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APPLIED PROBLEMS OF ARID LANDS DEVELOPMENT

Natural Vegetation Cover Dynamic under Grazing-Rotation Managements in Desert Rangelands of Tunisia[1]

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Abstract—Two treatments were used to evaluate the effect of grazing intensity (continuously grazing and controlled grazing). The schedule is as follows: 1) Rest 3 years (2004 to 2007), 2) Graze 2 months (August and July) 2007, 3) Rest 7 months (September to March) 2007–2008. The grazing impact at the area of 2000 ha was by 1700 sheep and goats during two months, followed by second rest (7 months) maintain resilient rangelands and ensure a sustainable flow of rangelands goods and services to livestock. The control was at grazing system, allows animals unrestricted and uninterrupted access to a grazing unit for all or most of the grazing season. Novelty of this studies is in the new data, which demonstrates that the rest periods allow plants to recover before they are grazed again, and if controlled grazing can avoid overgrazing effects.

Keywords: desert rangelands, grazing, plant cover, productivity, restoration, Tunisia

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INTRODUCTION

Although the effects of protection and continuous grazing on vegetation structure have been widely studied in a wide range of ecosystems, the effects of controlled grazing on desert land are still largely unknown. However, little information is available to elucidate differences between continuous and controlled grazing. Grazing activity is among the spatially most relevant land use forms in southern Tunisia where annual rainfall is less than 200 mm/year. Hence water and fodder availability become limiting for both plants and herbivores, resulting in regular losses of herds in droughts and rendering livestock a driven rather than driving variable in the system. These so-called non-equilibrium conditions, also known as "New Rangeland Ecology", are expected to occur under dry climates (Gillson and Hoffman, 2007). In time of drought natural vegetation becomes scarce and insufficient, animals need feed supplement and the livestock access to key resources is limited to water (Milchunas and Lauenroth, 1993). Such situation buffers their populations against collapses and allows them to exert a relatively high continuous grazing pressure and thus trigger rangeland degradation. According to the World Resource Institute (WRI, 1992), overgrazing is considered the main cause of land degradation in Africa where affects approximately 49 % of its arid areas. It changes the morphological structure and distribution patterns of dominant plant species (Zhao et al., 2007). However the moderate grazing can easily enhances plant development by reducing aerial part of plant species and, therefore, decreasing the water loss through transpiration in drylands (Gallacher et al., 2008), and is likely a preferred practice for conserving biological soil crusts and the ecological services it provides in N fixation and soil stabilization (Liu et al., 2009). Moreover, low to moderate levels of grazing can increase production over no grazing, but that the level of grazing that maximizes production depends upon the growing conditions of the current year (Patton et al., 2007). Furthermore, livestock grazing alters soil physical properties and surface water hydrology which might render serious consequences for plant growth in a dry Mediterranean climate where water is a scarce resource.

Grazing activity is the main factor in shaping Mediterranean rangelands landscape (Röder et al., 2007). It is commonly associated with changes in rangelands species composition. Changes in species composition are mainly due to the replacement of palatable by unpalatable species as well as annual plants when degradation is important (Tarhouni et al., 2007). Some authors show that the replacement of palatable by unpalatable plants decreases rangeland productivity and plant diversity (Cingolani et al., 2005).

Once unpalatable species became dominant, it is difficult to undo progressive change in vegetation by reducing or removing grazing impact (Noy-Meir and Walker, 1986). For this reason, the application of some management practices such as restoration technique becomes a necessity for optimizing ecosystems pro-

