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Source: Rangeland Ecology and Management, 83(1) : 10-19

Published By: Society for Range Management

URL: https://doi.org/10.1016/j.rama.2022.02.013

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Rangeland Ecology & Management 83 (2022) 10–19

Contents lists available at ScienceDirect

Rangeland Ecology & Management

journal homepage: www.elsevier.com/locate/rama

Original Research

Impact of Grazing Regimes, Landscape Aspect, and Elevation on Plant Life Form Types in Managed Arid Montane Rangelands ☆

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ARTICLE INFO

Article history:
Received 17 June 2021
Revised 20 January 2022
Accepted 28 February 2022

Keywords:
Adaptation
Drylands
Grazing management
Mountain ecosystems
Plants

ABSTRACT

Arid steppes, with scattered vegetation, are commonly qualified as degraded ecosystems. Their natural vegetation cover is affected by both abiotic stresses and human activities and, therefore, suitable managements are needed for their sustainability. This study was carried out in the mountain rangeland chain of Matmata (southern dryland of Tunisia) during the springs of 2 rainy yr, 2019 and 2020. Our aims were to evaluate the impact of three grazing regimes (grazing exclusion [over 42 ys; 1978–2020]; seasonal [protected in spring and summer and grazed in autumn and winter, since the 1960s]; and continuous grazing [control; grazed over time]) on the cover of some plant life forms (Raunkiaer, Noy-Meir, and Grime types), under various conditions (sites, aspects, and elevations). To achieve this goal, the pseudoreplicated-nested design was applied, taking into account the site locations (grazing regimes), aspects (exposure to sunlight), and elevations. The cover of the retained plant life forms was measured using the quadrat point method. The main results showed that plant life forms are strongly affected by the grazing regime since the chamephytes *(Ch_R),* arido-active *(AA_NM),* and competitive stress-tolerant species *(CS_G)* are higher under seasonal grazing than control. All these species are qualified as less resistant to grazing. However, arido-passive *(AP_NM),* ruderal stress-tolerant *(RS_G),* and therophytes (*Th_R*) seem to be more resistant to grazing. Studying the impact of grazing management on the plant life form types provides useful information to find the most adapted species for rangeland sustainability all around the world.

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Introduction

The central goal of comparative ecology is to understand the diversity of functional and life history strategies among co-occurrence species (Ackerly 2004). In terrestrial ecosystems, many studies have been conducted to identify some adaptive strategies of plants to survive under harsh conditions. The arid steppe vegetation, with climatic and edaphic determinism, is characterized by a set of communities owing their physiognomy and composed mainly with grasses, forbs, and shrubs. This composition is essentially marked by the abundance of some perennial grasses (*Stipa tenacissima* L., *Lygeum spartum* Loefl. Ex. L…) and shrubs (*Artemisia herba-alba* L., *Haloxylon scoparium* Pomel…) growing in sparse tufts with irregular distribution of annual species (Aïdoud et al. 2006; Benaradj 2009). In this ecosystem, vegetation cover is subject to several constraints related to edaphoclimatic conditions and human activities that affect both the biophysical environment and the plant tufts. Tunisian drylands, with a mean annual rainfall < 200 mm, are currently facing degradation and desertification, mainly in the most arid rangelands. To conserve biodiversity and maintain the autoregeneration capacity (i.e., ecosystem resilience potential), defined as maintaining their capacity in the face of disturbances (Adger 2000), it is important to use appropriate management techniques. Fencing is one of the main management practices used to protect the rangeland plant communities. It significantly improves the aboveground vegetation productivity but decreases plant diversity and density after long protection (Wu et al. 2011). Among many authors, Ouled Belgacem et al. (2019) reported that seasonal grazing, including strategic rest periods, is generally better for rangeland vegetation than long-term animal exclusion. The adaptive strategies of the existing plants in already managed/protected areas can be assessed in order to select the more adaptive species and use them in future rehabilitation programs of very degraded or unresilient rangelands.

☆ This study was financed by the Arid Regions Institute of Medenine, Tunisia.

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https://doi.org/10.1016/j.rama.2022.02.013
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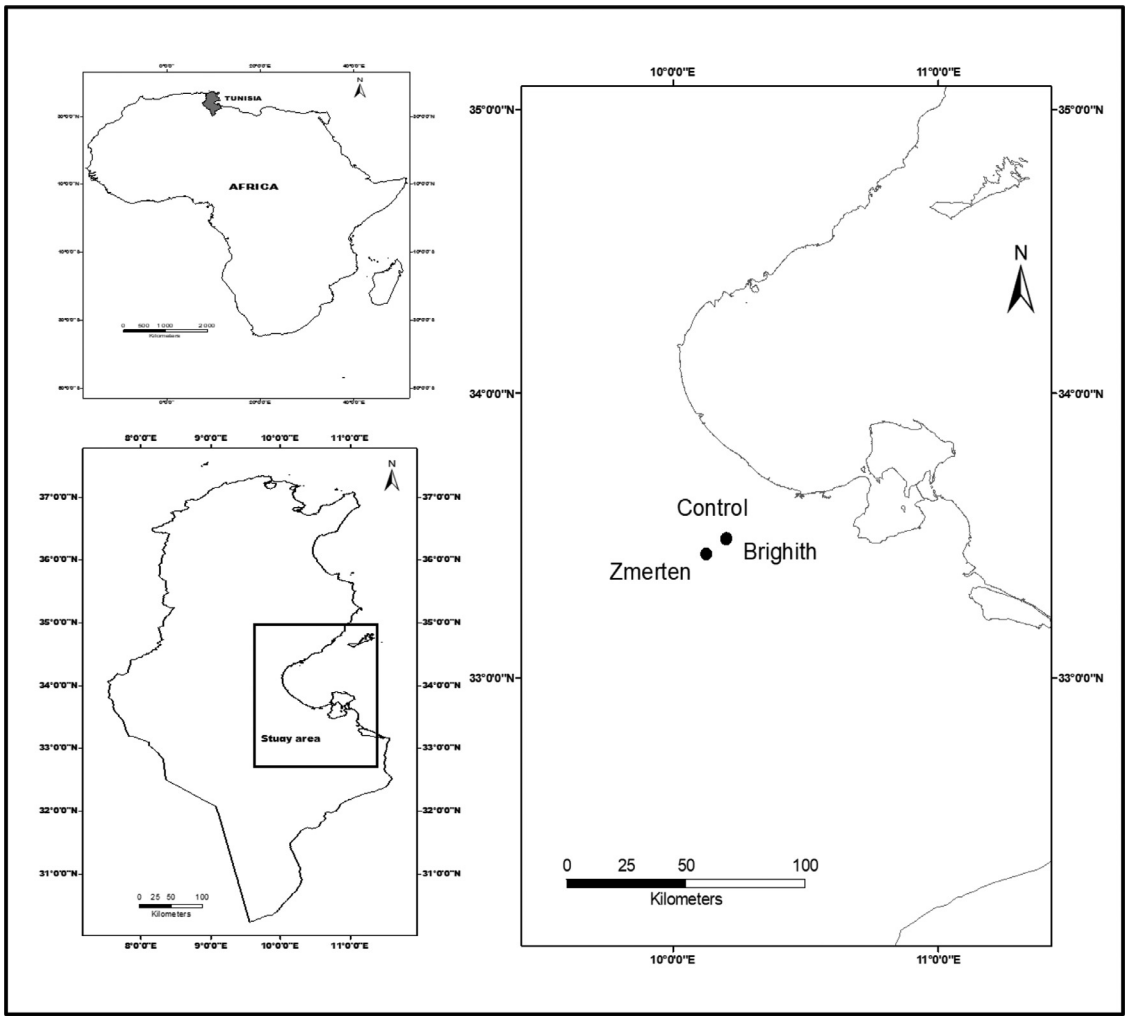


