Technical Report

Rangeland restoration and management in relation to land tenure and vegetation type: the revival of the resting "Gdel" technique in southern Tunisia

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Rangeland restoration and management in relation to land tenure and vegetation type: the revival of the resting “Gdel” technique in southern Tunisia, the case of Chenini community

1. Background

Rangelands, mainly those communal, are still the dominant land use in southern Tunisia (under arid and desert climate). These rangelands suffer since some decades from severe degradation due to deep socioeconomic changes as expressed by the emergence of the agro-pastoral society instead of the former pastoral one. Traditional grazing systems (transhumance and nomadism) which had historically allowed for grazing deferment and control of grazing livestock were abandoned (Le Floc'h et al., 1999). Almost all rangelands in arid area of Tunisia (mean annual rainfall less than 200 mm) are now grazed continuously without any restriction on stocking rate. Such changes have led to rangeland deterioration. The degradation of soils and the loss of perennial palatable species, mainly grasses, are two of the direct results driven by the increase of anthropic pressure on arid rangelands of Tunisia (Ouled Belgacem et al., 2006a&b; Tarhouni et al., 2007a). Overgrazing is the main anthropic factor leading to the decline of the perennial plant cover. Its negative effect is excessive removal of the living parts of the high range value species, which may lead to their extinction. This factor is being more harmful when coupled with the climatic aridity effect. In southern Tunisia, drought has become more frequent (Ben Salem et al., 2007). Such drought is being different from the drought cyclic phenomena known in the region, and could result from a global climatic warming. It has disturbed the normal functioning of ecosystems and exacerbated by human activities. Studies on the quantification of the drought effect on plant cover dynamics are rare (DePauw, 2002; Ouled Belgacem and Louhaichi, 2013).

Covered essentially by sparse steppic plant communities, rangelands of Chenini community are also the dominant land use and cover about 40 000 ha (53% of the community area). Most of them (24 000 ha) are communal and subjected to continuous heavy grazing. In addition, the balance of ecosystems was disturbed, during the last decades, the frequency and the severity of droughts. The unpredictability of rains and dry year successions constitute the most prominent features of the climatic aridity of the region. Our knowledge on this phenomenon, its predictability, its intensity and its effects are still incomplete.

To face degradation and the negative effects of drought on rangelands, the rest technique locally called “Gdel” is one of the common practices used since many centuries by local people in arid area of Tunisia. This technique is based on the principle of leaving in rest (without grazing) the rangeland to reconstitute its plant cover. Applied in several types of natural environments (rangeland improvement, dunes stabilization, national parks, etc.), this technique allowed good results in arid and even desert Tunisia. However, several works showed that the efficiency of this technique varies according to several factors which determine the potential of regeneration of the treated area (rainfall, soil nature, level of degradation reached, period of validity of this technique, etc.).

Within the frameworks of the CRP livestock project and in collaboration with the local institutions including the Management Unit of the IFAD-funded PRODESUD project (Agro-pastoral Development and Promotion of Local Initiatives in Southern Tunisia), the Office of Livestock and Pasture (OEP), the Institute of Arid Lands (IRA) and the Community Based Organisation (Agricultural Development Grouping), a research activity is implemented in the rangelands of the Chenini community, aiming at assessing the impact of rangeland resting on plant cover dynamics and productivity in relation to the vegetation type, duration of implementing this technique and land tenure (communal, family and private) in order to develop the suitable management tool for these rangelands to cope with climate change and improve the resilience of the community livelihood.

2. Methodology

2.1. Study area

The study was conducted at the Chenini Community which is located in the Governorate of Tataouine, South-Eastern Tunisia. It is characterized by an arid Mediterranean bioclimate with a moderate winter. Rainfall is low and sporadic; the mean annual is estimated to be around 100mm. Temperatures are generally cold in winter and hot in summer with a mean annual of about 20.1°C. The water balance is greatly affected by the low dense soil cover and exposition to winds. Potential evapo-transpiration is estimated around 1700mm.year-1 in average (Tataouine weather station, 19489-2000 period). Soils are mostly raw mineral on hard rocks, coarse colluvium or calcareous and gypsum crusts. Rangelands are the dominant land use and cover about 40,000 ha (53% of the Chenini community area). About 16,000 ha are private and 24,000 ha are communal and subjected to overgrazing.

2.2. Experimental sites

The first field visits were carried out during March 2017, and allowed to identify and classify the sites subjected to resting according to the land tenure system and age of the implementation of the technique. During these visits, the main plant communities of the protected rangeland as well as the open grazing sites to be used as control, were characterized and the existing plant communities based on the dominant species were identified and delimited. A total of 7 sites covering 10600 ha including 5 private rangelands and one communal in addition to the freely grazed site considered as control were retained for detailed monitoring-assessment study. The vegetation type is mostly consisting of different degraded stages of Stipa tenacissima in the private lands and three main dominant plant communities in the collective lands (table 1).

Table 1. Land tenure and characteristics of the study sites in the Chenini community

Site Number	Land tenure	Owner	Area (ha)	Plant community	Management Mode
1	Private	Mohamed Aloui	180	Degraded S. tenacissima	1 year Rest
2	Private	Ahmed Missaoui	100	Stipa tenacissima	2 years Rest
3	Private	Said Boughrara	100	Stipa tenacissima	3 years Rest

4	Private	Hedi Missaoui	180	Stipa tenacissima	1st year Grazing
5	Private	Belgacem Bouchriha	40	Stipa tenacissima	2nd Year grazing
6	Collective Rangeland of Galb El Fguira	Community	3000	Haloxylon schimittianum	1st year Rest
				Retama raetam	1st year Rest
				Anthyllis henoniana	1st year Rest
7	Control		7000	Mosaique	Freely grazed

2.3. Measurements and data collection

Both within the rested sites and the open grazing one (control), experimental plots were established for collecting data on plant cover attributes and biomass production.

