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THE PROTECTION EFFECTS ON FLORISTIC DIVERSITY IN A NORTH AFRICAN PSEUDO-SAVANNA

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Abstract

A study was carried out in northern Africa to investigate vegetation in Bou Hedma National Park 13 years after it was completely protected from livestock grazing and other anthropogenic activities which have largely depleted the vegetation. This vegetation was compared with that in seriously overgrazed area outside the park, where negative influences persist.

Thirteen years of protection against grazing and human impacts of the vegetation in the pseudo-savanna of North Africa has lead to an increase of 58.30% in the total cover, 21.7% in plant density, 7% in the species richness and 9.5% in species diversity. Many of the species with significantly higher abundance in the protected area are important forage (*Stipagrostis ciliata*, *Stipagrostis plumosa*, *Cenchrus ciliaris* and *Argyrolobium uniflorum*) and/or fuel plants (*Gymnocarpos decander* and *Hammada schmittiana*). Soil nutrients (N, K, Na and Mg) are significantly higher in the protected area witch may be attributable to the degradation of the soil surface in the free grazed area.

Introduction

Overgrazing by domestic livestock is one such inappropriate land use practice and has been widely cited as an important cause of land degradation in arid (Perveen *et al*., 2008) and semi arid ecosystems (Huang *et al*., 2007). Other causes such as climate and global changes have also been proposed as relevant influences on the ecological equilibrium (Fernández, 2002). Grazing frequently operate through the reduction of plant cover and fragmentation followed by disappearance of vegetation patches, reducing their size and/or numbers (Perveen & Hussain, 2007) and leading to soil erosion and losses of nutrients from the exposed soil (Holm *et al*., 2002). Grazing increased, reduced or lacked consistent effect on plant diversity (Proulx & Mazumder, 1998). These contrasting patterns of response have frequently been attributed to differences in grazing intensity. Some intermediate level of disturbance by grazing would likely be associated with maximum species diversity (Noy-Meir *et al*., 1989) in exposed soil areas, in particular by soil scarification by livestock and reducing the competitive effect of the most abundant species. Despite this, the overuse by grazing of these areas could result in irreversible vegetation changes (Van de Koppel *et al*., 2002). These changes are generally characterized by the replacement of grasses by woody species, leading to shrub and/or tree invasion and the concomitant increase in the scale of the spatial pattern of plant patches and soil resources (Adler *et al*., 2001).

Many of the empirical conclusions for grazing effects on arid land plant communities have emerged from enclosure studies that compared a fenced, ungrazed condition with ambient levels of grazing by wild and domestics herbivores (Ruthven, 2007). However, lack of replication, unreliable measurement techniques and inadequate duration of exclusion treatments has made it difficult to draw definitive conclusions from these studies. In addition, vegetation recovery is generally regarded as a slow process in arid ecosystems (Bolling & Walker, 2000).

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Unfortunately the available information on the level of grazing and other forms of degradation in the study area is poor. Some studies have recently documented this impact eg., Abdallah *et al.*, (2008) have shown that heavy, continuous grazing leads to replacement of palatable species by unpalatable ones which are often considered less desirable such as *Astragalus armatus* and *Asphodelus tenuifolius*. Protection against overegrazing provides a chance for regeneration of vegetation and for improvement of phytomass levels.

The aim of the Bou Hedma national park (BHNP) is to conserve the biodiversity under arid bioclimate of the south of Tunisia. The vegetation of the park is one of particular scientific interest because it represents a transition between semi arid and desert vegetation, corresponding to semi arid and arid ecosystems, respectively. Such transitional areas are highly sensitive to human-induced change and therefore offer an effective index of human perturbation (Schlesinger *et al*., 1990).

The main aim of this study was to investigate vegetation recovery in BHNP in northern Africa that has been enclosed and now enjoys complete protection from anthropogenic activities. Vegetation and soil characteristics of the park were compared inside and outside of the enclosure, 13 years after the fence was erected.