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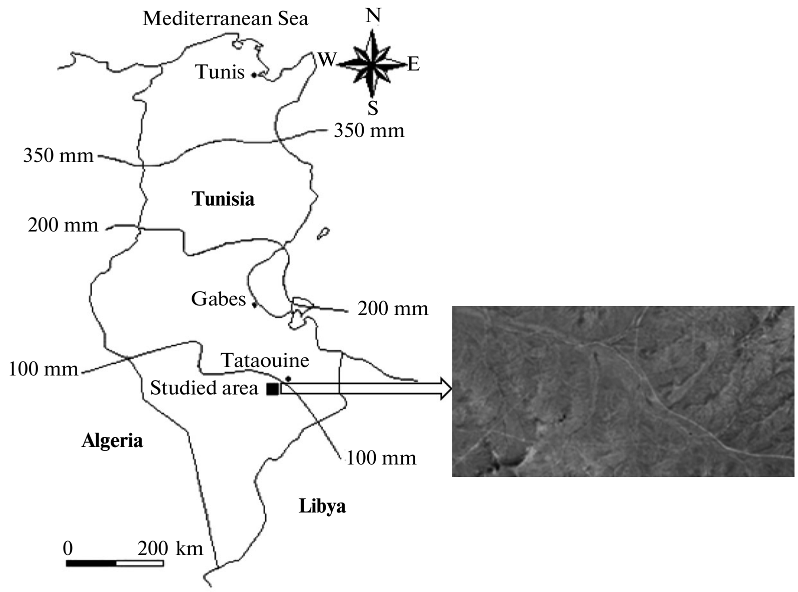

Fig. 1. Geographical location of the studied zone.

ductivity and conserving biodiversity (Villagra et al., 2009). The rest technique is considered as vital strategy for human being and its sustainable development (Clewell and Aronson, 2006). Decreasing land use pressure can favour natural restoration of the degraded southern Tunisian arid lands (Jauffret and Lavorel, 2003) and can provides essential ecological services to the livestock (Gamoun et al., 2012). The assessment of the rest impact on rangelands dynamics can be evaluated through long-term monitoring of biotic and abiotic attributes (Havstad and Herrick, 2003). Effects of varying management such as stocking densities and grazing systems on plant species diversity and the relative abundances of different plant growth forms or functional groups may have important consequences for ecosystem function (Hickman et al., 2004). In arid zones, suffering from the fluctuations of rainfall and fragile soils, there are conflicting opinions and data on the effects of the timing of grazing and the period of rest after drought on plant diversity (Gamoun et al., 2011). However, very long-term protection may not yield better results, due to accumulation of dead old material that reduced the new fresh growth. Controlled grazing may produce similar or better results than exclosures in some cases (Le Houérou, 2000).

In the desert areas of Tunisia, rangelands have a key role as grazing lands for pastoral use. Their degradation caused by inappropriate management practices, coupled with climate change, has a profound environmental impact. The management objective is to have a highly productive rangeland for livestock grazing or to enhance biodiversity and improve ecosystem health. The rotational grazing system is the most important approach to defy logic and yet is one of the most productive grazing systems now used worldwide.

This method was employed to assess the effect of continuous grazing and controlled grazing on the vegetation of a desert rangelands in southern Tunisia that solved the following question: the rest periods allow plants to recover before they are grazed again? And controlled grazing can avoid overgrazing effects?

MATERIALS AND METHODS

Study area. The study was carried out at the Dahar communal rangelands, located in southern Tunisia (33°00′83″ N, 10°05′54″ E). It has an average altitude of 1340 m above sea level. The studied site (2000 ha) is located in these rangelands (Fig. 1) and had been protected from grazing during 2004 to 2007. The unique land use of the zone is rangeland. Goats, sheep and camels are the most important stock species grazing in these rangelands. The study area has an extremely arid climate which belongs to the desert climate, with a mean annual rainfall of 40–100 mm (Gamoun et al., 2011) with about 70% received during the 120-day, mid-October to mid-March growing season (Fig. 2). The soil is skeletal with vast plate and moderate slopes crossed by wadi dominated with a mixture of sand and gravel. The vegetation cover is mainly dominated by *Anthyllis henoniana* Batt. [*A. sericea* subsp. *henoniana* (Batt.) Maire], *Gymnocarpos decander* Forssk., *Stipagrostis pungens* (Desf.) de Winter, *Hammada schmittiana* (Pomel) Botsch. and *Pennisetum dichotomum* (Forssk.) Delile. *Pennisetum dichotomum* dominates the vegetation communities in wadi where the soil is mainly calcareous silt.

