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Grazing intensity effects on the vegetation in desert rangelands of Southern Tunisia

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Abstract: Although the effects of non-grazing and heavy grazing on vegetation structure have been extensively studied in a wide range of ecosystems, the effects of moderate grazing on desert land are still largely unknown. Many management opportunities exist for increasing forage intake. In order to determine an optimal management method of desert rangelands with high heritage value, we examined the respective effects of heavy grazing, moderate grazing and non-grazing on total vegetation cover, species richness, the Shannon-Wiener diversity index and rangeland productivity. Sampling was done from 2010 to 2012 (from the second year after treatments were imposed) using permanent transects under different grazing intensities. While total vegetation cover, species richness, Shannon-Wiener diversity index, species composition and primary production were significantly greater on the ungrazed site and significantly weaker on the heavily grazed site, in contrast, moderate grazing had no significant effect on total vegetation cover, species richness, Shannon diversity index, species composition and primary production. These studies suggest that desert rangelands plant communities in general lack response to moderate grazing disturbance, and if managed properly they can provide a valuable source of feed for livestock.

Keywords: rangelands management; grazing pressure; richness; diversity; productivity

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In recent decades, the rangelands of Tunisia faced natural resources degradation, especially in the desert zones. Climatic and anthropogenic factors were the main causes of this degradation. The rangelands in Tunisia's desert cover 6,500,000 hm^2, accounting for 40% of the total area. The mean annual rainfall does not exceed 100 mm per year (Floret and Hadjej, 1977), and despite annual fluctuations in weather conditions, the southern Tunisian desert rangelands play a key role in providing pastoral grazing (Gamoun et al., 2012a). According to Roder et al. (2007), livestock grazing may also have been an important factor in shaping Mediterranean rangelands.

Fodder production varies here in different years and this depends especially on the rainfall efficiency coefficient which is frequently weak in the Saharan bio-climate region (Le Houérou, 1964, 1982; Le Houérou and Hoste, 1977). Although abiotic and biotic conditions have not changed much in the past decades, traditional, subsistence oriented, migratory pastoralism has virtually disappeared as a land use system throughout the Old World Dry Belt. In Tunisia, the southern rangelands are largely depopulated because many pastoralists have opted for livelihood opportunities in other sectors of the economy.

The concept of ecosystem-based management has become broadly accepted and implemented over the last two decades. Productive management of these rangelands has proven unlikely when the natural vegetation becomes severely degraded. However this situation can be remedied if restoration work is undertaken (Le Houérou 2002; Gamoun et al., 2012a),

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and this is why rangelands protection is necessary to maintain sustainable management and resilience (Gamoun et al., 2011a). This technique is generally beneficial in improving vegetation (Brown and Al-Mazrooei, 2003; Gamoun et al., 2010a, b). As mentioned by Gamoun et al. (2012a), rainfall and soil type are the main factors which determine natural regeneration in pastures. Operative tools are needed to identify the threshold associated with the loss of resilience, which might be easy to evaluate and monitor in the field to carry out sustainable management on rangelands and prevent desertification (Briske et al., 2006, 2008).

Heavy grazing has been reported to reduce the diversity of herbs and shrubs in the range land (Zhao et al., 2006), and while some species have disappeared, others have survived through the use of morphological or other adaptations (Wang et al., 2002). Heavy grazing decreases the occurrence of palatable and mostly perennial species, and it can cause a long-term reduction in the capacity of vegetation to respond to rain, particularly after drought (Kinloch and Friedel, 2005). Louhaichi et al. (2009) found that selective grazing of more palatable species during year-long grazing shifted plant community composition toward less desirable forage species. As more livestock are grazed in an area over long periods, the area's value as grazing pasture decreases (Hoshino, 2009). Likewise, Haynes et al. (2013) suggest that if herd sizes remain large and suitable areas for grazing continuously to decline, the cumulative impacts of grazing appear likely to degrade the rich diversity of the region and reduce rangeland quality, threatening its ability to sustain current grazing levels.

Moderate grazing can be effective in promoting greater diversity in vegetation in desert areas (Holechek, 1991), and it can increase the diversity of plants by decreasing the ability of any one of plant species to become dominant and exclude other species (Society for Range Management (SRM), 2003). In addition, Thalen (1979) showed that moderate grazing may be necessary to maintain productivity levels in desert rangelands. Species richness and diversity tended to decrease with increased grazing pressure, but the difference was not significant between ungrazed and moderately grazed rangelands. The diversity and vegetation biological spectrum were only slightly affected by controlled grazing. This study demonstrates the value of this management practice for biodiversity conservation (Gamoun et al., 2012b). A previous study has mentioned that the responses of vegetation to grazing are associated with plant growth form, mainly plant height, and to a lesser extent with palatability (Noy-Meir et al., 1989).

Degradation of desert rangeland represents an undesirable change towards decreased sustainability. Despite lower biological production in desert lands, special utilization values of these resources play important roles in their sustainable development. Thus, ecological restoration and sustainable agriculture in drylands are the main methods used to preserve their sustainable use and to prevent "desertification" (Reynolds et al., 2007), and long-term stocking density is a key management variable for rangelands (Batabyal et al., 2001; Briske et al., 2003). Today, the science of modern ecosystem management studies how to manage ecosystems to ensure that they remain stable, healthy and sustainable (Christensen et al., 1996).

