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ECOLOGÍA

Phytoecological study of a Biosphere Reserve in arid climate in Tunisia

Estudio fitoecológico de una Reserva de la Biósfera en clima árido en Túnez

Alaeddine Rouissi[1], Olfa Ezzine[2*], Islem Yangui[3], Walid Nouainia[4], Refka Zouaoui[5], Youssef Ammari[6]

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ABSTRACT

Anthropic effects and global change threaten biodiversity and genetic resources. Thus, their conservation becomes a primary necessity. This work aims to assess the conservation conditions for vegetation and causes that limit the progressive dynamics of the vegetation cover after a long period of defense. Using the quadrat point method, this work was conducted in two fenced zones and an unfenced zone of the Biosphere Reserve of BouHedma in a Tunisian arid climate. A total of 66 transects were investigated. In each transect species richness and, α and β indices were determined. The α and β diversity showed a low similarity in family and species composition in the studied zones. The Poaceae and Asteraceae families were the most representative in the studied zones and the most used for grazing. These results highlight that long-term conservation contributes to minimizing the reduction of biodiversity in the reserve. It is necessary to minimize grazing and deforestation, especially in the unfenced zone. Thus, the setup of barriers and fences is highly recommended to retain the soil. In addition, finding an effective communication plan with the local population and visitors seems to be crucial.

Keywords: BouHedma, diversity index, fence, North Africa, richness, similarity index.

[1] Estudiante de doctorado en la Universidad de Túnez El Manar, Facultad de Ciencias Matemáticas, Físicas y Naturales de Túnez (FST), Campus Universitaire El-Manar, 2092 El Manar Túnez; y el Instituto Nacional de Investigación en Ingeniería Rural, Agua y Bosques (INRGREF), Calle Hédi Karray, BP. 10, Ariana, 2080 Túnez. R.ala.rouissi@gmail.com
[2] Instituto Nacional de Investigación en Ingeniería Rural, Agua y Bosques (INRGREF), Calle Hédi Karray, BP. 10, Ariana, 2080 Túnez. olfa.ezzine@gmail.com
[3] Instituto Nacional de Investigación en Ingeniería Rural, Agua y Bosques (INRGREF), Calle Hédi Karray, BP. 10, Ariana, 2080 Túnez; y Universidad de Sousse, Instituto Superior de Agronomía de Chott Mariem, Túnez. yanguiislam@gmail.com
[4] Instituto Nacional de Investigación en Ingeniería Rural, Agua y Bosques (INRGREF), Calle Hédi Karray, BP. 10, Ariana, 2080 Túnez. nouainia.walid@gmail.com
[5] Instituto Nacional de Investigación en Ingeniería Rural, Agua y Bosques (INRGREF), Calle Hédi Karray, BP. 10, Ariana, 2080 Túnez. refkazouaoui19@gmail.com
[6] Instituto Nacional de Investigación en Ingeniería Rural, Agua y Bosques (INRGREF), Calle Hédi Karray, BP. 10, Ariana, 2080 Túnez. ammari_youssef@yahoo.fr
* Corresponding author.

RESUMEN

Los efectos antrópicos y el cambio global son una amenaza para la biodiversidad y los recursos genéticos. Así, su conservación se convierte en una necesidad primordial. El objetivo de este trabajo es evaluar las condiciones de conservación de la vegetación y las causas que limitan la dinámica progresiva de la cubierta vegetal tras un largo periodo de defensas. Este trabajo se realizó en dos zonas cercadas y una zona no cercada de la Reserva de la Biosfera BouHedma en el clima árido de Túnez, utilizando el método de punto cuadrado. Se investigó un total de 66 transectos. En cada transecto se determinaron la riqueza de especies y los índices de similitud y diversidad. La diversidad α y β mostraron una baja similitud en la composición familiar y de especies en las zonas estudiadas. Las familias Poaceae y Asteraceae fueron las más representativas en las zonas y la más utilizada para el pastoreo. Estos resultados destacan que la conservación a largo plazo contribuye a minimizar la erosión de la biodiversidad en la reserva. Es necesario minimizar el pastoreo y la deforestación especialmente en la zona no cercada. Así, se recomienda encarecidamente la instalación de barreras y cercas para retener los suelos. Además, encontrar un plan de comunicación eficaz con la población local y con los visitantes parece ser fundamental.

Palabras clave: BouHedma, índice de diversidad, norte de África, valla, riqueza, índice de similitud.

INTRODUCTION

Tunisia is located in northern Africa. According to Emberger (1955), the country ranges from the most arid to the wettest with five bioclimatic zones (Saharan, arid, semi-arid, sub-humid, and humid floor). The Biosphere Reserve of BouHedma represents the last ecosystem of the steppe of *Vachellia* (=*Acacia*) *tortilis* (Forssk.) Galasso & Banfi subsp. *radiana* (Savi) Kyal. & Boatwr. of the arid climate (Chaieb and Boukhris 1998; Jaouadi *et al.* 2013). This gum tree covered all southern Tunisia in Roman times, and its excessive exploitation was the cause of its scarcity from 1881 to 1986 (Jaouadi *et al.* 2013). The Biosphere Reserve of BouHedma constitutes a transition environment between semi-arid and desert vegetation in Tunisia (Schlesinger *et al.* 1990). It is a genetic and biological resource threatened by anthropogenic activities, mainly grazing and climatic pressure (drought), to which are added recent global changes (Floret and Pontanier 1982; Ouled Belgacem *et al.* 2013). The protection and conservation of natural habitats is becoming a global concern (Dupuy *et al.* 1999; Noumi 2010). Despite its positive impact on biodiversity, recorded in several regions, this protection had a negative impact on other, which recorded an increasing number of extinct or threatened species (Dupuy *et al.* 1999). In North Africa, defenses and grazing have been shown to cause degradation of steppe vegetation and hinder the reconstitution of major characteristics (cover, composition, and production) of pre-existing vegetation from three to six years of defense (Bourbouze 1997). Studies of Abdallah *et al.* (2008); Ouled Belgacem *et al.* (2013) reported that heavy grazing make palatable species replaced by less desirable ones. Nevertheless, defending can turn out to be harmful, and can lead to a drop in productivity, the recovery and externalization of interspecific competition and a blockage of the biological recovery after more than ten years (Noumi 2010). The setting in defense (between five and 25 years) has a beneficial effect on the vegetation cover (Foudil *et al.* 2015), and allows a return to formations with high wealth, but with lower pastoral value compared to plantations (Amghar *et al.* 2012). In this context, this work aims to assess the effect of the protection of the Biosphere Reserve of BouHedma on its biodiversity, after 40 years of conservation. Two objectives were set for this work: (i) to determine species composition and (ii) to study α and β diversity among different zones of the Biosphere Reserve of BouHedma.