Once the experimental plots selected, 3 permanent transects of 50 m long each, were established in the different representative plant communities of the target rangeland site, and used to determine plant cover parameters according to the points-quadrats method described by Daget and Poissonet (1971). This design will permit to appreciate the potential of regeneration and the persistence of plant species by monitoring the evolution of some descriptors (global plant cover, specific frequencies, flora richness and the plant density). The state of the soil surface (wind veil, crust, stones, litter) is also studied in order to monitor and assess changes of soil structure. Both in the rested area and its respective control, biomass production permitting the estimation of the carrying capacity is determined.

The first measurement campaign was experiment was conducted during spring (April) 2017 (initial state). In each sampling plot, annual plants densities were measured by counting species individuals inside randomly established 5 quadrats with 1m^2 area each. However, the density of perennial plants consisted of counting the number of each species tuft within 5 quadrats of 20 m^2 area each.

Range biomass production were estimated by clipping the vegetation inside 5 quadrats of 1m^2 each for annual species and by clipping the half of the potentially grazeable biomass (according to the rule take the half and leave the half) of 10 tufts of each species for perennial vegetation. The total biomass of perennial species was estimated by multiplying the mean available biomass per individual by the density of the species. For determining the carrying capacity, two methods have been used. The first is based on biomass production and the needs of Animal Unit. The second take into account the plant species covers and its palatability factor or palatability factor (PF) or acceptability index according to the following formula (INRA, 1978):

$$P = 1.5 \sum_{i=1}^{n} SC_i \times PF_i \times TPC/100$$

With P = total rangeland production in Forage Units (FU) /ha/year; SCi: Species i cover in %; PFi: Palatability factor of the species I; TPC: Total plant cover (in %).

The Carrying capacity is determined by the ration of P and the annual needs of a sheep unit which is estimated to 400 FU per year.

3. Main results

3.1. Rainfall quantity and distribution during the year of the experiment

The amount of rainfall recorded in Tataouine, the nearest weather station to the study area (at 15 Km) during the biological year 2016-2017 is 153 mm (Table 2). It can be considered exceptionally high as it has significantly exceeded the average (100 mm). Furthermore, the occurred rainfall was well distributed during the seasond with a good fall amount (30 mm), considered by many authors as very efficient for seedlings emergence and vegetation growth. Thable 2 shows that 51% of the total rainfall occurred in autumn and winter and about 49% in spring (April). This latter is very beneficial for seed production of C3 plants and for growth of C4 plants, particularly chenopodiaceae species.

Table 2. Amount and distribution of rainfall during the season 2016-2017 in Tataouine (15 Km from the study area).

Month	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Total
Rainfall (mm)	30	8	0	40	0	0	0	75	0	0	0	0	153

Source: Weather Station of Tataouine

Previous studies (Miranda et al., 2009; Mathias and Chesson, 2012) have shown that precipitation may affect seed germination, seedling growth and survival, and phenology, and thereby alter the productivity and species richness of annuals in many arid and semiarid ecosystems. Both observational and experimental studies suggest that precipitation may also impact species richness of annuals in dry areas.

3.2. Total plant cover and soil surface states

The results of plant cover and soil surface states both in the private and communal rangelands subjected to different restoration and controlled management mode pas compared to the freely grazed site are presented in figures 1 and 2. Regarding the private rangelands, the effects of the duration of resting were significant on total plant cover (P = 0.0253) and highly significant on bare soil percentage (P= 0.0002) but not significant on litter and stones (P= 0.1591 and 0.2047 respectively). The highest total plant cover was recorded at the site subject to 2 years' rest (63%), followed by the first year grazing (37%). The freely grazed site (control) had the lowest plant cover rate (14.6%) as compared to all other sites. Regarding the other elements of the soil surface, the bare soil is, as expected very high at the grazed site (78%) and expressing therefore a higher threat of desertification.

On the other hand, the one-year rest showed a highly significant effect between the studied plant communities of the collective rangeland on the total cover rate (p=0.0094%), bare soil (p= 0.0008) and stones (p=0.0002). There was no significant effect of the restoration technique on litter cover whatever the plant community (p= 0.4519). Despite the short period (only 1 year), the rest technique showed a positive effect on the total cover rate since the lowest value was observed in the freely grazed rangeland (14.66%). Among the three rangeland types, the highest total cover rate (71.3%) was recorded in the *Haloxylon schmittianum* community, while the lowest was in the Antyllis henoniana type (25.33%). As expected, the rate of bare soil is very high in the control due to animal pressure and the rate of stones is the highest in the *A. henoniana* community, typical shallow soil vegetation type.

