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Vegetation dynamics under variable conditions in the famous sandy steppe of southern Tunisia

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Abstract

During last decades, the natural vegetation cover in southern Tunisia, mainly dominated by dwarf and sparse shrub, was continuously disturbed under various human activities especially on sandy soil (easily eroded). The ecological characteristics (soil structure and texture, vegetation, topography…) of sandy steppes, with *Rhanterium suaveolens* Desf., enhanced their sharp decline. This study aims to investigate the vegetation status of two *R. suaveolens* steppes (*R*: protected; *r*: degraded) under different conditions in five sites belonging to southern Tunisia using the quadrat point method and some ecological indicators. Main results show that vegetation cover is related to climatic conditions. Plant density is mainly affected by rainfall and human activities. The annual and perennial density and cover are high during the rainy season (spring) compared with the dry one (fall). The degraded steppes (*r*) are mainly dominated by annual plants but the protected steppes (*R*) contain more perennials. This work can be very useful for the sustainable sandy steppes management under different stress and human disturbances in dry area. It presents a great national and international importance (economic, social, nature conservation…) such as job creation and limiting rural exodus.

Key words: degradation, restoration, sandy steppes, Tunisia, vegetation

Résumé

Au cours des dernières décennies, le couvert végétal naturel du sud de la Tunisie, principalement dominé par des arbustes nains épars, a été continuellement perturbé par diverses activités humaines, spécialement sur les sols sableux facilement érodés. Les caractéristiques écologiques (structure et texture des sols, végétation, topographie…) des steppes sableuses, avec *Rhanterium suaveolens* Desf., ont vu leur déclin s'accélérer. Cette étude vise à étudier le statut de la végétation de deux steppes à *R. suaveolens* (*R*: protégée; *r*: dégradée) sous diverses conditions au niveau de cinq sites du sud de la Tunisie en utilisant la méthode des points-quadrats et quelques indicateurs écologiques. Les principaux résultats montrent que le couvert végétal est lié aux conditions climatiques. La densité des plantes est surtout influencée par les chutes de pluie et par les activités humaines. La densité et la couverture des plantes annuelles et pérennes sont plus élevées pendant la saison des pluies (printemps) qu'en saison sèche (automne). Les steppes dégradées (*r*) sont surtout dominées par des plantes annuelles alors que les steppes protégées (*R*) comptent plus de plantes pérennes. Cette étude pourrait s'avérer très utile pour la gestion durable des steppes sableuses qui subissent diverses pressions et perturbations humaines en zone aride. Elle est d'une grande importance nationale et internationale (économique, sociale, conservation de la nature) dans plusieurs domaines tels que la création d'emplois et la limitation de l'exode rural.

Introduction

In Tunisia, as the case of all north African countries, natural vegetation cover known, during last decades, rapid regressive dynamic under the combined effects of climate and human disturbances (Quezel, 2000; Ben Brahim *et al.*, 2004; Bouazza *et al.*, 2004; Ouled

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Belgacem *et al.*, 2004; Tarhouni *et al.*, 2007). According to Quezel (2000), the natural vegetation regressive dynamic of Mediterranean regions follows five stages: matorralisation, dematorralisation, steppe, therophytization and desertification. This dynamic is usually accompanied by the rarefaction/extinction of some plant species supplying local population's requirements (Boussaid *et al.*, 2004; Tarhouni *et al.*, 2010). As results, plant biodiversity decreased by losing species in one hand and the dominance of some other invasive plants on the other hand (Muller, 2000; Julien, 2006; Chalghaf *et al.*, 2007; Tlig, 2007).

