



RESEARCH ARTICLE

EFFECT OF TWO RESTORATION TECHNIQUES ON: PLANT AND SOIL SURFACE COVER AND PASTORAL VALUE IN STEPPIC ALGERIAN RANGELANDS

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ABSTRACT

In Algeria, the fight against desertification begins with a restoration of steppic rangelands seriously degraded. In this framework more than two million hectares of pastoral land throughout the steppe have been exempted from agropastoral activities and fencing from grazing using enclosure and pastoral plantation with *Atriplex canescens*. This study aims to evaluate the impact of the two techniques on the restoration of degraded steppic rangelands. The methodological approach is the comparative analysis (One-way-ANOVA) of vital attributes of the ecosystem. The total plant cover (with a contribution of perennials and annuals species) and soil surface cover (bare ground, litter, stones, bare silty crust and wind veil) and pastoral value has been estimated inside and outside each technique (enclosure and pastoral plantation). The results obtained highlighted significant differences between the inside and outside of the restored rangelands, with an increase within the restored and protected rangelands of the recovery rate of vegetation and litter and pastoral value, and a decrease in bare ground, stones and wind veil, This improvement ensures both more stability to the various disturbances and proper functioning of the steppic ecosystem. However, the results emphasized a negative effect of the long term protection of these restored rangelands, this was observed by the occurrence of the bare silty crust on the soil surface, which has a negative effect on the installation of the vegetation and the emergence of seedlings (young plants) and the infiltration of water, where the importance of considering this parameter as an indicator for the opening of the fencing.

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INTRODUCTION

Rangelands cover more than one third of the earth's land surface area. These important landscapes provide clean water and air, produce forage and cover for wildlife, store carbon and support a wide diversity of plant and animal communities. They also provide forage for livestock, generate renewable energy, provide genetic material for pharmaceutical products, create opportunities for recreation, and support the livelihood of at least one billion people (UNCCD, 2004; Louhaichi *et al.*, 2012) In Algeria, steppic rangelands, which extend over 20 million hectares, have an estimated total population of 7.2 million. Steppes are grazed by 19 million sheep (HCDS, 2012). Breeding which is the key activity for the development of this area magnified degradation of vegetation, sometimes up to an irreversible desertification of arid and semi-arid ecosystems (Mainguet, 1991; Kassas, 1995), the drought effect is

combined with the impact of sheep grazing (Aidoud and Touffet, 1996). The degradation of steppes led the government to set up measures to protect these rangelands. The plans for preserving these ecosystems from desertification were drawn up. In this context more than two million hectares of pastoral land across the steppe have been exempted from agropastoral activities and protected from grazing using between techniques, enclosure (natural regeneration) and pastoral plantation (planting of forage species such as *Atriplex canescens*), these practices have been extensively used in the Maghreb and Middle East (Amiraslani and Dragovich, 2011). Managed by the High Commission for the Development of the Steppe (HCDS), all these techniques have been employed in Algeria over large areas since 1994.

MATERIALS AND METHODS

Study Area

The study was conducted in four sites of Djelfa departement (Fig 1), Two sites in the town of Taadmit located inside and

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outside to Menkeb Ben Hammed enclosure and two other sites in the town of Benhar located inside and outside to Lakdar pastoral plantation. These stations are situated within the steppe area of North Africa (Quézel, 1978). Taadmit and Benhar sites have an average altitude of 1035 m and 810 m respectively. They are characterized by a Semi-arid bioclimate. The average annual rainfall is 111mm and 252mm for Taadmit and Benhar respectively (Tab.1).

Sampling method

Vegetation was monitored during spring, in April 2012, in the peak season of primary production and when development of the annual vegetation was at its prime. To study the effect of each restoration techniques, two parameters were measured:

- Total plant cover (TPC %) with a contribution of perennials (PSC %) and annuals species (ASC %);

