GRAZING EXCLOSURE AND PLANTATION: A SYNCHRONIC STUDY OF TWO RESTORATION TECHNIQUES IMPROVING PLANT COMMUNITY AND SOIL PROPERTIES IN ARID DEGRADED STEPPES (ALGERIA)

F. Amghar[1,*], E. Forey[2], P. Margerie[2], E. Langlois[2], L. Brouri[3] & H. Kadi-Hanifi[1]

Résumé.— *Mises en défens et plantations : étude synchronique de deux techniques de restauration pour améliorer les communautés végétales et les propriétés du sol dans des steppes arides dégradées (Algérie)*.— Le processus de désertification menace depuis de nombreuses années les milieux steppiques arides du bassin méditerranéen. Afin d'arrêter ou atténuer les problèmes écologiques et économiques associés à cette désertification, des actions de gestion ont été mises en œuvre depuis les trois dernières décennies. Cette lutte est devenue pour certains pays une priorité nationale. En Algérie, plusieurs techniques de gestion visant à limiter le surpâturage ont été utilisées parmi lesquelles la plantation d'*Atriplex canescens* provenant d'Amérique centrale et la mise en défens de larges surfaces. Cette étude synchronique compare l'impact de ces deux pratiques de gestion après quatre ans de mise en œuvre sur la flore, la valeur fourragère et plusieurs paramètres édaphiques. Les 49 relevés phytoécologiques effectués montrent des modifications de la composition floristique, ainsi que des augmentations de la diversité, du recouvrement de végétation et de la valeur pastorale avec la protection des parcelles. L'ordination des résultats sur un plan factoriel permet de caractériser les trajectoires des différentes formations en fonction du mode de gestion qui leur est appliqué. Ces résultats mettent en évidence des groupements à richesse modérée et haute valeur pastorale dans les plantations, alors que les mises en défens conduisent à des formations à richesse élevée mais à valeur pastorale plus faible. Les paramètres édaphiques mesurés sont également affectés par la gestion : diminution de la fraction sableuse, des éléments grossiers, de la pellicule de glaçage, du sol nu et augmentation de la teneur en matière organique et azote total. Les conséquences de ces deux modes de gestion en termes de restauration et de réhabilitation écologiques sont discutées.

Summary.— Steppes of arid Mediterranean zones are deeply threatened by desertification. To stop or alleviate ecological and economic problems associated with this desertification, management actions have been implemented since the last three decades. The struggle against desertification has become a national priority in some of these countries. In Algeria, several management techniques have been used to cope with desertification. This study aims to investigate the effect of two management techniques on vegetation, soil properties and pastoral value after four years of implementation. The two techniques were grazing exclosure which was widely set up in degraded steppes and plantations (consisting in plantation and grazing exclosure) in deeply degraded ones. 49 phytoecological and soil samples have been studied. Results showed that plant diversity, composition, vegetation cover and pastoral value were significantly higher in protected areas. Management techniques also affected soil surface elements (percentage of sand, coarse soil elements, bare silty crust, and bare ground), organic matter and soil nitrogen content. We also demonstrated that important differences between both techniques remain: plantation technique on heavily degraded soil results in a higher pastoral value of plant communities whereas grazing exclosure technique on lesser degraded soil favours plant diversity.

[1] Laboratory of Ecology and Environment, FSB, USTHB, BP 32 El Alia Bab Ezzouar. Algiers, Algeria. E-mail: hykadihanifi@hotmail.com

[2] Laboratoire d'Écologie – EA 1293 ECODIV, FED SCALE, Bâtiment IRESE A, Place E. Blondel, UFR Sciences et Techniques, Université de Rouen. F-76821 Mont Saint Aignan Cedex, France. E-mails: estelle.forey@univ-rouen.fr; pierre.margerie@univ-rouen.fr; estelle.langlois@univ-rouen.fr

[3] High Commission for the Development of the Steppe, BP 1308 Djelfa. Algeria. E-mail: brourilakh@yahoo.fr

* Corresponding author. E-mail: amgharfateh@umbb.dz

Rev. Écol. (Terre Vie), vol. 67, 2012.

The main factors impacting the plant communities in semi-arid ecosystems are climatic conditions and anthropogenic activities (Verstraete, 1986; Reynolds & Stafford Smith, 2002). In Sahelian zone, the two successive waves of drought (1968-1987) have strongly affected North Africa, correlated with an important desertification of arid and semi-arid areas (IPCC, 2007). General consequences led from soil erosion to destruction of plant communities, with socio-economic issues on local populations (Mainguet, 1990).

In Algeria, the drought effect is combined with the impact of sheep grazing (Aidoud & Touffet, 1996; Slimani *et al*., 2010). The Algerian steppes, which extend over 20 million hectares, harbor a human population estimated at 7.2 million among which numerous shepherds. Steppes are grazed by 15 million sheep (data from the Algerian Ministry for Agriculture and Rural development, 2009). This 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). This underlines the difficulty to manage and combine the protection of forage and the economic development of an area. The scarcity and unpredictability of the resource (forage) is a major feature of these semi-arid systems (Olsson, 1993). The growing demographic pressure (Le Houérou, 1984), the development of mobile phones and motorization of stocks transport led to an increasing use efficiency of forage patches and thus faster overgrazing of these fragile systems.

The degradation of steppes led the government to set up measures to protect the fertility of threatened ecosystems. In November 1994, plans for preserving these ecosystems from desertification were drawn up. Among techniques implemented, revegetation to stabilize the sediment, planting of forage species and grazing exclosure have been extensively used in the Maghreb and Middle East (Amiraslani & Dragovich, 2011). The grazing exclosure technique is almost always an effective instrument for the regeneration of the steppe vegetation (Le Houérou, 1985). It has been widely applied in arid Australia, United States, dry tropical Africa and North Africa. In situations where degradation has not overcome the threshold of irreversibility (Holling, 1973; Wissel, 1984), spontaneous recovery of vegetation can be initiated by a prolonged period of grazing exclosure (Le Houérou, 1985). The plantation technique, regarded as a mean of struggle against desertification by Berthe (1997), has been adopted by several countries in North Africa, West Asia, America, the Middle East and Australia, especially in the case of very advanced degradation (Mulas & Mulas, 2004).

In Algeria, these techniques have been employed over large areas since 1994, managed by the High Commission for the Development of the Steppe (HCDS). However, few exploratory studies taking into account Algerian specificities were early undertaken to assess techniques effectiveness and their impact on medium- and long-term trajectories of natural plant communities, biological and pastoral values. This synchronic study aimed at characterizing the effects of two restoration techniques in Algerian steppes: grazing exclosure and forage plantation of *Atriplex canescens* on (1) floristic diversity, (2) pastoral value and (3) soil properties and thus to provide evaluation tools of these two different techniques for restoration of the steppes, in accordance with the following lecture grid: in degraded ecosystems, three alternative options can be defined according to the degradation level (Aronson *et al.,* 1993). The first one is the restoration option which aims at the complete return of the site to a pre-existing state: same species, same ecological functions. The second one is the rehabilitation option. The objective is to repair damaged or blocked ecosystems functions. In this case, the goal is to raise quickly a productive ecosystem even if the biotic composition is different. In the last option, damage is too important to plan a restoration or rehabilitation option. Only reallocation, corresponding to new uses of site, can be set up.

