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Restoration and rehabilitation of degraded Saharan communal rangelands in southern Tunisia

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Abstract - This study was carried out at the communal rangelands of Dhahar, Saharan area of Southern Tunisia, to assess the impact of restoration and rehabilitation techniques on natural vegetation cover. Two rangeland types (*Rhanterium suaveolens* and *Anthyllis sericea*) were subjected to three management modes: two years rest (M), reseeding *Stipagrostis pungens* (S) and free grazing (T). In all plots, total plant cover, species richness and grass density where determined in spring 2008. Results showed that despite the negative effect of drought, considerable and positive effects of protection and at lesser degree of reseeding on all scored parameters. This is an indication that when degradation is still reversible, restoration techniques are more effective in addition to their low costs. However, the good establishment of *S. pungens* seedlings may encourage the recourse to the rehabilitation technique by reintroducing some promoting native Saharan species when ecosystems loose their resilience capacities.

Keywords: Restoration, Rehabilitation, Communal rangelands, Saharan area, Tunisia.

1. Introduction

In North Africa arid and Saharan areas and more specifically in Southern Tunisia, several studies (Floret and Pontanier 1982; Ouled Belgacem 1999; Caieb and Zaâfouri 2000; Oueld Sidi Mohamed 2003; Jauffret and Visser 2003; Ouled Belgacem et al. 2006; Ouled Belgacem et al. 2013) show that human pressure constitutes the origin of various disturbances which modify considerably the functioning of rangeland ecosystems. Among these destructive actions, overgrazing generates a reduction of plant cover and biomass of perennial plants and consequently the deterioration of these ecosystems (Le Houérou 1959; Floret and Pontanier 1982; Jauffret and Visser 2003; Ouled Belgacem et al. 2006; Tarhouni et al. 2007; Abdallah et al 2008). In the same way, Akrimi and Neffati (1993) stress that overgrazing is the agent responsible for rarefaction even the disappearance of the high range value species and the extension of the unpalatable species (Ouled Belgacem and Louhaichi 2013).

The communal rangelands of Dhahar, characterized by a more or less diversified vegetation types, constitute a representative sample of the disturbed Saharan rangelands in southern Tunisia. They are characterized by a degraded plant cover (Chehma et al. 2005) and qualified as "very poor ecosystems" on the basis of the small number of the available plant species compared to the huge surface they cover (Ozenda 1977). Given the harsh climatic conditions and increasing human activities, these rangelands are now subject to severe degradation reducing their biological potential (Ben Abdellatif 2008). The improvement and the reconstitution of these degraded ecosystems necessitate the recourse to some appropriate management techniques such as restoration (rangeland rest) and rehabilitation by reseeding native species (Ferchichi and Neffati 1992; Aronson et al. 1993b; Ouled Belgacem et al. 2008). These techniques which encounter several constraints (social acceptability, choice of the most promising species, and control of the technique…) offer to the disturbed ecosystems a sufficient capacity to be reconstituted after moderate disturbances (Le Floc'h et al. 2002). Considered among the most promising species for rangeland rehabilitation according to its biological characteristics (growth

period, root systems…), *Stipagrostis pungens*, a C4 perennial grass species, seems to allow optimal use of soil water resources and increases range production (Arhab et al. 2006).
Within the IFAD-funded PRODESUD project (Agropastoral Development and Promotion of Local Initiatives in Southern Tunisia), a participatory community development plan (CDP) of the agropastoral community of Douz was established. Among the main achievements of this CDP, a community based organization, called Agricultural Development Grouping (ADG), was constituted for the management of communal resources and for the first time, the local population suggested the short term protection (rest) of collective rangeland.
This study is carried out at El Mahmouda area, in the collective rangelands of Dhahar, aiming at assessing the impact of rangeland rest and reseeding of *S. pungens*, on plant cover dynamics of two rangeland steppe types (*Rhanterium suaveolens* and *Anthyllis sericea*).

2. Material and Methods

2.1. Study area

El Mahmouda zone belongs to the communal rangelands of Dhahar (figure 1), desert area of southern Tunisia (mean annual rainfall is less than 80 mm). It covers 40000 ha with many micro-reliefs (small depressions, large sand dunes...). It has been subjected to rational management in the framework of the PRODESUD project (Agropastoral Development and Promotion of Local Initiatives in Southern Tunisia) which is funded by the International Fund for Agricultural Development (IFAD). The natural vegetation cover is mainly dominated by perennial species such as *Laegos raetam*, *Rhanterium suaveolens*, *Stipagrostis pungens*, *Hammada schmittiana* and *Anthyllis sericea*. Annual species like *Savigna parviflora*, *Asphodelus spp*., *Schismus barbatus* and *Matthiola longipetala* are observed during wet seasons.