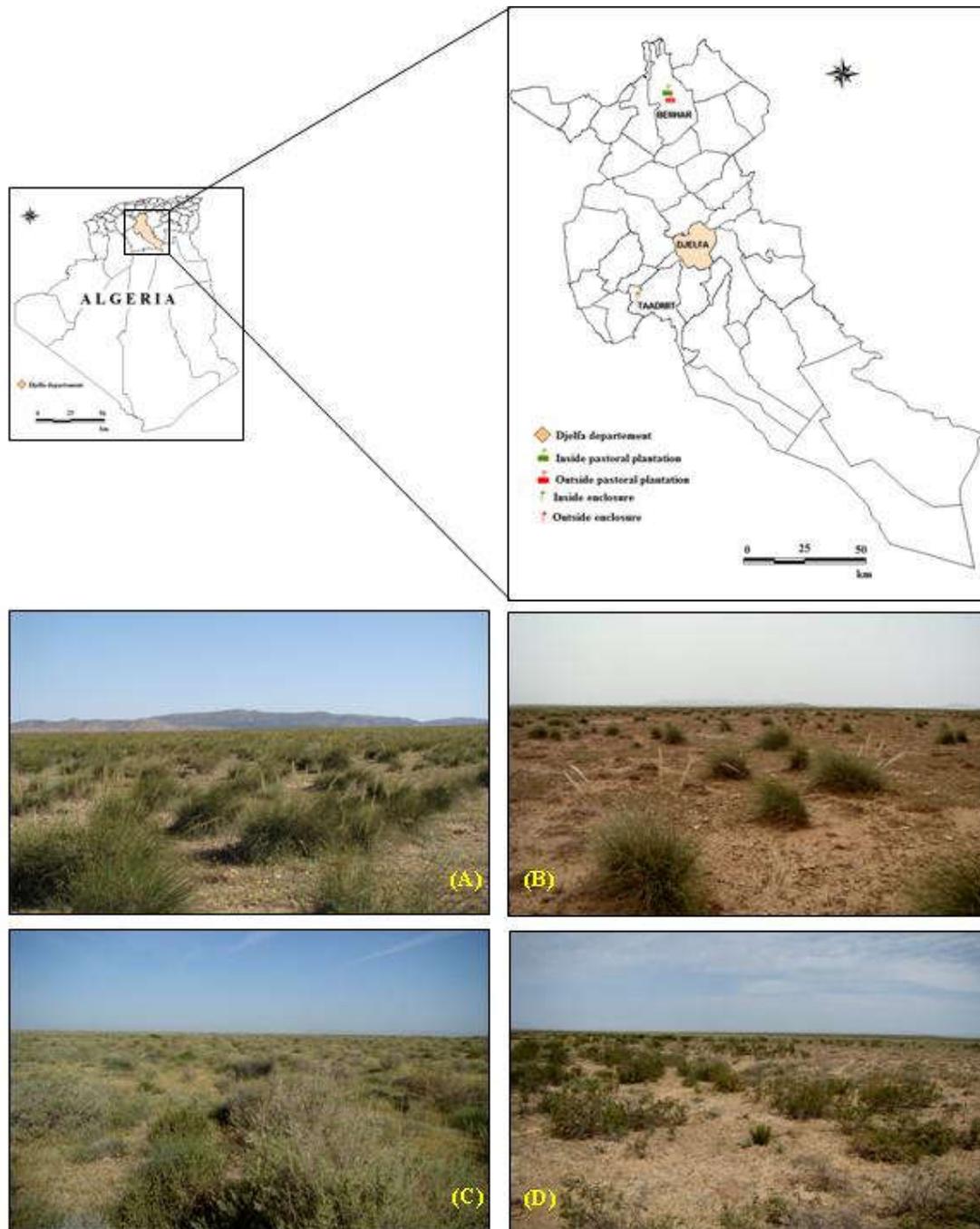


Figure 1. Location of the study area and general view of the sampled stations, (A) Inside enclosure; (B) Outside enclosure; (C) Inside pastoral plantation ; (D) Outside pastoral plantation.

Table 1. Geographical coordinates and climatic characters of study stations

Station	Altitude (m)	Longitude (E)	Latitude (N)	P (mm)	M (°C)	M (°C)	Q_2 (%)
Benhar	810	34° 22' 56".6	35° 31' 51".4	252	37.0	1.1	24.08
Taadmit	1035	02° 51' 05".0	03° 03' 13".3	111	36.8	1.6	10.78

- Soil surface cover (bare ground, litter, stones, bare silty crust and wind veil);
- Pastoral value index (PVI)

The quadrat point method (Daget and Poissonet, 1971; Floret, 1988) was used in each station. A total of 40 tapes of 20 m length each were randomly established (10 inside and 10 outside the restoration techniques). A fine pin was descended to the ground every 10 cm along the tape. Each of the 200 hits per tape was recorded according to the plant species touched, in the absence of species, other elements of the soil surface like: bare ground, litter, stones elements (size > 2mm), bare silty crust and wind veil are noted.

The total plant cover, in each tape, was calculated as (1):

$$TPC = (n/N) * 100 \quad \dots\dots\dots (1)$$

With n: the number of hits of all plant species or each elements of the soil surface.