MATERIALS AND METHODS

Study area

The Biosphere Reserve of BouHedma (BRB) is a part of the South Eastern Saharan Atlas (Orbata chain) with a total area of 16488 ha (Noumi 2010), located in both the Gafsa and Sidi Bouzid Governorates. According to Karem *et al.* (1993), the BRB includes three fenced zones: Borj BouHedma (BBh.) on the east side, the Corridor (Co.) in the center, and Haddej (Ha.) in the southwest. In 2011, over-

grazing occurred in the corridor that now has become an unfenced zone (*personnel observ.*). Thus, investigations were conducted in two fenced zones (zone I, Borj BouHedma and zone II, Haddej) and an unfenced zone III, the corridor (Fig. 1; Table 1). BBh. and Ha. are protected by fences against anthropic activities and grazing. These two zones are linked by the Co. located in the neighboring pastures and heavily grazed by herbivores, mainly sheep and goats (Abdallah *et al.* 2008).

The region is characterized by an arid Mediterranean climate with moderate winter (Emberger 1955). The average annual rainfall is 180 mm on the plain and 250 mm on the mountain crest. The average temperature varies from 32° to 36°C in summer and from 4° to 7°C in winter (Floret and Pontanier 1982).

Methods

Surveys were carried out over three years, during the periods of full plant growth (March and October 2018; April and December 2019; January 2020). We used the quadrat point method, according to Daget and Poissonet (1971). Thereby, a total of 66 transects were installed (Fig. 1), with 43 transects in Borj BouHedma (BBh.), nine transects in Haddej (Ha.) and fourteen transects in the corridor (Co.). Each transect consisted of a straight line 50 m in length and 1 m in width (50 cm on the left and 50 cm on the right side of the line). This protocol was used to consider all plant species to the left and to the right of the transect. In each transect, the total number of plant species was determined and identified using Maire *et al.* (1955), Ozenda (1977), and Pottier-Alapetite (1979, 1981) keys. The soil map (Fig. 2) was produced using ArcGis software (10.3.1) based on data from the agricultural map of Sidi Bouzid (2003) available from the General Direction of Forests.

Plant community structure

In order to define the important role of the protection in the conservation of this ecological heritage (BRB), a comparison among the three zones using biodiversity indices was used.