These communal rangelands are exploited by individuals and although overgrazing can occur. They are

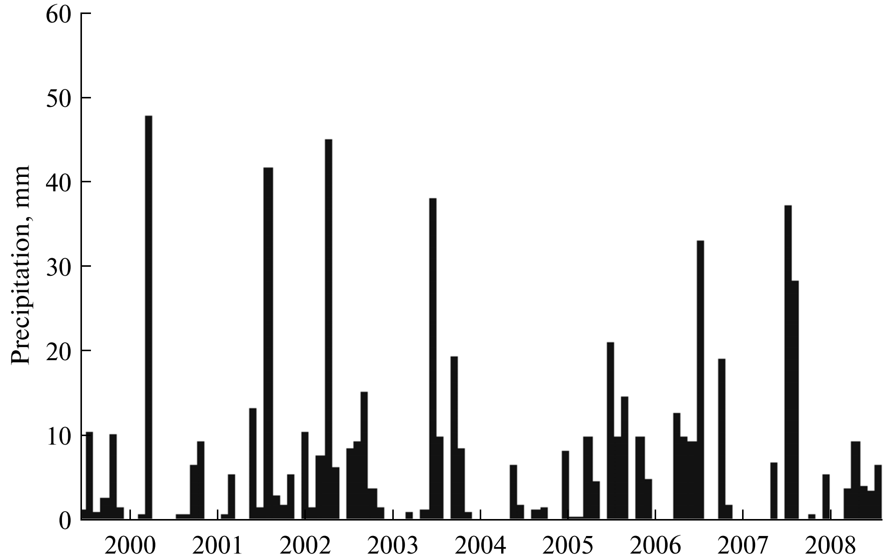

Fig. 2. Monthly precipitation (mm) from January 2000 through December 2008.

largely composed of plants that have resisted or benefitted from grazing and drought (Gamoun, 2005).

Data collection. Pasture size, timing and duration of grazing periods, and number of animals are discussed as precision tools to manage grazing systems (Laca, 2009).

The experiment was set up in the spring of 2007, autumn of 2007 and spring of 2008. The treatments were controlled grazing and continuously grazing (free grazing). The controlled grazing treatment consisted of rangelands with 2000 ha who has been protected for 3 years. After summer grazing, the rangelands were protected again. The grazing period was 2 moths in the summer 2007 (August and July) by 1700 sheep and goats. The continuous grazing treatment was established in one grazing area available for the treatment and with a not controlled carrying capacity, rather than a grazing system, allows animals unrestricted and uninterrupted access to a grazing unit for all or most of the grazing season. Thus the schedule is as follows: 1) Rest 3 years (2005 to 2007), 2) Graze 2 months (August and July), 3) Rest 7 months (September to March).

Four permanent transects per treatment are installed in the protected and in the continuous grazing plots. Each transect consisted of three lines with 20 m long each. These lines were assessed and monitored using the quadrat point method as define by Daget and Poissonnet (1971) and Floret (1988). A fine pin was descended to the ground every 20 cm along the line. Each of the 100 hits per line was recorded according to the plant species and type of ground touched. The total vegetation cover is calculated as: $VC = (n/N) \times 100$ with n: the number of hits of all plant species and N: the total number of hits (100 hits in our case). Plant density in each line is calculated inside 20 m^2 for perennial species and 2 m^2 for the annual ones. Biomass production is estimated using destructive method. A total of 32 plots of 4 m^2 each were installed in each rangeland. The net primary productivity was estimated by removing all fresh plant material a series of 32 quadrats of 4 m^2 each. Representative samples are dried at 100°C, then weighed. These measures were carried out simultaneously in the protected (before and after grazing) and the grazed rangelands.

Data analysis. We ran one-way ANOVA for testing the effects of seasons and the management practices ($N = 12$) on the studied parameters (SPSS Inc, 2002). These last were treated as categorical explanatory variables. Significant differences in the treatment means were separated by the least significant difference (LSD) method. The Multivariate General Linear Model Test was used to show the crossed effect of seasons and management practices on these parameters.

RESULTS

Plant cover. Changes in plant cover under grazing activities both in the continuous grazing and the controlled grazing are done in Fig. 2. Inter-seasonal differences of plant cover are significant in the controlled grazing and the continuous grazing ($P < 0.01$). In the controlled grazing, the Fisher LSD Posthoc test is significant between the spring covers (2007 and 2008) and the autumn one ($P < 0.01$). However, this test is not significant between the spring covers ($P > 0.05$). In the continuous grazing, the Fisher LSD Posthoc test is significant ($P < 0.01$) between the spring 2007 and the two others studied seasons which present no significant difference of their plant cover ($P > 0.05$).