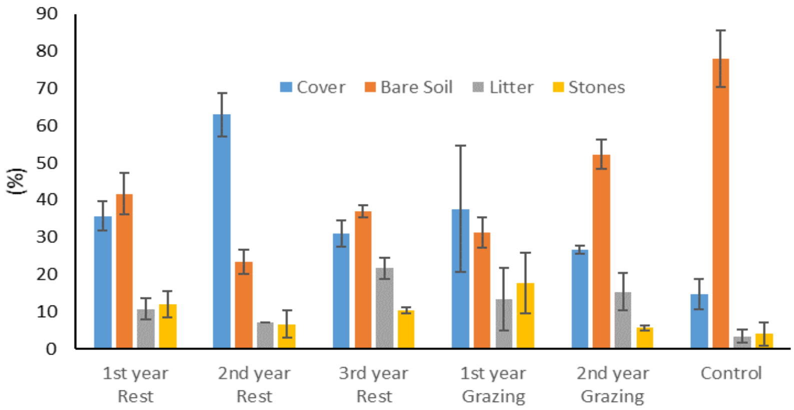


Figure 1. Variation of total plant cover and other soil surface states in relation to the applied restoration and management mode used in the private rangelands of Chenini community.

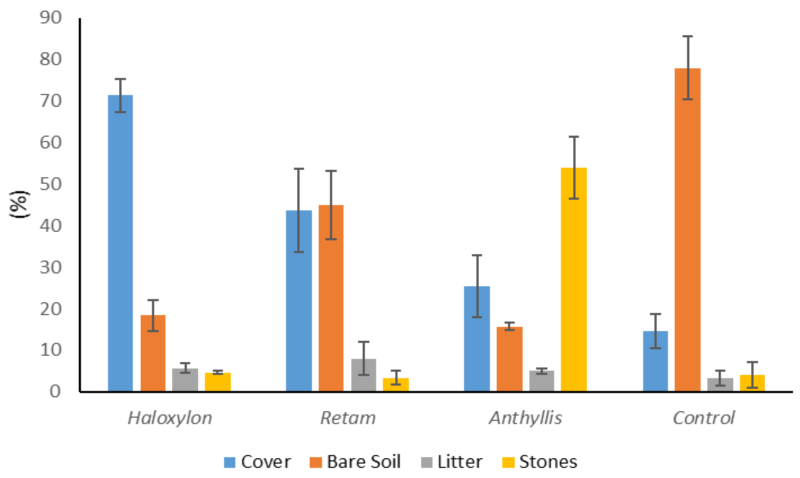
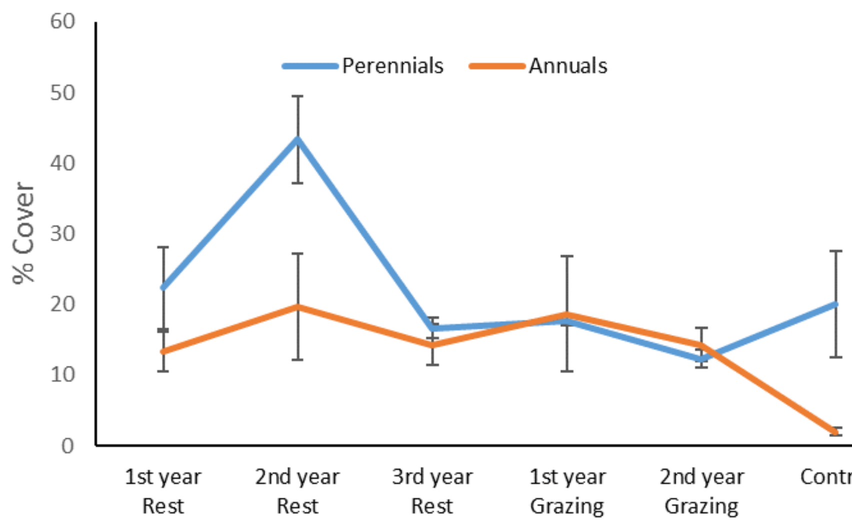


Figure 2. Variation of total plant cover and other soil surface states in three different plant communities of a one year rested collective rangeland of Galb El Feguira compared to the freely grazed site (control).

The variation of the cover rate of perennial and annual plants for both private and collective rangelands in relation to the management mode and the plant communities are presented in figure 3 and 4. In the private rangelands, perennials are the most dominant in all treatments including the control, but they have the highest cover in the 2^{nd} year rested site. In the collective rangeland of Galb El Fguira where the plant communities are characterizing drier ecosystems, annuals plants are more abundant in the Haloxylon schmittianum rangeland type after one year of rest. This could be justified by the presence of more or less stabilized sandy horizon compared to the Retama raetam type where sand is mostly mobile. The low presence of annuals in the control is also due to the early grazing by community herds since animals and mainly small ruminants prefer to graze fresher annual species before pernnials.



3.2.1.

Figure 3. Evolution of percentage cover of perennial and annual species in relation to the applied restoration and management mode used in the private rangelands of Chenini community.

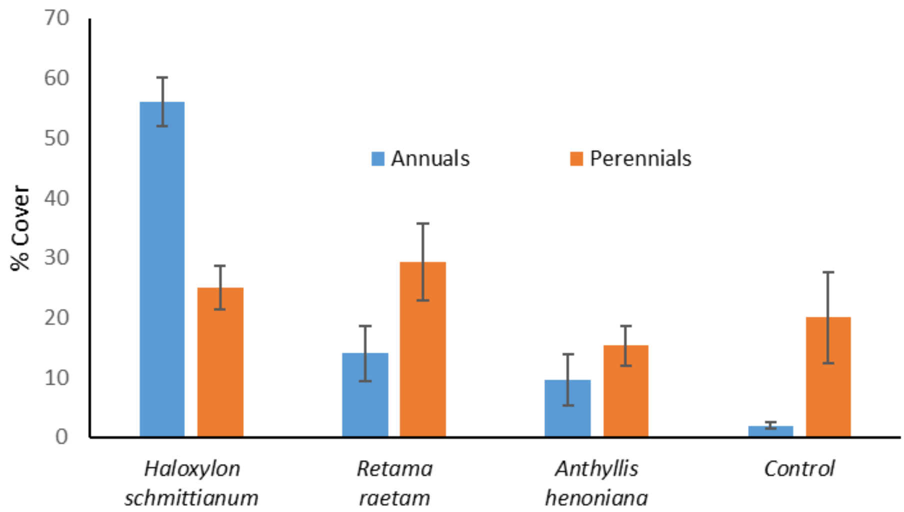


Figure 4. Variation of percentage cover of perennial and annual species in relation to the applied restoration and management mode used.