Figure 1. Geographical location of the three studied sites in southern Tunisia. Zmerten (Site 1), Brighith (site 2), Control (site 3).

The Raunkiaer biologic types are considered as a flora adaptation strategy to climate (Raunkiaer 1934) Noy-Meir (1973). classified plants to arido-passive species *(AP_NM),* without photosynthetic activity during the dry period, and to arido-active species *(AA_NM),* which maintain such activity, even reduced, during this same period. To assign components of stress tolerance *(S_G),* survival under disturbance *(R_G),* and competitive ability *(C_G),* Grime (1974) developed a simplified determination key based purely on species characteristics. Investigating all these plant life forms is strategic to know the flora diversity and adaptation and to propose management programs for conservation of natural resources (Encina et al. 2016). In this context, the present study aims to understand the vegetation response by assessing plant life forms' distribution under the effects of several factors including human disturbances (i.e., grazing regimes), exposure to sunlight (north and south aspects), and elevation levels in arid montane rangelands. The main questions are what are the better life forms that describe the rangeland situation under various grazing regimes, on one hand, and which life forms can be grouped to indicate the resilience of these ecosystems, on the other hand?

Materials and Methods

Study area

Three study sites belonging to the Toujane region (Matmata mountain chain, southeast of Tunisia) were studied (Fig. 1). The mean annual precipitation in the region is about 150 mm with notable interannual variations. The physical environments of the three sites are similar (same soil substratum, topography, and geology), but they differ in altitudinal range and grazing regime (Fig. 2). Zmerten (site 1, 33.435332°N, 10.124727°E, 3 000 ha) is located in the middle of the mountain chain and has been strictly protected from grazing for 42 yr. Its natural vegetation is dominated by *Juniperus phoenicea* L., *S. tenacissima,* and *Rosmarinus officinalis* L. Brighith (site 2, 33.489832°N, 10.200800°E, 100 ha) is located on the northeastern border of the chain. This site is dominated by *S. tenacissima* and is devoted to seasonal grazing (protected in spring and summer and grazed in autumn and winter) with controlled animal charge (100 animals, sheep and goats, in the whole site). The control (site 3, 33.487485°N 10.199511°E) is closed to site 2 and dominated by *S. tenacissima*. It is continuously open to grazing (100 animals, sheep and goat, all over the year).

Data collection

In each site, three 20-m line-transects, 100 m apart, are installed at three elevation levels (low, medium, and high) and two aspects to sunlight (south [high], north [low]) of the mountain hill (18 lines per site in total) in order to measure the floristic composition using the quadrat point method (Daget and Poissonet 1971; Floret 1988). A metal fine pin (1-m length) was entered perpendicularly (above-down) into the vegetation every 20 cm along the line (in total 100 hits per line). Each plant species touching the

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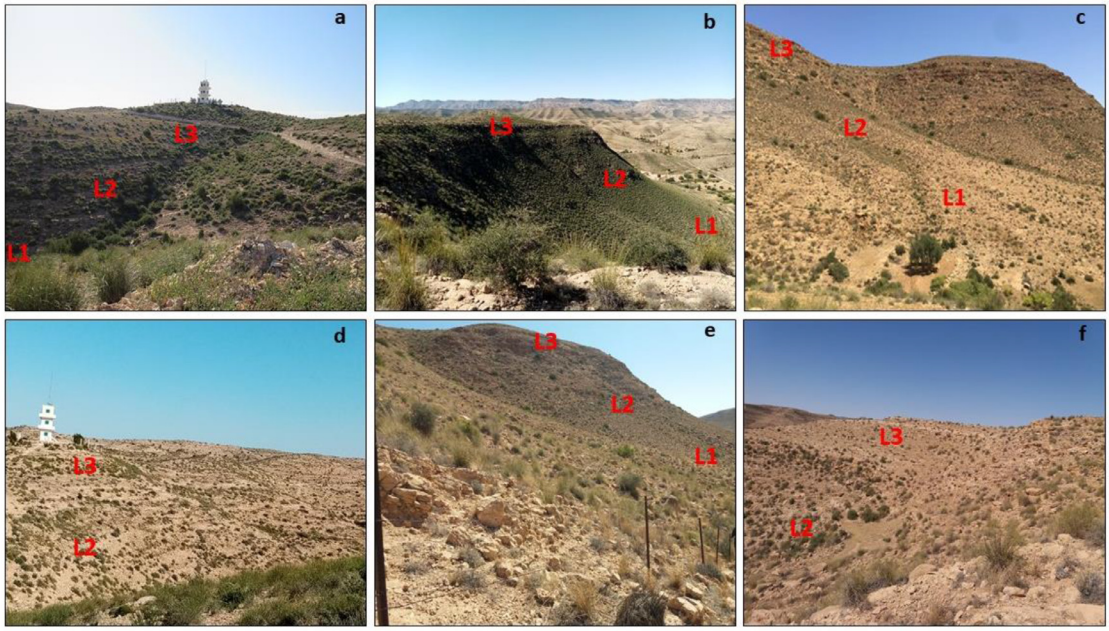


Figure 2. Overview of **a–c,** northern and **d–f,** southern aspects of the livestock exclusion (Zmerten, **a, d**), seasonal grazing (Brighith, **b, e**), and continuous grazing (Control, **c, f**) sites during spring 2020. *L1, L2,* and *L3* indicate low, medium, and high elevations, respectively.

pin was recorded. Unknown plant species were identified using the Flora books (Alapetite 1979, 1981; Le Floc'h et al. 2010). The methodological approach is a pseudoreplicated-nested design, with the three grazing treatments (exclusion, seasonal, and continuous grazing) confounded with sites, within each of which is a nested aspect (north aspect vs. south), within which again is nested altitude (low, medium, high). Measurements were carried out in the springs of 2019 and 2020 (each site was sampled once per year). These 2 yr were rainy (190 mm and 322 mm, respectively, for 2019 and 2020).