During the studied period, differences in plant cover between the continuous and the controlled grazing are significant ($P < 0.01$). The continuous plant

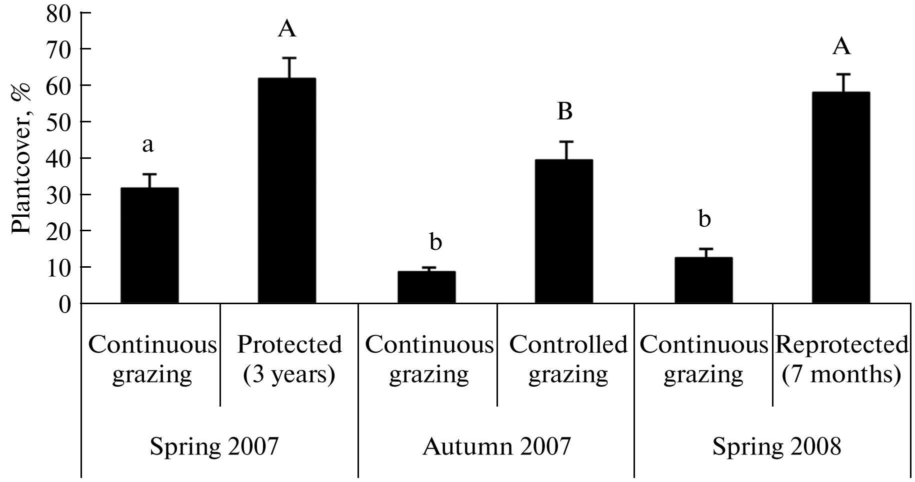

Fig. 3. Mean (±SE) of vegetation cover (%) under grazing management during the three studied seasons. a/b indicate differences in continuously grazed rangeland and A/B indicate differences for the managed rangeland.

cover varies from 32 to 9 % respectively during the spring and the autumn 2007. This difference can be explained both by the grazing and the seasonal drought impacts. Changes between the continuous covers during the autumn 2007 and the spring 2008 are not significant ($P > 0.05$). Under animal activities, the plant cover of the protected rangeland decreases from 62 to 40% during the spring 2007 and the autumn 2007 respectively and increases under protection from 40 to 59% during the autumn 2007 and the spring 2008 respectively (Fig. 3). Differences between the protected and the reprotected covers are not significant ($P > 0.05$). It seems that the grazing management was enhancing plant regeneration in the protected rangeland.

Flora richness. A total of 69 species were recorded from the study site. Species richness in protected and grazed rangelands had a significant difference ($P < 0.01$). Flora richness variation according to the management mode during the studied seasons is done in table 2. In the protected rangeland the perennial richness is about 33, 23 and 28 respectively during the spring 2007, the autumn 2007 and the spring 2008 (Table 1). Inter-seasonal differences in perennial richness between protected, grazed and reprotected rangeland are significant ($P < 0.01$). During the autumn 2007, the perennial richness in the grazed rangelands is high than in the control one. The application of rest technique permits a good regeneration and establishment of seedlings of some perennial plants such as *Anthyllis sericea*, *Stipagrostis pungens*, *Hammada schmittiana*, *Pennisetum dichotomum* and *Argyrolobium uniflorum*. The number of annual species such as *Savignya parviflora*, *Cutandia dichotoma* and *Schismus barbatus* is higher in the managed rangelands mainly in the rainy seasons. It seems that these species found their optimal growth conditions in the managed rangelands. In our case the abundance of perennial plants can enhance annual development by decreasing climatic effects on annual species (decreasing evaporation and changing micro-climates).

Plant density. Plant density in both the managed and the grazed rangelands during the monitored seasons is given on Table 2. The annual density is higher than the perennial one during the spring 2007 and 2008 for the control and the managed rangelands. Both the annual and the perennial densities are lower in the continuous grazing rangelands during the three studied seasons. In the controlled grazing rangelands, inter-seasonal variation of the perennial density is not significant ($P > 0.05$). However, differences in annual densities are significant ($P < 0.01$). In the control, inter-seasonal variation of the perennial and the annual species are significant ($P < 0.01$).

