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Qualification of Rangeland Degradation Using Plant Life History Strategies Around Watering Points in Southern Tunisia

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Abstract: In this reserch we review the effects of animal activities on plant life history strategies (CRS) around watering points using phyto-ecological studies and vegetation cover data. The objective of this study was to understand the impact of disturbance degree simulated by distance from wells on CRS strategies (Grime types). The main results indicate that annualisation is a reality. We show the dominance of RS-species in the more disturbed sites (nearest transect from watering points), CRS- and CS-species at medium disturbance and CS- and S-species in lower disturbance sites (further from water). The floristic homogenisation is discernible at long period of exploitation. With lower grazing disturbance, *Stipagrostis pungens* can appropriately survive but it cannot tolerate the high degradation levels.

Key words: Dry area, Tunisia, watering points, distance, grazing, CRS strategies

INTRODUCTION

Gradients of grazing over increasing distances from watering points have been used extensively in rangeland research to look at the impact of livestock on rangeland vegetation (Kintoch and Friedel, 2005a, 2005b; Thrash, 2000). Distance from water can be used as a surrogate of grazing pressure-high near water, low away from water (Ludwig *et al*., 2001). At the beginning of dry season animals exploit, preferentially, grazing in the immediate neighborhood of wells and induce an intense stamping which rarefy, even disappeared, vegetation (Grouzis, 1988). This zone of extreme degradation surrounding wells carries the name of piosphere according to several authors (Andrew, 1988; Craig *et al*., 1999; Thrash, 1998, 2000). Tongway *et al*. (2003) revealed significant change in resources distribution processes at different grazing intensities and show that "piosphere" effect is discernible even on a radius of 1 to 3 km from water.

Grime (1977) has developed a simplified key of determination, based on species characteristics independently of their growth sites. Plant life history strategies are determined by the CRS-Grime model which completes the classification of plant species to climatic constraints and human disturbance. These species are qualified like: Competitive ability (C) plants monopolizing resources with their strong vegetative development; Stress tolerant (S) plants occupying poor nutriments habitats; Survival of disturbance (R) species live in a frequent and stern disruptions habitats. The Grime concept is very attractive when it describes plant species adaptation in particular to their environment and along a disruption and stress degree (Jauffret, 2001). The use of the CRS strategies, conceived on the herbaceous vegetation of the moderate Europe, required an adapted interpretation to the north-African steppe because of the knowledge gap on the majority of its species (Jauffret and Visser, 2003).

In terms of life history or CRS-strategies (Grime, 1974, 1977; Grime *et al*., 1988), the dwarf shrub steppe of arid northern Africa (annual rainfall 100-400 mm) is a fine example of high stress (S), high disturbance (R) adapted vegetation (Jauffret and Visser, 2003). In southern Tunisia, also characterized by the elevated stresses and the strong human disruptions, flora shows the presence of a resistant and adapted species. These last and their proportion in the local flora could serve like a degradation indicators (Jauffret, 2001). However, for most the north-African steppic species, the comparative and specific data describing plant adaptive strategies are rare and the information of the regional floras (Cuénod *et al*., 1954; Ozenda, 1977; Pottier-Alapetite, 1979, 1981; Quézel and Santa, 1962, 1963) is insufficient to study these indicators. Besides, the Tunisian arid zone plant species, in spite of some recent studies (Jauffret, 2001; Jauffret and Visser, 2003), are not well classified following their adaptive strategies sensu Grime (1977). In this study, we want to test the hypotheses of Jauffret and Visser (2003), (Fig. 1),

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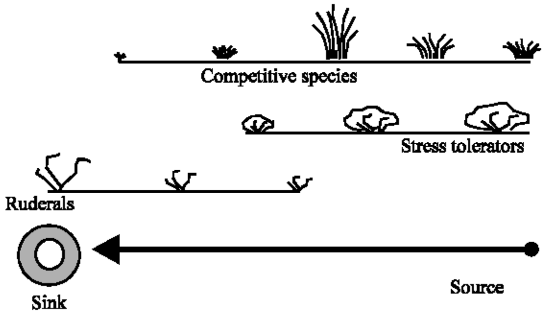

Fig. 1: Gradients of species dominance in a source and sink scheme (Jauffret and Visser, 2003)

around three watering points in the tunisian arid zone. Aims are to show that the more degraded areas are marked by RS- species but at lower disturbance CS- and S- species dominate.