Many authors noted the importance of *R. suaveolens* steppes in southern Tunisia as historical grazing area (Le Houerou, 1959, 1969; Floret *et al.*, 1978; Floret & Pontanier, 1982). *R. suaveolens* steppes are located on deep sandy alluvial soil (Khatteli, 1981; Hanafi & Jauffret, 2008). They are the largest and the richer steppes with many pastoral species such as *R. suaveolens, Stipa lagascae* R. & Sch., *Lotus creticus* L., *Argyrolobium uniflorum* (Decne.) Jaub. & Spach… and characterized by an important dynamic rate (Telahigue, Floret & Le Floc'h, 1987). According to Le Houerou (1969), these steppes occupied 500.000 ha. Their actual area is about 50.000 ha (Hanafi & Jauffret, 2008). The two major plant associations of these steppes are *R. suaveolens* and *Artemisia campestris* L. in one hand and *R. suaveolens* and *Asphodelus refractus* Boiss. on the other hand (Le Houerou, 1959; Bendali *et al.*, 1986). Their wide extension, their attractive soil to agricultural activities and their highly palatable vegetation cover are the main causes of their high degradation rate.

The geographical extend of *Rhanterium* steppes and their attractiveness for agricultural practices (field and tree crops) lead to their decline and fragmentation (Hanafi & Ouled Belgacem, 2006; Genin & Hanafi, 2010). Consequently, the grazing area is reduced, and the overgrazing is more obvious causing the rarefaction of palatable plants (*S. lagascae, Plantago albicans* L., *A. uniflorum, Echiochilon fruticosum* Desf., *Helianthemum sessiliflorum* (Desf.) Pers., *Hedysarum spinosissimum* L.) in one hand and the dominance of unpalatable ones on the other hand (*Astragalus armatus* Willd., *Artemisia campestris, Cleome amblyocarpa* Barratte & Murb.) (Chaieb, 1991; Gamoun *et al.*, 2010; Tarhouni *et al.*, 2010). This study aims to evaluate the vegetation status in the protected (*R*) and the degraded (*r*) *Rhanterium* steppes in five sites of southern Tunisia. Vegetation cover, plant density and flora diversity monitoring were used for this purpose.

Material and methods

Studied sites

Five sites (site 1: Menzel Habib; site 2: Alamet Machlouch; site 3: Beni Ghzeil; site 4: Sidi Makhlouf and site 5: Dar Dhaoui) containing protected (*R*) and degraded (*r*) *Rhanterium* steppes were retained in this study (Fig. 1, Table 1). These sites were selected on the basis of their comparable soil conditions and vegetation composition. They are similarly disturbed and managed. They are also the major and the last actual locations of *Rhanterium* steppes in southern Tunisia. During the studied period (2005–2009), a very remarkable interannual variation of precipitation was recorded in the five sites (Table 2). For this reason, the averages of vegetation measurements were used both in fall (from 2005 to 2008) and spring (from 2006 to 2009).

Data collection

The quadrat point method as define by Daget & Poissonet (1971) and Floret (1988) was used for the vegetation measurements. Three sampled tapes, 20 m of length each, were installed and monitored in each steppe during the studied period. A fine pin was descended to the ground every 20 cm along the tape. Each of the 100 hits per tape was recorded according to the plant species and type of ground touched. Plant species and their nomenclature are identified with flora books (Cuenod, Pottier-Alapetite & Labre, 1954; Quezel & Santa, 1962, 1963; Ozenda, 1977; Pottier-Alapetite, 1979, 1981; Le Floc'h, Boulos & Vela, 2010).

Plant cover (PC) is calculated as: $PC = (n/N) \times 100$ with n: the number of hits of all plant species and N: the total number of hits (100 hits in our case). The specific frequency of presence (SFP) is the number of hits of the specific species: $SFP_i = (n_i/N) \times 100$ with n_i: the number of hits of species i. Plant density (number of species/m²) is counted in 20 m² for the perennials and 2 m² for the annuals in each sampled tape. The Jaccard's index, which indicates the floristic similarity between sites and steppes, is calculated as:
P_j (*relevés* x and y) = c/(a + b − c) with: P_j = Jaccard's index; a = number of species in the *relevé* x; b = number of species in the *relevé* y; c = number of common species between the *relevés* x *and* y.