Data analysis

Since the 2 studied yr are rainy, the data collected during the two springs were combined to obtain the mean cover of Noy-Meir, Raunkiaer, and Grime types ($n = 6$). The log transformation was used when data normality is nonrespected. Multiple separate one-way analyses of variance (ANOVAs) were undertaken to compare these types within and among sites. The multivariate general linear model was used to analyze the combined effect of elevation and aspect in the same site, using two-way ANOVA, on one hand, to study the combined effect of sites, elevations, and aspects and using three-way ANOVA, on the other hand. When an ANOVA was significant, the Duncan test was applied for classification. All these statistical analyses were performed using SPSS 20.0 software. The Origin Pro software (version 2021, Origin-Lab Corporation, Northampton, MA) was used for nonmetric multidimensional scaling analysis. Ordination distances between plant life forms and their relationship with sites were measured by Kruskal's stress.

Results

Raunkiaer biological types

Chamephytes, hemicryptophytes, and therophytes are the dominant life forms in the studied sites (> 80%). The dominant Chamephyte species are *Argyrolobium uniflorum* (Decne.) Jaub. & Spach, *Gymnocarpos decander* Forssk. and *Teucrium polium* L. The hemicryptophyte species are mainly composed of *S. tenacissima, Herniaria fontanesii* J. Gay., and *Helianthemum semiglabrum* auct. The dominant therophytes are *Fagonia glutinosa* Delile, *Plantago ovata* Forssk, and *Stipa capensis* Thunb (Table 1).

Variations within sites

Changes in Raunkiaer biological types within the three sites are shown in Figure 3. After long-term protection (Zmerten, site 1), chamaephytes *(Ch_R),* hemicryptophytes *(He_R),* and therophytes *(Th_R)* covered 19.05%, 31.44%, and 10.33%, respectively, in the northern aspect. Their respective covers are 14.94%, 27.94%, and 10.67% in the southern aspect. The *Ch_R* and *Th_R* covers did not differ between the north and south aspects nor between elevations on the same aspect ($P > 0.05$). In the northern aspect, *He_R* showed high significant differences ($P = 0.004$) between elevations. The interaction between aspect and elevation was not significant for all types ($P > 0.05$).

Under seasonal grazing (Brighith, site 2), *Ch_R*, *He_R,* and *Th_R* covered 18.89%, 59.28%, and 0.28%, respectively, in the northern aspect. Their respective covers in the southern aspect are 24.94%, 39.67%, and 1.22%. *Ch_R* did not differ between elevations in the southern aspect nor between the two aspects for all elevations ($P > 0.05$). A significant difference was noted between the south and north aspects at low elevation ($P = 0.012$) for *He_R*. At the same time, a significant effect of elevation is found in the northern aspect ($P = 0.013$). Very low cover of *Th_R* was noted in all elevations for both aspects.

In the control site, *Ch_R, He_R,* and *Th_R* showed no significant variations between elevations in the northern aspect. However, there was a significant effect on the *He_R* group between the north and south aspects at low elevation ($P = 0.015$).

Variations between sites

Th_R participated with 10.5%, 0.75%, and 4.67% in the total plant cover of sites 1 (livestock exclusion), 2 (seasonal grazing), and 3 (continuous grazing), respectively. These species varied significantly between sites at low, medium, and high elevations in the north aspect ($P = 0.037$, $P = 0.02$, and $P = 0.031$, respectively). The

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Table 1
Average cover (%) of the dominant plant species in the three studied sites during the springs 2019 and 2020.

	Raunkiaer types	Noy-Meir types	Grime types		Grazing exclusion			Seasonal grazing			Control		
					L1	L2	L3	L1	L2	L3	L1	L2	**L3**
Argyrolobium uniflorum (Decne.) Jaub. & Spach	*Ch_R*	*AP_NM*	*CRS_G*	N	0.33	–	–	0.5	1	–	–	0.17	0.5
				S	–	–	–	4.67	1.33	0.83	–	0.33	0.33
Artemisia herba-alba L.	*Ch_R*	*AA_NM*	*S_G*	N	–	–	–	0.33	–	–	–	0.5	3.5
				S	–	–	–	–	–	-	1	–	1.83
Astragalus armatus Willd.	*Ch_R*	*AA_NM*	*CR_G*	N	–	–	–	1.5	–	-	–	–	–
				S	–	–	–	–	–	-	3.5	0.83	–
Cenchrus ciliaris L.	*He_R*	*AP_NM*	*CS_G*	N	–	–	–	–	–	-	–	–	–
				S	–	–	–	0.83	1.67	4.67	–	1.83	–
Diplotaxis harra (Forssk.) Boiss.	*Th_R*	*AP_NM*	*RS_G*	N	–	–	–	–	–	–	–	–	–
				S	–	0.17	–	0.33	0.67	–	–	–	–
Echium humile Desf.	*He_R*	*AP_NM*	*RS_G*	N	–	–	–	–	–	–	–	0.17	0.5
				S	–	–	–	–	–	–	–	–	–
Fagonia glutinosa Delile.	*Th_R*	*AP_NM*	*RS_G*	N	1.33	–	0.33	–	–	–	0.17	–	1.17
				S	0.17	0.33	3.33	0.17	0.17	–	–	–	–
Gymnocarpos decander Forssk.	*Ch_R*	*AA_NM*	*S_G*	N	–	–	1.17	1	–	0.16	0.67	–	4
				S	0.33	12.67	–	0.17	–	–	0.33	–	2.33
Helianthemum semiglabrum auct.	*He_R*	*AP_NM*	*CRS_G*	N	2.17	2	1.92	1.16	3.5	2.5	1	0.17	–
				S	–	–	1.5	0.5	0.33	–	–	–	–
Herniaria fontanesii J. Gay.	*He_R*	*AA_NM*	*CS_G*	N	–	–	0.17	–	0.5	–	0.5	0.67	0.33
				S	–	–	3	0.5	–	–	0.17	–	–
Linum strictum L.	*Th_R*	*AP_NM*	*RS_G*	N	2.67	0.83	0.33	–	–	–	0.17	–	–
				S	–	–	–	–	–	–	–	–	–
Plantago ovata Forssk.	*Th_R*	*AP_NM*	*RS_G*	N	–	0.33	3.17	–	–	–	–	0.17	–
				S	0.67	2.33	–	0.17	–	–	1.33	1.5	0.67
Stipa capensis Thunb.	*Th_R*	*AP_NM*	*RS_G*	N	–	–	–	–	–	–	0.17	–	2.33
				S	–	1.39	–	–	–	–	0.83	–	–
Stipa tenacissima L.	*He_R*	*AA_NM*	*CS_G*	N	19.83	29.16	18	67.2	65.16	25.75	22	32.5	28.49
				S	9	35.67	30.83	25.16	30.33	19.5	9.83	17	14.67
Teucrium polium L.	*Ch_R*	*AA_NM*	*RS_G*	N	1	1.83	–	–	0.83	0.5	1.17	2.5	0.17
				S	1.5	–	0.17	–	–	–	1.5	0.67	–

L1, L2, and L3 indicate low, medium, and high elevations, respectively; N, northern aspect; S, southern aspect; *Ch_R*, chamaephytes; *He_R*, hemicryptophytes; *Th_R*, therophytes; *AA_NM*, arido-active species; *AP_NM*, arido-passive species; *C_G*, competitive; *R_G*, ruderal; *S_G*, stress tolerant.