These results corroborate those achieved in other ecologically comparable zones (Gallacher and Hill, 2006; Ouled Belgacem et al., 2006a) which indicate progressive increase of the total plant cover (TPC) in the protected area as compared to the overgrazed one, characterized by the bare soil extension. In fact, protection permits soil fixation and the improvement of its structure as due to the abundance of litter resulting from trapping plant dead parts (Ould Sidi Mohamed et al., 2002). Even if there was no significant effect of the rest technique on the litter abundance in the present study, dead parts of plants, either from the protected site or outside it, are transported by wind or collected by a good protected plant cover where it will be deposited. The significant increase of perennial cover (PC) in the protected rangeland may be attributed to the improvement of organic matter content in the soil and thus the development of the vigour of the adult individuals as well as by the good establishment of new seedlings (Ouled Belgacem et al., 2006b; Tarhouni et al., 2007b). The effect of protection on annual cover (AC) is not significant since the abundance of annuals is more dependent on rainfall availability (Westbrooke et al., 2005).

The remarkable increase of the bare soil, mostly composed of wind veil, more specifically in the freely grazed areas and the first year rested communal rangelands explains the high degree of sensitivity of the whole site to desertification. The fixation of these veils will lead to the establishment of psammophile species such as *Calligonum comosum*, *Rhanterium suaveolens, Plantago albicans* and mainly annual species. The stones, indicators of water erosion, cover a very small area and present the highest percentage in *Anthyllis henoniana* community in the collective rangelands.

3.3. Plant density

The data presented in Tables 3 and 4 illustrate the great variability in plant density according to the applied restoration and management mode and the previous state of the site before applying the resting technique. Both in the private as well as the communal rangelands, perennial species are more affected by protection or disturbance. The highest value (4.43 plants.m^{-1}) was recorded at the private site subjected to the 2nd year of controlled grazing. This confirm the common belief that adequate grazing can have a beneficial effect over the duration of the vegetative period of certain species and alternation of short periods of grazing with periods of vegetative rest is generally more favourable than strict or long term protection (Ouled Belgacem et al., 2008).This was followed by collective and private sites subjected to only 1 year rest (3.24 and 2.84 plants.m^{-1} respectively). Regardless to the land tenure, the main outputs of tables 3 and 4 regarding the variability of the density of perennial species can be summarized as follows:

- The species with higher density in the protected plots than that of grazed plot. It is about *Gymnocarpos decander*, *Salsola vermiculata*, *Stipa lagascae*, *S. parviflora* and *Artemisia herba-alba,* etc, whose dynamics were supported by the protection and their presence was not recorded in the plots established within sites subjected to other treatments;
- The species which appeared in the sites subjected to either 1 year rest or controlled grazing. It is the case of *Argyrolobium uniflorum*, *Helianthemum lippii*. It is well known that these species are characterized by their high dynamics and regeneration under light grazing. According to Ouled Belgacem et al. (2013), the abundance of these species in the grazed area is probably because their germination is stimulated by grazing.
- The species seem to be indifferent at the level of their densities to the management mode such as *Haloxylon schmittianum*, *Anthyllis henoniana* and *Atractylis serratuloides*. They also constitute an indicator of desertification, since sites invaded by *Haloxylon spp*. are generally characterized by an accumulation of moving sand or sites colonized by *Anthyllis henoniana* and *Atractylis serratuloides* generally of gypsum-bearing sierozems. Whatever the soil conditions, these species react rapidly to early rainfall even in small quantities. In this context, Ouled Belgacem and Louhaichi (2013) have showed that the low susceptibility or even invulnerability of *Haloxylon schmittianum* to projected climate changes is mainly due to the low grazing pressure exerted on these species due to their very low palatability and range value and concluded that species with low range value and broad ecological niches were favored by the impacts of climate change and seemed to be able to survive under future environmental conditions of their adaptation range.
- *Stipa tenacissima* which would be the key species of the plant communities of the studied sites, and mainly the private ones, recorded very low density. This means that a rest period of 3 years is not sufficient in an arid zone for the species to appear in the sites from where it has disappeared. In addition to the human pressure on the species, it is known by its high vulnerability to climate variability. Ben Meriem and Chaieb (2017) have emphasized a negative impact of climate change on the Stipa ecosystems for the next 50 years, with a severe loss of suitable habitats.
- The species of which the density is higher in the disturbed area (control). It is about *Plantago albicans.* It is a very good pastoral species in the arid areas. Its abundance is well expected following very exceptional rainy season. this very high density of the species seedlings is not in any way expressing a significant

contribution to the biomass and rangeland production. In all cases, this high density of *Plantago albicans* can be attributed to its high reproductive capacity, its ability of vegetative multiplication and its resistance to drought (Henchi et al., 1986; Neffati, 1994) and seems to adapt well to frequent rejuvenation under the effect of grazing (Poissonnet et al., 1980).