MATERIALS AND METHODS

Studied zone

El Ouara communal rangelands: El Ouara region is a part of Presaharian Tunisia in the sense of Floret and Pontanier (1982), which corresponds roughly with the Tunisian part of the lower arid zone of North-Africa, comprised between the isohyets of 100 and 200 mm of annual rainfall (Fig. 2). Rainfall pattern and temperature regime are Mediterranean. The rainfall (256 mm) recorded in Sidi Toui National Park during the studied period (2003/2004 biological year) exceeds annual averages of the region (100 mm). Hence plant species can appropriately survive because water availability is not limiting anymore for plant growth in Presaharian Tunisia when annual rainfall exceeds 250 mm (Chaieb, 1989). The unique land use of the area is rangeland. Topographically, this region is mainly composed of vast encrusted glacis with sandy and thin top layer (CNEA, 1991). The vegetation cover, essentially constituted by dwarf shrub steppe with perennial grasses is about 12, 23 and 37% during a dry, medium and rainy year, respectively. The potential productivity of this region, which varies with the dominant plant species, is between 15 and 60 UF ha^{-1} an^{-1} (CNEA, 1991) with 1UF is the equivalent of the energy produced by 1 kg of barley. During the rainy season the pasture productivity can exceed the herd's needs but during the dry period animals need feed supplements.

Watering points: Three watering points, situated in El Ouara communal rangeland, were retained for this study. These wells differ by the duration of exploitation, their geographical locations and the nature of surrounding vegetation. The first watering point (well 1, exploited for 150 years) is located in the North of the studied zone, the second (well 2, exploited for 100 years) and the third (well 3, exploited for 5 years) are situated in the south of Sidi Toui National Park. Well 1 is located on a stony soil with truncated top layer and surfacing rock due to erosion with *Anthyllis sericea* Lag. sub sp. *henoniana* (Coss.) Maire and *Gymnocarpos decander* Forssk. The east of this watering point is occupied by *Stipagrostis pungens* (Desf.) de Winter and *Hammada schmittiana* (Pomel) Iljin. Wells 2 and 3 are situated on a sandy substratum with *S. pungens* and *H. schmittiana*. The absence of *A. sericea* around these water points is due to the soil characteristic on one hand and it's a well grazed leguminous dwarf shrub on the other. *Stipagrostis pungens*, a fibrous rhizomatous grass, is regarded as a pioneering species in the succession of vegetation on mobile sand dune (Bendali *et al*., 1990; Bornkamm *et al*., 1999) but its ecology makes its local presence fugacious.

Data collection: Several transects have been established at 250 m (1), 500 m (2), 1 km (3) and 2 km (4) from each watering point and following the four cardinal directions (Fig. 2). The choice of distances is explained by the fact that on woodlands the cover of perennial plant patches remained low for a considerable distance from water (5-8 km), compared to that for an ungrazed area, but on grasslands plant cover reached its expected maximum within 2 km from water (Ludwig *et al*., 2001). Two perpendicular measuring tapes, 20 m of length each, were installed in each transect. Eight lines by distance and 32 lines by well were assessed and monitored during the spring 2004 using the quadrat point method as define by Daget and Poissonnet (1971) and Floret (1988). 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.

The Vegetation Cover (VC) is calculated as: VC = (n/N)*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: $SFP_i = (n_i/N) * 100$ with n_i: the number of hits of species I. The Specific Contribution of Presence (SCP in%) of the species I, on the total plant cover, is calculated as: $SCP_i = (SFP_i/\Sigma\ SFP) * 100$. Eight variables are treated: CRS, CS, RS, S, Stpu (*S. pungens*), VC, CP (perennial contribution) and CA (annuals contribution). VC is subdivided into annuals and perennials in order to study the interaction of these plants along a disturbance gradient. *Stipagrostis pungens* is used like a separate variable because it's a perennial