MATERIAL AND METHODS

STUDY AREA

The study was conducted in two sites of Laghouat department: the 3400 ha grazing exclosure of Sahou Lahmer (34° 16' - 34° 14' N and 1° 58' - 1° 57' E), located 5 km south of the town of Gueltet Sidi Saad, and the 220 ha plantation of Djenaiane (34° 25' - 34° 24' N and 1° 50' - 1° 51' E), 20 km north of the town. Both restoration techniques were set up in September 2004. The choice of the restoration technique depended on the steppe degradation level: grazing exclosure was applied to degraded soil and plantation to very advanced degradation (Fig. 1). Differences at the station scale between the degradation states of both stations were due to grazing pressure, whereas initial plant communities and pedoclimatic situations were similar with respect to the whole Algerian steppe (Amghar, 2002).

These two stations are situated within the steppe area of North Africa (Quézel, 1978). Sahou Lahmer and Djenaiane have an average altitude of 1170 and 1142 m, respectively. They are characterized by an arid bio-climate. The two stations meet a yearly dry period of six months from April to September. The average annual rainfall for the period 1950-2007 is 256.8 mm (239.9 mm for the period 2004-2007). Maximum and minimum monthly mean temperatures for the period 1992-2007 are 35.3 °C and 0.6 °C respectively. Rainfall and temperatures data are extrapolated from those of Laghouat meteorological station, situated 50 km SE from study sites and at 765 m a.s.l. The main soils in the study area belong to the broad group of calcareous-magnesian storage xeric limestones (Djebaïli, 1982). These soils are colonized by vegetation dominated by *Stipa tenacissima*, *Lygeum spartium*, *Artemisia herba alba* (Pouget, 1980; Le Houérou, 1992; Amghar, 2002) and belong to the phytosociological class *Lygeo – Stipetea* (Kaabèche, 1990).

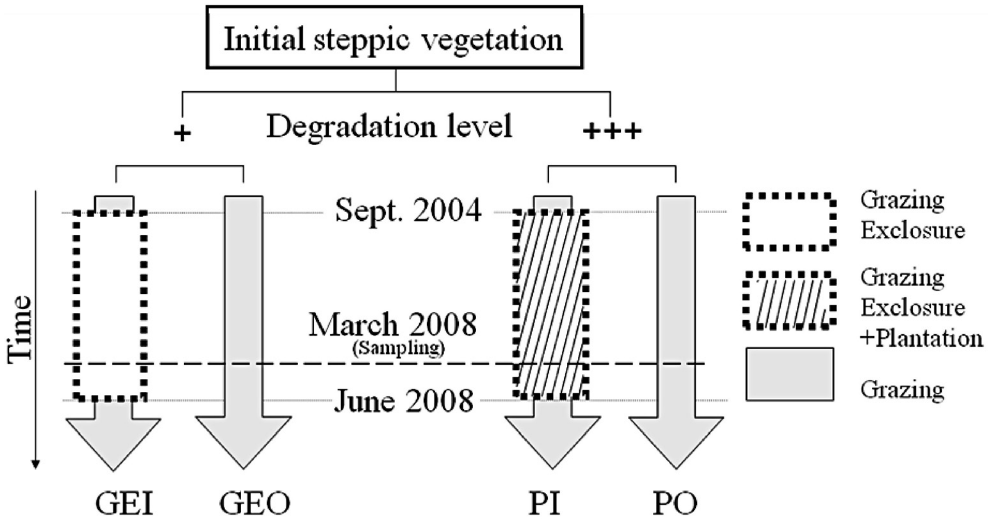

Figure 1.— Chronogram of the restoration practices in two Algerian steppes. GEI = Grazing exclosure In; GEO = Grazing exclosure Out; PI = Plantation In; PO = Plantation Out.

Description of the two restoration techniques

The state of degradation reached by the Algerian steppe following inappropriate practices (overgrazing, clearing, fire, ploughing, etc.), has led the High Commission for the Development of the Steppe (HCDS: national agency in charge of land protection and integrated development of farming) to balance between long-term grazing exclosure and planting of forage species (Fig. 1). Sahou Lahmer grazing exclosure was set aside in September 2004 to June 2008. Grazing exclosure of livestock concerns so large surfaces that, better than physical grazing exclosure, HCDS opted for a consensus setting of those parcels with nomad shepherds, which are strongly socially structured. Boundary stones were set up around the area. A continuous survey of the area by a salaried local was thought to warrant the factual grazing exclosure which was achieved as neither sheep dungs nor grazing scars on plants were observed during grazing exclosure period. The integration of bottom-up information in the management decision by HCDS is thus important to insure the respect of grazing interdiction (S. Kelil, pers. communication).

Depending on climate, on soil and on the degree of degradation of the area, several species of *Atriplex* were tested for introduction in Algeria. *Atriplex canescens*, native from North America, was chosen and massively planted since 1994 due to its drought and cold winter temperature resistances in Algerian steppe, and its ability to bridge the food deficit of livestock during winter (Shoop *et al*., 1985). Our study was conducted in a plantation of *Atriplex canescens*, species covering over 76 % of the 326 489 ha planted by the HCDS. In September 2004, seedlings of *Atriplex canescens* were transplanted every 2.5 m within rows, with 4 m between rows; grazing was prohibited from then to May 2008. The seedlings were watered by 10 litres per individual per month during the first year of planting to maximize chance of survival. Since 2008, both areas have successfully been proposed to lease to shepherds.

Sampling

The comparative goals of the study led us to opt for a comparative protocol of restoration techniques (plantation *vs.* grazing exclosure) and non restored surrounding respective areas (i.e. control areas) in March 2008. We thus compared

Inside Grazing Exclosure (thereafter GEI) *vs.* Outside Grazing Exclosure (GEO), and Inside Plantation (PI) *vs.* Outside Plantation (PO, Fig. 2), GEO and PO being considered as control zone.

Vegetation Species-area curve method (Braun Blanquet & De Bolos, 1957) allowed to identify a minimum area of 64 m^2. A total of 49 plots of 64 m^2 were sampled along two lines, each 2300 m long, for both restoration techniques, with a distance of 94 m between each plot, thus resulting in an unbalanced design. The 49 plots were scattered as follows:

— Twenty four plots in and out of the grazing exclosure of Sahou Lahmer: eighteen plots in the grazing exclosure (GEI) and six outside (GEO).

— Twenty five plots in and out of the Djenaiane plantation: seventeen plots in the plantation (PI) and eight outside (PO).

In each plot an inventory of plant taxa was compiled during the month of March 2008, the nomenclature follows Quezel (1978). For each taxon we implemented the abundance dominance index (A/D index) of Braun-Blanquet & De Bolos (1957). The A/D index was converted in Specific Contribution index following Tomaseli formula (Long, 1954). Vegetation cover was described with pin-point technique, i.e. the identification of first element (vegetation or soil) met by a pin descending to the ground on 100 points separated by 10 cm along a 10 m long line within the 64 m^2 plot.

Soil sampling and analysis

Description of the soil surface (with the following typology: litter, bare silty crust, sand, bare ground, coarse) and that of vegetation cover were carried out by the same pin-point sampling technique used by Jauffret & Visser (2003). The frequency of plant species and abiotic elements at the 100 points is used to estimate the frequency that can be treated as a percentage of surface cover (Godron, 1968). In order to identify possible changes in the soil environment, in each of the 49 plots a sample of soil, from the surface horizon (typically five upper centimeters unless a shallow calcareous crust was met), was 2 mm sieved and air-dried before chemical analyses. The chemical parameters were pH, total and active calcium carbonate, organic matter and total nitrogen. pH was determined using a 1:5 soil water suspension. Total calcium carbonate was determined by back-titration and active calcium carbonate using the Bernard calcimetry method (carbonate content by volumetric method following ISO 10693). Organic matter (OM) was determined using the Anne method (organic carbon by sulfochromic oxydation following ISO 14235) and total nitrogen was determined using the Kjeldahl method (Bremmer, 1996). We used C/N ratio as a proxy for soil organic matter mineralisation status in each plot.