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- The density of annual plants varied greatly as a function of the annual precipitation distribution but also to the degradation stage reached before applying the resting technique and controlled grazing. A value of 4.1 plants.m^{-1} was reached the first year of rest in the private rangelands. However this parameter has showed a very high variability in the collective sites depending on the plant community, soil conditions, disturbance stage and rainfall consistency. It has reached a very high value in the *H. schmittianum* community (about 70 plants.m^{-1}). At the exception of *Daucus syrticus* and *Echium humile*, there did not seem to be a tendency for particular species to develop following protection. In the collective rangeland and more specifically in the sandy soil of the *H. schmittianum* community, *Plantago ovata* and *Asphodelus tenuifolius* were the species that covered most of the surface area of the ground, even though there was a greater number of individuals of launeacea such as *Launaea resedifolia* and poaceae such as *Cutandia dichotama*.

Table 3. Variation of plant density (individuals.m^{-2}) in relation to the applied restoration and management mode used in the private rangelands of Chenini community.

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	1st Year Rest	2nd year Rest	3rd year Rest	1st year Grazing	2nd year grazing	Control
Anabasis articulata	0	0	0.012	0.08	0.017	0
Anthyllis henoniana	0.14	0	0.125	0	0	0.23
Argyrolobium uniflorum	0.17	0	0.4	0.02	2.233	0.03
Artemisia herba alba	0	0.17	0.087	0	0	0
Atractylis serratuloides	0.64	0.01	0.22	0	0.283	0.03
Gymnocarpos decander	0.5	0.07	0.5	0.2	0.183	0.3
Haloxylon schmittianum	0.04	0	0	0	0.2	0.29
Haloxylon scoparium	0.17	0	0	0	0	0
Helianthemum kahiricum	0.86	0	0	1.87	0.7	2.7
Helianthemum lipii	0	0	0.25	0	0.783	0.11
Linaria aegyptiaca	0	0.01	0	0	0	0
Plantago albicans	0	0	0	0	0	15.33
Reaumeria vermiculata	0	1.22	0.112	0	0	0
Rhanterium suaveolens	0.05	0.04	0	0	0	0
Salsola vermiculata	0	0	0	0.02	0.033	0.03
Stipa tenacissima	0	0.2	0	0	0	0
Stipa lagascae	0.28	0	0.05	0	0	0
Teucrium polium	0.01	0	0.187	0	0	0
Traganum nudatum	0	0	0.18	0	0	0

Total Perennials	2.86	1.72	2.13	2.19	4.433	19.05
Anacyclis clavatus	0.5	0	7.375	0	0	0
Asphodelus tenuifolius	0.4	0	0	0.5	3.5	0.8
Asphodeus tenuifolius	0	0	1	0	0	0
Asteriscus pigamaeus	0	0	0	0.6	0.833	0
Astragalus Corrigatus	0	0	0	0.2	1.167	0
Atractylis flava	0.4	0	0	0.1	0	0
Centaurea contracta	0	0	0	0.2	0.167	0
Cutandia dichotoma	0	0	15.25	0	0.167	0
Daucus syrticus	0	16.8	28.375	0	0	0
Echium humile	0.5	0	2.875	0	0	0
Euricaria pinnata	0	4.6	0	0	0	0
Fagonia glutinosa	0.2	0	0.75	0.6	0.167	0
Hernaria fontanesii	0	0	0	0	1.333	0.4
Hippocrepis bicontorta	0	0	1.125	0.1	1.667	0
Hordeum murinum	0	0	1.37	0	0	0
Ifloga spicata	0	0	0	0.7	0	1
Launaea residifolia	1.1	0	9.25	5.2	2.333	0
Lotus pisillus	0.8	0	0	0	0.333	0
Matthiola lengipetala	0.2	6.4	2.5	0.2	0.667	0
Medicago minima	0	0	1.5	0	0	0
Plantago ovata	0	0	13.5	0.1	1.767	0
Savigna parviflora	0.2	0	0	2.2	0.333	0.2
Shismus barbatus	0	0	0	0	0	0.2
Total annuals	4.3	27.8	84.87	10.7	14.433	2.6

Table 4. Variation of plant density (individuals.m-2) between plant communities of the collective rangelands after 1 year rest.

	H. schmittianum	R. raetam	A. henoniana	Control
Anthyllis henoniana	0.18	0.01	0.02	0.23
Argyrolobium uniflorum	0.01	0	0.27	0
Atractylis serratuloides	0.24	0	0.09	0.03
Bassia indica	0	0.04	0	0
Calligonum comosum	0	0.14	0	0
Gymnocarpos decander	0.22	0	0.52	0.3
Helianthemum kahiricum	0.09	0	2.15	2.7
Haloxylon schmittianum	0.26	0.18	0.13	0.29
Haloxylon scoparium	0	0	0.03	0
Heliantemum lippii	1.01	0	0	0.11
Plantago albicans	0	0	0	15.33
Retama raetam	0	0.02	0	0
Salsola vermiculata	0.13	0.01	0.02	0.03