Biomass production. In Fig. 4 are presented the primary productivity. The productivity in the protected rangelands was significantly higher ($P < 0.01$) than

Table 1. Perennial and annual richness in the managed and the control rangeland

	Spring 2007		Autumn 2007		Spring 2008	
	continuous grazing	protected (3 years)	continuous grazing	controlled grazing	continuous grazing	reprotected (7 months)
Perennials	6	33	6	23	6	28
Annuals	8	36	0	6	3	32

Table 2. Perennial and annual densities (±SD) variations under different range management modes. Density unit is plant/m^2

	Spring 2007		Autumn 2007		Spring 2008	
	continuous grazing	protected (3 years)	continuous grazing	controlled grazing	continuous grazing	reprotected (7 months)
Perennials	1.8 ± 0.1	2.4 ± 1.4	1.1 ± 0.2	1.4 ± 0.5	0.8 ± 0.2	2.1 ± 1.2
Annuals	11.7 ± 1.0	44.4 ± 18.7	0	0	12.8 ± 2.6	26.6 ± 13.3

that of grazed rangelands. In the continuous grazing rangelands, differences in productivity are not significant ($P > 0.05$). However, in the controlled grazing rangelands, the ANOVA is significant ($P < 0.01$). The LSD post hoc test is significant between the spring productions and the autumn one. During the fall 2007, differences between continuous grazing and controlled grazing rangelands productivity are not significant ($P > 0.05$). The decrease in biomass productivity in the grazed rangelands by 1700 heads during the fall 2007 (July and August) can be explained by the animal impact on plant species (consumption and trampling) and the climatic drought which reduce the production and the growth of annual and perennial plants.

DISCUSSION

Management of rangelands and natural resources in general, has become increasingly complex (Boyd et al., 2009). In dry areas, rainfall is the first factor influencing temporary (seasonally) plant distribution. Grazing pressure alone cannot affect annual richness variability which is mainly conducted by rainfall pattern (Sheuyange et al., 2005; Westbrooke et al., 2005). They form a major component of desert vegetation, with their unique traits playing a key role in vegetation restoration in arid deserts. In these areas the responses of annual species to environmental variation are more sensitive than those of perennials.

During the rainy season a remarkable annual germination is occurred in drylands but woody plant species are slowly and irreparably affected by human disturbance such as overgrazing, trampling and wood cutting which can be the reason for their low reproduction rates via seeds (Ni, 2003; Bonet, 2004; Belem et al., 2007; Gaoue and Ticktin, 2007). Such disturbance can alter the soil seed bank by loosing viable seeds or by inhibiting their emergence capacity. Therefore, this strong and chronic disturbance leads to the flora richness decrease and induces the replacement of ligneous by annuals herbaceous plants as well as perennial herbaceous species which the floristic composition rest with a great accordance with the impact of this disturbance on soil properties (Rodriguez-Rodriguez et al., 2005). For this reason the monitoring of perennial density can provides clear ideas about the trends of installation or disappearance of plant species and permits to assess the ecosystem ability to regenerate (Floret, 1988). A high number of individuals promotes the accumulation and fixation of soil particles, improve the water balance and makes possible the re-installation of other plant species, etc. (Floret and Pontanier, 1982; Jauffret, 2001).