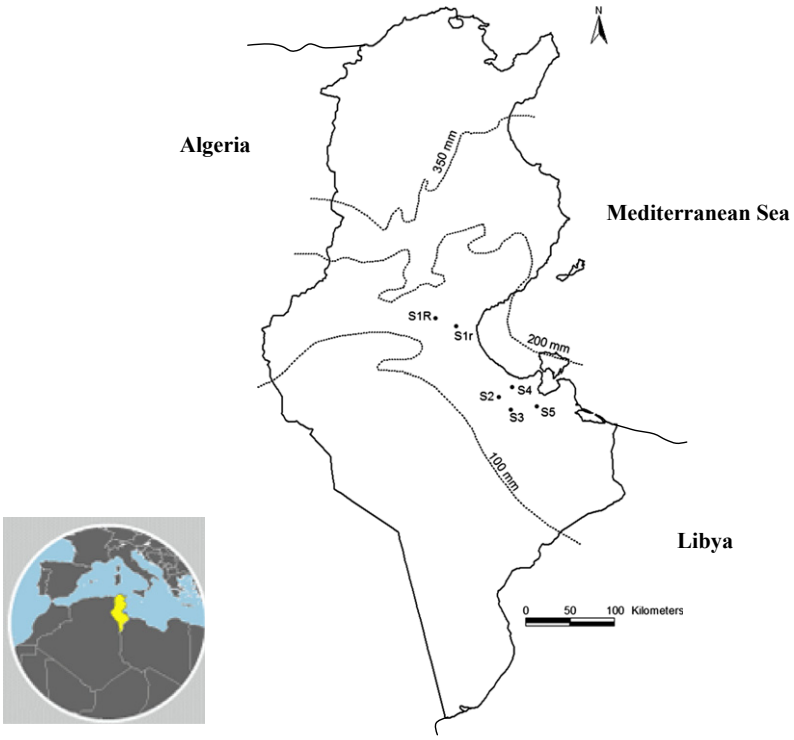

Fig 1 Geographical location of the studied sites on the map of Tunisia (S1*R*: Menzel Habib (protected); S1*r*: Menzel Habib (degraded); S2: Alamet Machlouch; S3: Beni Ghzeil; S4: Sidi Makhlouf and S5: Dar Dhaoui)

Table 1 Geographical coordinates of the protected (*R*) and degraded (*r*) *Rhanterium suaveolens* steppes belonging to the five studied sites in southern Tunisia

Sites	Steppes	Geographical coordinates
S1	*r*	34°06′37″N, 9°49′18″E
	R	34° 11′ 27″N, 9° 34′14″E
S2	*r*	33°24′28″N, 10°18′14″E
	R	33°23′45″N, 10°19′39″E
S3	*r*	33°18′24″N, 10°23′45″E
	R	33°16′03″N, 10°27′56″E
S4	*r*	33°29′18″N, 10°29′15″E
	R	33°29′40″N, 10°29′11″E
S5	*r*	33°13′53″N, 10°51′44″E
	R	33°17′44″N, 10°46′54″E

S1: Menzel Habib; S2: Alamet Machlouch; S3: Beni Ghzeil; S4: Sidi Makhlouf and S5: Dar Dhaoui.

Data analysis

The obtained data were statistically analysed (one-way ANOVA, Student–Newman–Keuls test) using the SPSS 11.5 software (SPSS Inc., 2002).

Results

Vegetation cover

Total vegetation covers in the degraded (*r*) and the protected (*R*) sandy steppes during the fall (2005–2008) and the spring (2006–2009) are carried out in Fig. 2. Interseasonal variations are significant in sites 2 ($P = 0.000$) and 5 ($P = 0.001$) for the (*r*) steppes and sites 1 ($P = 0.018$) and 5 ($P = 0.008$) for the (*R*) ones. During the autumn, the vegetation cover is significantly different between sites for the (*r*) steppes ($P = 0.017$) and not significant for the (*R*) steppes ($P = 0.38$). During the spring, both (*r*) and (*R*) steppes show significant differences between sites ($P = 0.008$ and $P = 0.01$, respectively). The comparison between (*r*) and (*R*) steppes is significant in site 2 ($P = 0.000$) during the fall and sites 3 ($P = 0.029$) and 4 ($P = 0.016$) during the spring.