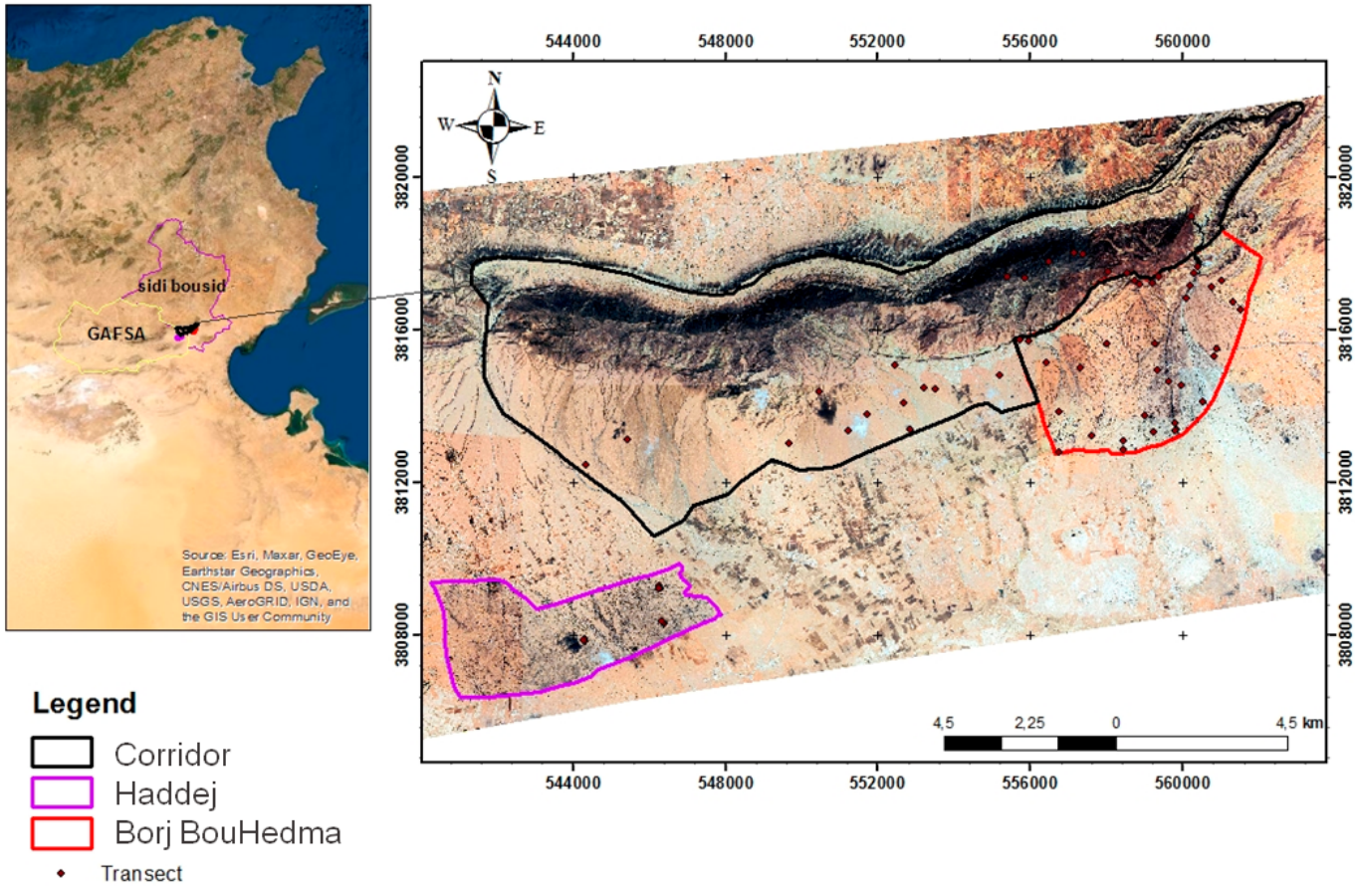

Figure 1. Localization of the Biosphere Reserve of BouHedma

Table 1. Characteristics of study zones; **BBh.** Borj BouHedma; **Ha.** Haddej; **Co.** Le corridor

Characteristics	sites		
	zone I (BBh.)	zone II (Ha.)	zone III (Co.)
Ground	Gypsum, limestone, sandy loam, stony	Sandy loam	Gypsum, limestone, stony
Ground depth (cm)	shallow (30-60)	deep (90-120)	Very shallow (10-30)
Altitude (m)	77 - 786	65 - 182	67 - 252
Latitude (UTM)	556407	546244	549725
Longitude (UTM)	3815162	3809287	3813040
Area (ha)	5144	1000	2400

Relative frequency

The relative frequency was used to check the homogeneity of the studied sites. It was calculated according to the formula: $F(\%) = pi / P*100$; pi=the number of transects with the species observed, P=66 (total number of transects).

Beta diversity

The Jaccard index (1901) was used to determine the similarity between the three zones with $J = \frac{a}{(b+c-a)}$; where a is the number of common species between two zones; b is the number of species specific to the first zone; and c is the number of species specific to the second one. This index varies from zero (specific richness is low) to one (a significant number of species are found in both zones).

Alpha diversity

The Alpha diversity was calculated per transect and then means per zone. The Shannon and Weaver (1948) index was calculated to establish the specific diversity.

$$H = -\sum_{i=1}^{s} pi * \ln pi;$$

where pi is the proportion of the total sample belonging to the species in the same zone. H varies between zero (a single species) and S (number of species; 109, 23 or 41). This index represents a measure of the species composition of an ecosystem including rare species, considering their distribution and relative occurrence; it is usually referred as diversity.

The distribution of occurrences was calculated according to the Pielou (1966) formula: $E = H / Hmax$.

With Hmax = ln (S). This index varies between zero and one (0 all the numbers are concentrated on one species; 1 all the species have the same occurrence).

The Simpson diversity index does not consider rare species. The Simpson diversity (1949) index was calculated to measure the dominance of a species, expressed as 1-D; $D = \sum Ni(Ni-1) / N(N-1)Ni$); where Ni is the occurrence of individuals of a given species and N is the total number of individuals. D varies between zero (maximum diversity) and 1 (minimum diversity).

Statistical analysis

The statistical analysis was performed using the SPSS-20.0 software package for Windows. Average of α diversity (H, Pielou evenness and 1-D) was statistically evaluated by using analysis of variance (ANOVA) and complemented by multiple comparisons of means by Duncan test. Pearson's correlation coefficient was tested between species richness, altitude, longitude, and latitude. The two-proportion z-test was used to compare species frequency per zone.

RESULTS

Richness of the Biosphere Reserve of BouHedma

In the three study zones, 115 species belonging to 93 genera and 41 families were identified. Among these families, Chenopodiaceae, Fabaceae, Asteraceae, Poaceae and Lamiaceae were the most representative in the BRB. Poaceae was represented by 21 species. The BBh. was the most diverse, with 109 species belonging to 85 genera and 41 families, followed by the Co., with 41 species belonging to 36 genera and 18 families. Ha. was the least diversified with 23 species belonging to 21 genera and fifteen families. The founder species of the reserve, *Vachellia tortilis* subsp. *radiana* (family Fabaceae sub-family Mimosoideae), was observed in the three zones (Table 2). Further, the two-proportion z-test showed a highly significant difference of relative frequency (χ^2_{228}= 2216.210; P<0.0001).

Table 2. Flora diversity expected by relative frequency (%); **BBh.** Borj BouHedma (43 transects), **Ha.** Haddej (9 transects), **Co.** corridor (14 transects)