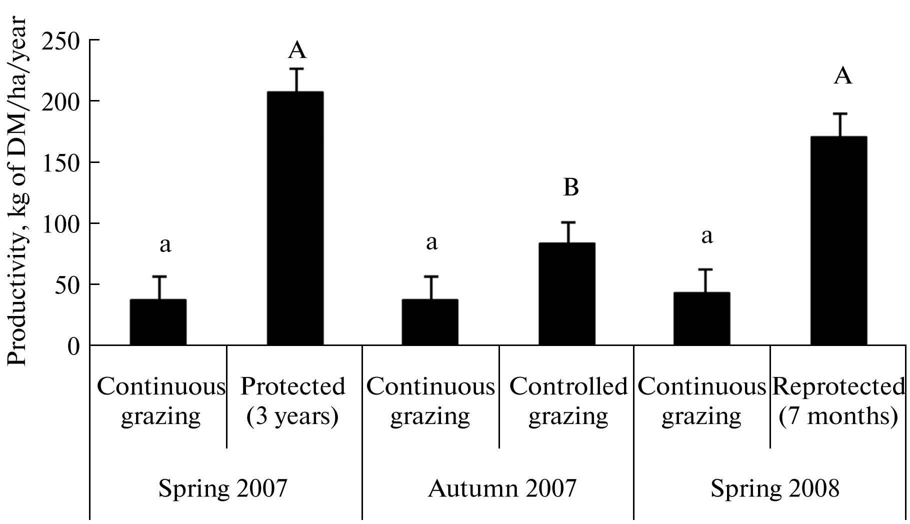

Fig. 4. Mean (±SE) of productivity under grazing management during the three studied seasons. a/b indicate differences in continuously grazed rangeland and A/B indicate differences for the managed rangeland.

Table 3. A list of the plant species present at the experimental site

Perennials	Annuals
Anabasis oropediorum	*Allium roseum*
Anonis natrix	*Anacyclis cyrtolopoides*
Anthyllis sericea	*Anarthrocarpus clavatus*
Argyrolobium uniflorum	*Asphodelus tenuifoluis*
Aristida ciliata	*Astragalus corrigatus*
Artemisia campestris	*Attractyllis flava*
Attractyllis serratuloides	*Bassia muricata*
Calligonum comosum	*Bromus rubens*
Cleome arabica	*Centaurea furfuracae*
Echiochilon fructicosum	*Cutandia dichotoma*
Erodium glaucophyllum	*Daucus carota*
Farsetia aegyptiaca	*Didesmus bipinnatus*
Gymnocarpos decander	*Diplotaxis harra*
Hammada schmittiana	*Echium humile*
Hammada scoparia	*Erodium triangulare*
Helianthemum kahiricum	*Fagonia glutinosa*
Helianthemum sessiliflorum	*Filago germiniaca*
Herniaria fontanesii	*Hypocrypis bicontortis*
Limonium pruinosum	*Iflago spicata*
Lycium arabicum	*Koeleria pubecens*
Lygeum spartum	*Koelpinia linearis*
Nolletia crysocomoides	*Launea angustifolia*
Pennisetum dichotomum	*Launea residifolia*
Pethurathus chloranthus	*Lobularia lybica*
Plantago albicans	*Lotus pusillus*
Polygonum equisetiforme	*Matthiola longipetala*
Reaumuria vermiculata	*Medicago minima*
Retama raetam	*Medicago traculata*
Rhanterium suaveolens	*Paronichia arabica*
Salsola vermiculata	*Plantago ovata*
Stipa tenacissima	*Reseda alba*
Stipagrostis pungens	*Savignya parviflora*
Ziziphus lotus	*Schismus barbatus*
	Scorzonera undulata
	Silene arenareoide
	Thesium humile

In this study we focus on the response of natural vegetation to the management mode and grazing activity. Grazing management strategies should consider not only the rangeland loading capacity but also the rest period duration and the grazing frequency (Blanco et al., 2008). Jawasreh et al. (2012) found that a proper stocking rate should be applied in each grazing scenario in order to avoid overgrazing. Moreover, sustainable natural resource management, including conservation and livestock production, requires integration of relevant and timely understanding of range utilization and spatial animal requirements (Ngugi and Conant, 2008). The present study indicates that the protection of the vegetation of desert rangelands in Southern Tunisia for three years has resulted in remarkable increases in total density and cover, and in flora richness and productivity. On the other hand, grazing animals constantly influence vegetation, directly (by eating it) and indirectly (trampling). These effects will occur both at the time of grazing and increasingly over time.

The vegetation of the study area is floristically very rich, especially during the growing season. Most of these species are referred to as good rangeland species.