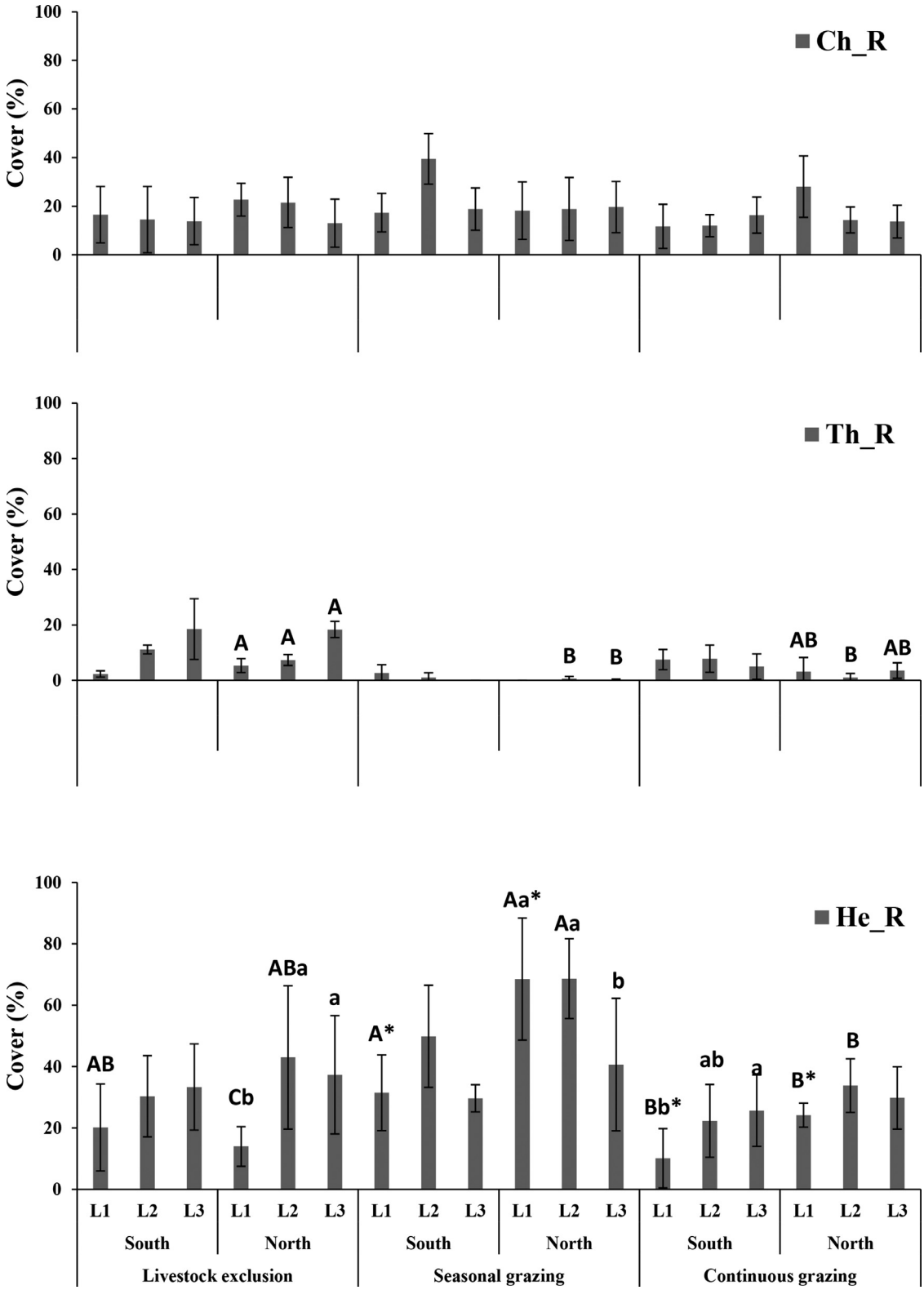


Figure 3. Variation of Raunkiaer biological types covers (means [%] ± standard deviation, $n = 6$) in the three studied sites. *L1*, *L2*, and *L3* indicate low, medium, and high elevations, respectively; *Ch_R*, chamaephytes; *He_R*, hemicryptophytes; *Th_R*, therophytes; a/b/c, differences between elevations in the same aspect of each site; A/B/C, differences between sites in the same aspect and same elevation; *, significant difference between northern and southern aspects in the same site and same elevation. Multiple comparisons are according to the Duncan test when the analysis of variance is significant.

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Table 2
General linear model analysis showing the interaction of sites, elevation, and aspects on the plant life form types ($n = 36$). Only significant effects are mentioned here.

Plant types	Location	Main effects	Sum of squares	df	Mean of squares	F	*P*
Hemicryptophyte	North	Site × Elevation	4.069	4	1.017	5.325	0.001
Therophyte	Level 1	Site × Aspect	5.578	2	2.789	3.655	0.038
Arido-active	Level 1	Site × Aspect	5.578	2	0.467	4.659	0.018
Arido-passive	Level 1	Site × Aspect	10.673	2	5.336	5.739	0.008
	South	Site × Elevation	17.691	4	4.423	2.739	0.041
Competitive-stress-tolerant	Level 1	Site × Aspect	4.999	2	2.500	3.556	0.042
	North	Site × Elevation	818	4	2.205	6.947	0.000
Ruderal-stress-tolerant	Grazing exclusion	Elevation × Aspect	7.277	2	3.638	5.157	0.012
	Level 1	Site × Aspect	7.207	2	3.604	4.429	0.021
	South	Site × Elevation	19.479	4	4.70	4.498	0.004

interaction between sites and aspects was significant at low elevation ($P = 0.038$, Table 2).

The highest *Ch_R* and *He_R* covers were obtained in sites 1 and 2. For *Ch_R,* no significant difference between sites at both aspects was noted. In the northern aspect, *He_R* differed significantly between sites at low ($P = 0.000$) and medium elevations ($P = 0.027$). In the southern aspect, *He_R* varied significantly between sites only at low elevations ($P = 0.036$). High significant interaction between sites and elevations was noted for *He_R* in the northern aspect ($P = 0.001$, see Table 2).