N: the total number of hits (200 hits in our case).

The majority of encountered plant species were identified in the field. Specimens of unidentified species in the field were collected and dried using a plant press and were brought to CRSTRA's herbarium at Biskra for identification. The detailed eco-characterization of plant taxa and plant nomenclature was based on the flora of Quezel and Santa (1962 et 1963) and flora of Ozenda (1977). The quality of the forage supply is expressed by the Pastoral Value Index (PVI) on the basis of the Isi quality index assigned to each species according to its palatability. Is is a "score" ranging from 1 (unconsumed plant) to 10. The assignment of the indices was established on a bibliographical basis (Le Houérou and Ionesco, 1973), supplemented by surveys of breeders (Aidoud, 1989). For each statement, a PVI value is calculated on the basis of the following equation (2):

$$PVI = 0,1 * \sum C_{si} * I_{si} \quad \dots\dots\dots (2)$$

This formula, having been established (Daget and Poissonet, 1972) for meadows with a cover often close to 100%, the bias due to the bare soil is negligible. For steppe vegetation whose cover rarely exceeds 50%, the formula has been adapted by introducing a weighting (Aidoud *et al.*, 1983) as follows (3):

$$PVI = 0.1 * TPC \sum C_{si} * I_{si} \quad \dots\dots\dots (3)$$

Statistical analysis

All data were subjected to analysis of variance (ANOVA) using Minitab 16 statistical package programme (Minitab, 2010). Stations (inside or outside each restoration techniques) were the independent variables whereas, total plant cover (TPC %) with a contribution of perennials (PPC %) and annuals species (APC %), soil surface cover (bare ground, litter, stones, bare silty crust and wind veil) and pastoral value were the dependent variables.

RESULTS AND DISCUSSION

Total plant cover

The total plant cover, as a better indicator of plant community health (Meyer and Garcia-Moya, 1989), the statistical analysis

of TPC % (total plant cover), showed a significant difference between the restored and unrestored areas, the results showed the higher rate inside the restored (enclosure and pastoral plantation) areas than in the unrestored (outside enclosure and outside pastoral plantation) areas (Table 2). The TPC % (Total plant cover) was increased by 2 times in restored areas compared with the unrestored areas, these results suggest that protection affected significantly the total plant cover but overgrazing affects ecological succession and regeneration by removing photosynthetically active tissues from the palatable plant species required for prairie maintenance and survival (Louhaichi *et al.*, 2009). Our results corroborate those achieved in other ecologically comparable zones (Ayyad and El-Kadi, 1982; Ouled Belgacem *et al.*, 2005; Akbarzadeh *et al.*, 2007; Louhaichi *et al.*, 2009), indicating progressive increase of total vegetation cover in protected areas as compared to overgrazed areas which are characterized by the expansion of bare soil. Also, the results showed that in each area (restored or unrestored) the vegetation cover was mainly dominated by perennials species but the annuals were fewer (Tab.4). Perennial species contribution was significantly different between the restored and the unrestored areas. We estimate that the perennial plant cover is different and higher 1.5 times between inside and outside enclosure and 2 times between inside and outside pastoral plantation. On the other hand, the annual species cover is different and higher 3.4 times between inside and outside enclosure and 2.5 times between inside and outside pastoral plantation. Higher plant cover reduces water losses by evapotranspiration, maintains a favourable microclimate for regeneration of annual herbaceous species and permits the development of perennial species (Floret and Pontanier, 1982; Ouled Belgacem *et al.*, 2005), knowing that the rarefaction of perennials species constitutes, according to several authors (Ouled Sidi Mohamed *et al.*, 2002; Le Houérou, 1977), a good indicator of the determination of the plant cover.

Soil surface cover

Changes at the soil surface induce changes in the distribution of the different elementary surface states, which can be characterized by simple field observations (Jauffret, 2001). In the arid regions where it is directly in contact with the atmosphere, the soil surface plays an important part especially in the development of the spontaneous or cultivated plants, in the water cycle and in the erosion processes (Escadafal, 1981; Valentin, 1985). In this study, the ANOVA analysis (Table 3), showed a significant difference between the restored and unrestored areas for the rates of different soil surface elements, the results showed a significant and higher difference in cover of bare ground, stones and wind veil in the unrestored (outside enclosure and outside pastoral plantation) areas than in the restored areas (inside enclosure and inside pastoral plantation). However, the litter and bare silty crust cover rate are significantly different and higher in the restored areas (inside enclosure and inside pastoral plantation) than in the unrestored (outside enclosure and outside pastoral plantation) areas (Table 3). Bare ground surface was significantly more than five times and three times higher in outside enclosure and outside pastoral plantation respectively than in inside enclosure and inside pastoral plantation. Equally, the rate of stones was significant and higher almost eight times and seventeen times in outside enclosure and outside pastoral plantation comparatively to inside enclosure and inside pastoral plantation. Also, the rate of wind veil was significant and higher almost three times and seven times in outside enclosure