Family	Species	Relative frequency (%)		
		BBh.	Ha.	Co.
Alliaceae	*Allium roseum* L.	2.325	0	0
Amaryllidaceae	*Pancratium trianthum* Herb.	18.604	0	0
Anacardiaceae	*Pistacia atlantica* Desf.	2.325	0	0
	Pistacia lentiscus L.	4.651	0	0
	Rhus tripartita (Ucria)	13.953	0	28.571
Apiaceae	*Deverra tortuosa* Coss. & Durieu	6.976	11.111	0
	Deverra scoparia Coss. & Durieu	16.279	0	28.571
	Deverra denudata (Viv.) Pfisterer & Podlech	0	44.444	7.142
	Foeniculum vulgare Mill.	9.302	0	0
Apocynaceae	*Nerium oleander* L.	2.325	0	0
	Periploca angustifolia Labill.	6.976	0	7.142
Arecaceae	*Phoenix dactylifera* L.	9.302	0	7.142
Asclepiadaceae	*Pergularia tomentosa* L.	2.325	0	42.857
Asparagaceae	*Asparagus albus* L.	9.302	0	0
	Asparagus stipularis L.	11.627	11.111	0
Aloaceae	*Aloe vera* (L.) Burm.f.	2.325	0	0
Asteraceae	*Artemisa herba-alba* Asso	25.581	22.222	14.285
	Artemisia campestris L.	6.976	0	7.142
	Atractylis serratuloides Sieber ex Cass.	2.325	22.222	14.285
	Cynara cardunculus L.	2.325	0	0
	Dittrichia viscosa (L.) Greuter	4.651	0	0
	Limbarda crithmoides (L.) Dumort.	9.302	0	0
	Phagnalon rupestre (L.) DC.	2.325	0	0
	Phagnalon saxatile (L.) Cass.	4.651	0	0
	Rhanterium suaveolens Desf.	11.627	55.555	0
	Pallenis hierochuntica (Michon) Greuter	2.325	0	0
Boraginaceae	*Echiochilon fruticosum* Desf.	11.627	44.444	0
Brassicaceae	*Diplotaxis harra* (Forssk.) Boiss.	6.976	0	0
	Farsetia aegyptia Desv.	2.325	0	7.142
	Moricandia suffruticosa (Desf.) Coss. & Durieu	30.232	0	0

(*Continued*)

Family	Species	Relative frequency (%)		
		BBh.	Ha.	Co.
Capparaceae	*Cleome amblyocarpa* Barratte & Murb.	4.651	0	0
Caryophyllaceae	*Gymnocarpos decander* Forssk.	18.604	11.111	35.714
Chenopodiaceae	*Anabasis oropediorum* Maire	25.581	0	7.142
	Arthrocnemum macrostachyum (Moric.) K.Koch	2.325	0	0
	Atriplex halimus L.	4.651	0	0
	Atriplex mollis Desf.	4.651	0	0
	Hammada schmittiana (Pomel) Botsch.	30,232	100	0
	Hammada scoparia (Pomel) Iljin	34.883	55.555	92.857
	Salsola oppositifolia Desf.	6.976	0	0
	Salsola tetrandra Forssk.	2.325	0	0
	Suaeda mollis Delile	6.976	0	0
Cistaceae	*Helianthemum hirtum* (L.) Mill.	13.953	0	0
	Helianthemum kahiricum Delile	18.604	0	7.142
	Helianthemum lippii (L.) Dum. Cours.	11.627	55.555	7.142
	Helianthemum semiglabrum (Badaro) B.Bock	11.627	0	7.142
Crassulaceae	*Umbilicus horizontalis* (Guss.) DC.	2.325	0	0
Cupressaceae	*Juniperus phoenicea* L.	16.279	0	0
Cyperaceae	*Scirpus maritimus* (L.) Palla	4.651	0	0
	Schoenus nigricans L.	2.325	0	0
	Scirpoides holoschoenus (L.) Sojàk	4.651	0	0
Ephedraceae	*Ephedra altissima* Desf.	9.302	0	7.142
Euphorbiaceae	*Euphorbia bivonae* Steud.	13.953	0	0
Fabaceae	*Vachellia* (=*Acacia*) *tortilis* (Forssk.) Galasso & Banfi subsp. *radiana* (Savi) Kyal. & Boatwr.	23.255	0	35.714
	Argyrolobium uniflorum (Decne.) Jaub. & Spach	0	0	14.285
	Astragalus armatus Willd.	9.302	55.555	50
	Genista cinerea (Vill.) DC.	4.651	0	0
	Ononis natrix L.	0	0	7.142
	Prosopis julifera (Sw.) DC.	13.953	0	0
	Parkinsonia aculata L.	2.325	0	0
	Retama raetam Forssk.	27.906	0	14.285
Geraniaceae	*Erodium chium* (L.) Willd.	11.627	0	0
	Erodium crassifolium (Forssk.) L'Hér.	2.325	0	7.142

(*Continued*)

Family	Species	Relative frequency (%)		
		BBh.	Ha.	Co.
Juncaceae	*Juncus acutus* L.	11.627	0	7.142
Lamiaceae	*Ajuga iva* (L.) Schreb.	2.325	0	0
	Ballota hirsuta Benth.	13.953	0	21.428
	Marrubium deserti (de Noé) Coss.	0	44.444	0
	Lavandula coronopifolia Poir.	2.325	0	7.142
	Lavandula multifida L.	6.976	0	21.428
	Rosmarinus officinalis L.	9.302	0	0
	Salvia aegyptiaca L.	2.325	44.444	57.142
	Thymus algeriensis L.	2.325	0	0
	Teucrium polium L.	6.976	22.222	14.285
	Teucrium ramosissimum Desf.	2.325	0	0
Oleaceae	*Olea europaea* L.	11.627	0	7.142
Globulariaceae	*Globularia alypum* L.	18.604	0	0
Peganaceae	*Peganum harmala* L.	2.325	11.111	0
Plumbaginaceae	*Limoniastrum guyonianum* Dur.	6.976	0	0
	Limonium pruinosum (L.) Kuntze	6.976	0	0
Poaceae	*Aeluropus littoralis* (Gouan) Parl.	11.627	0	0
	Cenchrus ciliaris L.	34.883	66.666	64.285
	Cynodon dactylon (L.) Pers.	4.651	11.111	0
	Digitaria nodosa Parl.	25.581	11.111	0
	Eragrostis papposa (Roem. & Schult.) Steud.	0	0	7.142
	Hyparrhenia hirta (L.) Stapf	9.302	0	14.285
	Imperata cylindrica (L.) Räusch.	0	0	21.428
	Lolium multiflorum Lam.	2.325	0	0
	Lygeum spartum L.	2.325	0	0
	Oryzopsis miliacea (L.) Benth. & Hook.f. ex Asch. & Schweinf.	11.627	0	7.142
	Pennisetum divisum Poir.	2.325	0	0
	Phragmites australis (Cav.) Trin. ex Steud.	13.953	0	0
	Saccharum ravennae (L.) H.Scholz	4.651	0	0
	Stipa capensis Thunb.	2.325	0	0
	Stipa tenacissima L.	32.558	0	28.571
	Stipagrostis (=Aristida) adscensionis L.	16.279	0	21.428

