelands. Overall, the rangeland species seem to be sensitive to drought at the germination and initial growth phases. The germination recovery potential of stressed species can be regarded as a promising candidate in the rehabilitation of Mediterranean disturbed coastal habitats (Zbiri et al., 2019b).

This work is intended to enrich our knowledge of steppe plant formations, especially those that developed on the soils poor in organic matter and nutrients, yet under heavy animal pressure.

Material and methods

Study area

The study area is located in the commune of Beni Mathar in the east of Moroccan highlands (Fig. 1). Almost all of the rangelands in the east of Morocco are linked to the province of Jerada (Hachmi et al., 2015). They are limited to the north and east by the horst chain and the borders between Morocco and Algeria, respectively. In the south, they are limited by the province of Figuig.

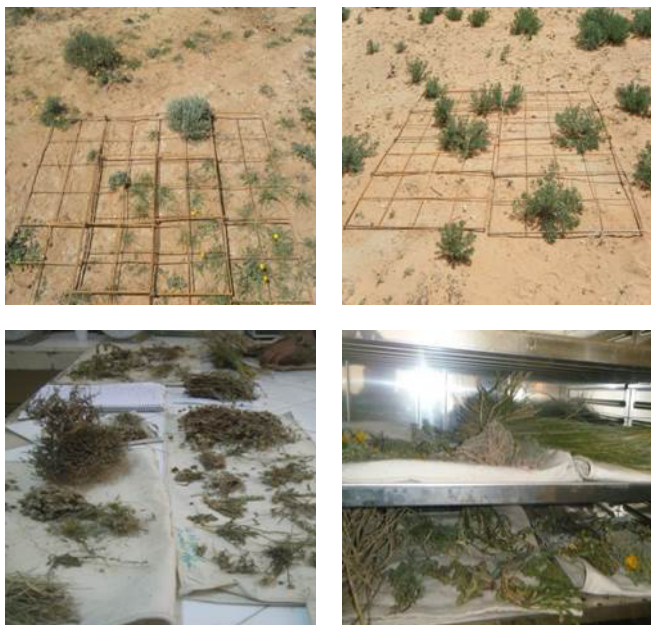


Fig. 2. Illustration of phytomass measurements method in Eastern Moroccan rangelands (year 2014).



Fig. 3. Field and laboratory soil analysis.

The rangelands of eastern Morocco have a transition zone between arid bioclimatic in the north and Saharan in the south. This transition is characterized by a precipitation gradient that results in changes in plant forms and species. The potential evapotranspiration is 1153 mm/year. Soil texture is sandy-loamy, with low organic matter content and vulnerability to water and wind erosion (Hachmi et al., 2015). On the other hand, wet months are from October to April, since the histograms exceed the temperature curve. In summer, the average maximum temperatures vary around 37 °C; there is no transition between the low temperatures of March and the strong heat accompanied by the sandy winds of April and May. The geomorphologic zone of this study area is located in the highlands just south of the Horsts range, which marks the transition from the Saharan zone in the south to the mountainous zone in the north. The topography of the study area is flat with an altitude ranging from 900 to 1100 m. The topography is fairly regular, with slopes varying from 0 to 5%, except in areas near valley or ravines, where the slope begins to be steep and reaches values above 25%.

Field sampling

This study was conducted on the basis of field work carried out in 2014, 2015, 2016, 2017, and 2018, which enabled us to create a herbarium with all the necessary information. The floristic inventory was carried out during March and April, corresponding to the growth peak of most steppe species. To list the plant species, the vegetation sampling method called “minimal area” of Braun-Blanquet (1926) was used. The principle of the method consists in listing the species present on surfaces of increasing size (Gounot, 1969), starting from 0.25 m² (0.5 × 0.5 m) to 256 m². Thus, from an area of 256 m², there were no new species. The homogeneous sampling plot was later used for sampling in the study of floristic diversity and biological types of vegetation (Fig. 2). The classification of biological types was carried out according to Raunkiaer (1934). The latter considers the biological types as an expression of the adaptation strategy of the flora to environmental conditions. The method was used by Hachmi et al. (2015) to describe the physiognomy and structure of plant grouping.