Materials and Methods

Study area: The study area lies in Tunisian Bou Hedma National Park in northern Africa (BHNP), pseudo-savanna of *Acacia tortilis* ssp. *raddiana* (34° 39’ N and 9° 48’ E) (Fig. 1), protected since 1994 and since ranked by UNESCO as a biosphere reserve. Climatically, the study area is classified as a lower arid (Emberger, 1954). Climate is characterized by hot summers, cool winters and low unpredictable rainfall (annual rainfalls vary between 100 and 200 mm).Mean temperature varies from 32 to 36°C in summer and from 4 to 7°C in winter (Derbel *et al*., 2007).The soil of the experimental areas is composed of quaternary sandy deposits and covered by *Acacia tortilis* pseudo-savanna. *Acacia tortilis* subsp *raddiana* (Savi) is the most important woody species in the site. The lower vegetation layer (< 1m) is composed by perennial grasses (*Cenchrus ciliaris*, *Digitaria nodosa* and *Stipagrostis ciliata*) and two species of the genus *Hammada* (*Hammada schmittiana* and *Hammada scoparia*), which belong to Chenopodiaceae family (Abdallah *et al*., 2008).

Climatic parameters in 2007: The growing seasons of 2006/2007 can be regarded as being reasonably favorable for vegetation development. The total quantity of rainfall, recorded at BHNP was 284.9 mm (Fig. 2). Precipitations started with an important quantity during September (64.4 mm) and well distributed in the time. The abundance of annual species is most likely the result of precipitation patterns (Ruthven, 2007) and the received precipitations during fall (September-November) are vital for colonization of annual species and for the beginning of development of perennial species.

Data sampling: The present study was conducted during the spring 2007, period of peak vegetation cover. A total of 70 transects (20 m long) were sampled in order to represent the prevailing habitat and community variations inside and outside the BHNP. Transect data were collected in nine random blocks of five transect each (45 transects) and five blocks (25 transects) inside and outside the park respectively.

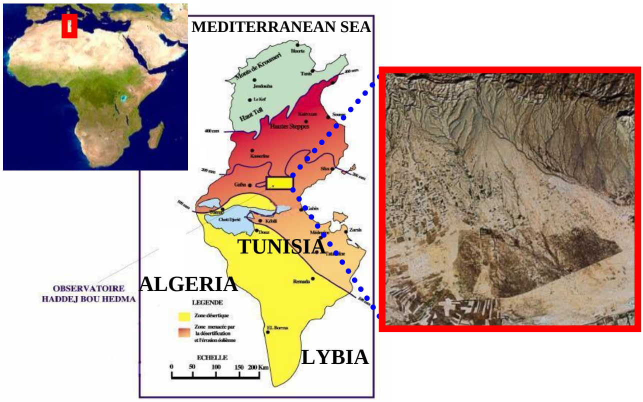

Fig. 1. Location of the Bou Hedma National Park.

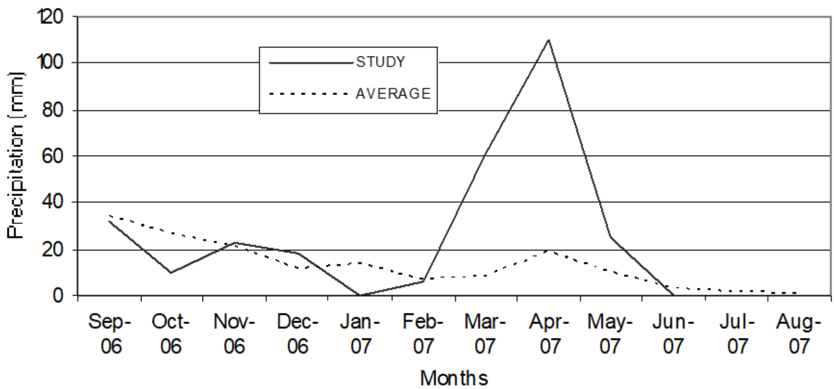

Fig. 2. Changes of the monthly mean precipitation in the study site during the experimental period (2006/2007).

Analysis of plant community structure: In each transect the following records and measurements were made: presence of species, cover of species using the quadrat point method (Daget & Poissonet, 1971). Observations were made every 10 cm, for a total of 200 points along each transect.

The absolute (1) and relative cover (2) of species were calculated as follows:

(1) Absolute cover = (nbS / TnbP) × 100.

(2) Relative cover = (FS / TF) × 100.