Data analysis

The dimensionality of data matrix crossing the 49 plots and the 84 identified species after removal of rare species (less than 3 records) was reduced by correspondence analysis (CA) (Hill, 1973) using the software R version 2.11.1 (package ADE4) (Thioulouse *et al.*, 1997). Data were Braun-Blanquet abundance-dominances, each class replaced by its mean value (i.e. class 3 from 25 to 50 % was taken as 37.5 %). To take in account the diversity of vegetation, the species richness R (Whittaker, 1972), Shannon index H' (Shannon & Weaver, 1949) and evenness E (Pielou, 1966), (package Vegan) were computed for each plot. The pastoral value (Pv) of each plot was obtained by weighting the specific contribution of each species extracted from pin-point data (Csi) by its specific quality index (Isi), the plot global vegetation cover (GVC) and by a factor of 0.1. The pastoral value (Pv) is expressed by the following formula (adapted from Daget & Poissonet, 1990).

$$Pv = GVC \times 0.1 \sum_{i=1}^{R} \left(CS_i \times IS_i \right)$$

The specific quality index (Isi) used was proposed by the CRBT (1978). Isi of all species is reported in Appendix. The mean of R, H, E, Pv, the condition of the soil surface and chemical descriptors of the surface horizon were measured for each of the 49 plots. The differences between the indices computed, the measured surface elements and chemical descriptors determined between the two restoration techniques and their surroundings were tested by the nonparametric Kruskal-Wallis test due to unbalanced model. Post hoc comparisons between different treatments were made using the Wilcoxon rank sum test. Both tests were conducted using R version 2.11.1 software (R Development Core Team, 2007).

RESULTS

Ordination of species assemblage (CA)

We recorded a total of 153 plant species in the 49 sampling plots of the study area. After eliminating the rare species occurring in fewer than 5 % of plots (i.e. 1 or 2 plots), 84 plant species remained. The projections of plots of each treatment (GEI, PI, GEO or PO) were relatively clumped in the factorial plan (Fig. 2) as shown by the 4 ellipses. The first three factorial axes of the correspondence analysis explained 24.34 % of the inertia, with A1 = 12.46 %, A2 = 6.88 % and A3 = 5 %. The first ordination axis (Fig. 2) separated plots with plantations from plots with grazing exclosure. This axis can be interpreted as reflecting the restoration type whose choice (plantation or grazing exclosure) depended on the initial state of degradation (Fig. 1). The second axis reflected the restoration impact (In *vs*. Out) with GEO and PO in the negative part of A2 and GEI and PI in the positive part of A2. The negative part of the axis 2 was characterized by non-therophytic species related to overgrazing as *Peganum harmala*, *Moraea sisyrinchium* and O*nopordum acaulon* (Le Houérou, 1985) and species with low pastoral index such as *Atractylis serratuloide*s, *Bassia muricata*, *Bombycilaena discolor*, *Echium humile* subsp., *Pycnanthum* sp., *Filago pyramidata*, *Paronychia arabica* and *Thymelaea microphylla* (Fig. 3B and Appendix). Conversely, the positive part of axis 2 showed presence of species with high pastoral index (> 3) as *Artemisia herba alba, Ctenopsis pectinella, Rostraria litorea, Sixalix arenaria* and *Onopordum arenarium* (Fig. 3B and Appendix).

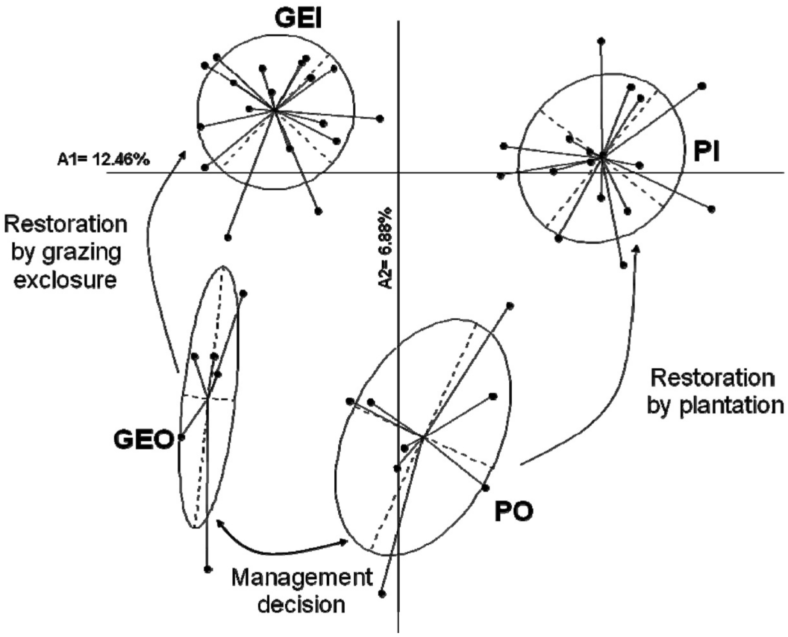

Figure 2.— Projection of plots on the Correspondence Analysis (CA) factorial map 1-2. The four ellipses represent the different treatments with the abbreviated letter (PI= Plantation In, PO= Plantation Out, GEI= Grazing exclosure In, GEO= Grazing exclosure Out). Arrows are the dynamic trajectories in the factorial map.

Floristic characteristics

Floristic richness (Tab. I) was found to be highest in GEI, intermediate in PI and lowest in PO and GEO ($\chi 2 = 36.75$, $p < 0.0001$). Restoration impact significantly increased twofold the plots richness from RGEO = 11 to RGEI = 23.28 species and from RPO = 8.63 to RPI = 23.28 species. This restoration effect also increased percentage of therophytic and non-therophytic species and increased threefold plant cover in “In” plots vs. “Out” plots (see Tab. I for statistical values). This low plant cover resulted in a lowest amount of litter on the soil surface in PO and GEO ($\chi 2 = 23.11$, $p < 0.0001$).

Among the two diversity indices calculated, only the Shannon diversity index (H’) showed a difference linked to restoration effect with highest H’ in “In” plots (H’GEI = 1.56, H’PI = 1.3) than in “Out” plots (H’FO = 0.99, H’PO = 0.69). Maximum H’ was recorded in GEI suggesting that this community was more diverse ($\chi 2 = 21.09$, p <0.001). Evenness index was globally low in the 4 treatments. This index was similar in GEI, GEO and PI (average evenness = 0.32) but significantly higher than in PO (Evenness = 0.22) suggesting highest single-species dominance in PO. As regard to the Pastoral Value, this index was significantly higher in PI, intermediate in GEI and lowest in PO and GEO ($\chi 2 = 42.52$, $p < 0.0001$).