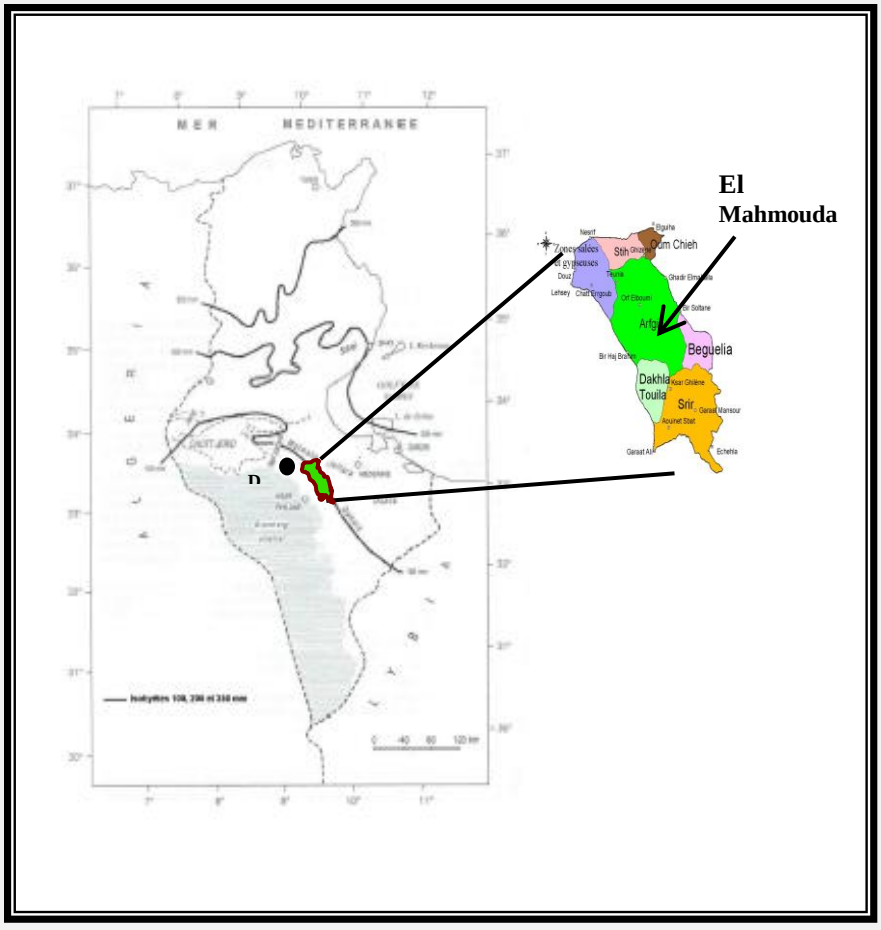

Figure 1. Geographical location of the site El Mahmouda in southern Tunisia.

2.2. Experimental design

The study was carried out during the spring 2008. The experiment is designed as split-plot model. The first tested factor in the plot is the vegetation group and the second is the management technique. Three management modes tested were: i) two years protection, ii) one year reseeding with *Stipagrostis pungens* and iii) free grazing (control) (Table 1).

Table1. The adopted management methods ($\mathbf{R_T}$: control *Rhanterium suaveolens*, $\mathbf{R_M}$: protected *R. suaveolens*, $\mathbf{R_S}$: *R. suaveolens* reseeded by *Stipagrostis pungens*, $\mathbf{A_T}$: control *Anthyllis sericea*, $\mathbf{A_M}$: protected *A. sericea*, $\mathbf{A_S}$: *A. sericea* reseeded by *S. pungens*).

Rangeland type	Management mode		
	Control	Protection	Stipagrostis pungens reseeding
Rhanterium suaveolens	R_T	R_M	R_S
Anthyllis sericea	A_T	A_M	A_S

Five lines, 50 m long each, were installed in each rangeland type. A fine pin was descended to the ground every 20 cm along the line. Each of the 1000 hits per line was recorded according to the plant species and type of ground touched. The results are expressed in terms of vegetation cover as R = (n / N) * 100 with n: the number of hits of all plant species and N: the total number of hits. The perennial grasses density is counted in 5 quadrats of 100 m² each. The flora richness is determined by counting annual and perennial species on the sampled surface.