Noy-Meir types

Variations within sites

Figure 4 presents variation of Noy-Meir types covers. The highest covers were recorded in the northern aspects of site 1 (51.89% and 23.39%, respectively, for *AA_NM* and *AP_NM*) compared with those of the southern side (41.22% and 16.39%). No significant difference was noted for both *AA_NM* and *AP_NM* between elevations ($P > 0.05$), aspects ($P > 0.05$), and their interactions ($P > 0.05$).

In site 2, *AA_NM* covers are higher in the northern aspect (75.67%) compared with those of southern (43.56%). Inversely, *AP_NM* showed the highest covers in the southern aspects. *AA_NM* covers varied significantly between aspects in all elevations ($P < 0.05$). It appears that aspects influenced the *AP_NM* covers mainly in low elevation ($P = 0.012$). *AA* covers varied significantly according to elevations in the northern aspect ($P = 0.027$), where no significant interaction between aspects and elevations is noted for both *AA_NM* and *AP_NM* species.

In site 3, *AA_NM* covers are higher in the northern aspect with 45.78% compared with 31.83% in the southern one. The corresponding covers of *AP_NM* species are around 6.11% and 10.44%. The difference between aspects is highly significant ($P = 0.007$) at low elevation for *AA_NM* and at medium elevation for both *AA_NM* ($P = 0.045$) and *AP_NM* ($P = 0.004$). No elevation effects were noted for *AA_NM* and *AP_NM* in the northern aspect.

Variations between sites

The highest covers of *AA_NM* species are recorded under seasonal grazing (59.61%), followed by those of livestock exclusion (46.56%) and control (38.81%). In southern aspects, *AP_NM* covers varied significantly between sites at low elevation ($P = 0.049$). In northern aspects, high significant differences of *AA_NM* covers are noted between sites in low ($P = 0.001$) and medium elevations ($P = 0.019$). In this same aspect, the variation of *AP_NM* covers between sites is also significant at medium ($P = 0.046$) and high elevation ($P = 0.03$). A high interaction between sites and aspect is noted for both *AA_NM* and *AP_NM* species at low elevation ($P < 0.01$, see Table 2). Likely, the interaction between sites and elevation was significant for *AP_NM* in southern aspects ($P = 0.041$).

Grime types

Variations within sites

Grime-type covers in the three studied sites are shown in Figure 5. The *CRS_G* species showed the lowest cover in the three sites. In site 1, *CS_G, RS_G,* and *S_G* species cover, respectively, were 28.17%, 11.39%, and 16.5% in the southern aspect and 26.61%, 16.22%, and 29.94% in the northern one. *CS_G* covers varied among elevations in the northern aspect ($P = 0.002$), but only *RS_G* varied between aspects at low elevation ($P = 0.04$).

In site 2, *CS_G* and *S_G* covers were higher in the northern aspect (61.94% and 13.72%, respectively) when compared with the southern one (41.44% and 9%). The effect of elevation was significant only for *RS_G* in the southern aspect ($P = 0.012$). A significant effect of aspects was noted for *CS_G* ($P = 0.006$) at low elevations and *RS_G* ($P = 0.006$) at high elevations. The interaction between aspects and elevations is only significant for *RS_G* ($P = 0.012$).

In site 3, the highest covers of *CS_G, CRS_G,* and *S_G* are recorded in the northern aspect (29.17%, 0.56%, and 19.94%, respectively). Their respective covers in the southern aspect are 20.0%, 0.22%, and 11.27%. Aspects were significant for *CS_G* ($P = 0.029$) and *RS_G* ($P = 0.025$) at low and medium elevations, respectively. In the southern aspect, the elevation was significant for *CS_G* ($P = 0.022$). No significant interaction between aspects and elevations was obtained.

Variations between sites

The covers of *CS_G* and *CRS_G* are lower under open grazing (24.58% and 0.39%, respectively) when compared with livestock exclusion (27.39% and 1.64%) and seasonal grazing (51.69% and 3.39%). The ANOVA showed high significant difference between sites for *CS_G* ($P < 0.001$) and *S_G* ($P = 0.017$) in low elevation and for *CS_G* ($P = 0.016$) in medium elevation in the northern aspect. In the southern one, a significant difference between sites is noted for *CRS_G* ($P = 0.015$), *CS_G* ($P = 0.009$), and *RS_G* ($P = 0.024$) in low, medium, and high elevations, respectively. According to the two-way ANOVA, the interaction between sites and elevations is highly significant for *CS_G* ($P < 0.001$, see Table 2) in the northern aspect and for *RS_G* ($P = 0.004$) in the southern one. A significant interaction between sites and aspects is noted for *CS_G* ($P = 0.042$) and *RS_G* ($P = 0.021$) at low elevation.

Plant life forms ordination

The nonmetric multidimensional scaling analysis combined the plant life forms and sites (Fig. 6). It shows difference in plant life forms within and between sites. Three main life forms group can be identified. The first group contains *He_R, Ch_R, AA_NM, CRS_G,* and *CS_G*. The second contains *Th_R, AP_NM,* and *RS_G*. The last one includes only *S_G* species. These groups hold life forms with same signification, so it seems that using one plant life form type from each group can explain the studied approach about the ecosystem resilience and plant adaptations.