TABLE I

Effect of management options on floristic and soil characteristics

Means ± SE are given. The differences between the treatments were tested by nonparametric Kruskal-Wallis test (X^2 and p-value). Asterisks indicate significance of tests (= p < 0.05, ** = p < 0.01, *** = p < 0.001, ns: non significant). Different letters indicate differences between the four treatments (Wilcoxon test, p <0.05). For more details on variables, refer on material and methods section*

	Grazing Exclossure (GE)		Management effect		Plantation (P)		Management effect		OVERALL EFFECT	
	GE In (GEI)	GE Out (GEO)	X^2	*p*	Plantation in (PI)	Plantation Out (IPO)	X^2	*p*	X^2	*p*
Floristic richness and vegetation structure										
Floristic richness (R)	23.28 ± 0.90 a	11 ± 0.97 c	13.05	***	15.94 ± 0.93 b	8.63 ± 0.35 c	15.8	***	36.75	***
Therophyte	12.39 ± 0.67 a	4 ± 0.58 bc	13.07	***	6.76 ± 0.76 b	2.88 ± 0.51 c	7.92	**	33.34	***
Other plante life forms	10.89 ± 0.59 a	7 ± 0.68 bc	9.11	**	9.18 ± 0.7 ab	5.75 ± 0.48 c	8.76	**	21.04	***
Diversity index										
Shannon index (H')	1.56 ± 0.07 a	0.99 ± 0.10 bc	9.4	**	1.3 ± 0.11 ab	0.69 ± 0.13 c	8.83	**	21.09	***
Evenness (E)	0.34 ± 0.01 a	0.29 ± 0.03 ab	3.48	ns	0.32 ± 0.02 ab	0.22 ± 0.04 b	3.47	ns	8.63	ns
Pastoral value										
Pastoral Value (PV)	21.97 ± 1.70 b	5.97 ± 1.19 c	12.97	***	40.43 ± 0.94 a	6.89 ± 1.15 c	15.69	***	42.52	***
Soil surface elements (%)										
Plant cover	64.56 ± 2.64 a	24.83 ± 2.76 b	12.97	***	72.76 ± 1.122 a	21.5 ± 2.05 b	15.74	***	32.11	***
Litter	8.67 ± 0.62 a	3.67 ± 0.49 b	10.14	**	9.41 ± 0.57 a	4.13 ± 0.44 b	15.44	***	26.11	***
Bare silty crust	10.11 ± 1.22 a	2.83 ± 0.54 c	9.98	**	4.53 ± 0.66 b	1.5 ± 0.59 c	8.69	**	27.42	***
Sans	5.89 ±0.87 b	12.83 ± 1.07 a	10.12	**	8.12 ± 0.82 ab	11.38 ± 1.4 a	3.19	ns	16.24	***
Bare ground	4.78 ± 0.77 b	47.17 ± 3.12 a	13.03	***	4.29 ± 0.70 b	56.63 ± 1.91 a	18.82	***	30.1	***
coarse elements	6 ±1.36 a	8.67 ± 0.99 a	2.27	ns	0.88 ± 0.28 b	4.88 ± 0.93 a	13.09	***	22.96	***
Soil chemical analysis										
pH	8.20 ± 0.06 a	8.53 ± 0.29 a	0.16	ns	8.41 ± 0.08 a	8.36 ± 0.19 a	0.58	ns	4.76	ns
Active lime	5.84 ± 0.91 a	5.84 ± 2.41 a	0.04	ns	3.6 ± 0.8 a	4.93 ± 1.56 a	0.34	ns	3.48	ns
Total lime	11.4 ± 2.13 a	9.1 ± 2.59 a	0.05	ns	6.34 ± 0.88 a	9.88 ± 2.4 a	1.16	ns	3.52	ns
% OM	6.95 ± 0.38 a	5.36 ± 0.74 ab	2.29	ns	4.24 ± 0.16 b	3.99 ± 0.40 b	0.01	ns	25.49	***
% N	0.65 ± 0.06 a	0.4 ± 0.04 a	6.57	ns	0.64 ± 0.06 a	0.43 ± 0.06 a	3.89	*	9.73	ns
C/N	6.67 ± 0.49 a	7.73 ± 0.71 a	1.44	ns	4.59 ± 0.47 a	5.90 ± 0.72 a	3.06	n*s	11.31	ns

Soil characteristics

Soil surface elements showed strong differences between the 4 treatments and also between both restoration techniques (Table I). Bare ground surface was significantly tenfold higher ($\chi 2 = 30.1$, $p < 0.0001$) in Out plots (PO and GEO) than in PI and GEI. Similarly, the amount of bare crust (Tab. I) was threefold lower in GEO and PO comparatively to GEI and PI ($\chi 2 = 9.89$, $p < 0.0017$ for grazing exclosure and $\chi 2 = 8.69$, $p < 0.0032$ for plantation). Sand cover and coarse soil also showed significant differences between the 4 treatments (Tab. I).

According to soil chemical characteristics (Tab. I), no differences were recorded between the four treatments except for Organic Matter content. OM was found to be significantly highest in GEI, intermediate in GEO and lowest in plantations ($\chi 2 = 25.49$, $p < 0.0002$). Lastly, PO had a lower nitrogen content in soil than PI ($\chi 2 = 3.89$, $p < 0.046$).

DISCUSSION

Restoration effects

Both restoration techniques have important effects on plant community, pastoral value and soil properties.

This study demonstrates that plantation and grazing exclosure lead to an increase of plant cover, plant diversity and pastoral values only 4 years after implementation of these two restoration techniques. The observed increase of the total plant cover inside the protected areas is in agreement with other studies in such semi-arid ecosystems (Belsky, 1992; Brown & Al Mazroœi, 2003; Jeddi & Chaieb, 2010). Indirect effects might also explain this positive effect on plant cover. Su *et al.* (2005) noted that due to frequent trampling by sheep and cattle, the ground surface becomes bare and exposed to wind erosion. This results in soil coarsening and loss of soil fertility, which in turn has negative effect on vegetation (Yates *et al.,* 2000; Su *et al.,* 2005). In addition, trampling associated with overgrazing leads to soil compaction, preventing water infiltration and therefore seed germination, thus undergoing lower vegetation cover (Schlesinger *et al.,* 1990; Fleischner, 1994; Van de Koppel & Rietkerk, 2000). Lastly, the increase of plant biomass caused by cessation of grazing might enhance the amount of litter entering the soil system (Mikola *et al.,* 2001; Hai *et al.,* 2007), and improve N content in soil and plant biomass. In our study, both diversity indices tested (Shannon and Evenness) exhibit greater values in protected areas (grazing exclosure and planting) and might be the result of subtracting livestock from these areas (Vickery *et al.,* 2001). Shaltout *et al.* (1996), Eweg *et al.* (1998) and Jeddi & Chaieb (2010) report comparable findings in similar environments. Grazing exclosure allows plants to complete their phenological cycles and produce seeds, thereby increasing their stocks in the soil. In contrast, in non-protected areas, species with high specific quality index are grazed at different phenological stages, resulting in the reduction of the seeds in the soil. Non protected areas are dominated by non therophytic species (mostly chamaephytes) resistant to aridness (Floret *et al.,* 1990; Orshan *et al.,* 1984) and grazing (Kadi-Hanifi, 1998) such as *Atractylis caespitosa*, *Atractylis carduus*, *Atractylis serratuloides*, *Filago pyramidata*, *Herniaria fontanesii*, *Moraea sisyrinchium, Peganum harmala*, *Thymelaea microphylla* and *Thymelaea virgata* which are rejected by livestock due to their low quality index. Conversely, protected areas are dominated by many therophytes species such as *Anacyclus monanthos* subsp. *cyrtolepidioides*, *Astragalus corrugatus*, *Astragalus sinaicus*, *Erodium glaucophyllum*, *Erodium crassifolium*, *Medicago littoralis*, *Trigonella polycerata* and *Xeranthemum inapertum*.