(*Continued*)

Family	Species	Relative frequency (%)		
		BBh.	Ha.	Co.
	Stipagrostis obtusa Nees	20.930	11.111	28.571
	Stipagrostis pengens (Desf.) De Winter	2.325	0	0
	Stipagrostis ciliate (Desf.) De Winter	18.604	0	0
	Tricholaena teneriffae (L.f.) Link	9.302	0	0
	Tetrapogon villosus Desf.	6.976	0	0
Polygonaceae	*Polygonum equisetiforme* Sibth. & Sm.	6.976	0	0
Primulaceae	*Coris monspeliensis* L.	4.651	0	0
Pteridaceae	*Adiantum capillus-veneris* L.	4.651	0	0
Rhamnaceae	*Rhamnus lycioides* L.	2.325	0	0
	Ziziphus lotus (L.) Lam.	9.302	11.111	0
Rutaceae	*Ruta chalepensis* L.	2.325	0	0
Scrophulariaceae	*Anarrhinum brevifolium* (Coss. & Kralik)	4.651	0	0
Solanaceae	*Lycium arabicum* Schweinf. ex Boiss	11.627	11.111	7.142
Tamaricaceae	*Tamarix africana* Poir.	2.325	0	0
	Tamarix gallica L.	2.325	0	0
Thymelaeaceae	*Thymelaea sempervirens* Murb.	4.651	0	0
Urticaceae	*Forsskaolea tenacissima* L.	2.325	0	7.142
Zygophyllaceae	*Fagonia glutinosa* Delile	4.651	55.555	0
	Fagonia cretica L.	9.302	0	28.571
	Nitraria retusa Asch.	6.976	0	0
	Zygophyllum album L.f.	2.325	0	0
Species richness	115	109	23	41

The α and β diversity among zones of the Biosphere Reserve of BouHedma

The Jaccard index (β diversity) varied between 0.189 and 0.316 (Table 3). Statistical analysis showed a non-significant difference of H and D indexes among the three zones with ($F_{(2, 63)}$=2.629, P=0.08) and ($F_{(2, 63)}$=3.022, P=0.056), respectively. Nevertheless, Pielou evenness index was significant ($F_{(2, 63)}$=4.127, P=0.021). For the α diversity, the BBh. zone was the most diverse showing a Shannon and Weaver index of 3.922 bits, a Simpson diversity index of 0.970 and a Pielou evenness index of 0.836. However, the least diverse was Ha. with 2.190, 0.706 and 0.811, respectively (Table 3). A highly significant Pearson's correlation coefficient was observed between species richness and altitude (R^2= 0.36, p=0.003), while it was significant between species richness and longitude (R^2= 0.58, p=0.037).

DISCUSSION

The severe natural conditions (drought, lack of rainfall, and high temperature during summer) in BRB have made it a very particular landscape (Schlesinger *et al.* 1990). Although, the three zones of the BRB differ floristically but some species occur in two or all three zones are similar.

The three study zones share nine families: Apiaceae, Asteraceae, Chenopodiaceae, Cistaceae, Fabaceae, Lamiaceae, Poaceae, Solanaceae, and Zygophyllaceae. The β diversity among the three zones was low in the families and species composition. In fact, 23 families were represented at least by only one species. Three families were represented by eight to ten species. Poaceae was the richest family with 21 species: 19 species in BBh., 8 species in Co. and 4 species in Ha. These results are consistent with those found in southern Senegal (Cornet and Poupon 1977) and in the wooded savannah of Côte d'Ivoire (Mitja and Puig 1990). According to these authors Poaceae tolerates high temperatures, resists drought and grazing. In addition, the work of Le Houérou (1986) in North Africa confirms that Chamephytic steppes protected for a long time (> 4 years) have contributed to the expansion of this family. The α diversity represented by the Shannon and Weaver index varied among zones, the lowest was recorded at Haddej. The Pielou evenness was low in the BRB. On one hand, the index was high in BBh. (0.836) showing the occurrence of different species in this zone. On the other hand, it was low in Co. (0.706) and in Ha. (0.698) indicating evenness in the distribution of species. The Simpson diversity index showed minimal diversity in the three zones. This difference is probably linked to the geology characterized by the presence of plains, glacis, and wadis in Borj BouHedma, also to the diversity of the soil texture (sand, silt, and gypsum) and to the altitude (173 m). However, Haddej is composed by a simple relief (plain), a sandy soil and a low altitude (114 m). In addition, the occurrence of *Vachellia tortilis* is greater in the region of Haddej than that of Borj BouHedma, which gives a landscape of wooded savannah in Haddej and a complex landscape in Borj BouHedma (Tarhouni 2003).