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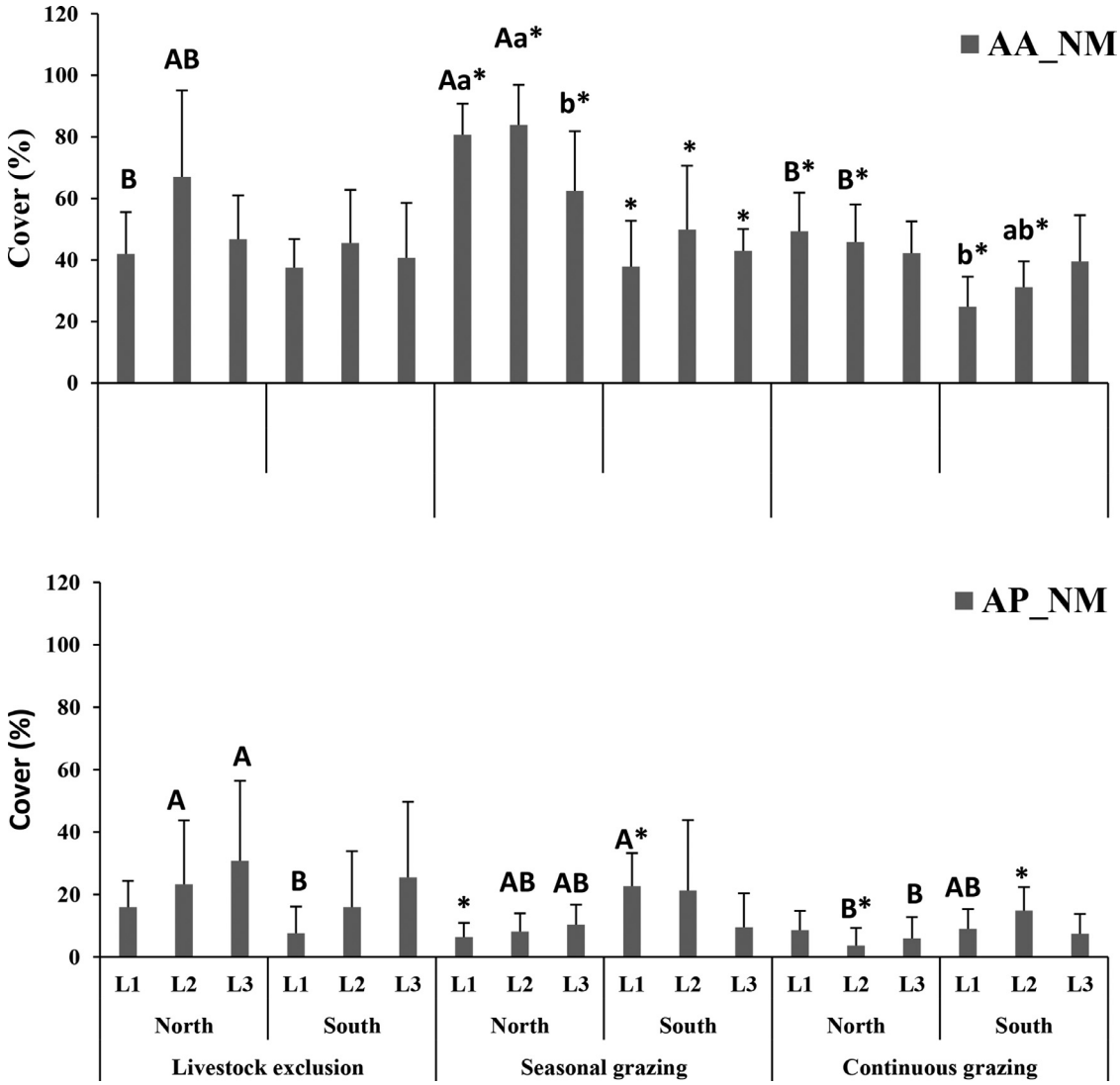


Figure 4. Noy-Meir type covers (means [%] ± standard deviation, $n = 6$) in the three studied sites. *L1, L2,* and *L3* indicate low, medium, and high elevations, respectively; *AA_NM,* arido-active species; *AP_NM,* arido-passive species; a/b/c, differences between elevations in the same aspect of each site; A/B/C, differences between sites in the same aspect and same elevation; *, significant difference between northern and southern aspects in the same site and same elevation. Multiple comparisons are according to the Duncan test when the analysis of variance is significant.

Discussion

The plant life forms were generally used as descriptive tools to characterize the vegetation communities' adaptation to different stress and disturbances. The main results showed that *Ch_R*, *AA_NM,* and *CS_G* are the most dominant types in the three sites, mainly in the seasonal grazing one (see Fig. 6). It appears that these plants are particularly sensible to both high disturbance and/or long protection. Pastoral plants in arid free-grazed rangelands presented lower covers compared with rested areas (Ouled Belgacem et al. 2019). Our results confirmed this and showed that under seasonal grazing, the *Ch_R*, *AA_NM,* and *CS_G* covers are higher compared with the control site. Similar results are obtained by Vecchio et al. (2019) showing an increase in plant species as a response to seasonal grazing after improvement of soil characteristics. In fact, seasonal grazing, including short grazing periods alternated by fencing during the growing season, modified the soil by increasing its organic matter content and improving its physical and chemical properties (Vecchio et al. 2018). We showed that *He_R* species (mainly *S. tenacissima*) varied strongly among the tested management regimes. Its specific cover was higher in the fenced site compared with the control due to its high ability to compete for water and nutrients in absence of disturbances. In fact, protection favors the development of more competitive and stress-tolerant species regardless of their palatability (Louhaichi et al. 2012; Tarhouni et al. 2017). The *S. tenassicima* cover is higher under seasonal grazing than control and livestock exclusion sites. Short fencing periods (provided by seasonal grazing) enhanced the fast-growing and competitive species (especially the highly preferred plants by animals) to develop, flower, and disperse their seed (Vecchio et al. 2019). Our results corroborate these findings and showed that seasonal grazing with controlled animal charge seems to be better for natural vegetation than long-term protection or continuous grazing. To conclude, improved species cover, in the Brighith site (seasonal grazing), concerns mainly *He_R* and *CS_G* species. These plant life forms are principally presented by *S. tenacissima* (highest cover) and some other palatable, less palatable, and unpalatable grasses. The better resilience ability noted in this site permitted both ecological and pastoral benefits.

Aspect and altitudinal effects on *Ch_R, AA_NM,* and *CS_G* are masked under livestock exclusion, despite the slightly higher covers at the low and/or medium elevations on the southern aspect.

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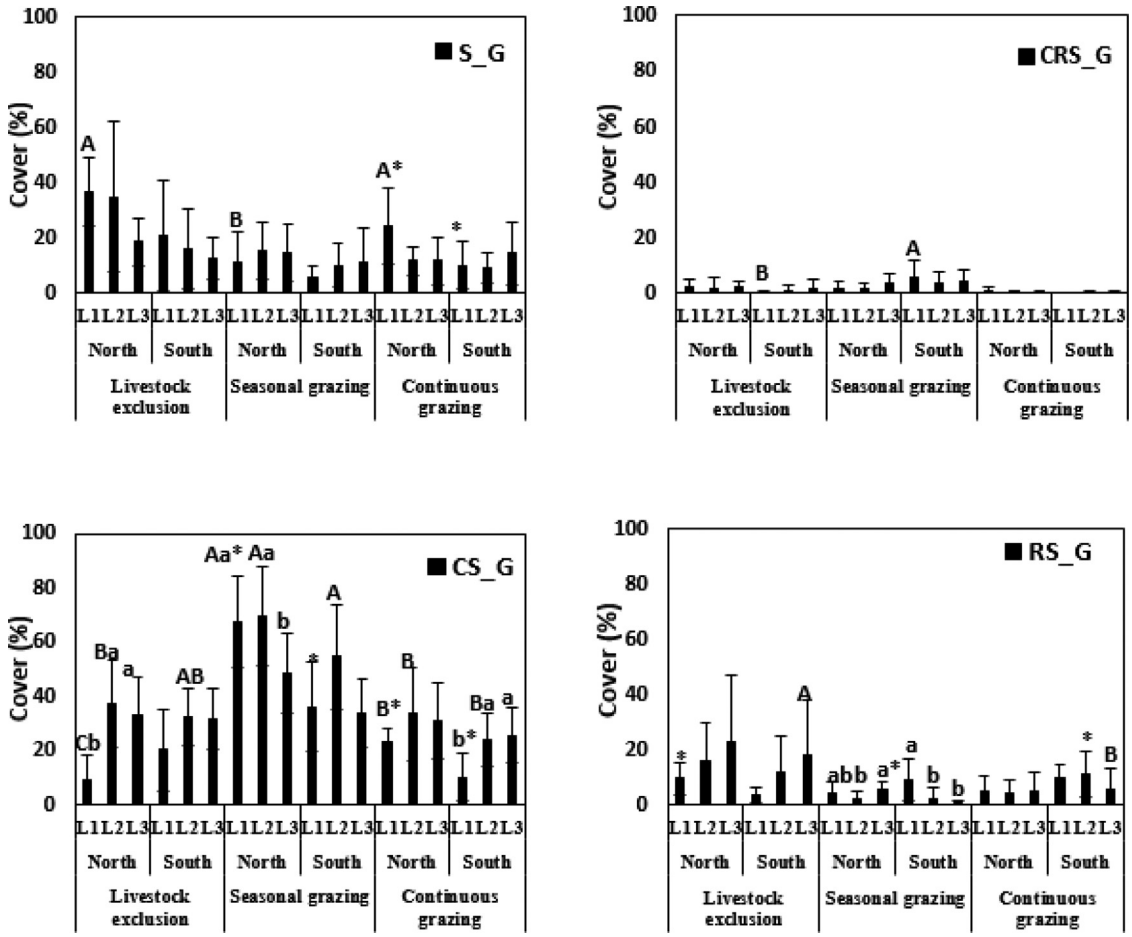