Vegetation cover in spring is higher than fall both for (*r*) and (*R*) steppes belonging to the five studied sites. This difference can be explained by the presence of annual plants under good climatic conditions in spring (rainfall

Table 2 Rainfall (mm) recorded inside the five studied sites (S1–S5) during the period 2005–2009

		Fall			Winter			Spring			Summer			
		September	October	November	December	January	February	March	April	May	June	July	August	Total
2005–2006	S1	0	0	0	0	0	0	0	0	0	0	0	0	0
	S2	8.4	55.4	4.3	62.5	20.8	20.6	0	0.9	0.9	0	0	0	173.8
	S3	11.6	29.5	13.4	53.8	18.9	20.6	0	2.9	12.7	0	0	5.4	168.8
	S4	15.75	27.5	22.6	56.5	35.5	25.5	0	0	11.5	0	0	0	194.85
	S5	5	39	18	34	20	3	0	2	0	0	0	0	121
2006–2007	S1	47	24	34	26	0	3	60	105	2	15	0	18	334
	S2	0	6.2	37.2	97	0	136	95.2	18.3	0	0	0	0	389.9
	S3	1.6	4.4	32.2	41	0.6	54	0	0	0	0	0	0	133.8
	S4	14	3	70.8	20.3	90	90	93.5	27.5	0	0	0	0	409.1
	S5	0	0	35	24	2	21	39	18	0	0	0	0	139
2007–2008	S1	0	2	0	39	0	0	1.5	0	0	0	0	0	42.5
	S2	0	10.8	0	32	0	0	0	0	0	0	0	0	42.8
	S3	0	33.9	0	94	0	0	0	0	0	0	0	0	127.9
	S4	0	42.5	0	212.9	1	4.5	0	0	0	0	0	0	260.9
	S5	0	45	0	95	5	0	0	5	0	0	0	0	150
2008–2009	S1	0	0	0	0	106	0	20	25	10.5	0	0	0	161.5
	S2	0	0	0	0	0	0	0	0	0	0	0	0	0
	S3	1.3	5.6	9.5	16	46.7	0	7.1	0	0	0	0	0	86.2
	S4	2.5	20	35.2	27.5	45	3	5.1	18	13.5	0	0	0	169.8
	S5	10.7	0	20	42	41	0	20	6	0	0	0	0	139.7

S1: Menzel Habib; S2: Alamet Machlouch; S3: Beni Ghzeil; S4: Sidi Makhlouf and S5: Dar Dhaoui.