Although plants are pivotal in rangeland management, their response to grazing is sometimes difficult to predict. One of the objectives of this work was to evaluate the influence of rangeland utilization and management practices on plant communities. For this purpose, the three systems of heavy grazing, moderate grazing and ungrazed treatment were instituted to evaluate the effect of grazing intensity on plant communities in the desert rangelands in southern Tunisia. The result was employed to provide experimental evidence that solved the following question: Can rangelands be maintained under moderate grazing practices?

1 Materials and methods

1.1 Study area

The experiments were conducted at a desert-steppe (10°32'E, 32°08'N; 200–250 m asl), in southeastern Tunisia (Fig. 1). The mean annual temperature is 22°C, with the highest monthly mean temperature of 40°C and the lowest of 11°C. The mean annual rainfall during 1981–2011 was 76 mm, with large inter-annual fluctuations, usually occurring in an approximately 10-day period between October and March. These rangelands lie mostly as sierozems on hard chalk of the Lower Cretaceous, and they are dominated with steppe vegetation, mainly in the form of *Hammada schmittiana*, *Anthyllis sericea*, *Gymnocarpos decander*, *Stipagrostis pungens*, and *Retama raetam*. The local soils are predominantly unsuitable for agricultural practices and they have become exclusively pastoral. In spring, the species richness, in the area under free grazing, amounted to about 20 species. While, in autumn, the species richness in the area under free grazing decreased to about 14 species (Gamoun, 2012).

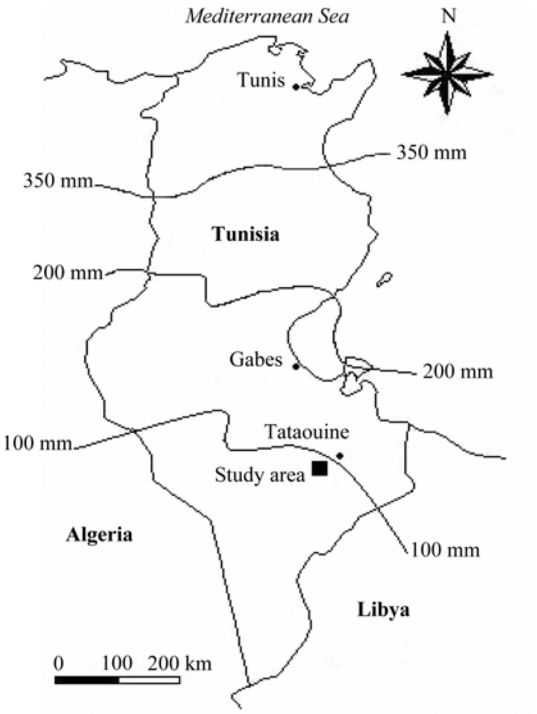

Fig. 1 Location of the study area (curves with mm values represent mean annual rainfall)

1.2 Sampling method

In this case study, rangelands under different grazing intensities were investigated. In autumn 2009, two grazing treatments were established that varied in grazing intensity. The following sites were investigated: ungrazed sites since autumn 2009 (100 hm^2), moderately grazed site since autumn 2009 (100 hm^2 with 0.2 head/(hm^2·a)). The heavily grazed site near the previous sites was subjected to continuous heavily grazing throughout the year at stocking rates exceeding 2 head/(hm^2·a). At the time of treatment establishment, pastures had similar plant composition. All selected sites had similar soil, landscape and climate.

Before autumn 2009, the vegetation in all treatments was characterized only by sparse perennials species due to overgrazing. The effects of grazing intensity on pasture vegetation can be observed only after treatment and during the growing season. For this reason, the measurements started from the next spring after treatments were imposed.

Vegetation was monitored during spring, in March 2010, 2011 and 2012, in the peak season of primary production and when development of the annual vegetation was at its prime. Vegetation cover and species composition were estimated using the point-quadrats method of Daget and Poissonet (1971) along ten 20-m long transects with 100 points per transect.

Percentage cover data was used to calculate the Shannon-Wiener diversity index (H'), calculated by the usual formula $H' = -\sum P_i \ln P_i$; where, H' is diversity index and P_i is relative importance value of species *i*.

Ten sub-samples were taken from 1 m×1 m quadrats to determine above-ground plant community productivity. The fresh consumable vegetation parts of encountered plant species were cut and then dried at 70°C for 48 hours and weighed.

1.3 Statistical analysis

Effects of grazing intensity on cover, productivity and plant diversity were analyzed by one-way ANOVA; within an experimental error of 0.05, and significant differences for all statistical tests were evaluated at the level of $P \leq 0.05$. All data analyses were conducted using SPSS software (SPSS for Windows, Version 18.0, Chicago, IL, USA).

2 Results

There was a general decrease in vegetation cover with increasing grazing pressure, thus confirming the well-known and accepted phenomenon.

2.1 Total vegetation cover

Results showed that while grazing intensity significantly altered total vegetation cover (F=93.677, P<

0.001). Vegetation cover increased significantly on the ungrazed site (F=7.950, P=0.002), whereby it increased from 49.2% in 2010 to 72.4% in 2012. In contrast, vegetation cover decreased significantly in the heavily grazed site from 28.3% to 17.3% during the three-year study period (F=9.690, P=0.001). However, the variation in total vegetation cover under moderate grazing registered no significant difference between 2010 and 2012 (F=0.458, P=0.637), remaining constant at approximately 40% lower than the ungrazed area but much higher than the heavily grazed site. After 3 years of study, the total vegetation cover under the ungrazed regime was approximately 4.2 times greater than that in the heavily grazed site and almost twice as much as in the moderately grazed site (Fig. 2).