Identification of plant species

The botanical determination of most species was *in situ*. The unidentified species are kept in a herbarium with their vernacular names (*Lalma*, *Harasat lahjar*, *Glyyat jarboue*, *Nachwa*, etc.) and identified by using various keys of botanical determination (Quezel and Santa, 1963; Ozenda, 2004) and Practical Flora of Morocco (Fennane et al., 2007). Various ecological indications collected in the field are reported by the Flora of the Moroccan cork oak (Sauvage, 1961) and by the catalog of Moroccan plants. These are simply broad features of taxon ecology, given in the form of indications on edaphic defined by the general texture (sandy, loamy, clayey or loamy-clayey, sandy-clayey, and clayey-sandy) and on the flowering period (January–February–March, etc.).

The phytogeographic types and degrees of rarity of the taxa encountered are those adopted by Jahandiez, Maire (1934), Nègre (1960), Quezel, Santa (1963), Fennane, Ibn Tattou (1998), Valdés et al. (2006), and Fennane et al. (2007). They are as follows: Mediterranean (MED); Western Mediterranean (WMED or MEDoccident); Ibero-Mauritanian (IBERO-MAUR); Central Mediterranean (CMED or centreMED); Eastern Mediterranean (EMED); Southern Mediterranean (SMED or MEDmérid); Northern Mediterranean (NMED or MEDseptentr); Canary-Mediterranean (CANAR-MED); North African (AFN); North Africa and Arabian Peninsula (AFN-ARAB); North Africa and Asia (AFNASIA); North Africa, Turkey, and Asia (AFN-TUR-ASIA); Eurasian (EURAS); European (EUR); Paleo-Temperate (PALEO-TEMP); Paleo-Subtropical (PALEO-SUBTROP); Circum-Boreal (CIRCUM-BOR); Euro-Mediterranean (EUR-MED); Macaronesian-Mediterranean (MACAR-MED); Eurasian-Mediterranean (EURASMED); Iranian-North African (IRANO-AFN); American (AMER); Canary-North African (CANAR-AFN); and (CANAR-AFN); Cosmopolitan (COSM); Saharo-Mediterranean (SAH-MED).

To get an idea of the rarity of the taxa sampled, several works of literature were used, in particular, the Pascal & Francis Bibliographic Database. The degree of rarity used in this work is that

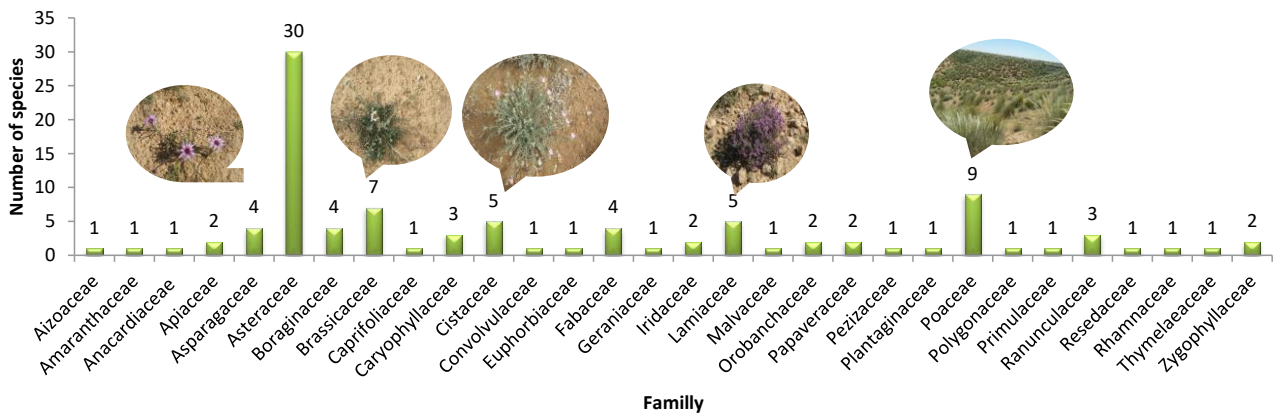


Fig. 4. Number of plant species in each family in the rangelands of eastern Morocco.

adopted by Fennane, Ibn, Tattou (1998). Thus, the degree of rarity comprises six categories:

1. RR: Very rare taxon, number of known localities.
2. R: Rare taxon, generally reported in one or two divisions of the Catalogue des Plantes du Maroc by Morocco by Jahan-diez, Maire (1931–1934) and Emberger, Maire (1941).
3. R?: Suspected rare taxon.
4. ??: Extinct or of doubtful presence.
5. V: Vulnerable taxon (or seems to be) in the process of regression and could become rare in the short term.
6. RR?: Taxon suspected to be very rare.