Where:

nbS: number of points a species occurs in

TnbP: total number of points analyzed

FS: frequency of species

TF: total frequencies of all species

Along each transects, two 1 m² quadrats were randomly placed to record the density of annual species. The perennial species density was recorded in 20 m². Species richness of the vegetation inside and outside the protected site was calculated as the average number of species per transect (Stirling & Wilsey, 2001). This is a simple and easily indicator of biological diversity (Huston, 1994).

The relative change (increase or decrease) "RID" of the protected sites compared with the unprotected sites was calculated as follows:

RID = [(protected-unprotected)/unprotected] × 100.

Diversity indices: In plant ecology, *H'* has been used to measure species diversity (Shannon & Weaver, 1949),

$$H' = -\sum_{i=1}^{s} p_i \log_2 p_i$$ The Shannon index (H'; Shannon and Weaver 1949),

where p_i is the probability of the frequency of the *i*-th species, and *N* is the number of species. The maximum value of *H'* occurs when all species are equally represented, $H'_{max} = \ln(N)$. The ratio $H' / H'_{max} = J$ is then the evenness index. Diversity and evenness were calculated on the basis of the relative cover of species.

Soil sampling: In each site (protected and unprotected), a total of 12 soil samples were collected at 0-60 cm depth (12 × 2 sites = 24 samples were collected). Soil-water extracts were prepared for the determination of electrical conductivity (EC) and pH using conductivity and pH meters, respectively. Total nitrogen (N) and % of OM were also determined. Potassium, Ca, Na, Mg and Na were determined by atomic absorption.

The significance of variation between the means of the density, absolute cover of species and soil variables of the protected and unprotected sites was tested using the F-test.

Results

When compared with the free grazing area, the vegetation inside the protected site had higher numbers of total species diversity (F=7.994, p=0.015), evenness (F=6.139, p=0.029), density (F=16.305, p=0.002) and total cover (F=13.137, p=0.003), but there was no significant difference in species richness (Table 1). Of 50 species of common occurrence, 29 species contributed with 89.15% of the total cover inside the protected site and 89.03% in the free grazing area. On the other hand, 9 species had significantly higher values of plant cover (p<0.05 – p<0.001) inside than outside the protected area (Table 2). Twenty-two species that occurred only inside the protected area had a cover of 5.05%, while 11 species that occurred only outside (Table 3) had a cover of 2.62%.

Densities of some of the dominant species were significantly higher outside the protected site (*Argyrolobium uniflorum* and *Cenchrus ciliaris*) (Table 2). The annual grass, *Stipa capensis*, has the greatest contribution in the total cover with 29% and 19.54% in the protected and the free grazed area respectively.

Organic matter percentage, Ca concentration and pH were nearly equal between protected and unprotected sites. In the 0-60 cm soil layer, CEC was slightly greater than that of the unprotected area (Table 4).

Total N, K, Na and Mg were significantly affected by overgrazing; they were, respectively, 44.4%, 51.8%, 55.1% and 43.9% lower compared to the protected site. We did not find significant effects of overgrazing on P concentration.

Table 1. Values of vegetation attributes on protected and unprotected sites. RID is the relative change between the protected and unprotected site.

Vegetation variable	Protected	Unprotected	p	RID
Total species	72	61		0.18
Species richness	9.68 ± 0.14	9.04 ± 0.17		0.07
Diversity (H')	1.16 ± 0.02	1.06 ± 0.03	*	0.09
Evenness (J)	0.51 ± 0.01	0.47 ± 0.01	*	0.24
Total density (Plants m^{-2})	68.19 ± 1.46	55.84 ± 3.21	**	0.22
Total cover (%)	59.65 ± 4.32	37.68 ± 1.86	**	0.58

*= p<0.05, **= p<0.01, ***= p< 0.001 according to the F-test.

Discussion

This study shows that grazing exclosure for 13 years has had a significant developmental effect on the species diversity and abundance of the BHNP vegetation in northern Africa having a mean annual rainfall between 100 and 200 mm y^{-1}.

It is important to define what is actually meant by vegetation recovery. In this study, recovery refers to a notable increase in vegetation number and cover. The total cover, as a better indicator of plant community health (Meyer & Garcia-Moya, 1989).in our study it was 58.30% greater inside than outside the protected area. Abdallah *et al*., (2008) showed that the total cover was 228.65% greater inside the protected site (53.67%) than in the free grazing area (16.33%) during 2003/2004 growing season in the same park. Under arid bioclimate, in Eastern Saudi Arabia, Shaltout *et al*., (1996) indicated that the total cover was 68% greater inside than outside the protected area.