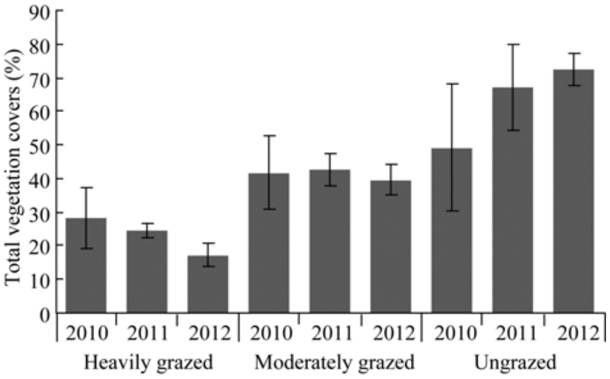

Fig. 2 Vegetation cover on heavily grazed, moderately grazed and ungrazed sites from 2010 to 2012; Mean±S.E.

2.2 Species richness

There were large significant differences between grazing treatments (F=488.441, P<0.001), and a significantly different year-effect existed in the ungrazed site (F=165.942, P<0.001). Mean species richness was greatest in the ungrazed site, where it increased from 48 species in 2010 to 66 species in 2012. On the other hand, species richness on the heavily grazed site decreased significantly from 21 to 14 between 2010 and 2012 (F=61.988, P<0.001). Compared to these two sites, moderate grazing application again showed no significant effect on species richness in this study (F=1.003, P=0.380), with species richness remaining constant around 48 species during the 3 years. In the same period, the species richness on the ungrazed area increased by approximately 4.7 times relative to the heavily-grazed regime and 1.4 times more than under moderate grazing (Fig. 3).

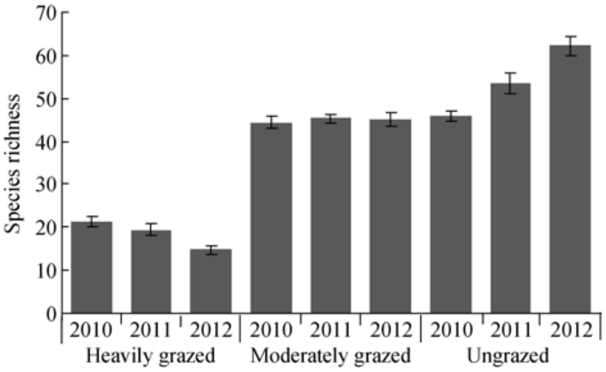

Fig. 3 Species richness on heavily grazed, moderately grazed and ungrazed sites from 2010 to 2012; Mean±S.E.

A total of 66 species were recorded during this experiment, and of these 40 were annuals. In addition, 21 were classified as highly desirable species, 13 desirable and 32 as less desirable. There were 23 species recorded on the heavily-grazed site. They were mostly annuals, and these 23 decreased in some years to 16 species. Meanwhile, the moderately grazed site registered 48 species, and this number remained constant during the three years of grazing. In contrast, the total number of species on the ungrazed site increased from 48 species in 2010 to 66 species in 2012. The largest difference between the ungrazed and heavily-grazed sites was the disappearance of very palatable species under the heavy grazing treatment, including *Anabasis oropediorum* (Maire), *Cutandia dichotoma* (Forssk.) Trab., *Echiochilon fruticosum* (Desf.), *Helianthemum kahiricum* (Delile), *Helianthemum sessiliflorum* (Desf.), *Hippocrepis bicontorta* (Loisel.), *Launaea resedifolia* (L.) O. Kuntze, *Launaea angustifolia* (Desf.) Muschler, *Koelpinia linearis* Pall., *Medicago truncatula* Gaertn., *Polygonum equisetiforme* S. & Sm., *Scorzonera undulata* Vahl., *Stipa lagascae* Roem. & Schult and *Thesium humile* Vahl. (Table 1).

2.3 Shannon-Wiener diversity index

ANOVA analyses showed that there were significant differences in diversity index between grazing intensities (F=48.669, P<0.001). While the diversity index of the ungrazed site increased significantly from 1.42 in

Table 1 Family, life cycle, life form and acceptability index of main species for different treatments