Figure 5. Grime type covers (means [%] ± standard deviation, $n = 6$) in the three studied sites. *L1, L2,* and *L3* indicate low, medium, and high elevations, respectively; *C_G,* competitive; *R_G,* ruderal; *S_G,* stress tolerant; a/b/c, differences between elevations in the same aspect of each site; A/B/C, differences between sites in the same aspect and same elevation; *, significant difference between northern and southern aspects in the same site and same elevation. Multiple comparisons are according to the Duncan test when the analysis of variance is significant.

These results can be related, in part, to improvements in soil characteristics at these two elevations (probably better organic matter content in soil, which improves its water balance). In fact, at high elevations the soil surface is more exposed to rainfall, runoff, and erosion (by water and wind). Such situations can negatively affect the plant growth and cover. The aptitude of some perennials plants for the vegetative multiplication and their resistance to drought could be the origin of their high covers on the southern aspects characterized by strong sun radiation (Neffati 1984). This may indicate the higher capacity of mountain ecosystems to withstand drought and disturbance (Ben Salem et al. 2009). *He_R* species, mainly the *S. tenacissima* key species, showed the highest covers on southern aspects. The same results were stated by Gasque and Garcıa-Fayos (2004) showing that direct effect of sun exposure favors seedlings and regeneration of *S. tenacissima* due to its high ability to compete for water and nutrients. The high covers of protected annuals plants (*Th_R, AP_NM,* and *RS_G*) on the northern aspects compared with those of the south are mainly due to shadows and cool, humid winds from the north. In southern exposure, more opened to erosion and intensive wind and temperature, the evaporation increases and soil moisture decreases (Broza et al. 2004).

Grazing services provided by an ecosystem are not necessarily related to its biodiversity. In cases of overgrazed areas, biodiversity and species richness can be highly favored by unpalatable and/or grazing-resistant plants (Tarhouni et al. 2017; Msadek et al. 2021). In fact, biodiversity can be increased by the grazing-resistant species despite their lower grazing value. Hence, the rangeland will be highly diversified (high environmental value) without palatable species (low economical value). Despite their high palatability, annual species (*AP_NM, RS_G,* and *Th_R* types) are higher in seasonal and continuous grazing areas, confirming their grazing resistance and qualification as indicators of disturbance in arid rangelands (Tarhouni et al. 2017). However, these species cannot ensure rangeland sustainability due to their high dependence to climate conditions. Otherwise, we suggest that perennials grouped in *AA_NM, CS_G,* and *He_R* types can help to achieve biodiversity and safeguard sustainability of resistant grazing systems thanks to their adaptive capacities, despite their low palatability.

It seems that the combined effects of climatic drought and human disturbance are more obvious in the southern aspect where the covers of *AA_NM, CS_G, CRS_G,* and *S_G* are lower in the grazed sites (continuous and/or seasonal) compared with the northern one. Contrasting results are shown for *AP_NM, RS_G,* and *Th_R,* which are preferred first over perennials to be grazed by livestock (Ouled Belgacem et al. 2019). The groups obtained from the ordination of various plant life forms can facilitate the assessment of vegetation. In fact, only one classification can be used from each group to understand the plant adaptation under the studied conditions. For example, in this study, only Grime's classification can be considered since the third group contains only *S_G* species. The similarity in covers of plant species during the two studied

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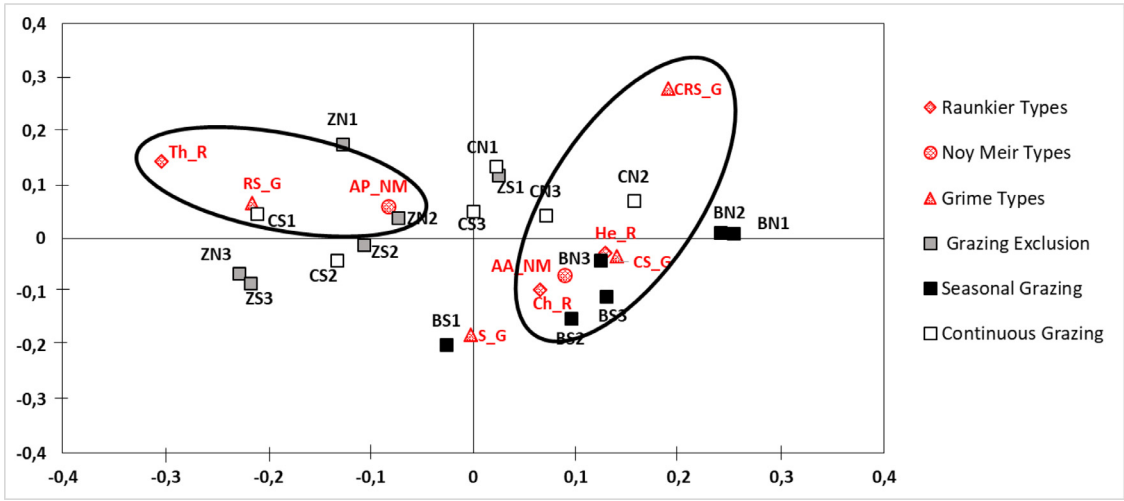


Figure 6. Nonmetric multidimensional scaling ordination of the plant life forms. *Ch_R* indicates chamaephytes; *He_R,* hemicryptophytes; *Th_R,* therophytes; *AA_NM,* arido-active species; *AP_NM,* arido-passive species; *C_G,* competitive; *R_S,* ruderal; *S_G,* stress tolerant; N, north; S, south; 1, 2, 3, low, medium, and high elevations, respectively.

seasons, mainly in the grazed sites (continuous and/or seasonal), can be explained by their regenerations after a succession of rainy years Ben Salem et al. (2009). showed a remarkable germination of plants species during the humid seasons. Our results prove that arid mountain ecosystems are endowed with an important capacity for resilience under good rainfall conditions, mainly with low disturbances. Further measurements during dry years (< 150 mm) are necessary in the future to study the impact of drought on the growth and resilience/regenerative capacity of plant species in these regions.