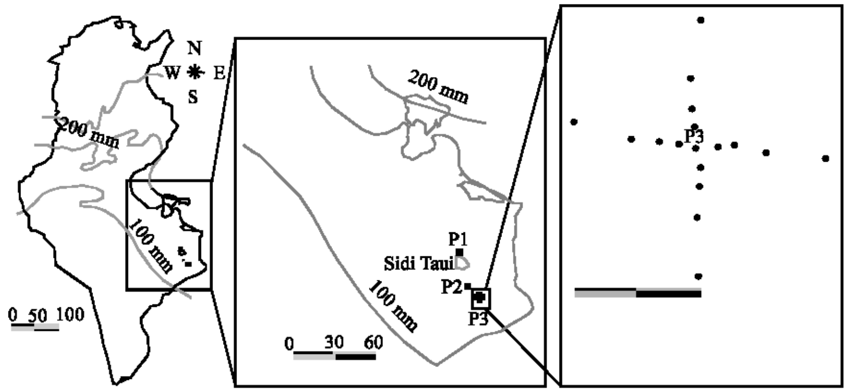

Fig. 2: Location of the three studied watering points (P1 = Well1 ; P2 = Well2 ; P3 = Well3), Sidi Toui National Park and the measured distance in each well (i.e., P3) on the Tunisian map

grasses with an RS strategy, hence it cannot be regrouped to RS-species (annuals). In our data all zeros (0) were replaced by one (1) to better statistical analysis. In each well, SCP of plant species in each distance are added by direction (for example SCP_i 250 m = SCP_i 250 m N + SCP_i 250 m S + SCP_i 250 m E + SCP_i 250 m W with N, S, E and W are the cardinal directions). In regard to CSR strategies; VC, CP and CA are presented as average on each distance. Every well is treated separately because we cannot average over the three watering points according to their floristic characteristics.

Data analysis: We carried out a principal component analysis (PCA) on a correlation matrix of a data set composed of 12 distances from watering points (4 in each well) with eight variables (see above). The measured sites are classified according to Pearson correlation coefficient and the hierarchical cluster is obtained with the between-group linkage method. All statistical analyses are carried out using SPSS for windows v. 11.5 (SPSS Inc., 2002).

RESULTS

It's clear that annual plants are more dominant at the neighbourhood of wells (most disturbed sites) and they become less dominant when the distance to water increase (low disturbed sites). While, VC and CP increase progressively as disturbance decreases (i.e., distance to water increases) (Fig. 3).

PCA loading plot: PCA yields two first principal components (PC1, PC2), with eigen values >1.5, together they explain 87.8% of the total variation (Fig. 4). This high percentage is partially explained by the artificial correlations of VC, CA and CP. The first PC (65.5%) has high positive loadings of CP, CRS, Stpu and VC. The negative loadings on PC1 came from, in decreasing order

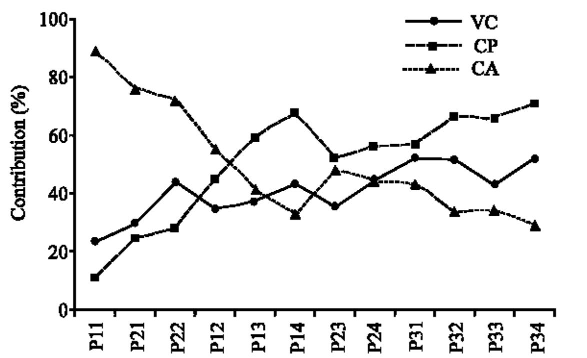

Fig. 3: Variation of VC (Vegetation Cover), CP (Contribution of Perennial species) and CA (Contribution of Annual species) according to distance from watering points (P11 is the transect situated at 250 m from the first watering points P1)

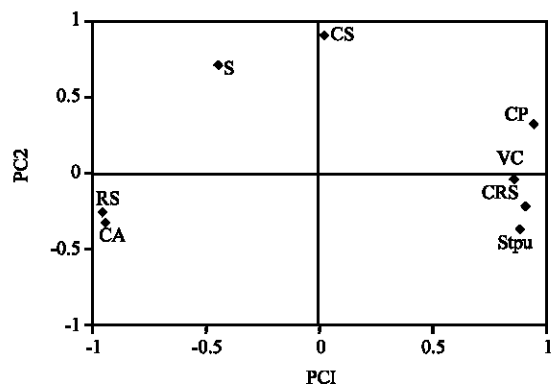

Fig. 4: Loading plot of the original variables on the first two principal components (PC1 and PC2)