2.3. Statistical analysis

All data were subjected to analysis of variance (ANOVA) on the basis of the split-plot statistical model by using SPSS (11.5) (SPSS Inc. 2002).

3. Results and Discussion

3.1. Climatic conditions of the year of the investigation

The total quantity of rainfall, recorded at the study area during the growing season 2006-2007, corresponding to the year of reseeding and protection, was very important (163 mm) and was very high nearly double the mean annual precipitation (80 mm). Precipitation started early with a good quantity during the months of fall (23 mm), higher than 10 mm considered to be efficient and beneficial for vegetation in arid and desert areas (Floret and Pontanier, 1982). Moreover; it was well distributed in time. However, the experiment year (2007-2008) was relatively dry (63 mm) and characterized by a very dry fall with the low quantity recorded in September (6.2 mm) (Table 2).

Table 2. Rainfall (mm) recorded at El Mahmouda site during the two biological years 2006-2007 and 2007-2008

	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Total
2006-2007	-	9,2(2)	13,5(2)	22(3)	-	16(1)	57,7(6)	41,3(3)	0,1(1)	-	-	3,7(1)	163,5(19)
2007-2008	-	6,2(1)	-	41(2)	2,4	0,9(1)	5(1)	3,5(1)	3(1)	-	-	1(1)	63(9)

( ): Between brackets number of rainy days.

3.2. Total plant cover

The analysis of variance (R^2 = 0.91) of total plant cover produced highly significant differences (0.001) between the two sites as well as between the applied management modes (0.002).

In both rangeland types, total plant cover was higher in the protected and reseeded sites as compared to the free grazing sites (R_T and A_T). The beneficial effect of the restoration and rehabilitation techniques is more obvious when applied on *Anthyllis* than on *Rhanterium* rangelands (figure 2)

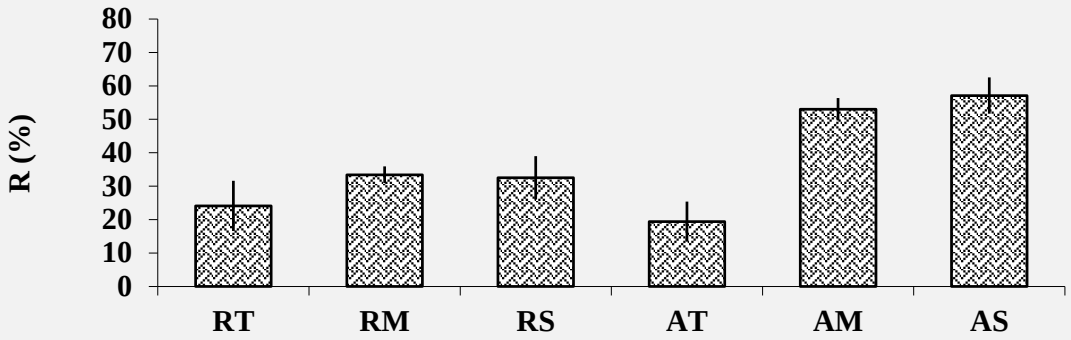

Figure 2. Variation of total plant covers in relation to study rangeland types and management modes during spring 2008.

This figure shows that both improvement techniques have significantly increased vegetation cover of the *A. sericea* rangeland compared to *R. suaveolens* rangeland. *A. sericea* seems respond better to management techniques and shows a good regeneration capacity. The differences between rangeland vegetation cover under the same management modes are significant (0.023). The use of reseeding by S. pungens improved the plant cover indicator in both types as compared to free grazed sites but it did not produce a significant effect as compared to short term protection (2 years). This may be explained either to the ecology of this grass species known as a psammophile preferring mobile sand (Bendali 1987) or by the state of degradation reached in both plant communities which did not reached in any way the irreversible state and the system still has a resilience capacity (Ouled Belgacem et al. 2008). Protection seems, therefore, to be the most recommended technique for rangeland management since it is easy to use and has the lowest economic cost.

3.3. Flora richness

We proceeded by determining the number of perennial and annual plants as well as annual/perennial (A/P) ratio from floristic lists from the different experimental sites. The obtained results are shown in Table 3.

Table 3. Variation of annual and perennial number and their ratio in relation to study rangeland types and management modes during spring 2008.