Species	Family	Life form	Life cycle	Acceptability index	Grazing intensity								
					Heavily grazed			Moderately grazed			Ungrazed		
					2010	2011	2012	2010	2011	2012	2010	2011	2012
Allium roseum L.	Liliaceae	Ge	A	1	–	–	–	–	–	*	–	–	*
Anabasis oropediorum Maire	Chenopodiaceae	Ch	P	5	–	–	–	*	*	*	*	*	*
Anacyclus clavatus Desf.	Asteraceae	Th	A	2	–	–	–	*	*	*	*	*	*
Anacyclus cyrtolepidioides Pomel	Asteraceae	He	A	2	*	–	–	*	*	*	*	*	*
Anthyllis sericea Lag. subsp. *henoniana* (Coss.) Maire	Fabaceae	Ch	P	5	*	*	*	*	*	*	*	*	*
Argyrolobium uniflorum (Decne.) Jaub. & Spach	Fabaceae	Ch	P	5	*	*	–	*	*	*	*	*	*
Aristida ciliata Desf.	Poaceae	He	P	5	–	–	–	–	–	–	–	–	*
Arnebia decumbens (Vent.) Coss & Kralik	Boraginaceae	Th	A	2	–	–	–	*	*	*	*	*	*
Artemisia campestris L.	Asteraceae	Ch	P	2	–	–	–	–	–	–	–	*	*
Asphodelus refractus Boiss.	Liliaceae	Th	A	0	*	*	*	*	*	*	*	*	*
Asphodelus tenuifolius L.	Liliaceae	Th	A	0	*	*	*	*	*	*	*	*	*
Astragalus corrugatus Bertol.	Fabaceae	Th	A	2	*	*	–	*	*	*	*	*	*
Atractylis flava Desf.	Asteraceae	He	A	0	*	*	–	*	*	*	*	*	*
Atractylis serratuloides Sieber ex Cass	Asteraceae	Ch	P	2	*	*	*	*	*	*	*	*	*
Bassia muricata (L.) Asch.	Chenopodiaceae	Th	A	2	–	–	–	–	–	–	–	*	*
Bromus rubens L.	Poaceae	Th	A	2	–	–	–	*	*	*	*	*	*
Centaurea urfuracea Coss. & Dur.	Asteraceae	Th	A	3	–	–	–	*	*	*	*	*	*
Cleome arabica Barratte & Murb.	Capparaceae	Th	P	0	–	–	–	*	*	*	*	*	*
Cutandia dichotoma (Forssk.) Trab.	Poaceae	Th	A	4	–	–	–	*	*	*	*	*	*
Daucus carota Murb.	Apiaceae	Th	A	3	–	–	–	*	*	*	*	*	*
Didesmus bipinnatus Desf.	Brassicaceae	Th	A	2	–	–	–	*	*	*	*	*	*
Diplotaxis harra Forsk.	Brassicaceae	Th	A	2	–	–	–	*	*	*	*	*	*
Echiochilon fruticosum Desf.	Boraginaceae	Ch	P	5	–	–	–	–	–	–	–	–	*
Echium humile Desf.	Boraginaceae	He	A	2	–	–	–	–	–	–	–	*	*
Enarthrocarpus clavatus Delile ex Godr.	Asteraceae	Th	A	2	*	–	–	*	*	*	*	*	*
Erodium glaucophyllum (L.) L'Hérit.	Geraniaceae	He	P	1	–	–	–	*	*	*	*	*	*
Erodium hirtum Willd.	Geraniaceae	He	P	3	–	–	–	–	–	–	–	*	*
Erodium triangulare (Forsk.)	Geraniaceae	He	A	1	*	*	–	*	*	*	*	*	*
Fagonia glutinosa Delile	Zygophyllaceae	Th	A	0	–	–	*	*	*	*	*	*	*
Farsetia aegyptiaca Turra	Brassicaceae	Ch	P	3	–	–	–	–	–	–	–	*	*
Filago germanica L.	Asteraceae	Th	A	1	–	–	–	*	*	*	*	*	*
Gymnocarpos decander Forssk.	Caryophyllaceae	Ch	P	5	*	*	*	*	*	*	*	*	*
Hammada schmittiana (Pomel) Ilji	Chenopodiaceae	Ch	P	1	*	*	*	*	*	*	*	*	*
Helianthemum kahiricum Delile	Cistaceae	Ch	P	4	–	–	–	*	*	*	*	*	*
Helianthemum sessiliflorum (Desf.)	Cistaceae	He	P	5	–	–	–	–	–	–	–	–	*
Herniaria fontanesii J. Gay	Caryophyllaceae	He	P	3	–	–	–	–	–	–	–	*	*
Hippocrepis bicontorta Loisel.	Fabaceae	Th	A	4	–	–	–	*	*	*	*	*	*
Ifloga spicata (Forssk.) Sch. Bip.	Asteraceae	Th	A	1	*	*	*	*	*	*	*	*	*