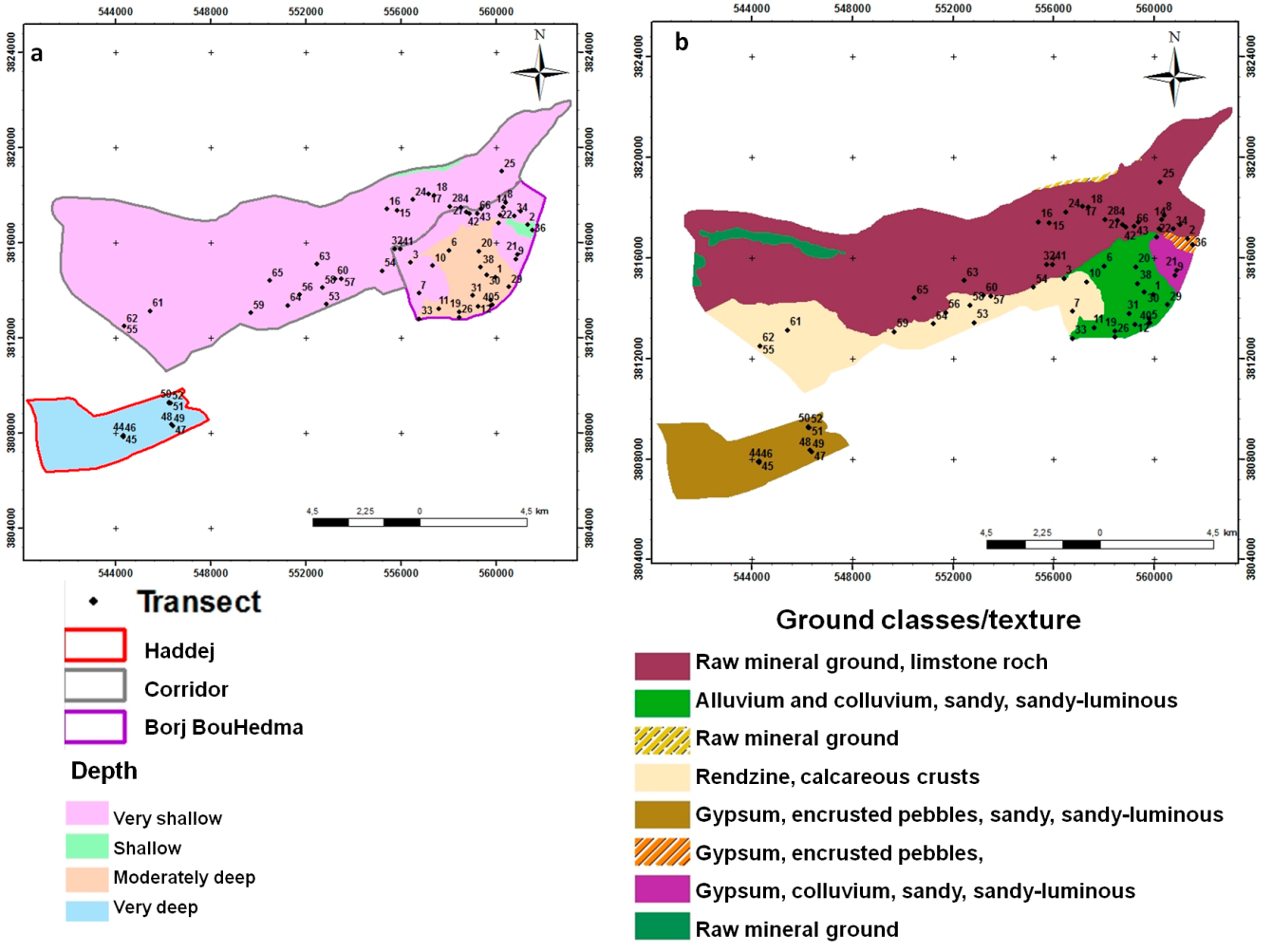

Figure 2. Edaphic characteristics of the Biosphere Reserve of BouHedma. a. depth; b. texture

*Numbers from 1 to 66 indicated in figures a and b represent the transects

Table 3. Alpha and beta diversity of the Biosphere Reserve of BouHedma; **BBh.** Borj BouHedma; **Ha.** Haddej; **Co.** Le corridor

Indices		BBh /Ha.	BBh. /Co	Ha./Co.
Beta diversity	Jaccard	0.189	0.316	0.231
Indices		BBh.	Ha.	Co.
Alpha diversity Per zone	Shannon and Weaver (H)	3.922	2.19	2.79
	Pielou evenness	0.836	0.698	0.706
	Simpson (1-D)	0.970	0.811	0.874
Indices		BBh.	Ha.	Co.
Alpha diversity (means per zone)	Shannon and Weaver (H)	1.771±0.083	1.389±0.191	1.442±0.191
	Pielou evenness	0.797±0.016	0.689±0.052	0.690±0.060
	Simpson (1-D)	0.761±0.023	0.641±0.067	0.643±0.070
number of species (means per zone)		9.83	7.88	7.64
Number of transects		43	9	14
Mean number of species= 9.1 species/ transect (50m²)				