	R_T	R_M	R_S	A_T	A_M	A_S
Annual (A)	11	11	9	7	7	16
Perennial (P)	11	13	17	13	16	16
A/P	1	0,85	0,53	0,54	0,44	1

The ANOVA showed a highly significant effect ($p<0.01$) of management modes on the perennial number in the R. suaveolens rangeland and a non significant effect for A. sericea rangeland. However, annual variation is significant ($p<0.05$) in both rangelands. The perennial number is more important in rehabilitated sites and confirms the beneficial effect of S. pungens reseeding which improves floristic richness. According to Aronson et al. (1993) the floristic richness may be at the origin of ecosystems auto regeneration process. However, Tarhouni (2008) showed that floristic richness can not explain alone the loss of ecosystem resilience in dry areas. Hence, it seems necessary to use quantitative parameters to characterize these sites.

3.4. Grass density

Grass density was significantly (0.01) affected by management mode as well as the rangeland type. For both rangeland types, this indicator was measurably higher in the reseeded areas than in protected and in areas open to grazing (Table 4). Contrarily to the plant cover, the reseeding operation was significantly more beneficial in term of grass density, in *R. suaveolens* rangelands (0.444 individuals per m^{-2}) than in *A. sericea* ones (about 0.332 individuals per m^{-2}). In both types, grass density (mostly of *S. pungens*) was lower in the rested areas (R_M and A_M) with 0.022 and 0.024 individuals per m^{-2} respectively.

Table 4. Variation of perennial grasses density in relation to study rangeland types and management modes during spring 2008.

Management modes	Grass density (plant/m²)
R_T	0,134
R_M	0,022
R_S	0,444
A_T	0,006
A_M	0,024
A_S	0,332

For *R. suaveolens*, the high grasses density in the freely grazed site, considered here as Control (C_R), can be explained by the abundance of S. *pungens* in this site before establishing the rehabilitation technique. Ben Dali (1987) has showed that the severe degradation of the *R. suveolens* steppe in the sandy soils due to overgrazing may lead to the development of different forms of mobile sand accumulations going from wind veils to large nebkas. These conditions are in fact very favourable for the development of S. *pungens* considered as pioneer of mobile sands. For *A. sericea*, the perennial grass density was higher in rehabilitated site compared to the protected one. For the two studied rangeland, it seems that *S. pungens* reseeding improves perennial grass density. The results of the study mainly those recorded in the free grazed sites (controls) confirm the common belief that the overuse of rangelands leads to the rarefaction or even the disappearance of good pastoral value species, mainly grasses which are appreciated in all circumstances. The rarefaction of grasses constitutes, according to several authors (Ould Sidi Mohamed et al. 2002; Ouled Belgacem et al. 2006), a good indicator of the state of deterioration of the plant cover. They showed that degradation by overgrazing affects firstly the perennial grasses then chamaephytes. Noy-Meir et al. (1989) reported that when there is a decrease in grasses whose superficial roots encourage soil aeration there is a decrease of water infiltration coupled with ligneous species regression. On the other hand, the results showed that the rangeland rest or short term protection is technically an efficient tool for plant regeneration including grasses when the rangeland ecosystem did not reach the irreversible phase of the degradation and still own its resilience. In situations where rangeland degradation has reached the threshold of irreversibility and where the regeneration of the ecosystem with a simple protection is no longer possible, rehabilitation by reintroducing native range species such *Stipagrostis pungens* is required.

4. Conclusion

The results of the evaluation of the impact of some restoration/rehabilitation techniques applied in two degraded rangeland types (*Anthyllis sericea* and *Rhanterium suaveolens*) of the Saharan area of southern Tunisia showed that the variation of the plant cover in is strictly dependent on the quantity of rain, the soil type and the degree of former disturbance. This indicator also varies with the mode of management. However for species richness and density of grasses, rehabilitation by reseeding *Stipagrostis pungens*, improved significantly these indicators regardless to the unfavourable climatic conditions characterizing the experiment growing season. At this period (2 years only), rest or short term protection seems to be the most suitable technique since it permitted, globally, the best results for both rangeland types in addition to its easiness and low cost . However, the success of the reseeding technique with local perennial grass species may be more beneficial in the coming next years. Once exceeded the critical phase of establishment, *S. pungens*, saharan species tolerating sand dunes and repeated droughts, is able to survive under any condition permitting thus sand fixation and the regeneration of the natural vegetation species composition. This requires a regular monitoring of the studied plant cover parameters.

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