To be continued

Continued

Species	Family	Life form	Life cycle	Acceptability index	Grazing intensity								
					Heavily grazed			Moderately grazed			Ungrazed		
					2010	2011	2012	2010	2011	2012	2010	2011	2012
Koeleria pubescens Boiss. & Reut.	Poaceae	Th	A	4	–	–	–	*	*	*	*	*	*
Koelpinia linearis Pall.	Asteraceae	Th	A	4	–	–	–	*	*	*	*	*	*
Launaea angustifolia (Desf.) Muschler	Asteraceae	He	A	4	*	*	–	*	*	*	*	*	*
Launaea resedifolia (L.) O. Kuntze	Asteraceae	Th	A	5	–	–	–	*	*	*	*	*	*
Lobularia libyca (Viv.) Meissn.	Brassicaceae	Th	A	3	–	–	–	*	*	*	*	*	*
Lotus pusillus Viv.	Fabaceae	Th	A	3	–	–	–	*	*	*	*	*	*
Matthiola longipetala (Vent.) DC.	Brassicaceae	Th	A	2	–	–	–	–	–	–	*	*	*
Medicago minima Grufb.	Fabaceae	Th	A	3	*	*	*	*	*	*	*	*	*
Medicago truncatula Gaertn.	Fabaceae	Th	A	5	*	*	–	*	*	*	*	*	*
Neurada procumbens L.	Neuradaceae	Th	A	2	*	*	*	*	*	*	*	*	*
Nolletia chrysocomoïdes (Desf.) Cass.	Asteraceae	Ch	P	2	–	–	–	–	–	–	–	–	*
Ononis natrix (Lam.) Sirj.	Brassicaceae	Ch	P	2	–	–	–	–	–	–	–	*	*
Paronychia arabica (L.) DC.	Caryophyllaceae	Th	A	1	–	–	–	*	*	*	*	*	*
Plantago albicans L.	Plantaginaceae	He	P	5	*	*	*	*	*	*	*	*	*
Plantago ovata Forssk.	Plantaginaceae	Th	A	3	–	–	–	*	*	*	*	*	*
Polygonum equisetiforme S. & Sm.	Polygonaceae	He	P	4	–	–	–	–	–	–	–	–	*
Reseda alba L.	Resedaceae	Th	A	1	*	*	*	*	*	*	*	*	*
Retama raetam (Forssk.) Webb	Fabaceae	Na	P	3	*	*	*	*	*	*	*	*	*
Rhanterium suaveolens Desf.	Asteraceae	Ch	P	2	–	–	–	–	*	*	–	–	*
Salsola vermiculata L.	Chenopodiaceae	Ch	P	3	–	–	–	–	–	–	–	*	*
Savignya parviflora (Del.) Webb	Brassicaceae	Th	A	1	–	–	–	–	–	–	–	*	*
Schismus barbatus (L.) P. Beauv.	Poaceae	Th	A	4	*	*	*	*	*	*	*	*	*
Scorzonera undulata Vahl.	Asteraceae	He	A	5	–	–	–	–	–	–	*	*	*
Silene arenareoide Desf.	Caryophyllaceae	Th	A	3	–	–	–	*	*	*	*	*	*
Stipa lagascae Roem. & Schult	Gramineae	He	P	5	–	–	–	*	*	*	*	*	*
Stipa parviflora Desf.	Gramineae	He	P	2	*	*	*	*	*	*	*	*	*
Stipagrostis pungens (Desf.) de Winter	Poaceae	He	P	3	*	*	*	–	–	–	–	–	*
Thesium humile Vahl.	Brassicaceae	Th	A	5	–	–	–	–	–	–	–	–	*

Note：Life cycle: A, annual; P, perennial. Life form: Ch, chamephyte; Ge, geophyte; He, hemicrytophyte; Na, nanophanerophyte; Th, therophyte. Acceptability index: 0, refusal or toxic; 1, occasionally palatable; 2, few palatable; 3, palatable; 4, very palatable; 5, extremely palatable (Le Houérou and Ionesco, 1973). Presence of each species in each sampling year (1–3 years) under the three grazing treatments is symbolised by (*), and absent species is symbolized by (–).

2010 to 1.82 in 2012 (F=3.689, P=0.038), this index decreased significantly from 0.93 in 2010 to 0.64 in 2012 as a result of heavy grazing (F=4.672, P=0.018), and for moderate grazing it remained relatively constant at 1.14, and it was not significantly affected (F=0.489, P=0.618). Moreover, the moderately grazed diversity index was always lower than that under the ungrazed condition but much higher than that for heavy grazing (Fig. 4).

2.4 Biomass productivity

The effect of grazing intensity on primary production was significant (F=242.043, P<0.001). In the ungrazed site, the overall biomass productivity differences between years tested by ANOVA were significant (F=78.564, P<0.001). The mean plant productivity here was 173 kg DM/(hm^2•a) in 2010 and it increased to more than 227 kg DM/(hm^2•a) in 2012. Conversely, plant productivity was negatively affected by heavy grazing in the same period (F=145.361, P<0.001), decreasing considerably from 116 to 61 kg DM/(hm^2•a). Meanwhile, plant productivity under the moderate grazing regime remained stable at 162 kg DM/(hm^2•a) over the 3-year study period and no significant difference was recorded between the years (F=1.325, P=0.282).

In this period, the productivity under the ungrazed regime increased by approximately 4.7 times relative to the heavily-grazed area and 1.4 times more than on the site treated with moderate grazing (Fig. 5).

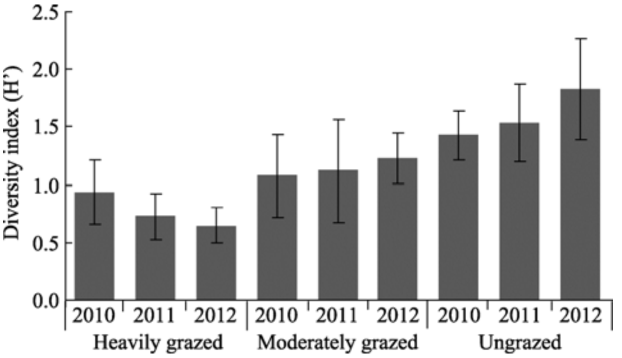

Fig. 4 The Shannon-Wiener diversity index (H') on heavily grazed, moderately grazed and ungrazed sites from 2010 to 2012; Mean±S.E.

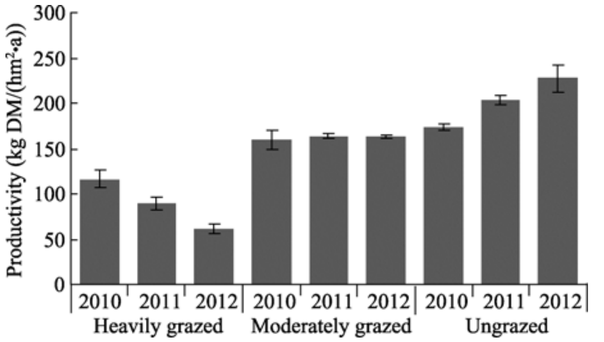

Fig. 5 Productivity on heavily grazed, moderately grazed and ungrazed sites from 2010 to 2012; Mean± S.E.