Plantation and grazing exclosure also impact soil physical properties and in a lesser extent chemical soil characteristics. Non protected areas (GEO and PO) are characterized by a large proportion of bare soil (52 % of the total soil surface) comparatively to protected ones (7 %), as observed by Schlecht *et al* (2009). The increase of soil organic matter and nutrient content which accompanies grazing exclosure might be a result of an increase in the amount of plant litter on the one hand and a decrease in soil compaction on the other hand (Xie & Wittig, 2004).

Contrasting effects of restoration techniques

We demonstrate that the two restoration techniques improve significantly plant cover, species diversity, pastoral value and soil nutrient content after only 4 years of restoration implementation. Nevertheless, differences between both techniques remain: plantation technique on heavily degraded soil results in a higher pastoral value of plant communities (Fig. 3B) whereas grazing exclosure technique on lesser degraded soil favours plant diversity (Fig. 3A).

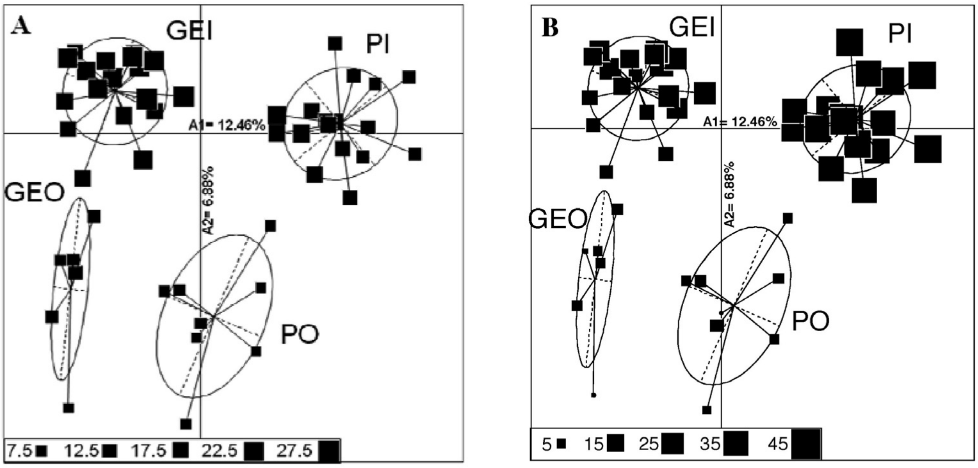

Figure 3.— Projection of plots on the Correspondence Analysis (CA) factorial map 1-2 with (A) plant richness and (B) Pastoral Value. PI= Plantation In, PO= Plantation Out, GEI= Grazing exclosure In, GEO= Grazing exclosure Out. The surface of the square of the 49 plots is proportional to diversity and Pastoral Values.

Positive effect of restoration on floristic richness is more pronounced for grazing exclosure technique and might be related to the initial state of the steppe degradation. In degraded steppes (GEI and GEO), shrub species are still present conversely to heavy degraded steppes (PI and PO). Although this study does not put in relation the specific richness of the study sites with the location of shrubs, it is now recognized that shrub species, in such stressful environment, might act as nurse species. They might increase growth, survival or reproduction of understory seedlings by improving the microclimate beneath their canopies and protecting other plants/seedlings against direct irradiance and over-heating (Franco-Piñaza *et al.,* 1996). This interaction is called facilitation. The canopy can also enhance water availability, soil nutrient content (Chambers, 2001) and may also protect against herbivores (grazing and trampling) (Rebollo *et al.,* 2002; Flores & Jurado, 2003). *Stipa tenacissima*, which is present in GEI and GEO (i.e. not too heavily degraded areas), may be one of the most studied and documented nurse species in scientific literature on facilitation mechanisms. Many authors have demonstrated that *S. tenacissima* tussocks constitute ‘islands’ of soil fertility and soil water supply (e.g. Cerdà, 1997; García-Fayos & Gasque, 2002; Maestre & Cortina, 2002; Gasque & García-Fayos, 2004; Aidoud *et al.,* 2006) with positive effects on other plant biomass and community diversity. Such positive interactions have been proposed as a tool to improve restoration success in degraded arid and semi-arid ecosystems (Padilla & Pugnaire, 2006) as well as in Mediterranean mountains (Castro *et al.,* 2002). According to Pueyo *et al.* (2009), restoration of semi-arid grasslands with a stable degradation state can be achieved by using either direct abiotic amelioration (ploughing and damming) or facilitation by nurse-plants. The latter method is preferred because it retains the fertility islands and is more economic and less intrusive than the former.

Plantation of *Atriplex canescens* leads to high pastoral value of plant communities due to the dominance of *Atriplex canescens,* an excellent forage species. On this plantation, we notice a dominance of non-therophytic species probably due to competition between *Atriplex canescens* and ephemerals (pers. observation). The physiology of *Atriplex canescens* has been extensively studied, e.g. respiratory system, chemical composition (Garza & Fulbright, 1988), genetics (Sanderson & Stutz, 1994), and response to defoliation (Benjamin *et al.,* 1995). Results show that this exotic species might strongly modify the habitat; however studies on the long-term effect of the species should be performed in order to not promote future potential invasive species.

RESTORATION OBJECTIVES AND CONCLUSION

In this study, the technique used by the HCDS to ensure grazing exclusion is original, efficient and relatively inexpensive. Boundary stones are set up around the area and a local salaried ensure a continuous survey of the area. There is no fencing for grazing exclosure. The respect and success of those plots are the result of two information processes. First, a bottom up approach from local population to administration (HCDS), allows choosing the most appropriate plots, depending on local socio-cultural context and ecological knowledge. Secondly, a top down approach informs the local population mainly through laws and keepers (local salaried employee). 1 to 4 keepers per plot unity ensure plot monitoring. These keepers are members of local tribes. After 4 years of area protection, the HCDS rent out these plots to shepherds. Cost of hiring is 1000 Da/ha for grazing exclosures and 2000 Da/ha for plantations, both for 2 months with a constraint of two livestock units per hectare. The local population acclaims these non-grazed plots rented by the HCDS. Some areas are not grazed any more since they provide important ecosystem services: road and house protection, fight against desertification, etc. This is the case of the *Atriplex canescens* plantation in Ain maabed (Djelfa region) never grazed since 2001. However, the recovery success of the grazing areas strongly depends on the climate variability. In the very dry years, the lack of forage leads shepherds to not respect these areas. Additionally, the demand for renting is lower than supply. Failures to respect these areas are guilty of immediate seizure of the livestock, legal proceedings and heavy fines.

In the present study, the two management techniques illustrate two of the three alternative management options of degraded steppes (restoration, rehabilitation, reallocation). The restoration corresponds to grazing exclosure, and led to an increase of the floristic richness, diversity and plant cover (Fig. 3). The second one (rehabilitation) corresponds to plantation of *Atriplex canescens*, an edible and good forage species that allows for an increase of community pastoral values (Fig. 3). In these two cases, the results obtained demonstrate that the ecosystem degradation is reversible. In a short period (4 years), without any heavy management action, the grazing exclosure allows to restore ecosystemic functions (biodiversity) whereas plantation restores economic function (quality and quantity of forage).