Stipa parviflora	0.15	0	0	0
Stipa tenacissima	0	0	0.01	0
Total perennials	2.29	0.4	3.24	5.19
Arnebia procumbens	0	0	0.1	0
Asphodelus tenuifolius	21	0.3	1.5	0.8
Centaurea contracta	2.2	0.1	0	0
Cutandia dichotoma	6.3	0.4	0	0
Daucus syrticus	0.2	0	0	0
Echium humile	0.1	0	0.2	0
Fagonia glutinosa	0.6	0	1.2	0
Filago germinica	0	0	0.1	0
Hernaria fantanesii	0.1	0	0.1	0.4
Ifloga spicata	0	0	0	1
Koelpenia linearis	0.4	0	0.2	0
Launaea resedifolia	0.9	0.1	0	0
Matthiola lengipetala	0.8	0.1	0.1	0
Plantago ovata	36.6	0	2.4	0
Savigna parviflora	0.7	0	1.5	0.2
Shismus barbatus	0	0	0	0.2
Total annuals	69.9	1	7.4	2.6

3.4. Species richness

Variation in species richness and composition across rangeland management of sampled sites are illustrated in table 5 and 6. In private rangelands, a total of 49 species were recorded during the data collection compaign. There were 22 perennials speceis and 27 annual species. The variation in species richness is clearly evident for most species recorded on the private site subjected to 3 years rest (32 species; 14 perennials and 18 annuals) and fewest species recorded in freely grazed site (16 species; 9 perennials and 7 annuals). By contrast, the effects of one and two years of controlled grazing on species richness were distinguishable from those of to 1 and 2 years rest only by some species (maximum 5 species). Species richness remained almost the same over the two years of the experiment in the controlled grazing, but it declined in the free grazed treatment. Grazing for one year can enhance the establishment and growth of some species such as *Helianthemum cinereum*, *Ifloga spicata* and *Centaurea contracta*. Therefore, it seems that moderate grazing would be effective in promoting plant diversity in vegetation in dry areas (Holechek, 1991). In keeping with the previous regional studies on the impacts of grazing on species richness, we found that impacts of grazing on plant diversity can be negative and sometimes positive accoding to the degree of pressure (Ouled Belgacem et al., 2008; Gamoun et al., 2012).

In the collective rangelands, one year rest from grazing can reverse rangeland degradation and led to improved specie richness than was seen under free grazing. For instance, species richness was higher in *Haloxylon schmittianum* rangeland community (21 species; 9 perennials and 12 annuals), while the lowest was recorded at *Retama reatam* rangeland community (11 species; 6 perennial and 5 annuals). Richness of annual plants was higher in *Haloxylon schmittianum* rangeland compared to other rangeland types. This suggests that the stabilized sandy soil in *Haloxylon schmittianum* rangeland provides a more favourable environment for seed entrapment and seedling establishment of annual species. Under free grazing, the annual species may increase in comparison with protected sites (*Anthyllis henoniana* rangeland). Perhaps grazing did not degrade the dwarf annuals species, who respond rapidly to seasonal and annual changes in precipitation, and able to cope with overgrazing, such as *Ifloga spicata* and *Shismus barbatus*. *Plantago albicans*, a perennial plant sought after by the animals but which seems to adapt well grazing and its ability of vegetative multiplication (Henchi et al., 1986; Chaieb 1989; Le Floc'h, 2000) did develop very much under free grazing. In *Retama reatam* rangeland, the species richness is lower as for perennial and annuals species. Possible explanation could be that the extensive root system for *Retama raetam* decreases the ability of the other plants to exploit soil water.

Table 5: Species richness and floristic composition in relation to the applied restoration and management mode used in the private rangelands of Chenini community.

Perennials species	1st year Rest	2nd year Rest	3rd year Rest	1st year Grazing	2nd year Grazing	Control
Anabasis articulata	-	+	+	+	+	-
Anarrhinum brevifolium	-	-	-	+	-	-
Anthylis henoniana	+	+	+	+	+	+
Argyrolobium uniflorum	+	-	+	+	+	+
Artemisia herba alba	-	+	+	-	-	-
Atractylis serratuloides	+	+	+	-	+	+
Gymnocapos decander	+	+	+	+	+	+
Haloxylon schimittianum	+	-	+	-	+	+
Haloxylona scoparium	+	-	-	-		-
Heliantemun kahiricum	+	-	-	+	+	+
Heliantemun lippii	+	+	+	+	+	+
Helianthemum cinereum	-	-	-	+	-	-
Helianthemum nummularium	-	+	-	-	-	-
Linaria aegyptiaca	-	+	-	-	-	-
Plantago albicans	+	-	+	-	-	+
Rantherium suaveolens	+	+	-	-	+	-
Reaumuria vermiculata	-	+	+	-	-	-
Salsola vermiculata	+	+	+	+	+	+
Stipa lagascae	+	-	+	+	-	-
Stipa tenacissima	-	+	-	-	-	-
Teucrium polium	+	-	+	-	-	-
Traganum nudatum	-	-	+	-	-	-
Total	13	12	14	10	10	9
Annuals species						
Anacyclis clavatus	+	-	+	+	+	-
Asphodeus tenuifolius	+	-	+	+	+	+
Asteriscus pigamaeus	-	-	+	+	+	-

Astragalus corrigatus	-	-	+	+	+	-
Atractylis flava	+	-	-	+	-	-
Centaurea contracta	-	-	-	+	+	-
Centauria dimorpha	-	+	+	-	-	-
Cutandia dichotoma	-	-	+	-	+	-
Daucus syrticus	-	+	+	-	-	-
Echium humile	+	+	+	-	-	-
Erucaria pinnata	-	+	-	+	-	-
Fagonia glutinosa	+	-	+	+	+	+
Hernaria fontanesii	+	-	-	-	+	+
Hippocrepis bicontorta	-	-	+	+	+	-
Hordeum murinum	-	-	+	-	-	-
Hordeum murinum	-	-	+	-	-	-
Ifloga spicata	-	-	-	+	-	+
Koelipinia liniaris	+	+	-	+	-	-
Launaea resedifolia	+	+	+	+	+	-
Lotus pisillus	+	-	-	-	+	-
Matthiola longipetala	+	+	+	+	+	+
Medicago minima	-	-	+	-	-	-
Plantago ovata	-	-	+	+	+	-
Savigna parviflora	+	-	+	+	+	+
Scorzonera undulata	-	+	-	-	-	-
Shismus barbatus	-	-	-	-	-	+
Stipa capensis	-	-	+	-	-	-
Total	11	8	18	15	14	7

Table 6: Species richness and floristic composition according plant communities of the collective rangelands after 1 year rest.