3 Discussion

Reductions in rangelands vegetation cover and productivity lead to the dynamic processes of "steppization" and "desertization" (Le Houérou, 1969). Rangeland degradation is caused by multiple factors including overgrazing and drought (Gamoun et al., 2011a, b).

Heavy grazing has a major impact on desert rangelands, primarily through its effect on loss of species diversity and lack of opportunity for plant regeneration. Heavy grazing by goats and sheep maintains rangeland vegetation at low levels and can also limit primary productivity. These effects translate into reduction in total vegetation cover and species diversity, promoted by selective grazing. When similar heavy grazing pressure is exerted in desert areas, the ground usually becomes barren (Zahran, 2010). Grazing pressure has a significant effect on total vegetation cover, species richness, species composition, diversity and productivity, and therefore the precise effect of different grazing pressures on desert rangelands requires careful assessment. Although non-grazing and grazing had opposite effects on rangelands productivity and species diversity, a slight disturbance suggests that species diversity should remain constant at moderate grazing levels.

Our experiment in the desert rangelands between 2010 and 2012 demonstrated that heavy grazing caused significant reduction, not only in total vegetation cover and diversity, but also in species composition and productivity. This reduction, however, could be mitigated by rest periods.

A short-term grazing ban by fencing an area for 3 years initiated rapid recovery in slightly degraded rangelands. Thus, partial protection and controlled grazing can be associated with profound changes in floristic composition (Peco et al., 2006, 2012), and can provide outcomes better than full protection (El-Kady, 1980; Floret, 1981).

Therefore, moderate grazing does not affect vegetation and it benefits the maintenance of diversity which can strengthen the rangeland's resilience to grazing. Plots under moderate grazing intensity contained a greater number of species than those which experienced heavy grazing. In addition, Gamoun et al. (2012a) suggested that moderate grazing should be an effective means to maintain diversity in the Saharan rangelands. This suggestion emanated from studies which showed that overgrazing resulted in deterioration of this vital resource which decreased by more than 75% (Gamoun et al., 2011b).

Although 10 to 15 palatable species increased in area, the total number of palatable species decreased dramatically because livestock imposed especially heavy selective grazing pressure on palatable plants. Meanwhile, unpalatable vegetation in more degraded sites was found to exceed that in less degraded sites. When disturbance is very intense, few plant species can persist, resulting in lower diversity. For example, Schonbach et al. (2009) reported that heavy grazing changed the botanic composition and reduced species richness and diversity indices. In our study, heavy grazing pressure reduced diversity because few species were resistant to defoliation. These included *Anthyllis sericea*, *Atractylis serratuloides*, *Gymnocarpos decander*, *Hammada schmittiana*, *Stipagrostis pungens, Argyrolobium uniflorum* and *Retama raetam*. In contrast, unpalatable plant species were recorded on the sites that could persist under heavy grazing but did not improve rangelands condition. These included *Asphodelus refractus*, *Asphodelus tenuifolius*, *Fagonia glutinosa*, *Ifloga spicata* and *Savignya parviflora.* However, protection from grazing did lead to an increase in the number of palatable plant species, such as *Echiochilon fruticosum*, *Aristida ciliata*, *Helianthemum sessiliflorum*, *Polygonum equisetiforme*, *Scorzonera undulate*, *Thesium humile* and *Stipa lagascae*. In addition, the existences of several highly palatable plant species under moderate grazing were recorded. These included *Anabasis oropediorum, Argyrolobium uniflorum, Cutandia dichotoma, Helianthemum kahiricum, Hippocrepis bicontorta, Launaea resedifolia* and *Koelpinia linearis.* Moreover, under moderate grazing, several reasonably palatable species survived, including *Centaurea furfuracea*, *Daucus carota*, *Lobularia libyca*, *Lotus pusillus*, *Medicago minima*, *Plantago ovata*, *Retama raetam* and *Silene arenareoide*. Since positive results were obtained by moderate grazing in this study, which is suggested that grazing management does not necessarily need to involve erecting total protection. Since moderate grazing allows palatable plant species to maintain themselves, but does not permit them to improve their total cover, diversity and productivity, which further suggested that moderately grazed pasture has less reduction in forage production than areas protected from grazing. This effect was highlighted in the study. Under water stress, moderate grazing has been shown to promote primary productivity (Luo et al., 2012). In addition, Eneboe et al. (2002) found that moderate grazing did not adversely affect primary native grasses during and after drought. In the same way, Bock and Bock (2000) reported that moderate livestock grazing reduced drought-caused mortality on perennial grasses in desert ecosystems, and Hoffmann et al. (2008) suggested that the practice of moderate grazing would provide adequate protection for the soil against particle loss by wind.

Heavy consumption of palatable plant species under heavy grazing treatment is a potential mechanism for reduced cover, diversity, species composition and primary production. Under this grazing regime, goats and sheep will increase their dietary range and their consumption of less palatable species. In contrast, the effects of moderate grazing can be exclusively regulated by simple defoliation influenced by resource availability. Comparable studies have shown that overgrazing can influence ecological succession and regeneration by removing photosynthetically active tissues from palatable plant species which are required for maintenance and survival (Briske and Richards, 1995).