ACKNOWLEDGMENTS

We wish to thank the High Commission for Development of the Steppe for the human and material resources provided for this study.

REFERENCES

Aidoud, A., Le Floc'h, E. & Le Houérou, H.N. (2006).— Les steppes arides du nord de l'Afrique. *Sécheresse,* 17: 19-30.

Aidoud, A. & Touffet, J. (1996).— La régression de l'alfa (*Stipa tenacissima* L.), graminée pérenne, un indicateur de désertification des steppes algériennes. *Sécheresse*, 3: 187-193.

Amghar, F. (2002).— *Contribution à l'étude de la biodiversité de quelques formations de dégradation en Algérie*. Master 2 thesis, Univ. Sci. Technol. H. Boumediene.

Amiraslani, F. & Dragovich, D. (2011).— Combating desertification in Iran over the last 50 years: an overview of changing approaches. *J. Envir. Manag*., 92: 1-13.

ARONSON, J., FLORET, C., LE FLOC'H, E., OVALLE, C. & PONTANIER, R. (1993).— Restoration and rehabilitation of degraded ecosystems in arid and semi-arid lands. II: Case studies in southern Tunisia, central Chile and northern Cameroon. *Restor. Ecol*., 1: 168-187.

BELSKY, J.A. (1992).— Effects of grazing, competition, disturbance and fire on species composition and diversity in grassland communities. *J. Veg. Sci*., 3: 187-200.

BENJAMIN, R.W., LAVIE, Y., FORTI, M., BARKAI, D., YONATAN, R. & HEFETZ, Y. (1995).— Annual regrowth and edible biomass of 2 species of Atriplex and of *Cassia sturtii* after browsing. *J. Arid Environ*., 29: 63-84.

BERTHE, Y. (1997).— The role of forestry in combating desertification. *Proc. XI World Forestry Congr.*, Antalya, Turkey: 307-326.

BRAUN-BLANQUET, J. & DE BOLOS, O. (1957).— Les groupements végétaux du bassin moyen de l'Ebre et leur dynamisme. *Anales Estacion Exper. Aula Dei,* 5: 1-226.

BREMNER, J.M. (1996).— Nitrogen – Total. Pp 1085-1121 *in*: D.L. Sparks *et al.* (eds). *Methods of soil analysis, Part. 3. Chemical methods*. SSSA Book Set. 5, Soil Science Society of America, Madison, WI.

BROWN, G. & AL-MAZROŒI, S. (2003).— Rapid vegetation regeneration in a seriously degraded *Rhanterium epapposum* community in northern Kuwait after 4 years of protection. *J. Envir. Manage*., 68: 387-395.

C.R.B.T. (1978).— *Rapport phytoécologique et pastoral sur les hautes plaines steppiques de la wilaya de Saida*. CRBT (Ed.), Alger.

CASTRO, J., ZAMORA, R., HODAR, J.A. & GOMEZ, J.M. (2002).— Use of shrubs as nurse plants: A new technique for reforestation in Mediterranean mountains. *Restor. Ecol*., 10: 297-305.

CERDA, A. (1997).— The effect of patchy distribution of *Stipa tenacissima* L on runoff and erosion. *J. Arid Environ*., 36: 37-51.

CHAMBERS, J.C. (2001).— *Pinus monophylla* establishment in an expanding *Pinus*-*Juniperus* woodland: Environmental conditions, facilitation and interacting factors. *J. Veg. Sci*., 12: 27-40.

DAGET, P. (1977).— Le bioclimat méditerranéen : Caractères généraux, mode de caractérisation. *Vegetatio,* 34.

DAGET, P. & POISSONET, J. (1971).— Une méthode d'analyse phytoécologique des prairies. *Ann. Agron.,* 22: 5-41.

DJEBAÏLI, S. (1982).— Diagnose phytosociologique de la végétation naturelle des hautes plaines et de l'atlas saharien Algériens. *Biocénoses,* 2: 5-20.

ELLENBERG I. & MUELLER-DOMBOIS D. (1967).— A key to raunkiaer plant life forms with revised subdivisions*. Ber. Geobot. Inst. ETH, Stiftg. Rübel, Zürich*, 37: 56-73.

EWEG, H.P.A., VAN LAMMEREN, R., DEURLOO, H. & WOLDU, Z. (1998).— Analysing degradation and rehabilitation for sustainable land management in the highlands of Ethiopia. *Land Degrad. Dev.,* 9: 529-542.

FLEISCHNER, T.L. (1994).— Ecological costs of livestock grazing in western North-America. *Conserv. Biol.,* 8: 629-644.

FLORES, J. & JURADO, E. (2003).— Are nurse-protégé interactions more common among plants from arid environments? *J. Veg. Sci*., 14: 911-916.

FLORET, C., GALAN, M.J., LE FLOCH, E., ORSHAN, G. & ROMANE, F. (1990).— Growth forms and phenomorphology traits along an environmental gradient - Tools for studying vegetation. *J. Veg. Sci*., 1: 71-80.

FRANCO-PINAZA, J.G., FULBRIGHT, T.E., GARDINER, D.T. & TIPTON, A.R. (1996).— Shrub emergence and seedling growth in microenvironments created by *Prosopis glandulosa*. *J. Veg. Sci*., 7: 257-264.

GARCIA-FAYOS, P. & GASQUE, M. (2002).— Consequences of a severe drought on spatial patterns of woody plants in a two-phase mosaic steppe of *Stipa tenacissima* L. *J. Arid Environ*., 52: 199-208.

GARZA, A. & FULBRIGHT, T.E. (1988).— Comparative chemical-composition of armed saltbush and fourwing saltbush. *J. Range Manage*., 41: 401-403.

GASQUE, M. & GARCIA-FAYOS, P. (2004).— Interaction between *Stipa tenacissima* and *Pinus halepensis*: consequences for reforestation and the dynamics of grass steppes in semi-arid Mediterranean areas. *Forest Ecol. Manag*., 189: 251-261.

GODRON, M. (1968).— Quelques applications de la notion de fréquence en écologie végétale. *Oecol. Plant.,* 3: 185-212.

HAI, R., WEIBING, D., JUN, W., YU ZUOYUE, Y. & QINFENG, G. (2007).— Natural restoration of degraded rangeland ecosystem in Heshan hilly land. *Acta Ecol. Sinica,* 27: 3593-3600.

HILL, M.O. (1973).— Reciprocal averaging: an eigenvector method of ordination. *J. Ecol*., 237- 249.

HOLLING, C.S. (1973).— Resilience and stability of ecological systems. *Annu. Rev. Ecol. Evol. Syst.,* 41: 1-23.

IPCC (2007).— *Climate Change 2007: the Physical Science Basis.* Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge.

JAUFFRET, S. & VISSER, M. (2003).— Assigning life-history traits to plant species to better qualify and land degradation in Presaharian Tunisia. *J. Arid Environ*., 55: 1-28.

JEDDI, K. & CHAIEB, M. (2010).— Changes in soil properties and vegetation following livestock grazing exclusion in degraded arid environments of South Tunisia. *Flora,* 205: 184.

KAABÈCHE, M. (1990).— *Les groupements végétaux de la région de Bou-Saada (Algérie): contribution à la synsystématique des groupements steppiques du Maghreb*. Thèse de doctorat es Sciences Université de Paris Sud – Centre d'Orsay – France. 2 vol.