Perennials species	H. schmittianum	R. raetam	A. henoniana	Control
Anthyllis henoniana	+	+	+	+
Argyrolobium uniflorum	+	-	+	+
Atractylis serratuloides	+	-	+	+
Bassia indica	-	+	-	-
Calligonum comosum	-	+	-	-
Gymnocarpos decander	+	-	+	+
Haloxylon schmittianum	+	+	+	+
Haloxylon scoparium	-	-	+	-
Heliantemum lippii	+	-	-	+
Helianthemum kahiricum	+	-	+	+
Plantago albicans	-	-	-	+
Retama raetam	-	+	-	-
Salsola vermiculata	+	+	+	+
Stipa parviflora	+	-	-	-

Stipa tenacissima	-	-	+	-
Total	9	6	9	9
Annuals species				-
Arnebia procumbens	-	-	+	-
Asphodelus tenuifolius	+	+	+	+
Centaurea contracta	+	+	-	-
Cutandia dichotoma	+	+	-	-
Daucus syrticus	+	-	-	-
Echium humile	+	-	+	-
Fagonia glutinosa	+	-	+	+
Filago germinica	-	-	+	-
Hernaria fantanesii	+	-	+	+
Ifloga spicata	-	-	-	+
Koelpenia linearis	+	-	+	-
Launaea resedifolia	+	+	-	-
Matthiola lengipetala	+	+	+	+
Plantago ovata	+	-	-	-
Savigna parviflora	+	-	+	+
Shismus barbatus	-	-	-	+
Total	12	5	9	7

3.5. Biomass, rangeland production and carrying capacity

Trends in biomass, rangeland production and carrying capacity, according to management options and continuously grazed site, are presented in tables 7 and 8.

Table 7. Variation of the biomass, rangeland production and carrying capacity of the studied private rangeland sites in relation to the restoration and management mode.

Management Mode	1 year Rest	2 years Rest	3 years Rest	1st year Grazing	2nd Year grazing	Control
Biomass (Kg DM.ha-1)	5336.01	3775.44	3587.07	3808.83	3441.11	6457.14
Rangeland production (FU/ha/year)	667	2250	667	680	451	120
Carrying Capacity (Sheep Unit/ha	1.6675	5.625	1.6675	1.7	1.1275	0.3
Total number of heads/year	300.15	562.5	166.75	306	45.1	2100

Table 8. Variation of the biomass, rangeland production and carrying capacity of the one year rested collective rangeland sites compared to the free grazed site.

Management Mode	A. schmittianum	R. raetam	A. henoniana	Control
Biomass (Kg DM.ha-1)	3552.82	5471.54	5254.63	6457.14
Rangeland production (FU//ha/year)	3725.43	869.82	229.598	120

Carrying Capacity (Sheep Unit/ha	9.31	2.17	0.57	0.3
Total number of heads/year	13965	976.5	598.5	2100

Regarding biomass, results show that grazing does not harm total biomass in the private as well as the communal rangelands. The highest value (6457.144 Kg DM.ha^{-1}) was recorded under free-grazing. Under the restoration technique based on strategic resting of rangelands and controlled grazing, biomass varies between 3000 and 5000 Kg DM.ha^{-1} in all sites. In term of biomass, the conservation status of the rangeland is, however, weaker under protection. As mentioned above, arid rangeland plants that are freely grazed may have lower cover. Yet, they may also have greater biomass and better survival than ungrazed plants. Consequently, grazing, rather than being destructive, is necessary for proper management of arid rangeland. On the other hand and since livestock grazing movement is seasonally regulated in traditional grazing systems, no heavy grazing is observed. Thus, it is implied a deferred grazing system, in which some areas are left ungrazed for long periods of time.

The freely grazed rangeland is dominated by *Anthyllis henoniana, Atractylis serratuloides, Gymnocarpos decander, Helianthemum kahiricum* and *Haloxylon schmittianum*. The abundance of latter large-sized specie (*Haloxylon schmittianum*) highly contribues to rangeland biomass at higher levels. The other shrub species are highly adapted to grazing and respond to persistent goat and sheep browsing by growing interlocking twigs. The woody twigs serve as a defense against herbivory and sometimes flowering is not hindered by heavy browsing. This can also be explained by the high density of perennial species recorded in the freely grazed site. The low biomass in rest rangeland may be influenced more by historical than by current grazing pressure and low biomass does not necessarily imply low production, and vice versa. Theses Chamaephytes were significantly benefited by grazing (Kahmen & Poschlod 2008) and can make up the greater part of the fodder production (from 60% to 80% of production) (Le Houérou et al., 1974; Floret & Pontanier 1978). Therefore, grazing pressure alone cannot explain current differences in biomass. In arid area, the principal driver is the precipitation, with its variability having a direct impact on the variability of biomass. During this study, favorable rainfall led one to conclude that rangelands are in good condition or improving from a degraded condition from the point of view of total biomass.