Soil experiment

In the study area, 90 soil samples were selected. In each vegetation survey, we took a soil sample between 0 and 20 cm deep. The samples were air-dried in bins for a week. Then, the composite samples were air-dried, sieved (<2 mm), and prepared for analyses (Fig. 3).

The parameters analyzed were pH, determined by using a pH meter (Skoog, Holler, 2004); organic matter (MO), evaluated by using the Walkley (Walkley et al., 1934) method; available phosphorus (P), determined by using the Olsen method (Olsen et al., 1954); exchangeable Ca and Mg (1 mol/dm³ NH₄OAc at pH 7); exchangeable potassium (K) and exchangeable sodium (Na), determined by a flame photometer (Blanchet, 1959).

Statistical analyses were performed by using analysis of variance (ANOVA) to test the influence of different soil properties on vegetation condition. For comparison of means, we used the Tukey-Kramer test (post hoc HSD honest significant difference) method with the level of significance being $p < 0.05$.

Results

The vascular flora of eastern Morocco’s arid rangelands is characterized by a great diversity and systematic richness (Hachmi et al., 2021). Floral surveys carried out from 2014 to 2018 revealed the existence of 99 species (47 perennial species and 52 annual or biennial species) spread over 23 orders and belonging to 30 families. The dominant families are Asteraceae (30 species),

Poaceae (nine species), Brassicaceae (seven species), Cistaceae (five species), Lamiaceae (five species), Borraginaceae (four species), Fabaceae (four species), Asparagaceae (four species), and Caryophyllaceae (three species). Other families with high ecological importance and floristic richness have a low presence: Apiaceae, Iridaceae, Orobanchaceae, Papaveraceae, Euphorbiaceae, Rhamnaceae, Resedaceae, Primulaceae, and Polygonaceae. The much degraded rangelands are characterized by the presence of species belonging to the Zygophyllaceae and Thymelaeaceae families (Fig. 4).

These species are divided into two systematic groups.

- Ascomycetes are represented by one family (Pezizaceae) and one species (*Tirmania nivea*).
- Angiosperms include 29 families, 22 genus, and 98 species. Among these angiosperms, eudicotyledons (Magnoliopsida) are dominant with 84 species (83% of the total number of species), followed by monocotyledons (Liliopsida) with 14 species (or 13.86%).

Types of plant formations

This work enabled us to identify five types of plant formations in the highlands of eastern Morocco. Thus, the five types of rangelands resulting from our investigation are as follows:

Group 1: Grass steppe rangelands (Poaceae): On various types of soils and substrates, and under various conditions, *Macrochloa tenacissima* is associated with *M. parviflora*, *Asphodelus microcarpus*, and *Thymus algeriensis*. These species constitute an important forage reserve during periods of drought and have the advantage of protecting the soil when it is not degraded.

Indeed, the steppes of *Macrochloa tenacissima* constitute the structure from which most steppe groups originate by degradation (Fig. 5). The other species that constitute the main part of the floral procession have significant phytosociological characteristics and physicochemical soil conditions. Thus, the pastoral facies surveyed during these years of research consist of several important species. We briefly describe below the major characteristics of these facies. The *M. tenacissima* facies has a significant plant cover and is characterized by the dominance of *M. tenacissima*. These facies occupied most northern parts



Fig. 5. Grass steppe rangelands (*Macrochloa tenacissima*), above. Development of small clumps of plants of *Macrochloa tenacissima* in slopes, below (group 1).