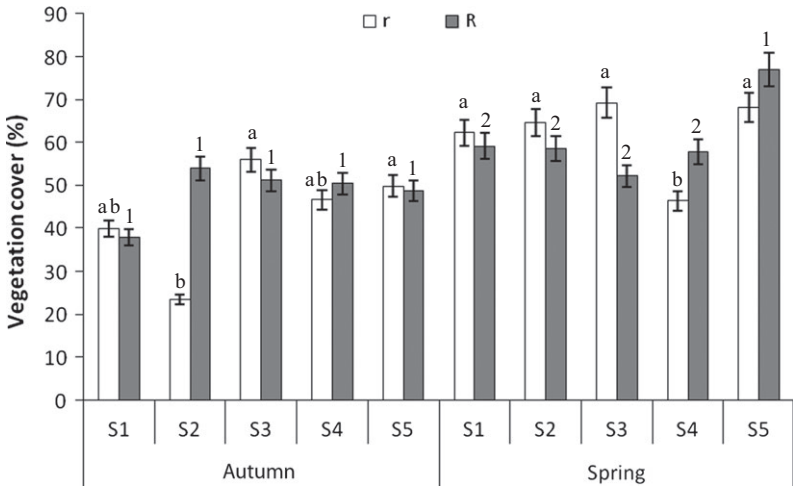

Fig 2 Vegetation cover (% ± SE) inside the degraded (*r*) and the protected (*R*) sandy steppes belonging to the five studied sites (S1–S5) during the dry (Fall 2005–2008) and rainy (Spring 2006–2009) seasons. a/b indicate differences for (*r*) steppes and 1/2 indicate differences for (*R*) steppes according to Student–Newman–Keuls test

especially). Annual species are dominated in the degraded steppes during this season [(*r*) steppes vegetation cover is higher than the (*R*) ones in sites 1, 2 and 3], and they are closely present in sites receiving sufficient precipitation quantities in fall. The difference between (*R*) steppes vegetation covers in spring can be explained by the

presence of annuals plants in one hand and the vegetative growth of perennials in the other hand. During the fall, (*R*) steppes are composed by very sparse perennial plants with comparable covers (no significant difference between sites).

Plant density

Perennial plants show a very low density in comparison with annuals for both (*r*) and (*R*) steppes during the dry (fall) and rainy (spring) seasons (Fig. 3). Interseasonal variations of the perennial density in (*R*) steppes are significant in site 1 ($P = 0.015$), site 2 ($P = 0.0001$) and site 3 ($P = 0.027$). Annual densities show significant difference between seasons in site 2 ($P = 0.006$), site 3 ($P = 0.018$), site 4 ($P = 0.0001$) and site 5 ($P = 0.013$). In (*r*) steppes, these variations are significant in site 1 ($P = 0.014$), site 2 ($P = 0.0001$) and site 5 ($P = 0.037$) for perennials and site 1 ($P = 0.016$), site 2 ($P = 0.0001$), site 3 (0.02), site 4 ($P = 0.009$) and site 5 ($P = 0.0001$) for annuals.

The comparison between sites in (*R*) steppes shows significant difference for perennial ($P = 0.0001$) and annual densities ($P = 0.002$) during the fall. These variations are also significant during the spring ($P = 0.0001$) both for annuals and perennials. These last actual locations show significant variation between sites during the fall ($P = 0.0001$) in (*r*) steppes. Differences between (*R*) and (*r*) steppes in fall are significant for