In the corridor, *Vachellia tortilis* colonizes erosion claws and wadis and compete with other plant species. It exerts an allelopathic effect inhibiting the natural germination of the seeds of competing species and consequently the evolution of herbaceous and woody trees (Noumi 2010). Nevertheless, the corridor is located at an altitude of 200 m and characterized with the limestone glacis and wadis with a complex substrate (silt, rocky and sandy). In this zone, the Poaceae family is represented by 10 species able to resist to deforestation and overgrazing. The Lamiaceae family, known for its aromatic and medicinal virtues (Lardry and Haberkorn 2007), occupies the three study zones; it is represented by 10 species in Borj BouHedma, 3 species in Haddej and 5 species in the corridor. The common species among the three zones are *Teucrium polium* L. and *Salvia aegyptiaca* L. These two species are the most resistant to the ecological conditions in the region (Ozenda 1977). *Marrubium deserti* (de Noé) Coss., a species characteristic of stony plains (Regs) (Bouallala 2013), was only found in Haddej, where the Gum tree is more frequent than in the two other zones. The two threatened species *Lavandula coronopifolia* Poir. and *L. multifida* L. are found in Borj BouHedma and the corridor, with a very low density and are absent in Haddej. *Ballota hirsuta* Benth. has been observed only in the Borj BouHedma. Its presence characterizes wadis and high altitudes (> 120m). *Teucrium ramosissimum* Desf. was weakly dense or even very rare and was found in Borj BouHedma (only one tree). The two Asteraceae, *Artemisia herba-alba* Asso and *Atractylis serratuloides* Sieber ex Cass. were encountered in the corridor. Indeed, *A. herba-alba* is widely distributed in pre-Saharan Tunisia and occupies a silty soil. *Atractylis serratuloides* characterizes degraded environment and occupies the old facies of *Lygeum spartum* L. (Kadi Hanifi 2003), which explains its presence in the overexploited zone by grazing. Haddej is a zone of accumulation of fine mobile sands and is occupied by *Rhanterium suaveolens* Desf., *Atractylis serratuloides* and *Artemisia campestris* L. According to Abdallah *et al.* (2008) and Ouled Belgacem *et al.* (2013), *Hammada scoparia* (Pomel) Iljin, *Salvia aegyptiaca*, *Astragalus armatus* Willd., *Pergularia tomentosa* L. are not used for grazing. Contrariwise, *Cenchrus ciliaris* L. is abundant in the three zones of the BRB and grazed by *Oryx dammah*, *Addax nasomaculatus*, *Gazella dorcas*, *Cten-Odactylus gundi*, *Jaculus deserti* (Chedli *et al.* 2016). The occurrence of this species is maybe due to its spreading by these herbivores. In fact, works of Neffati (1994) demonstrated that the occurrence of certain species is probably due to their germination stimulated by grazing.

This result is in concordance with that of Abaza and Hanafi (2018) who found these three species in the sandy environ-

ment of Mednine in southern Tunisia. The diversification of the Chenopodiacae family in Borj BouHedma is mainly due to the depth of the soil, the absence of watercourses and the salinity of the soil.

This result is consistent with that of Boughani *et al.* (2009) in the Ghouffi gorges, near Biskra in Algeria (North Africa). Indeed, the limited area of Haddej and the sandy nature of the substrate and the low altitude make this environment different from two others. The Borj BouHedma area is characterized by different reliefs of a diverse substrate nature and streams making this environment favorable to host many families and species.

CONCLUSION

This work deepens our knowledge concerning the restoration of threatened ecosystems. It allowed a data updating of the state of conservation of the BRB. Cigolani *et al.* (2005) found that the increase in grazing pressure can lead to a reduction in palatable species, which is the case for the corridor, an area subject to free grazing and considered to be the most threatened. To better conserve the flora of the BRB, it would be important to minimize grazing and deforestation, especially in the corridor. It is essential to install barriers to retain the soil, and a fence to minimize grazing. It is also fundamental to build a communication plan with the local population and visitors to explain the importance of this BRB. Additional works are required with an exhaustive inventory of the vegetation to allow a precise monitoring of the long-term protection impact on the restoration of this heritage. In addition, implementation of policies for the protection and restoration of this threatened ecosystem is needed.

AUTHOR'S CONTRIBUTIONS

AR collect field and laboratory data, concept the methodology, identified species and write the paper, OE design the project, write and review the paper, IY statistical analysis, WN perform, RZ identified species and YA supervised the work.

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LITERATURE CITED

Abaza K, Hanafi A. 2018. La diversité végétale dans un milieu de transition entre les étages bioclimatiques méditerranéens aride et saharien. Cas du secteur d'Ouled Babbeb, Tunisie. Rev. Roum. Géogr. 62(1):9-33.

Abdallah F, Noumi Z, Touzard B, Belgacem A, Neffati M, Chaieb M. 2008. The influence of *Acacia tortilis* (Forssk) subsp. *raddiana* (Savi) and livestock grazing on grass species composition, yield and soil nutrients in arid environments of South Tunisia. Flora. 203(2):116-125. doi: https://doi.org/10.1016/j.flora.2007.02.002

Amghar F, Forey E, Margerie P, Langlois E, Brouri L, Kadi-Hanifi H. 2012. Grazing exclosure and plantation: A synchronic study of two restoration techniques improving plant community and soil properties in arid degraded steppes (Algeria). Rev. Ecol. 67:257-269. doi: https://doi.org/10.3406/revec.2012.1965

Bouallala M. 2013. Etude floristique et nutritive spatio-temporelle des parcours camelins du Sahara occidental Algérien. Cas des régions de Bechar et Tindouf. [Tesis]. [Ouargla] : Université Kasdi Merbah.

Boughani A, Sadki N, Médail F, Nedjraoui D, Salamani M. 2009. Analyse floristique et phytogéographique d'une région de l'Atlas saharien constantinois, les gorges du Ghouffi (Algérie). Acta. Bot. Gallica. 156(3):399-414. doi: https://doi.org/10.1080/12538078.2009.10516166

Bourbouze A. 1997. Des Agdals et des mouflons. Courr. Envir. INRA. 30:63-72.

Chaieb M, Boukhris M, editores. 1998. Flore succincte et illustrée des zones arides et sahariennes de Tunisie. Tunis: Or du temps Ed.

Chedli H, Traouit B, Neffati M. 2016. Vegetative habitat selection of Scimitar horned Oryx (**Oryx dammah**) in BouHedma National Park, Southern Tunisia. J. King Saud Univ. Sci. 28(3): 261-267. doi : https://doi.org/10.1016/j.jksus.2016.04.003

Cigolani AM, Posse G, Collantes MB. 2005. Plants traits, herbivore selectivity and response to sheep grazing in Patagonia steppe grasslands. Japp. Ecol. 42(1):50-59. doi: https://doi.org/10.1111/j.1365-2664.2004.00978.x

Cornet A, Poupon H. 1977. Description des facteurs du milieu et de la végétation dans cinq parcelles situées le long d'un gradient climatique en zone sahélienne au Sénégal. Bull. IFAN. A. 39 (2):241-301.