Conclusion

Understanding the ecological context and complexity of the species' adaptive strategies can provide new insights into the mechanisms governing plant responses to grazing. Our results suggest that seasonal grazing, with controlled animal charge, enhances the majority of plant species types compared with the control and livestock exclusion sites. This indicates a higher capacity for the montane ecosystems to withstand drought and reasonable disturbance. Seasonal grazing regimes should therefore be developed and generalized for the sustainable use of these natural rangelands. The adopted life-form types could also be used to predict the response of natural vegetation to climate changes and variations. We suggest the combination of the three types of classification in order to offer more information about multiple functional characteristics of inventoried species as a response to disturbance factors (climate and human activities). This can be valuable to understand vegetation physiognomy and resilience ability of the ecosystems and to assess the impact of the applied managements on arid ecosystems. Hybrid classification between Raunkiaer and Grime classifications can be also useful for such purpose.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This study was funded by the Arid Regions Institute of Medenine (IRA, Tunisia) with support from the International Center for Agricultural Research in the Dry Areas (ICARDA) and the Consultative Group on International Agricultural Research (CGIAR). The authors would like to thank anonymous reviewers for their valuable contributions to this manuscript. The opinions expressed in this work belong to the authors and do not necessarily reflect those of IRA, ICARDA or CGIAR.

References

Ackerly, D., 2004. Functional strategies of chaparral shrubs in relation to seasonal water deficit and disturbance. Ecological Monographs 74, 25–44.
Adger, W.N., 2000. Social and ecological resilience: are they related? Progress in Human Geography 24, 347–364.
Aïdoud, A., Le Floc'h, É., Le Houérou, H.N., 2006. The arid steppes of northern Africa. Science Chang Planetary Sacheres 17, 19–30.
Alapetite, G.P., 1979. Flora of Tunisia angiosperms-dicotyledones apetal-dialypetals. Ministry of Higher Education of Scientific Research and the Ministry of Agriculture 269–287.
Alapetite, G.P., 1981. Flora of Tunisia: angiosperms, dicots. Gamopetals. Ministry of Higher Education for Scientific Research and the Ministry of Agriculture, p. 1190.
Benaradj, A., 2009. Fencing and biological ascent of steppe ranges in the Naama region dissemination and multiplication of some steppic species. Mohamed Boudiaf University of Science and Technology-Mohamed Boudiaf of Oran.
Ben Salem, F., Tarhouni, M., Ouled Belgacem, A., Neffati, M, 2009. Variations seasonal of some structural attributes of the ecosystems of the Matmata Mountains in southern Tunisia under the effect of drought and anthropozoic action. Science and Global Change/Drought 20 (2), 204–209.
Broza, M., Poliakov, D., Gruia, M., Bretfeld, G., 2004. Soil collembolan communities on north-and south-facing slopes of an eastern Mediterranean valley. Pedobiologia 48, 537–543.
Daget, P., Poissonet, J., 1971. A method of phytological analysis of grasslands: application criteria. Agronomic Annals 22, 5–41.
Encina, J.A., Castillón, E.E., Quintanilla, J.A.V., Villaseñor, J.L., Ayala, C.M.C., Arevalo, J.R, 2016. Floristic richness of the Sierra de Zapalinamé, Coahuila, Mexico. Phytotaxa 283, 1–42.
Floret, Ch., 1988. Methods of measuring pastoral vegetation: pastoralism and development. CIHEAM, Montpellier Cedex, France 95.
Gasque, M., Garcıa-Fayos, P., 2004. Interaction between *Stipa tenacissima* and *Pinus halepensis:* consequences for reforestation and the dynamics of grass steppes in semi-arid Mediterranean areas. Forest Ecology Management 189, 251–261.
Grime, J.P., 1974. Vegetation classification by reference to strategies. Nature 250 (5461), 26–31.
Le Floc'h, É., Boulos, L., Véla, E., 2010. Commented synonymous catalogue of the Flora of Tunisia. Republic of Tunisia: Ministry of Environment and Sustainable Development. National Bank of Genes, Tunisia.
Louhaichi, M., Ghassali, F., Salkini, A.K., Petersen, S.L, 2012. Effect of sheep grazing on rangeland plant communities: case study of landscape depressions within Syrian arid steppes. Journal of Arid Environments 79, 101–106.
Msadek, J., Tlili, A., Moumni, M., Louhaichi, M., Tarhouni, M., 2021. Community diversity, functional traits and adaptation of *Stipa tenacissima* L. under different grazing regimes in a North African arid montane rangeland. African Journal of Range & Forage Science 38 (1), 122–129.
Neffati, M., 1984. Allelopathic behavior of *Artemisia campestris* L. in the courses of the Tunisian Djeffara. Memory of End of Studies. INAT Tunisia, p. 133.

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Noy-Meir, I., 1973. Desert ecosystems: environment and producers. Annual Review of Ecology Systems 4, 25–51.
Ouled Belgacem, A., Ben Salem, F., Gamoun, M., Chibani, R., Louhaichi, M, 2019. Revival of traditional best practices for rangeland restoration under climate change in the dry areas: a case study from Southern Tunisia. International Journal of Climate Change Strategies and Management 11, 643–659.
Raunkiaer, C., 1934. The life forms of plants and statistical plant geography. Oxford, Clarendon Press, London, p. 632.
Tarhouni, M., Ben Hmida, W., Neffati, M., 2017. Long-term changes in plant life forms as a consequence of grazing exclusion under arid climatic conditions. Land Degradation and Development 28, 1199–1211.
Vecchio, M.C., Golluscio, R.A., Rodríguez, A.M., Taboada, M.A, 2018. Improvement of saline-sodic grassland soils properties by rotational grazing in Argentina. Rangeland Ecology & Management 71, 807–814.
Vecchio, M.C., Bolaños, V.A., Golluscio, R.A., Rodríguez, A.M., 2019. Rotational grazing and exclosure improves grassland condition of the halophytic steppe in Flooding Pampa (Argentina) compared with continuous grazing. Rangeland Journal 41, 1–12.
Wu, G.L., Li, W., Li, X.P., Shi, Z.H, 2011. Grazing as a mediator for maintenance of offspring diversity: sexual and clonal recruitment in alpine grassland communities. Flora-Morphology, Distribution, Function Ecology of Plants 206, 241–245.

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