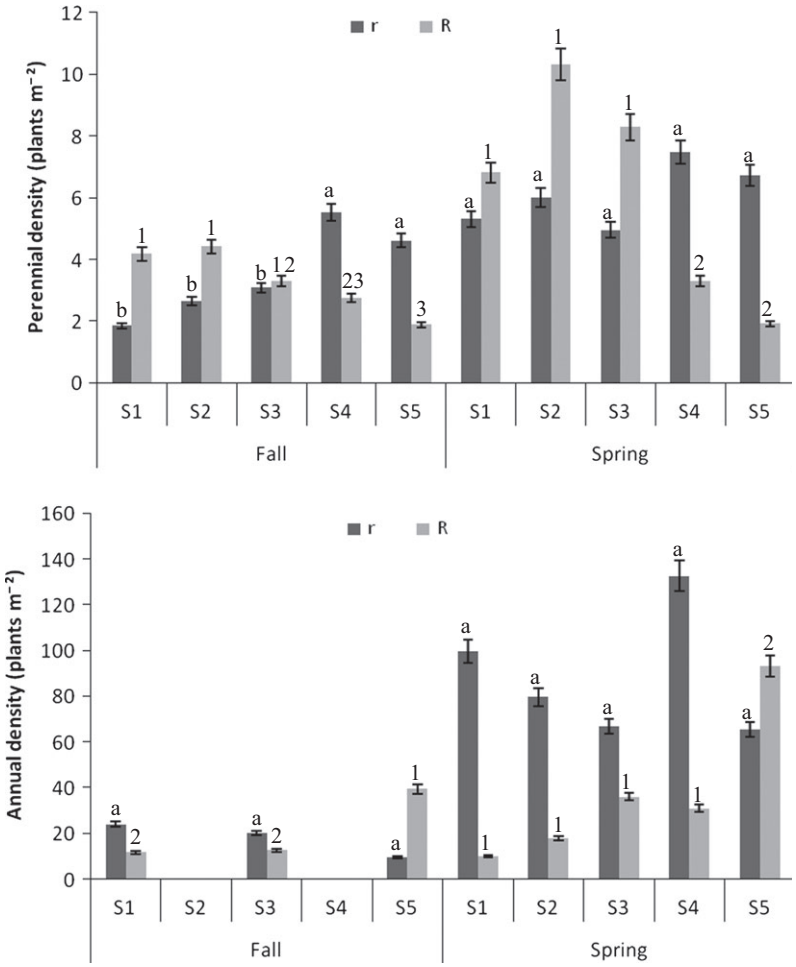

Fig 3 Perennial and annual densities (plants m^{-2}) (±SE) inside the degraded (*r*) and the protected (*R*) sandy steppes belonging to the five studied sites (S1–S5) during the dry (Fall 2005–2008) and rainy (Spring 2006–2009) seasons. a/b indicate differences for (*r*) steppes and 1/2/3 indicate differences for (*R*) steppes according to Student–Newman–Keuls test

perennials in site 1 ($P = 0.015$), site 2 ($P = 0.008$), site 4 ($P = 0.001$) and site 5 ($P = 0.0001$), which shows also a notable variation of annuals ($P = 0.046$). During the spring, perennial density shows significant variation between (R) and (r) steppes in site 2 ($P = 0.006$), site 4 (0.016) and site 5 ($P = 0.0001$) but the annual ones are significant in site 1 ($P = 0.003$), site 2 ($P = 0.004$) and site 4 ($P = 0.039$).

These results indicate that plant density is negatively affected by rainfall and human activities. The annual and perennial density is high during the rainy season (spring) compared with the dry one (fall). The degraded steppes (r) are mainly dominated by annuals but the protected ones (R) contain more perennials.

Flora diversity

Jaccard's index is used to compare flora diversity between the studied steppes (Table 3). This index was calculated on the basis of an exhaustive list containing all plant species founded in each steppe during the rainy seasons (spring). It reflects the floristic similarity degree between the studied steppes and sites. The majority of these indexes are <0.5 (more than 50% of plant species are different between sites). Indeed, a remarkable diversity of plant species between the protected and the degraded steppes belonging to the five studied sites was noted. This diversity can be explained by the vegetation composition variation between steppes (mainly annual plants) under the effect of the protection/degradation degree in one hand and precipitation difference between sites on the other hand.

Discussion

Several works showed the beneficial effect of fencing on plant communities in highly disturbed zones, such as sandy steppes in southern Tunisia (Floret & Pontanier, 1982; Waechter, 1982; Le Houerou, 1995; Ouled Belgacem & Neffati, 1996). Short grazing periods alternated with periods of fencing are more favourable than strict long-term protection (Floret, 1981; Ouled Belgacem, Tarhouni & Louhaichi, 2013). Controlled grazing reduces aerial parts of some plant species and allows the root system to support their water needs in arid areas where the evaporative demand is high (Le Floc'h, 2001). With regard to perennials, it appeared that grazing increase the individual cover (not the density) of some tolerable plants (Le Floc'h *et al.*, 1999). However, the overgrazing strongly decreases vegetation cover and facilitates erosion (Tarhouni *et al.*, 2007). Vegetation recovery is possible when the grazing pressure did not cause the total disappearance of plant species (Jauffret, 2001). Moreover, Floret (1981) showed the regression of annual species in favour of perennials after 7 years of fencing. Our study shows that precipitations are the main factor affecting the seasonal plant distribution in sandy arid steppe. Human disturbance has also a notable negative effect on natural vegetation cover in the degraded steppes compared with the protected ones.