Daget P, Poissonet J. 1971. Une méthode d'analyse phytologique des prairies. Critères d'application. Ann. Agronom. 22(1):5-41.

Dupuy B, Maître HF, Amsallem I, editores. 1999. Techniques de gestion des écosystèmes forestiers tropicaux : état de l'art. Rome. Organisation des Nations Unies pour l'alimentation et l'agriculture.

Emberger L. 1955. Une classification Biogéographique des Climats. Recl. Trav. Lab. Bot. Géol. Zool. Fac. Sci. Univ. Montpel. Sér. Bot. 7:3-43.

Foudil K, Khéloufi B, Boutkhil M. 2015. Impact de la mise en défens sur la lutte contre la désertification dans les parcours steppiques : cas de la région de Naâma (Sud-Ouest Algérien). Rev. Ecol. 70(1):16-31. doi :https://doi.org/10.3406/revec.2015.1766

Floret C, Pontanier R, editores. 1982. L'aridité en Tunisie présharienne, climat, sol, végétation et aménagement. Paris: ORSTOM.

Jaccard P. 1901. Distribution de la flore alpine dans le bassin des Dranses et dans quelques régions voisines. Bull. Soc. Vaud. Sci. Nat. 37(140):241-272. doi: https://doi.org/10.5169/seals-266440.

Jaouadi W, Mechergui K, Gader G, Khouja ML. 2013. Étude des secteurs écologiques, du milieu physique et des caractéristiques de production de la steppe arborée à *Acacia tortilis* dans le parc national de BouHedma (Tunisie méridionale). Rev. Écol. 68(2):143-156. doi: https://doi.org/10.3406/revec.2013.1689

Kadi Hanifi H. 2003. Diversité biologique et phytogéographique des formations à *Stipa tenacissima* L. de l'Algérie. Sécheresse (Montrouge). 14(3):169-179.

Karem A, Ksantini M, Schoenenberger A, Waibel T, editores. 1993. Contribution à la régénération de la végétation dans les parcs nationaux en Tunisie aride. Eschborn: GTZ.

Lardry JM, Haberkorn V. 2007. L'aromathérapie et les huiles essentielles. Kinesither. Rev. 7(61):14-17. doi: https://doi.org/10.1016/S1779-0123(07)70308-X

Le Houérou HN. 1986. The desert and arid zones of Northern Africa. En: Evenari M, Noy-Meir E, Goodall DW, editores. Hot deserts and Arid Shrublands. Ecosystems of the World. Amsterdam: Elsevier. p 101-147.

Maire R, Guinochet M, Faurel L, editores. 1955. La Flore de l'Afrique du Nord. Volume III Monocotyledonae Glumiflorae (Gramineae: sf. Pooideae p.p.). Paris : Paul Le chevalier.

Mitja D, Puig H. 1990. Phytomasse de la strate herbacée de cinq jachères en zone de savane humide (Booro-Borotou, Côte-d'Ivoire). Bull. Ecol. 21(1):19-32.

Neffati M. 1994. Caractérisation morphologique de certaines espèces végétales nord-africaines: implication pour amélioration pastorale. [Tesis]. [Ghent]: Université de Ghent.

Noumi Z. 2010. *Acacia tortilis* (Forssk.) Hayne subsp. *raddiana* (Savi) Brenan en Tunisie pré-saharienne: structure du peuplement, réponses et effets biologiques et environnementaux. [Tesis]. [Sfax]: Faculté des Sciences de Sfax.

Ouled Belgacem A, Tarhouni M, Louhaichi M. 2013. Effect of protection on plant community dynamics in the Mediterranean arid zone of southern Tunisia: a case study from BouHedma National park. Land. Degrad. Develop. 24:57-62. doi : https://doi.org/10.1002/ldr.1103

Ozenda P, editor. 1977. Flore du Sahara, 2ème édition (revue et complétée). Paris : Editions du Centre national de la recherche scientifique.

Pielou EC. 1966. The Measurement of Diversity in Different Types of Biological Collections. J. Theor. Biol. 13:131-144. doi: https://doi.org/10.1016/0022-5193(66)90013-0

Pottier-Alapetite G, editor. 1979. Flore de Tunisie. Angiospermes-dicotylédones. Tome 1, Apétales-dialypétales. Tunis: Ministère de l'Enseignement Supérieur et de la Recherche Scientifique et le Ministère de l'Agriculture.

Pottier-Alapetite G, editor. 1981. Flore de Tunisie. Angiospermes-dicotylédones. Tome 2, Gamopétales. Tunis : Ministère de l'Enseignement Supérieur et de la Recherche Scientifique et le Ministère de l'Agriculture.

Schlesinger WH, Reynolds JF, Cunningham GL, Huenneke LF, Jarrell WM, Virginia RA, Whitford WG. 1990. Biological feedbacks in global desertification. Science. 247(4946):1043-1048. doi: https://doi.org/10.1126/science.247.4946.1043

Shannon CE, Weaver W. 1948. The Mathematical Theory of Communication. Bell. Syst. Tech. J. 27:379-423, 623-656. doi: https://doi.org/10.1002/j.1538-7305.1948.tb00917.x

Simpson EH. 1949. Measurement of Diversity. Nature. 163:688. doi: https://doi.org/10.1038/163688a0

Tarhouni M. 2003. Cartographie des systèmes écologiques et étude de la dynamique de l'occupation des terres dans le parc national de BouHedma. [Tesis]. [Sfax]: Faculté des sciences de Sfax.