Beyond the effects of trampling, grazing effects on species composition remains dependent on selectivity. Several studies have shown that herbivores are likely to alter the species composition and richness of plant communities through species selection (Noy-Meir et al., 1989; Sternberg et al., 2000; Loucougaray et al., 2005). Due to high stocking rates, overgrazing has reduced the dominance of palatable grasses, increased the proportion of unpalatable and poisonous weeds and reduced ground cover. Under heavy grazing, it is suggested that animals select and return to individual plants previously grazed because the new growth would be more palatable and more nutritious than the older growth of ungrazed plants. Animals graze selectively, eating the best plants and plant parts first, avoiding coarser, less palatable, less nutritious feed. This is manifested in the severe reduction of total vegetation cover and the total disappearance of palatable species such as *Anabasis oropediorum*, *Aristida ciliata*, *Echiochilon fruticosum*, *Helianthemum sessiliflorum* and *Stipa lagascae*.

Here, moderate grazing may have resulted in light disturbance, so that partly grazed plants were not selected for further grazing, and therefore they recovered quickly. This system that puts pressure on the heterogeneous rangelands can provide a free and wide choice of plants for animal grazing. Thus, the persistence of valuable species under moderate grazing is indicative of their ability to recover following light disturbance.

4 Conclusions

There is considerable evidence that livestock grazing strongly affects the structure, richness, and composition of vegetation. Protection to exclude livestock grazing is widely considered to be a simple and effective method for restoring the vegetation structure in degraded desert rangelands. But these rangelands play a key role as grazing lands for pastoral use. Results indicate that moderate grazing facilitates greater plant species richness on grazing land than both heavy grazing and a complete absence of grazing. I suggest that moderate grazing can be used as a beneficial management method to maintain species diversity and rangelands productivity. The state of the vegetation remains constant under moderate grazing, and it can provide food security for domestic livestock. Properly managed, these rangelands can continue to provide the main feed resource in livestock management systems.

The desert rangeland is becoming degraded at an alarming rate through overgrazing. This degradation ensures unsustainable trends in relation to climate change and demographic pressure, and also puts pressure on the management of natural resources and biodiversity loss and control of desertification. Since these negative trends have now imposed an utmost sense of urgency, a short-term action is immediately required, whilst a long term perspective is still maintained. The main challenge here is to gradually change our current unsustainable consumption and production patterns.

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References

Batabyal A A, Biswas B, Godfrey B E. 2001. On the choice between the stocking rate and time in range management. Environmental and Resource Economics, 20: 211–223.

Bock C E, Bock J H. 2000. The View from Bald Hill: Thirty Years in an Arizona Grassland. Berkeley: University of California Press.

Briske D D, Richards J H. 1995. Plant responses to defoliation: a morphological, physiological and demographic evaluation. In: Bedunah D J, Sosebee R E. Wildland Plants: Physiological Ecology and Developmental Morphology. Society for Range Management, Denver, Colorado, USA, 635–710.

Briske D D, Fuhlendorf S D, Smeins F E. 2003. Vegetation dynamics on rangelands: a critique of the current paradigms. Journal of Applied Ecology, 40: 601–614.

Briske D D, Fuhlendorf S D, Smeins F E. 2006. A unified framework for assessment and application of ecological thresholds. Rangeland Ecology & Management, 59: 225–236.

Briske D D, Bestelmeyer B T, Stringham T K, et al. 2008. Recommendations for development of resilience-based state-and-transition models. Rangeland Ecology & Management, 61: 359–367.

Brown G, Al-Mazrooei S. 2003. Rapid vegetation regeneration in a seriously degraded *Rhanterium epapposum* community in northern Kuwait after 4 years of protection. Journal of Environmental Management, 68: 387–395.

Christensen N L, Bartuska A M, Brown J H, et al. 1996. The report of the Ecological Society of America Committee on the scientific basis for ecosystem management. Ecological Applications, 6: 665–691.

Daget P, Poissonet J. 1971. A method for phytological analysis of prairies. Annals of Agricultural, 22: 5–41.

El-Kady H F. 1980. Effect of Grazing Pressures and Certain Ecological Parameters on Some Fodder Plants of the Mediterranean Coast of Egypt. MSc. Thesis, Tanta: Tank University.

Eneboe E J, Sowell B F, Heitschmidt R K, et al. 2002. Drought and grazing: blue grama and western wheatgrass. Journal of Range Management, 55: 197–202.

Floret C, Hadjej M. 1977. An attempt to combat desertification in Tunisia. Ambio, 6: 366–368.

Floret C. 1981. The effects of protection on steppic vegetation in the Mediterranean arid zone of southern Tunisia. Vegetatio, 46: 117–129.

Gamoun M. 2012. The impact of rest from grazing on vegetation dynamics: application to sustainable management of Saharan rangelands in southern Tunisia. PhD Thesis. Tunis: University of Tunis El Manar, 202.

Gamoun M, Tarhouni M, Ouled Belgacem A, et al. 2010a. Effects of grazing and trampling on primary production and soil surface in North African rangelands. Ekologia, 29: 219–226.

Gamoun M, Chaieb M, Ouled Belgacem A. 2010b. Evolution of ecological characteristics along a gradient of soil degradation in the

South Tunisian rangelands. Ecologia Mediterrania, 36: 5–16.

Gamoun M, Tarhouni M, Ouled Belgacem A, et al. 2011a. Response of different arid rangelands to protection and drought. Arid Land Research and Management, 25: 372–378.