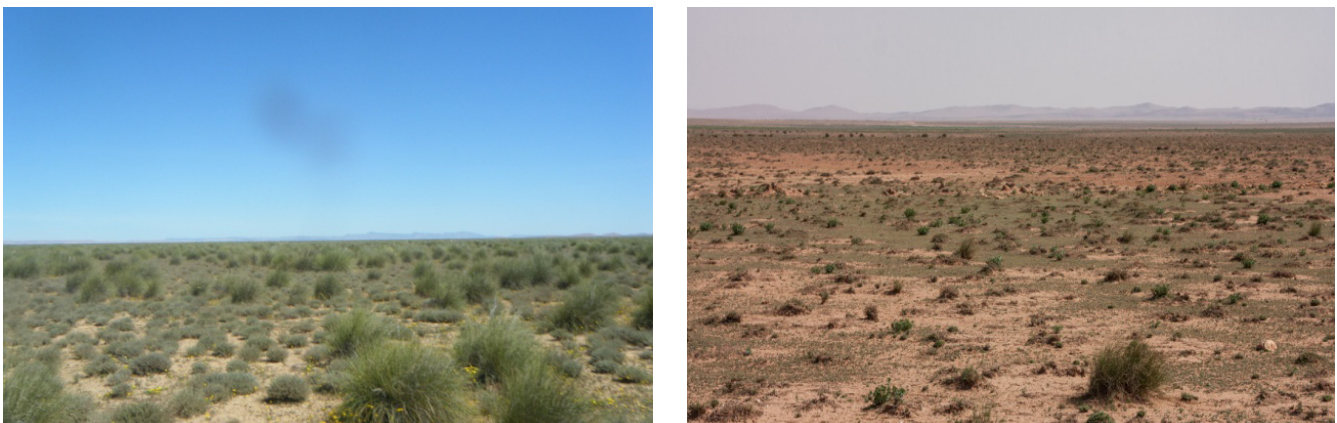


Fig. 6. Two mixed facies with *Macrochloa tenacissima* (left) and *Artemisia herba-alba* (right) (group 2).

of the study area. In degraded rangelands, small stands of *M. tenacissima* plants developed on steep slopes, thus contributing to protection of the part most sensitive to erosion factors (Fig. 5).

Group 2: Mixed facies with *M. tenacissima*, *Noaea mucronata*, *Peganum harmala*, and *Atractylis serratuloïdes* are located

on limestone plateaus. These facies are characterized by the presence of medium to low cover vegetation well adapted to the limestone substrate (Fig. 6, photo on the left). Mixed facies with *Macrochloa tenacissima* and *Artemisia herba-alba* dominate in the plateaus of small flat areas or in encrusted soils (Fig. 6, photo on the right).

Group 3: Steppe rangelands with psammophytes and gypso-halophytes: Steppe rangelands with psammophytes and gypso-halophytes are represented as small, widely dispersed, and rarely homogeneous facies. This is the case of steppes dominated by *Thymelaea microphylla*. This facies with *Th. microphylla* is very uncommon and corresponds to psammophytic vegetation. It is characterized by dominant wind inputs (Fig. 7).

Group 4: Steppe rangelands of Chamaephytes: These rangelands are composed of sub-shrub species and are dominated mainly by *Artemisia herba-alba*, *Helianthemum hirtum*, *H. lippii*, and *Atractylis serratuloïdes* (Fig. 8). These rangelands occupy about 200,000 km² of North Africa and show frequently a severity and spatial extent of grass rangeland degradation. (Le Houérou, 1995).

Group 5: Degraded and post-cropping rangelands: These rangelands are composed of degradation indicator species, mainly *Asphodelus microcarpus*, *Thymelaea microphylla*, *Noaea mucronata*, *Asatragalus armatus*, and *Peganum harmala* with other ephemeral species such as *Filago pyramidata*, *Adonis dentata*, *A. aestivalis*, *Aizoanthemum hispanicum*, *Althaea ludwigii*, *Biscutella didyma*, *Bromus madritensis*, *B. rubens*, *Erodium cicutarium*, *Eruca sativa*, *Euphorbia falcata*, *Hordeum murinum*, *Hypochaeris radicata*, and *Calendula arvensis*. The degraded rangelands of *Noaea mucronata*, *Atractylis serratuloïdes*, and *Peganum harmala* form a mosaic on brown calcareous soils (Fig. 9).

This mosaic is composed of other species such as *Launaea acanthoclada*, *Asphodelus microcarpus*, and *Ziziphus lotus*. The facies with *Noaea mucronata*, *Asphodelus microcarpus*, and *Ziziphus lotus* are found on cleared and very degraded land with stony soils. *Z. lotus* is mainly located in water collection areas (basins, ravines, and lakes). It also has a poor pastoral and forage quality.