Plant communities in arid areas are mainly dominated by chamaephytes in dry period and therophytes under strong human disturbance (Tarhouni *et al.*, 2006, 2010). Monitoring the perennial density evolution permits to know their progressive/regressive dynamic and the

Table 3 Jaccard's index in the protected (R) and the degraded (r) sandy steppes of the five studied sites

	R_1	R_2	R_3	R_4	R_5	r_1	r_2	r_3	r_4	r_5
R_1	1									
R_2	0.51	1								
R_3	0.41	0.4	1							
R_4	0.37	0.38	0.32	1						
R_5	0.38	0.33	0.51	0.38	1					
r_1	0.54	0.47	0.42	0.31	0.41	1				
r_2	0.44	0.52	0.43	0.39	0.51	0.52	1			
r_3	0.36	0.37	0.49	0.39	0.43	0.34	0.41	1		
r_4	0.41	0.37	0.35	0.47	0.39	0.41	0.38	0.4	1	
r_5	0.51	0.46	0.49	0.41	0.42	0.36	0.46	0.4	0.52	1

1: Menzel Habib; 2: Alamet Machlouch; 3: Beni Ghzeil; 4: Sidi Makhlouf and 5: Dar Dhaoui during the rainy seasons (spring 2006–2009).

ecosystem ability to regenerate (Floret, 1988). High resilience capacity was noted when the number of perennial is large. According to Jauffret (2001), restoration increases the vegetation cover and soil fertility (litter and soil fixation). Indeed, the big number of perennials increases ecosystem resilience, especially when the plant species emit strains and they are able to quickly colonize areas. In addition, the high number of individuals generates the accumulation and fixation of soil particles, which improves the soil water balance and makes possible the appearance of other plant species during the succession process (Floret & Pontanier, 1982; Jauffret, 2001).

The interseasonal difference of vegetation cover is mainly due to the annual species development during the rainy period (Enright, Miller & Akhter, 2005). The abundance of annuals is a sign of degradation in dry areas (Metzger *et al.*, 2005). It is the therophytization phenomenon evoked by several authors (Floret & Pontanier, 1982; Jauffret, 2001; Tarhouni *et al.*, 2007). It should be also noted that perennial cover (during fall, the vegetation cover is mainly composed by perennial) is higher than the threshold considered by Le Houerou (1995) as critical (20–25%) below which erosion occurs. Strong disturbance enhances the dominance of annuals and some weak and decaying perennial. Such phenomena have repercussions on biodiversity as well as the functional processes of plant communities and ecosystem resilience (Jauffret, 2001; Visser, 2001). In case of very severe degradation, annual plants dominate and the floristic homogenization is easily remarkable (Jauffret, 2001; Jauffret & Lavorel, 2003; Tarhouni *et al.*, 2006). According to Sheuyange, Oba & Weladji (2005), changes in floristic composition and plant species abundance are linked to spatial variability, which depends on rain distribution. Hence, the drought effect on flora diversity will be easily discernible in large areas compared with the small ones (Child, 2003).

Conclusion

Sandy steppes are the most common and widely used by human and animals in southern Tunisia. They are very threatened by desertification and require protection to guarantee their sustainable exploitation. The monitoring of vegetation dynamics in the protected steppes is needed to know the response of plant species. This study was carried out inside protected (*R*) and degraded (*r*) sandy steppes belonging to five sites in southern Tunisia. Main results show notable improvement in vegetation status inside the protected steppes. Plant community's dynamics are closely linked to the rainfall pattern. Under good climatic conditions, the natural vegetation cover can properly survive. However, in such situation, human activities (mainly ploughing) are dominant and sharply degrade soil and vegetation. With low rainfall, only grazing activity was encountered but the natural vegetation will be highly stressed by lack of water and high temperature. The manager should take into account all these situations in future programmes of the sustainable development of these areas and those with comparative environmental conditions.

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