After the grazing period, the natural vegetation cover in our studied zone is mainly dominated by small chamaephytes and some hemicryptophytes. Annual plant are absent because the climatic conditions of the period of grazing are not suitable for their development. According to Waechter (1982), sheep mainly prefer annual plants. In absence of these last, sheep are attracted by herbaceous plants like *Plantago albicans* and *Cynodon dactylon* and some chamaephytes as *Argyrolobium uniflorum*, *Echiochilon fruticosum*, *Herniaria fontanesii* and *Helianthemum sessiliflorum*. According to Le Houérou et al. (1974) and Floret and Pontanier (1978), these species can allocate the greater part of the fodder production (from 60 to 80%). Under the overgrazing effects, the natural vegetation cover decreases, the unpalatable plants dominate and reduce the ecosystem biodiversity (Vavra et al., 2007). However, our results show that the controlled grazing leads to a remarkable regeneration of natural vegetation after re-protection. Similar results were recorded by (Ayyad and E1-Kadi, 1982) such as density and cover, flora richness and productivity increased as a result of controlled grazing. In fact, controlled grazing can provide adequate forage for livestock while maintaining environmental quality. This management practice seems to be efficient for the floristic heritage sustainability and helps in nature conservation. However according to certain authors (Ayyad and E1-Kadi, 1982), controlled grazing there fore, and might be of better consequences than full protection.

Now, let's relate this back to the two pastures (continuous grazing and controlled grazing). The first case (continuous grazing) resulted in regrazing of plants...overgrazing. There would also be many plants that were completely ungrazed. There would be plants low quality but high quantity.

The second case (controlled grazing) may have resulted in severe grazing, but plants would not be grazed while they were recovering, there would be no overgrazing.

The growth rate also depends on the severity of grazing. When plants are severely grazed their recovery is slow. When grazing is less severe, the recovery is relatively rapid. In arid zones, where the evapo-transpiration is higher, controlled grazing can reduced the aerial biomass and allowed the root system to meet the plants water needs (Le Floc'h, 2001).

The sustainable use of natural vegetation and the reduction of land degradation processes seem to be more important to ensure the rural population subsistence, possess economic and social incomes and improve the economic productivity (Jauffret and Lavorel, 2003; Dembélé et al., 2006). The benefits economic offered by the rest rangelands include grazing, since domestic animals graze and browse on 69 species growing in this region. The highly palatable species in this area are *Echiochilon fruticosum*, *Plantago albicans*, *Anabasis oropediorum*, *Argyrolobium uniflorum*, *Helianthemum sessiliflorum*, *Aristida ciliata*, *Pennisetum dichotomum*, *Polygonum equisetiforme*, *Rhanterium suaveolens* and *Gymnocarpos decander*. The benefits offered by the rest rangelands are too environmental who include conserving biodiversity resources. Moreover, many of the plants play an important role in preventing soil erosion, increasing soil deposition and improving drainage of the lowlands (e.g. *Stipagrostis pungens* and *Calligonum comosum*).

CONCLUSION

Desert rangelands are typically characterized by low precipitation and drought. They are usually dominated by annuals species during spring and by perennial species during the other seasons. But, the grazing pressure exceeds the carrying capacity of the pasture. Continuous grazing allows livestock to selectively graze the most palatable plants over and over. These rangelands can be very productive, providing sustainable income for farmer communities while protecting valuable natural resources through appropriate grazing strategies. On these drier areas, stabilization of plant species composition and productivity appears to be possible under conditions of grazing management. In this case, controlled grazing is a proven method of increasing the efficiency of pasture systems. Intensively managed controlled grazing systems have the potential of maintaining pastures in a vegetative state for most of the growing season. A controlled grazing management plan need not be complex. It merely has to direct the grazing animal to eat when and which carrying capacity you want them to in order to keep the plants in their growing. A primary strategy of controlled grazing is to use rest and livestock carrying capacity as tools to manage forage growth and protect it from overgrazing.

Grazing and rest periods, height of grazing, carrying capacity, and herbage allowance are some of the important variables of a controlled grazing system. In our study a protection of rangelands during three years followed by an controlled grazing with a carrying capacity determined well, maintain resilient rangelands and ensure a sustainable flow of rangelands goods and services to livestock, which can be to grazing for the next year since a full year of rest before summer grazing allows residual vegetation to accumulate. Particularly in arid regions, the point to remember is that the benefits of a full year of rest can be nullified if previously rested pastures are overgrazed, where frequent drought conditions can impede rangeland recovery. And that severe grazing cannot be offset that by a longer rest period.

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