Mineral content of rangeland soil

The experiment highlights the richness of rangeland soil components. This is another investigation of the restoration and conservation of natural resources in these areas. Table 1 shows

the average of pH, P, MO, Mg, Ca, K, and Na values in the soils of the five facies (groups) studied. ANOVA of the mean values of all physicochemical soil parameters showed significant differences between the facies studied. When we compared two types of formations (group 1: grass steppe rangelands dominated by *Macrochloa tenacissima* and (group 2: mixed steppe rangelands with *M. tenacissima*, *Noaea mucronata*, *Peganum harmala*, and *Atractylis serratuloïdes*) we find that group 2 had a high level of phosphorus (P), while group 1 was rich in potassium (K), azote (N), and calcium (Ca).

Steppe with psammophytes and gypso-halophytes (group 3) was characterized by higher mean values of sodium (Na), magnesium (Mg), and potassium (K) than other facies. Rangelands of Chamaephytes (group 4) had values of sodium (Na) and organic matter (MO) close to those of degraded and post-cropping rangelands (group 5). Overall, the five defined groups showed stable calcium (Ca) and pH levels. Group 4 had a high level of phosphorus (P).



Fig. 7. Facies of *Thymelaea microphylla* (group 3).



Fig. 8. Facies dominated by *Artemisia herba-alba* and other species (group 4).





Fig. 9. Degraded rangelands with *Peganum harmala*, *Noaea mucronata* and *Atractylis serratuloïdes* (group 5).

Table 1. Means values of pH, P, MO, Mg, Ca, K and Na in the soils of five facies (ANOVA)

Group	Na (mg/kg)	K (mg/kg)	P (mg/kg)	MO (%)	N (%)	Ca (g/kg)	Mg (g/kg)	pH
1	103,88	408,95	0,66	1,96	1,71	1,98	0,19	7,86
2	113,48	398,6	0,88	1,97	1,49	1,8	0,11	7,81
3	276,97	645,24	0,54	1,18	1,35	1,64	0,35	7,25
4	187,13	454,04	1,06	1,81	1,12	1,7	0,18	7,64
5	170,36	476,71	0,78	1,73	1,42	1,78	0,21	7,64

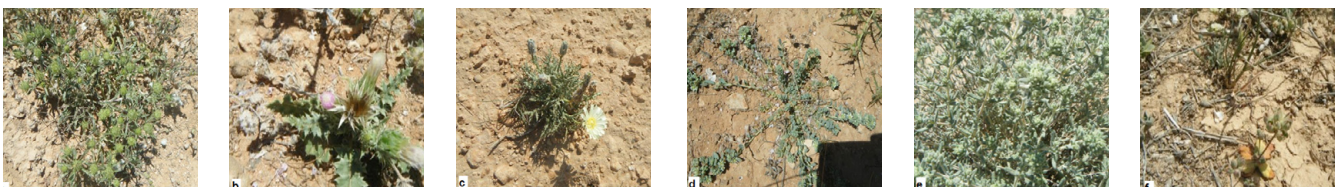


Fig. 10. Discovered species : *Atractylis cancellata*, *Carduus pycnocephalus*, *Scorzonera angustifolia*, *Telephium sphaerospermum*, *Teucrium luteum*, *Androsace maxima*.

Review of systematic richness

From the 30 botanical families identified, nine clearly dominated the flora of the arid ecosystems of eastern Morocco, in particular,

Asteraceae (30 species), Poaceae (nine species), Brassicaceae (seven species), Cistaceae (five species), Lamiaceae (five species), Borraginaceae (four species), Fabaceae (four species), Asparagaceae (four species), and Caryophyllaceae (three species). They alone accounted

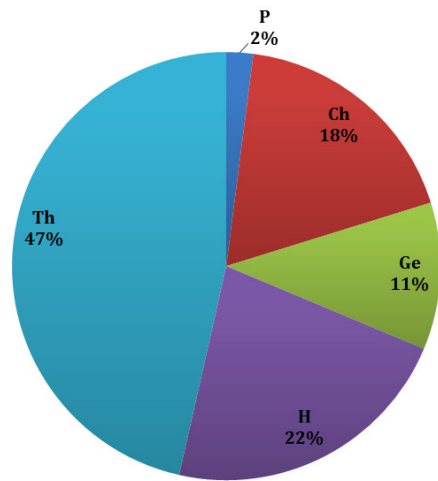


Fig. 11. Proportion (%) of biological types of species in Ain Beni Mathar's rangelands.

for 71 species, or 70.29% of the total specific, while the other families (21) contributed 27.72% of the total specific with a high ecological importance and floristic richness (Crassulaceae, Euphorbiaceae, Rhamnaceae, Rubiaceae, Resedaceae, Renunculaceae, Primulaceae, Polygonaceae). The importance of the families that hold the top nine places is explained by the overall contribution to Moroccan flora, their Mediterranean range, and their ability to adapt to unstable and diversified biotopes (Taleb et al., 1998).