KADI-HANIFI, H. (1998).— *L'alfa en Algérie: Syntaxonomie, relation: milieu-végétation, dynamique et perspectives d'avenirs*. PhD Thesis, University Science Technology, Boumerdes, Algeria.

KASSAS, M. (1995).— Desertification: a general review. *J. Arid Environ*., 30: 115-128.

LE HOUÉROU, H.N. (1984).— Forage and fuel plants in the arid zone of north Africa, the near and middle east. Pp. 117-141 *in*: G.E. Wikens, J.R. Goodin & D.V. Field (eds.). *Plants for arid lands.* Mackays, London.

LE HOUÉROU, H.N. (1985).— *La régénération des steppes algériennes*. Rapport de mission de consultation et d'évaluation.

LE HOUÉROU, H.N. (1992).— An overview of vegetation and land degradation in world arid lands. Pp 127-163 *in*: H.E. Dregne (ed.). *Degradation and restoration of arid lands.* International Center for Arid and semi-arid Land Studies, Texas Tech. Univ., Lubbock.

LONG, G. (1954).— Contribution à l'étude de la végétation de la Tunisie centrale. *Ann. Serv. Bot. Agron. Tunisie,* 27: 1-388.

MAESTRE, F.T. & CORTINA, J. (2002).— Spatial patterns of surface soil properties and vegetation in a Mediterranean semi-arid steppe. *Plant Soil,* 241: 279-291.

MAINGUET, M. (1990).— La désertification : une crise autant socio-économique que climatique. *Sécheresse*, 3: 187-195.

MAINGUET, M. (1991).— *Desertification, natural back-ground and human mismanagement.* Springer-Verlag, Berlin.

MIKOLA, J., YEATES, G.W., BARKER, G.M., WARDLE, D.A. & BONNER, K.I. (2001).— Effects of defoliation intensity on soil food-web properties in an experimental grassland community. *Oikos,* 92: 333-343.

MULAS, M. & MULAS, G. (2004).— *Potentialités d'utilisation stratégique des plantes des genres* Atriplex *et* Opuntia *dans la lutte contre la désertification*. Rapport d'activité du groupe de recherche sur la désertification, Université Sassari, Italy.

OLSSON, L. (1993).— Desertification in Africa: a critique and an alternative approach. *GeoJournal,* 31: 23-31.

ORSHAN, G., MONTENEGRO, G., AVILA, G., ALJARO, M.E., WALCKOWIAK, A. & MUJICA, A.M. (1984).— Plant growth forms of Chilean matorral. A monocharacter growth form analysis along an altitudinal transect from sea level to 2000 m. *Bull. Soc. Bot. Fr.,* 131: 411-425.

PADILLA, F.M. & PUGNAIRE, F.I. (2006).— The role of nurse plants in the restoration of degraded environments. *Front. Ecol. Envir*., 4: 196-202.

PIELOU, E.C. (1966).— The measures of diversity in different types of biological collections. *J. Theor. Biol.,* 13: 131-144.

POUGET, M. (1980).— *Les relations sol-végétation dans les steppes sud-algéroises*. Travaux et documents. ORSTOM, Paris.

PUEYO, Y., ALADOS, C.L., GARCIA-AVILA, B., KEFI, S., MAESTRO, M. & RIETKERK, M. (2009).— Comparing direct abiotic amelioration and facilitation as tools for restoration of semiarid grasslands. *Restor. Ecol*., 17: 908-916.

QUÉZEL, P. (1978).— Analysis of the flora of mediterranean and saharian Africa. *Ann. Mo. Bot. Gard.,* 65: 479-534.

R DEVELOPMENT CORE TEAM (2007). — *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org.

REYNOLDS, J.F. & STAFFORD SMITH, D.M. (2002).— *Global desertification: do humans cause deserts?* Workshop Report 88, Dahlem University Press.

REBOLLO, S., MILCHUNAS, D.G., NOY-MEIR, I. & CHAPMAN, P.L. (2002).— The role of a spiny plant refuge in structuring grazed shortgrass steppe plant communities. *Oikos,* 98: 53-64.

SANDERSON, S.C. & STUTZ, H.C. (1994).— High chromosome-numbers in Mojavean and Sonoran desert *Atriplex canescens* (Chenopodiaceae). *Am. J. Bot*., 81: 1045-1053.

SCHLECHT, E., DICKHOEFER, U., GUMPERTSBERGER, E. & BUERKERT, A. (2009).— Grazing itineraries and forage selection of goats in the Al Jabal al Akhdar mountain range of northern Oman. *J. Arid Environ*., 73: 355-363.

SCHLESINGER, W.H., REYNOLDS, J.F., CUNNINGHAM, G.L., HUENNEKE, L.F., JARRELL, W.M., VIRGINIA, R.A. & WHITFORD, W.G. (1990).— Biological feedbacks in global desertification. *Science,* 247: 1043-1048.

SHALTOUT, K.H., EL HALAWANY, E.F. & EL KADY, H.F. (1996).— Consequences of protection from grazing on diversity and abundance of the coastal lowland vegetation in Eastern Saudi Arabia. *Biodiv. Conserv*., 5: 27-36.

SHOOP, M.C., CLARK, R.C., LAYCOCK, W.A. & HANSEN, R.M. (1985).— Cattle diets on short grass ranges with different amounts of fourwing saltbush. *J. Range Manage*. 38, 443–449.

SLIMANI, H., AIDOUD, A. & ROZE, F. (2010).— 30 Years of protection and monitoring of a steppic rangeland undergoing desertification. *J. Arid Environ*., 74: 685-691.

SU, Y.-Z..,LI, Y.-L., CUI J.-Y. & ZHAO, W.-Z. (2005).— Influences of continuous grazing and livestock exclusion on soil properties in a degraded sandy grassland, Inner Mongolia, northern China. *Catena,* 59: 267-278.

THIOULOUSE, J., CHESSEL, D., DOLEDEC, S. & OLIVIER, J.M. (1997).— ADE-4: a multivariate analysis and graphical display software. *Stat. comput.,* 7: 75-83.

VAN DE KOPPEL, J. & RIETKERK, M. (2000).— Herbivore regulation and irreversible vegetation change in semi-arid grazing systems. *Oikos,* 90: 253-260.

VERSTRAETE, M.M. (1986).— Defining desertification: a review. *Clim. Change,* 9: 5-18.

VICKERY, J.A., TALLOWIN, J.R., FEBER, R.E., ASTERAKI, E.J., ATKINSON, P.W., FULLER, R.J. & BROWN, V.K. (2001).— The management of lowland neutral grasslands in Britain: effects of agricultural practices on birds and their food resources. *J. Appl. Ecol.,* 38: 647-664.

WHITTAKER, R.H. (1972).— Evolution and measurement of species diversity. *Taxon,* 21: 213-251.

WISSEL, C. (1984).— A universal law of the characteristic return time near thresholds. *Oecologia,* 65: 101-107.

XIE, Y.Z. & WITTIG, R. (2004).— The impact of grazing intensity on soil characteristics of *Stipa grandis* and *Stipa bungeana* steppe in northern China (autonomous region of Ningxia). *Acta Oeco. - Int. J. Ecol*., 25: 197-204.

YATES, C.J., NORTON, D.A. & HOBBS, R.J. (2000).— Grazing effects on plant cover, soil and microclimate in fragmented woodlands in south-western Australia: implications for restoration. *Austral Ecol*., 25: 36-47.