and outside pastoral plantation comparatively to inside enclosure and inside pastoral plantation. Unlike the above three soil surface elements, the rate of bare silty crust and litter was respectively significant and higher two and three times in inside enclosure and inside pastoral plantation than in outside enclosure and outside pastoral plantation. The more abundance of bare ground, stones and wind veil in free grazing or unrestored areas (outside enclosure and outside pastoral plantation) is due to overgrazing, which causes a very large

Dunkerle, 1999; Violle *et al.*, 2006). It is possible that the effect of the litter depends on its quantity and on the rains entering the system (Xiong and Nilsson, 1999). Also, the abundance of bare silty crust in restored areas is favored by the absence of trampling of the animals. In addition to the water stresses they generate, such as the evaporation of rainwater, these surfaces constitute a physical obstacle which prevents seed penetration into the soil and prevents germination of

Table 2. Values of vegetation cover (%), perennials and annuals species cover (%) inside and outside of each restoration techniques and their significance

Vegetation cover variables	Enclosure		Pvalue	Pastoral plantation		Pvalue
	In. Encl.	Out. Encl.		In. Past.plant.	Out. Past.plant.	
Total plant cover (%)	72±3.86	35.02±2.07	***	74.85±1.66	34.5±0.88	***
Perennial species cover (%)	36.35±3.06	24.7±4.55	***	40.3±4.72	21.2±6.8	***
Annual species cover (%)	35.65±4.01	10.5±4.15	***	34.55±4.75	13.65±6.96	***

*= p<0.05, **= p<0.01, ***= p< 0.001 according to the *T-test*.
Note: In. Encl., Inside Enclosure ; Out. Encl. Outside Enclosure ; In. Past.plant., Inside Pastoral plantation ; Out. Past.plant., Outside Pastoral plantation.

Table 3. Values of soil surface elements cover (%), inside and outside of each restoration techniques and their significance

Soil surface elements cover	Enclosure		Pvalue	Pastoral plantation		Pvalue
	In. Encl.	Out. Encl.		In. Past.plant.	Out. Past.plant.	
Bare ground (%)	3.25±0.79	17.95±2.16	***	4.1±1.15	11.25±1.62	***
Litter (%)	11.4±1.98	3.8±1.65	***	11.7±1.28	3.65±1.41	***
Stones (%)	3.95±1.53	30.75±1.75	***	1.65±0.68	28.25±2.96	***
Wind veil (%)	3.3±1.39	9.55±1.89	***	2.65±1.39	19.1±2.06	***
Crust (%)	6.1±0.9	2.75±1.65	***	5.05±1.96	2.9±1.28	***

*= p<0.05, **= p<0.01, ***= p< 0.001 according to the *T-test*.
Note: In. Encl., Inside Enclosure ; Out. Encl. Outside Enclosure ; In. Past.plant., Inside Pastoral plantation ; Out. Past.plant., Outside Pastoral plantation.

Table 4. Pastoral value inside and outside of each restoration techniques and their significance

Pastoral value	Enclosure		Pvalue	Pastoral plantation		Pvalue
	In. Encl.	Out. Encl.		In. Past.plant.	Out. Past.plant.	
Pastoral value	45.44±2.93	16.96±0.87	***	45.31±2.98	18.89±3.01	***

*= p<0.05, **= p<0.01, ***= p< 0.001 according to the *T-test*.
Note: In. Encl., Inside Enclosure ; Out. Encl. Outside Enclosure ; In. Past.plant., Inside Pastoral plantation ; Out. Past.plant., Outside Pastoral plantation.