Gamoun M, Ouled Belgacem A, Hanchi B, et al. 2011b. Floristic diversity variations according to management types in dry rangelands of Southern Tunisia. Ecologia Mediterrania, 37: 33–44.

Gamoun M, Hanchi B, Neffati M. 2012a. Dynamics of plant communities in Saharan rangelands of Tunisia. Arid Ecosystems, 2: 105–110.

Gamoun M, Ouled Belgacem A, Hanchi B, et al. 2012b. Impact of grazing on the floristic diversity of arid rangelands in South Tunisia. Revue d'Écologie (Terre Vie), 67: 271–282.

Haynes M A, Fang Z, Waller D M. 2013. Grazing impacts on the diversity and composition of alpine rangelands in Northwest Yunnan. Journal of Plant Ecology, 6: 122–130.

Hoffmann C, Funk R, Wieland R, Li Y, et al. 2008. Effects of grazing and topography on dust flux and deposition in the Xilingele grassland, Inner Mongolia. Journal of Arid Environments, 72: 792–807.

Holechek JL. 1991. Chihuahuan Desert rangeland, livestock grazing, and sustainability. Rangelands, 13: 115–120.

Hoshino A, Yoshihara Y, Sasaki T, et al. 2009. Comparison of vegetation changes along grazing gradients with different numbers of livestock. Journal of Arid Environments, 73: 687–690.

Kinloch J E, Friedel M H. 2005. Soil seed reserves in arid grazing lands of central Australia. Part 1: seed bank and vegetation dynamics. Journal of Arid Environments, 60: 133–161.

Le Houérou H N. 1964. Pasture lands in the Mediterranean Basin and their improvement. FAO: Goat Raising Seminar, 14.

Le Houérou H N. 1969. Vegetation of the Tunisian steppe (with the references to Morocco, Algeria and Libya). Ann. Inst. Nat. Rech. Agron. Tunisia, 42(5): 622.

Le Houérou H N, Ionesco T. 1973. Species palatability of the Tunisian steppe. Tunis, FAO, Project TUN: 71/525 and TUN/69/001, 68.

Le Houérou H N, Hoste C T. 1977. Rangeland production and annual rainfall relations in the Mediterranean basin and in the African Sahelo-Sudanian zone. Journal of Range Management, 30: 181–189.

Le Houérou H N. 1982. Perspective and evaluation study on agricultural development: the rangeland sector. Technical Paper, UNTF/Lib 18. Tripoli; Rome: Agricultural Research Center; Food and Agriculture Organization (FAO); 77.

Le Houérou H N. 2002. Man-made deserts: desertization processes and threats. Arid Land Research and Management, 16: 1–36.

Loucougaray G, Bonis A, Bouzille J B. 2005. Effects of grazing by horses and/or cattle on the diversity of coastal grasslands in western France. Biological Conservation, 116: 59–71.

Louhaichi M, Salkini A K, Petersen S L. 2009. Effect of small ruminant grazing on the plant community characteristics of semi-arid Mediterranean ecosystems. International Journal of Agriculture and Biology, 11: 681–689.

Luo G, Han Q, Zhou D, et al. 2012. Moderate grazing can promote above-ground primary production of grassland under water stress. Ecological Complexity, 1: 126–136.

Noy-Meir I, Gutman M, Kaplan Y. 1989. Responses of Mediterranean grassland plants to grazing and protection. Journal of Ecology, 77: 290–310.

Peco B, Sanchez A M, Azcarate F M. 2006. Abandonment in grazing systems: consequences for vegetation and soil. Agriculture, Ecosystems and Environment, 113: 284–294.

Peco B, Carmona C P, de Pablos I, et al. 2012. Effects of grazing abandonment on functional and taxonomic diversity of Mediterranean grasslands. Agriculture, Ecosystems and Environment, 152: 27–32.

Reynolds J F, Smith D M S, Lambin E F. 2007. Global desertification: building a science for dryland development. Science, 316: 847–851.

Röder A, Kuemmerleb T, Hilla J, et al. 2007. Adaptation of a grazing gradient concept to heterogeneous Mediterranean rangelands using cost surface modeling. Ecological Modeling, 204: 387–398.

Schonbach P, Wan H, Schiborra A, et al. 2009. Short-term management and stocking rate effects of grazing sheep on herbage quality and productivity of Inner Mongolia steppe. Crop Pasture Science, 60: 963–974.

Society of Range Management (SRM). 2003. Biodiversity of rangelands. Rangelands, 25: 60–65.

Sternberg M, Gutman M, Perevolotsky A, et al. 2000. Vegetation response to grazing management in a Mediterranean herbaceous community: a functional group approach. Journal of Applied Ecology, 37: 224–237.

Thalen D C P. 1979. Ecology and Utilization of Desert Shrub Rangelands in Iraq. The Netherlands: Junk. 430.

Wang Y S, Shiyomi M, Tsuiki M, et al. 2002. Spatial heterogeneity of vegetation under different grazing intensities in the Northwest Heilongjiang Steppe of China. Agriculture, Ecosystems and Environment, 90: 217–229.

Zahran M A. 2010. Climate–Vegetation. Afro-Asian Mediterranean and Red Sea Coastal Lands. Plant and Vegetation. London New York: Springer Dordrecht Heidelberg, 344.

Zhao W Y, Li J L, Qi J G. 2006. Changes in vegetation diversity and structure in response to heavy grazing pressure in the Northern Tianshan Mountains, China. Journal of Arid Environments, 68: 337–508.