APPENDIX

Plant life forms (T. Therophyte, G. Geophyte, H. Hemicryptophyte, C. Chamephyte), Specific quality index (Isi) and coordinates of species on the two first axes of the Correspondence Analysis (CA). Isi were provided by the CRBT (1978). This index categorizes species according to their palatability (0 = non palatable, and 10 = highly palatable). This list of 84 plant species corresponds to the species recorded on plots after eliminating the rare species occurring in fewer than 5 % of plots for the CA.

			CA coordinates					CA coordinates	
Species names	Life forms	Isi	A1	A2	Species names	Life forms	Isi	A1	A2
Adonis dentata Delile	T	1	-0.69	0.63	*Herniaria fontanesii* Gay.	C	3	-0.91	-0.24
Aizoanthemum hispanicum (L.) H.E.K. Hartman	T	1	-0.94	0.73	*Hordeum murinum* L.	T	4	0.08	-0.17
Althaea ludwigii L.	T	2	-0.56	0.71	*Moraea sisyrinchium* (L.) Ker Gawl.	G	2	-0.59	-0.60
Alyssum granatense Boiss. & Reut.	T	5	-0.52	0.43	*Rostraria litorea* (All.) Holub	H	6	-0.50	0.64
Alyssum linifolium Willd.	T	5	-0.69	0.97	*Lappula patula* (Lehm.) Gürke	T	6	0.05	0.30
Alyssum scutigerum Durieu	T	5	-0.39	0.13	*Launaea nudicaulis* (L.) Hook.F.	T	5	0.16	0.59
Anacyclus monanthos subsp. *cyrtolepidioides* (Pomel) Humphries	T	7	0.32	0.38	*Leontodon hispidulus* (Del.) Boiss.	T	6	1.28	-0.03
Argyrolobium uniflorum (Dene.) Jaub & Spach.	H	8	-0.23	0.50	*Lonchophora capiomontiana* Durieu	T	4	1.38	-0.26
Arnebia decumbens (Vent.) Coss & Kral.	T	5	-0.47	0.12	*Lygeum spartum* L.	G	4	0.40	-0.37
Artemisia campestris L.	C	3	0.60	-0.38	*Malva aegyptiaca* L.	T	3	-0.26	0.32
Artemisia herba-alba Asso.	C	6	0.16	0.47	*Mathiola longipetala* (Vent.) DC.	T	6	0.75	0.28
Pallenis hierochuntica (Michon) Greuter	T	2	-0.46	-0.93	*Medicago laciniata* (L.) Miller	T	8	-0.20	0.43
Astragalus corrugatus Bertol.	T	6	-0.60	0.31	*Medicago litoralis* Loisel.	T	8	0.54	0.40
Astragalus sinaicus Boiss.	T	6	-0.33	-0.15	*Bombycilaena discolor* (Pers.) M. Lainz	T	2	-1.03	-0.15
Atractylis carduus (Forsk.) H. Christ.	C	2	0.15	0.33	*Muricaria prostrata* (Desf.) Desv.	T	4	-0.65	0.44
Atractylis caespitosa Desf.	H	1	-0.89	0.21	*Muscari comosum* (L.) Miller	G	0	0.06	0.13
Atractylis serratuloides Sieb.	C	3	-0.14	-0.24	*Noaea mucronata* (Forsk.) Asch & Schweinf.	C	4	-0.95	-0.93
Atriplex canesens	C	6	1.27	0.12	*Nolettia chrysocomoides* Desf.	H	4	0.28	0.36
Bassia muricata (L.) Asch.	T	0	0.30	-1.16	*Ononis natrix* L.	C	5	0.21	0.48
Bromus rubens L.	T	4	-0.05	-0.16	*Onopordum acaulon* L.	H	4	-0.16	-0.78
Bromus tectorum L.	T	6	1.39	0.41	*Onopordum arenarium* Pomel	H	5	0.26	0.31

			CA coordinates					CA coordinates	
Species names	Life forms	Isi	A1	A2	Species names	Life forms	Isi	A1	A2
Calendula sancta L.	T	5	-1.12	0.10	*Orobanche cernua* Loefl.	Parasite	0	1.29	0.14
Carthamus pinnatus Desf.	H	1	-0.83	0.70	*Paronychia arabica* (L.) DC.	H	2	0.10	-0.34
Heteromera fuscata (Desf.) Pomel	T	5	-0.12	0.28	*Peganum harmala* L.	C	3	-0.51	-2.28
Ctenopsis pectinella (Del.) De Not.	T	5	-0.85	0.80	*Plantago albicans* L.	H	7	0.11	-0.24
Cutandia dichotoma (Forsk.) Trab.	T	5	-0.56	0.75	*Poa bulbosa eu-bulbosa* L.	G	7	-0.75	0.50
Echinaria capitata (L.) Desf.	T	6	-0.44	0.81	*Reseda alba eu-alba* L.	T	3	-0.57	0.69
Echium humile subsp pycnanthum (Pomel) Greuter & Burdet	T	3	-0.28	-0.13	*Reseda arabica* L.	T	2	1.03	-0.08
Echium trygorrhizum Pomel.	H	3	-0.71	-0.15	*Salvia verbenaca* L.	H	5	0.21	0.25
Enarthrocarpus clavatus Godr.	G	4	1.33	-0.42	*Sixalix arenaria* (Forsskal) Greuter & Burdet	T	5	0.01	0.66
Erodium glaucophyllum (L.) l'Hérit.	T	1	-0.87	0.53	*Schismus barbatus* (Loefl. ex L.) Thell.	T	6	-0.33	-0.14
Erodium crassifolium L'Hér. [non Jacq.]	T	3	0.13	0.46	*Scorzonera undulata* Vahl.	H	6	0.41	0.23
Erodium laciniatum (Cav.) Willd.	T	5	-0.80	0.37	*Stipa balansae* Scholz [Afr. N. non Parl.]	H	5	0.89	-0.40
Eruca vesicaria (L.) Cav.	T	5	0.13	-0.34	*Stipa parviflora* Desf.	H	7	-0.49	0.13
Euphorbia calyptrata Coss. & Dur.	T	0	-1.14	0.17	*Macrochloa tenacissima* (L.) Kunth	G	3	-0.51	0.17
Filago argentea (Pomel) Chrtek & Holub	T	3	-0.17	0.90	*Teucrium polium* L.	C	5	0.10	0.46
Filago pyramidata L. (non C.Presl)	T	2	-0.47	-0.40	*Thymelaea microphylla* Coss. & Dur.	C	0	-0.74	-0.39
Glaucium corniculatum (L.) Rudolph	T	3	-0.30	-0.37	*Thymelaea virgata* (Desf.) Endl.	C	1	0.89	0.02
Hedypnois rhagadioloides (L.) F.W.Schmidt.	T	5	0.20	0.54	*Thymus algeriensis* Boiss. & Reut.	C	5	0.88	-0.44
Helianthemum hirtm Mill.	C	7	0.27	-0.64	*Thymus willdenowii* Boiss.	C	5	1.03	-0.13
Helianthemum lippii (L.) Pers.	C	8	-0.32	-0.78	*Trigonella polycerata* (L.) Trautv.	T	7	-0.89	0.64
Helianthemum lippii sessiliflorum (Desf.) Murb.	C	6	-0.08	0.41	*Xeranthemum inapertum* (L.) Mill.	T	6	-0.82	0.48