Conversely, the same study based in the private as well as the communal rangelands showed that rangeland productivity is more limited at managed rangelands. In a private rangeland, the site subject to 2 years' rest provided highest production (2250 FU/ha/year) followed by the first year grazing (680 FU/ha/year), while the lowest is 120 FU/ha/year in the freely grazed site. Allowing the rest from grazing for less than 3 years led to improved rangeland production than was seen under free grazing. Over-resting from grazing for more than 2 years, has not increased rangeland production any more than two years of rest or short-duration grazing (one year). Two years of rest showed rapid recovery of the rangeland production once rains occured. In addition, light to moderate grazing of one year may stimulate plant production, leading to rangeland production that is more important than that produced by longer period of protection (2 and 3 years rest) or free grazing.

Furthermore, in the collective rangelands, the one year rest led to increased rangeland production with an average of 2073.5 FU/ha/year in ungrazed as compared to grazed areas with an average of 120 FU/ha/year. The amount of forage produced differs markedly according to plant communities. The study on three rangelands type, showed that productivity is the highest on *Haloxylon schmittianum* rangeland (3725.425 FU/ha/year) followed by *Retama raetam* rangeland (869.82 FU/ha/year), while the lowest at *Anthyllis henoniana* rangeland (229.5975 FU/ha/year). Between rangeland types, differences in productivity may be determined by differential water and nutrient availability (Noy-Meir, 1993; Li et al., 2011). Rangeland productivity is high along the stabilized sandy soil, which probably receives higher amounts of water and nutrients by runoff and subsurface flow what provides the highest and most dependable production on the long term (Guevara et al., 1997; Le Houérou 1992). Thus, soil depth, in such coarse sands, appears as key factor in capacity to store water (1 mm of rain moistens 1 cm of soil depth, and the amount of available water is 0.75 mm cm^{-1}) (Le Houérou, 2009). In arid rangeland, sandy substrates are usually favourable for plant growth because water percolates through the surface layers quite rapidly (Noy-Meir, 1973). At *Retama raetam* rangeland, where sand is mostly mobile, productivity is considered as low could be explained by that evaporation loss is relatively high, and the negative effects of sand accumulation on shrubs may dominate over the potentially positive effects. Otherwise, all soil moisture is evaporated, and layers beyond that depth are permanently dry. At *Anthyllis henoniana* rangeland on limestone soil (soil surface higly covered by stone), low productivity may partly be explained to high water-holding capacity of the loamy substrate, the lack of water due to high runoff rates and the low nutrient content. This rangeland is most affected by drought, this may be attributed to soil sealing, which plays a key role in crusts formation.

During this study, climatic conditions are favorable and rain use efficiency should increase with annual rainfall, as the proportion of effective rain increases with decreasing aridity (Le Houérou, 1984).

Stocking density can be regulated according to potential carrying capacity. This latter can be predicted according to rangeland production. Productivity is usually used to estimate the carrying capacity for of the rangeland. This production may be converted to carrying capacity for sheep by the ration of rangeland production and the annual needs of a sheep unit which is estimated to 400 FU per year. In private rangeland, the highest carrying capacity of livestock is estimated as 5.625 Sheep Unit/ha in the site subject to 2 years' rest followed by the site subject to 1 years' grazing as 1.7 Sheep Unit/ha. While, under free grazing, the lowest carrying capacity of livestock is estimated as 0.3 Sheep Unit/ha. Under free grazing, rangeland production is less than average and stocking rates were far beyond the carrying capacity and vegetation was badly overgrazed (Le Houérou, 1969). Two years of rest can improve carrying capacity to 18 times more than under free grazing. Therefore, this last rangeland of 100 ha can support 562.5 Sheep Unit/ha/year.

In collective rangeland, the mean carrying capacity of livestock is estimated as 5.18 Sheep Unit/ha. It was linked to plant communities. The higher was recorded in *Haloxylon schmittianum* rangeland (9.31 Sheep Unit/ha) followed by *Retama raetam* rangeland (2.17 Sheep Unit/ha) and *Anthyllis henoniana* rangeland (0.57 Sheep Unit/ha). This collective rangeland of 3000 ha rested only for one year can support 7338 Sheep Unit/ha/year without being damaged. Contrariwise, the freely grazed rangeland of 7000, can support only 2100 Sheep Unit/ha/year.

4. Conclusion

Even if preliminary results have shown that a protection period of 3 years is not sufficient for disappeared species to appear nor for succession to reach a next stage, mainly in the degraded *Stipa tenacissima* community, the reintroduction of the rest “gdal” practice seems to be beneficial and a suitable tool to manage sustainably the arid rangelands under changing climate. Thus, the evidence suggests that, during short-term rest from grazing (2 years), vegetation cover, density, rangeland production and carrying capacity can be improved. During relatively rainy years, grazing for short period (1 year or less) is apparently not harmful for rangeland vegetation in the dry areas. In this context, if rangelands are grazed by a number of animals lower than the carrying capacity, there will be no risk of rangeland degradation and vice versa. Adequate grazing can have a beneficial effect over the duration of the vegetative period of certain species and alternation of short periods of grazing with periods of vegetative rest is generally more favourable than strict or long term protection. These results are still preliminary and need to be confirmed by further monitoring and assesment of the vegetation growth and production in relation to the different tested grazing management techniques.

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