Discovered species

This work led us to discover the following six species: *At. cancellata*, *Carduus pycnocephalus*, *Scorzonera angustifolia*, *Telephium sphaerospermum*, *Teucrium luteum*, *Androsace maxima* (Fig. 10). Four of them are therophytes (Th) (annual or biannual plants), one is a chamaephyte (Ch) (perennial plants), and another is a hemicryptophyte (H).

- *Atractylis cancellata* L. Ecol: Forest clearings, rangeland, uncultivated fields of the plain and low mountains, very arid places on the coast of the Alps-Maritimes. April–June. S, A, SA, SH, H. The geographic distribution or Rep: Southern Europe, Western Asia, Septet Africa, Canary Islands. Var. *eremophila*, South Algerian and Tunisian. Morocco. Th.
- *Carduus pycnocephalus* L. Ecol: grazed forests, field edges, uncultivated areas. March–June. SA, SH, H. Rep: Western and Southern Europe, Western Asia, North Africa, Canary Islands, Azores, Morocco. Th.
- *Scorzonera angustifolia* L. Ecol: Rocks, arid lawns. May–June. SA, SH. Rep: Iberian Peninsula, North Africa. Morocco. Th.
- *Telephium sphaerospermum* Boiss. Ecol: rangelands and crops; shallow and stony clayey-loamy soil. April–June. A, SA. Rep: Africa septet, Morocco. H.
- *Teucrium luteum* (Mill.) Degen. Ecol: salty soils (Le Houérou, 1960) or on “fixed dunes and grazed rockeries” (Vanden Berghen, 1981). May–July. SA, SH. Rep: Western Mediterranean, Morocco. Ch.
- *Androsace maxima* L. Ecol: Steppes, rocky mountain range-

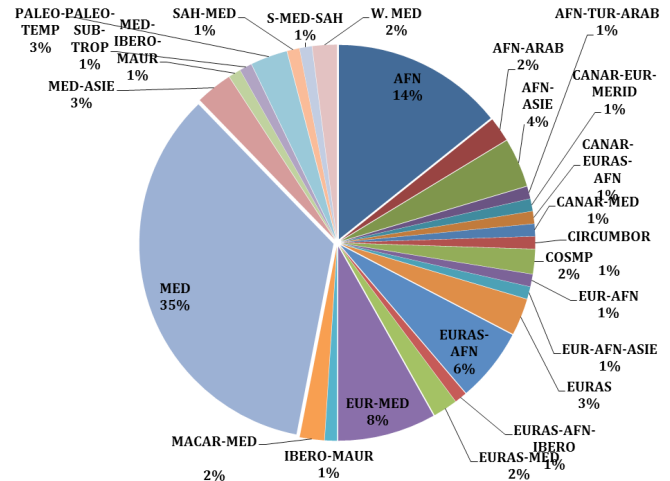


Fig. 12. Phylogeography types of species in the Ain Beni Mathar rangelands.

lands, limestone, and basic fields. April–June. A, SA, SH. Rep: Southern and Central Europe, Western and Boreal Asia, Northern Africa, Morocco. Th.

Discussion

The three main factors influencing the distribution of plant species in these rangelands were overgrazing, silting, and agricultural practices. Referring to the Bruce, Rayment (1982) interpretation standards, the results show that the soils of these rangelands have neutral to slightly alkaline pH. Also, according to the classification of Delaunoy et al. (2008), the soils of these rangelands are poor in phosphorus, magnesium, nitrogen, and organic matter, but rich in potassium. These rangelands are composed of the following perennial species: *Macrochloa tenacissima*, *Artemisia herba-alba*, *Noaea mucronata*, *Helianthemum* sp., *Atractylis* sp., *Thymelaea microphylla*, *Argyrolobium uniflorum*, *Dactylis glomerata*, *Herniaria hirsute*, *Moricandia suffruticosa*, *Plantago albicans*, *P. harmala*, *Macrochloa parviflora*, *Thymus algeriensis*, *Asphodelus microcarpus*, and *Thymus algeriensis*. *Astragalus armatus*, *Peganum harmala*, *Atractylis serratuloïdes*, *Thymelaea microphylla*, *Fagonia cretica*, and *Noaea mucronata* nonpalatable plants have proliferated widely in degraded rangelands.