The maximum phytomass observed inside the protected site during the present study may have been attained some years earlier. Shaltout *et al*., (1996) indicated that the maximum phytomass was attained after 2 years of protection, after witch it dropped dramatically inside and not outside the protected area. This author concluded that both continuous protection and continuous free grazing have deleterious effects on vegetation. Other studies in similar habitats have shown that four years of protection have led to the regeneration of vegetation e.g., Brown, (2003 in northern Kuwait and under arid bioclimate). Manier & Hobbs (2006) concluded that fives decades caused minor changes in cover and diversity of herbaceous plants, but caused a clear increase in the cover of shrubs.

Species richness vary with disturbance and fertility levels due to the differential response of species to various environmental gradients (Wellnitz & Poff, 2001). It is commonly assumed that plants are able to recover from herbivory when growing in high resource conditions (Hawkes & Sullivan, 2001), although high stoking rate or grazing in poor soils can decrease plant diversity (Olff & Ritchie, 1998). In this study we observed that heavy grazing negatively influenced diversity and Evenness in BHNP in southern Tunisia. In contrast, other studies have found grazing to increase plant species diversity (Milchunas *et al*., 1988). Some authors have postulated that a moderate level of disturbance maximizes the diversity of species, while in the absence of disturbance; competition exclusion reduces diversity (Huston, 1994). In this study, we observed a recovery of species diversity after 13 years of protection.

Table 3. Density (plants m^{-2}), absolute cover (%) and relative cover (%) of the species that occur only in the unprotected or protected site. Species were arranging in descending order according to their absolute cover value.

Species	Family	density	Absolute cover	Relative cover
Protected site				
Vella annua	Brassicaceae	0,99	0,77	1,29
Aegilops geniculata	Poaceae	1,40	0,54	0,91
Medicago minima	Fabaceae	0,06	0,40	0,67
Brassica tournefortii	Brassicaceae	0,08	0,32	0,54
Pallenis hierochuntica	Asteraceae	2,91	0,31	0,52
Volutaria lipii	Asteraceae	0,47	0,30	0,51
Marrubium desertii	Lamiaceae	0,01	0,26	0,43
Reseda alba	Resedaceae	0,01	0,25	0,42
Salsola vermiculata	Chenopodiaceae	0,00	0,24	0,41
Atractylis carduus	Asteraceae	0,28	0,23	0,39
Onopordon espinae	Asteraceae	0,06	0,19	0,32
Matthiola longipetala	Brassicaceae	0,26	0,18	0,30
Eruca vesicaria	Brassicaceae	0,38	0,16	0,26
Centaurea dimorpha	Asteraceae	0,16	0,14	0,24
Astragalus gombiformis	Fabaceae	0,00	0,13	0,22
Polygonum equisetiforme	Polygonaceae	0,00	0,13	0,22
Atractylus serratuloides	Asteraceae	0,01	0,11	0,19
Centaurea contracta	Asteraceae	0,05	0,10	0,17
Teuchrium polium	Lamiaceae	0,00	0,10	0,17
Adonis dentata	Ranunculaceae	0,06	0,07	0,11
Stipagrostis obtusa	Poaceae	0,06	0,06	0,09
Senecio gallicus	Asteraceae	0,30	0,06	0,09
Total (22 species)		**7.54**	**5,05**	**8,47**
Unprotected site				
Echium humile	Boraginaceae	0,88	0,84	2,23
Chenopodium murale	Chenopodiaceae	0,24	0,42	1,11
Malva aegyptiaca	Malvaceae	2,18	0,36	0,96
Lotus pisillus	Fabaceae	1,52	0,24	0,64
launaea angustifolia	Asteraceae	0,05	0,20	0,53
Euphorbia retusa	Euphorbiaceae	0,10	0,14	0,37
Astragalus corrigatus	Fabaceae	0,08	0,14	0,37
Artemisia herba alba	Asteraceae	0,03	0,10	0,27
Muricaria prostrata	Brassicaceae	0,04	0,08	0,21
Iflago spicata	Asteraceae	0,60	0,06	0,16
Linaria aegyptiaca	Scrophulariaceae	0,06	0,04	0,11
Total (11 species)		**5.78**	**2,62**	**6,95**

Table 4. Comparison between mean soil variables (mean ± standard deviation) in the protected and unprotected sites.