regression of the vegetation cover, which leaves the soil surface horizons undergoing wind erosion (Enright *et al.*, 2005), which reflects a sharp deterioration that is manifested by the presence of sand and stones elements, because the wind veil is the result of strong wind erosion that immediately following the destruction of the vegetation cover and the upgrade bare ground (Yong-Zhong *et al.*, 2005; Tarhouni, 2008) and according to Gutterman (1986) overgrazing reduces the amount of sand trapped, also and according Eldridge (1998) the action of trampling may be important in rupturing the soil surface and breaking litter which aid their transport by the wind. In other hand, trampling reduces niches for water capture and seed germination, and compromises the ability of the surface to capture and store soil water. Unlike the three surface elements of the soil (bare soil, stones, wind veil) the litter cover is more abundant in restored areas, this is due to the stoppage of the grazing and protection which allows the increase of the quantity of litter entering the soil (Mikola *et al.*, 2001; Hai *et al.*, 2007). Several authors agree that the rate litter increases with the protection (restored areas) and guarding (Pei *et al.* 2004; Zhao *et al.*, 2005), and its presence in protected environments, may constitute "islands" of fertility where sediment and nutrients are trapped (Tongway *et al.*, 1989), which contributes to the increased of the floristic diversity of these environments. Indeed, studies have shown the positive effect of litter on soil moisture because litter generally provides protection against water evaporation (Geddes and

seedlings especially annual species (Tarhouni, 2008; Wallace and Wallace, 1986 a). We can say that the formation of the bare silty crust on the surface of the soil constitute a negative point for the good success of the restoration techniques like enclosure and pastoral plantation, hence many authors testify that a reasoned pasture in the in the rangelands with bare silty crust rates is beneficial (Amghar *et al.*, 2012), because trampling breaks down the crust formed on the surface, imbricates much more plant material in the soil and consequently improves its structure and porosity (Valentin, 1983; Savory and Parsons, 1980). Our results are consistent with those of several authors (Tarhouni, 2008; Amghar *et al.*, 2012, Khalid *et al.*, 2015; Salemkour *et al.*, 2016).

Pastoral value

As regard to the pastoral value, this index showed a significant difference between the restored and the unrestored (free grazing) areas (Tab.4). It was increased by more than 2 times in restored areas (inside enclosure and inside pastoral plantation) comparatively with the unrestored areas (outside enclosure and outside pastoral plantation). Le Houérou *et al.* (1983) reported in detailed study of five protected areas totalling 140000 ha in Libya, that, after five years of enclosure, the pastoral value of the vegetation had tripled with a spectacular regeneration of palatable species. It should be made clear that the considered areas had previously suffered a

strong degradation, but not extreme, the species sought had been reduced, but not eliminated. The low pastoral value in unrestored (free grazing) areas is due to the overgrazing, the effect of intense grazing is expressed by the appearance and the increased of the proportion of undesirable species and poisonous weeds (Chaieb and Boukhris, 1998 ; Abdallah *et al.*, 2012), which have a poor quality index, such as in our study *Atractylis flava*, *Atractylis serratuloides*, *Echinops spinosis*, *Noaea mucronata*, conversely, restored and protected areas are dominated by many species which have high quality index such as *Stipa parviflora*, *Schismus barbatus*, *Plantago albicans*, *Medicago lactiniata*, *Koelpinia liniaris*, *Astragalus cruciatus*, *Anacyclus cyrtolepidiodes*, *Artemisia herba alba*, *Argyrolobium uniflorum*. In grazed areas, pasture is generally selective, the palatable species are very threatened. Intense grazing (overgrazing) of rangelands often results in highly competitive palatable perennial species being replaced by less palatable species which are often considered less desirable or even worthless plants (Callaway and Tyler, 1999 ; Olf and Ritchie, 1998). In agreement with many other studies (Aronson and Le Floch, 1995; Amghar *et al.*, 2012; Salemkour *et al.*, 2013 and 2016), our results prove the rarefaction of good pastoral value species in the free grazed areas.

Conclusion

The research carried out in the framework of this study was motivated by a problem of management of the steppic rangelands, the objective of which was to evaluate the effect of two techniques of pastoral management, namely enclosure and pastoral plantation by *Atriplex canescens* on some vital attributes of the ecosystem compared to the free grazing rangelands located near the restored and protected courses. Indeed, field experience confirms that the improvements that have resulted from these techniques are numerous and diverse, including: Increased plant cover and litter, decreased on bare ground, stones and wind veil, improvement of pastoral quality. However, there is a disadvantage which could hamper objectives, good behavior and the success of these techniques (enclosure and pastoral plantation), this disadvantage is the bare silty crust, which increases with the long durations of closure and rest, namely that this crust has a negative effect on the installation of vegetation and the emergence of young plants, infiltration of water, hence the importance of retaining this parameter as an indicator for the opening of the fence.

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