Figure 11 presents the proportion (%) of each biological type in Ain Beni Mathar's rangelands. Overall, the biological types include 47% terophytes, 22% hemicryptophytes, 18% chamaephytes, 11% geophytes, and 2% phanerophytes. The dominance of terophytes over other biological types is relatively significant. These species are characterized by high production of seeds and a short life cycle and can occupy the soil for short periods favorable to their development in all bioclimatic areas and all steps of vegetative cycle (Quezel, 2000). According to Grime (1977) and Daget (1980), the percentage of terophytes increases in Mediterranean plant formations with aridity and degradation. Many previous studies have shown the relationships between the distribution of biological types and environmental factors, particularly climate (precipitation and temperature) (Daget, 1980), altitude, and the

nature of substrate (Floret et al., 1990). Hemicryptophytes are described as the best adapted species to aridity and gradually settle down with the degradation of forest ecosystems (Ghezlaoui et al., 2011). Geophytes are associated with the climatic gradient that favors the development of ephemeral species (Aidoud, 1983). The low percentage of phanerophytes in these rangelands is an indicator of advanced degradation in this pastoral area.

Phytogeography is used to explain the ranges of plants in terms of their origin, dispersal, and evolution (Dahmani, 1996). Molinier (1934) confirmed that this distribution is not a result of chance, but a consequence of needs of each part of the world. According to Olivier et al. (1995), phytogeography is a true model to interpret the regression of every phenomenon. According to Quézel (1991), phytogeographic study is an essential step for any challenge to conserve the biodiversity. Figure 12 shows a high proportion of Mediterranean biogeographic species in the study area, with a percentage of 35%. North African species follow the Mediterranean, with 14%. Euro-Mediterranean species constitute the major flora in the arid regions and play a significant role in the Mediterranean rangelands with 8%. The percentage of North African and Eurasian species is 6%, followed by North African and Asian with 4% of the total species. Eurasian, Palearctic, and Mediterranean Asian species have the same percentage (3%). The remains represent a low percentage, but contribute to the diversity and richness of the phytogeographic potential in the rangelands of eastern Morocco. The absence of Moroccan endemism is mainly related to the low altitude of these ecosystems. Quézel (1999) emphasized the role of high mountains in the evolutionary processes of local progressive speciation.

Different studies were used as a reference to characterize the rarity of all species in this study area (Sauvage, 1961; Fennane, Ibn Tattou, 1998; Valdés et al., 2006). Of the 99 species inventoried, 14 species are very rare (RR) (14% of the total flora), six are rare (R), five are suspected rare (R?), three species are extinct or of doubtful presence (??), two are vulnerable (or seem to be), in decline, and could become rare in the short term (V), and one is a suspected very rare taxon (RR?).

Species diversity, richness, herb biomass, basal cover, and soil physicochemical attributes showed distinct differences in relation to grazing management practices. Based on the findings, one can conclude that the establishment of enclosures has a positive impact in restoring rangeland vegetation diversity and distribution, in increasing herb productivity, and in boosting soil fertility (Hailu, 2017). The rangeland ecosystems in the arid and semi-arid areas have suffered from huge land and vegetation degradation mainly due to poor management, population growth, traditional open grazing systems, deforestation, continuous heavy grazing, as well as land use and climate changes (Tessema et al., 2011; Flintan et al., 2013). These problems have led to a huge decline in rangeland resources and degradation of biodiversity, thereby having negative impacts on the rangeland ecosystems, livestock production, and the livelihoods of the pastoral communities (Abule et al., 2007; Kassahun et al., 2008; Angassa et al., 2012).

This work enabled us to identify five types of plant formations and six species (*Atractylis cancellata*, *Carduus pycnocephalus*, *Scorzonera angustifolia*, *Telephium sphaerospermum*, *Teucrium luteum*, *Androsace maxima*) in the highlands of eastern Morocco. The soils of these rangelands have neutral to slightly alkaline pH and are poor in phosphorus, magnesium, nitrogen, and organic matter, but rich in potassium. The most important

families in this area were Asteraceae (30 species), Poaceae (nine species), Brassicaceae (seven species), Cistaceae (five species), Lamiaceae (five species), Boraginaceae (four species), Fabaceae (four species), Asparagaceae (four species), and Caryophyllaceae (three species). These families account for 70.9% of the total flora in the eastern Moroccan rangelands.