Soil variable	Protected	Unprotected	p
Organic matter (%)	0.30 ± 0.02	0.29 ± 0.02	
N (%)	0.27 ± 0.06	0.15 ± 0.06	***
P (mg Kg^{-1})	21.12 ± 1.24	15.05 ± 1.42	
Ca (mg Kg^{-1})	19.20 ± 0.58	18.66 ± 1.41	
K (mg Kg^{-1})	14.77 ± 0.88	7.11 ± 0.65	***
Na (mg Kg^{-1})	13.68 ± 0.79	6.14 ± 0.90	***
Mg (mg Kg^{-1})	5.21 ± 0.45	2.92 ± 0.19	*
pH	7.74 ± 0.01	7.69 ± 0.01	
EC (ms cm^{-1})	0.72 ± 0.03	0.56 ± 0.04	

*= p<0.05, **= p<0.01, ***= p<0.001 according to the F-test.

Many of the species found to be significantly more abundant inside than outside the protected site are important forage and/or fuel plants including *Gymnocarpos decander*, *Hammada schmittiana*, *Helianthemum kahiricum*, *Deverra tortuosa*, *Cenchrus ciliaris* and *stipagrostis* sp. Le Houérou (1986) reported that when chamephytic steppes dominated by dwarf shrubs are protected long enough, a graminaceous steppes characterized by palatable perennial grasses such as *Stipagrostis lagascae*, *Stipa parviflora* and *Cenchrus ciliaris* tends to develop. An increase in grazing pressure can lead to a reduction of a palatable grasses and herbs coupled with an increase in both unpalatable grasses and herbs and woody plants (Cingolani *et al*., 2005). The species that are grazed only when the highly palatable species are unavailable (often during summer) exhibit no significant improvement due to protection (e.g. *Cynodon dactylon*, *Helianthemum sessiliflorum* and *Echiochilon fruticosum*). The species that are found only in the protected site and have effective contributions to the total cover are also important for grazing such as *Vella annua*, *Medicago minima*, *Aegilops geniculata* (Table 3). The species that occur only in the free grazing area have a minor functional role from the dominance viewpoint (cover <1% and relative cover <1% for 9 out of 11 recorded species) some of them are weeds of disturbed habitats such as *Echium humule*, *Malva aegyptiaca* and *Chenopodium murale*.

The high contribution of *Stipa capensis*, in the total cover, inside and outside the park may be due to its high reproductive capacity and its low palatability. This plant species has a facultative long day response for the age of the plant at the first appearance of spikes (Boeken *et al*., 2004). The abundance of *Argyrolobium uniflorum* and *Cenchrus ciliaris* outside the park shows the fundamental role played by the park in the process of restoring the ecological balance of its environment.

The high nutrient content, particularly of N inside the protected area may be related to the occurrence of N fixation due to microbial activities under leguminous trees (Palm, 1995). *Acacia tortilis*, the most important woody species in the site, is classified among the trees with a high N_2 fixing potential (Gueye & Ndoye, 2003). In free grazing area, trampling by animals promotes the loss of top soil by wind erosion; this degradation directly resulted in depletion of total N. Overgrazing reduce vegetation growth and expose soil surface to erosion, leading to direct soil nutrient losses (Huang *et al*., 2007). There was not significant difference in the total soil P between the two sites. The animal wastes may be the primary factor that promoted the total P maintained higher levels.

This study has given an insight into the recovery of the vegetation under arid bioclimate in northern Africa, and the results agree well with those presented by Le Houérou (2000) for arid and semi-arid Mediterranean ecosystems. BHNP, pseudo-savanna of *Acacia tortilis*, is probably an important site for vegetation regeneration. This park represents a focal point for larger-scale vegetation regeneration in the neighbor environments. In this context, Le Houérou (2002) emphasizes that protection can be a cheap and efficient tool for restoring arid lands. Finally, although the vegetation of transitional areas between semi-arid and arid ecosystems deteriorates rapidly as a result of detrimental human practices, as underlined by Schlesinger *et al*., (1990), this study shows that it can also possess considerable powers of regeneration.

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