The remaining 29.10% of the species belong to 21 families with high ecological importance and floristic richness. Among all species identified in this region, 14 species were very rare (14.14% of the total flora), six were rare, five were suspected rare, three species were extinct or of doubtful presence, two were vulnerable, and one was a suspected very rare one. The review of geographic distribution of plants showed that the species belonged to different chorotypes, and Mediterranean (34 species) and North African had the highest number of plant species. Investigation of life forms based on Raunkiaer method showed that there were various plants in different life forms. Among them, terophytes (47%) and 2% phanerophytes had the highest and the lowest plant species, respectively. According to the catalog of rare, threatened, or endemic vascular plants in Morocco, 14 species are very rare (RR) (14% of the total flora), six are rare (R), five are suspected rare (R?), three species are extinct or of doubtful presence (??), two are vulnerable (or seems to be), in decline, and could become rare in the short term (V), and one is a suspected very rare (RR?) species. These rare species have a great interest for the protection, valuation of biodiversity and economic development. For example, the seeds of these species can be used to rehabilitate these rangelands. We argue that given the paucity of data on rare species, understanding the contribution of rare species to community functional diversity is an important first step to understanding the potential role of rare species in ecosystem functioning.

Thirty-four species found in these rangelands are endemic to the Mediterranean territory. Fourteen species are known to be endemic to North Africa. Eight species are endemic to the Euro-Mediterranean territory, and six species are endemic to the Eurasian Mediterranean territory.

However, recent studies have shown that these rangelands are rich in wildlife. Ethological research has focused on areas rich in animal species. Hachmi et al. (2021) reported that their qualitative and quantitative study of animal species revealed a total of 87 species. Examining diversity according to the pastoral improvement actions reveal a better organization and sharing of resources on these rang. These areas, as natural points of biodiversity, also represent a bank of genetic resources that can be used in the cosmetic or agronomic field. The study results of Rambo, Faeth (2001) suggest that vertebrate grazing may increase plant richness, even in nutrient-poor, semi-arid grasslands, but may decrease insect abundance. Relative abundances of forbs, grasses, trees, and shrubs, and native and introduced plants did not differ between the long- and short-term grazing enclosures and their grazed counterparts. Relative abundances of some plant species changed when grazers were excluded, however. In contrast, insect species richness was not different between grazed and ungrazed habitats, although insect abundance increased 4- to 10-fold in ungrazed vegetation (Rambo, Faeth, 2001).

Recent research tries to test whether particular patterns of variation in cover, diversity, and richness can be applied generally to distinguish between the mechanisms responsible for organizing vegetation.

Rangeland vegetation is highly dynamic due to climatic variability and extensive ecosystem degradation by increased population pressure from both humans and animals. The spatial scale strongly influences vegetation. Similarly, drought represents a determinant component of arid ecosystem dynamics and maintenance of vegetation biodiversity. Results indicate that changes in cover, species richness, and species diversity depend on the spatial scale and rainfall. Drought affects the vegetation cover on loamy soil to a greater extent than on other soils, and while diversity was affected by drought in all soils, this was particularly noted in limestone and loamy soils (Gamoun, 2013).

Conclusion

Our rangelands are rich in fauna, flora, and soil biodiversity, which mean that great care must be taken in their use. The present study has made it possible to develop a flora catalog of eastern Moroccan rangelands, which constitutes a basic reference for future diachronic studies. Taking into account the results of our investigations, emergency and support plans and conservation or restoration actions must be proposed and operationalized as part of the necessary pastoral program. A detailed analysis (medicinal aspect, regeneration, forage value, etc.) of the data obtained from the floristic study of these rangelands will be the subject of another research to be published later.

The field survey is reliable, but we encourage the use of remote sensing. Copernicus land cover viewer data can be used to detect change of ecosystems. The visualization interface gives percentages of the classes of forests, shrubland, herbaceous vegetation, and bare/sparse vegetation (Zbiri et al., 2022b). The ecological modeling and performance of virtual work needs to be proven by more research in these areas (Hachmi et al., 2021).

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