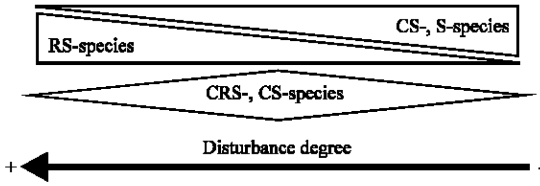

Fig. 5: Variation of species dominance on term of life history strategies with disturbance degree around watering points

of importance, RS, CA and S. So in sites with low CP, CRS, Stpu and VC, pure annuals (with RS strategies) hangs on and dominate. Stpu is negatively correlated with RS, this means that Stpu definitely behaves differently from annuals (other RS-species). Stpu remains dominant as well at the furthest distances from the wells because around well 2, this species is very degraded in the nearest transect and can benefit of low disturbance at the furthest one. Around well 3 the situation is inverse.

The loadings on the second PC (22.3%) are dominated by CS and S at the positive side and RS at the negative side. It seems that this PC indicated the gradient of disturbance around the first well, because the analysis of this well (PCA, not shown here) shows a positive correlation between CS- and S-species on the positive side of PC1 (69%) and a negative side with RS-species. CRS correlate positively with CS and negatively with S-species. This means that the most disturbed sites are dominated by RS-species; at medium disturbance CRS-species dominate and CS-species appear but when the disturbance is lower only CS- and S-species dominate (Fig. 5). The positive correlation of CS with S and with CP shows that CS- and S-species give perennial cover to relatively low disturbed sites. CR-species, which have no grazing value, are not found in our sites. This is probably due to the fact that aridity is more pronounced in the studied zone on one hand and to the unfavourable soil characteristics on the other.

PCA score plot: The classification of 12 distances from watering points using the between-group linkages method and Pearson correlation shows 2 groups. Group 1 includes only three transects: One W11 (250 m) at well 1 and two W21 (250 m) and W22 (500 m) at well 2. The second (Group 2) includes the rest of the sites. It seems that the classification of these transects is in relation with the disturbance degree. Hence group 1 consists of the most disturbed sites, which are exploited during a long period and group 2 contains the low disturbed sites (Fig. 6).

PC1 indicates the grazing intensity as well as disturbance degree. It begin with W11 (the oldest and

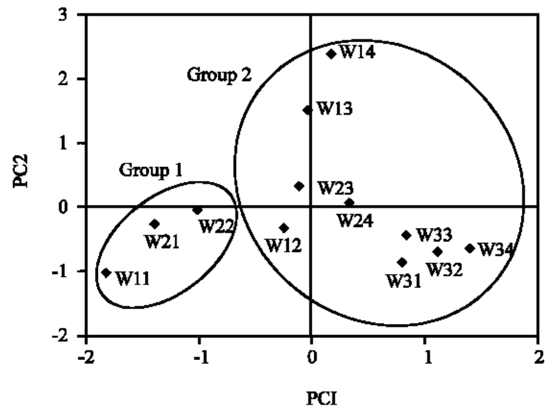

Fig. 6: Site score plot in the (PC1, PC2)-plane. For example W11 is the transect situated at 250 m from the first watering point (W1)

most disturbed site) in the negative side and finish with W34 in the positive one (the youngest and low disturbed site). PC2 is in close relationship with distance around the first well because it shows W11 in the negative side and W14 in the positive one. Close transects to old wells are most degraded (group 1) but all sites at various distances from Well 3, most recent well, are least degraded (degradation means less VC and more RS). Hence, distances of Well 3 have not had the time yet to differentiate. For Well 1 it is very obvious that the co-dominance of S and CS is replaced by RS but that even W14 has not got the VC of the transects around Well 3. This means that degradation tends to exacerbate with time and that disturbance is in close relation with the nature of surrounding steppe. When the disturbance increases, only annual plants (RS-species) dominate. It is probably due to the fact that Stpu is an RS-species as well and that *Hammada* and *Stipagrostis* make up the bulk of the remaining perennial cover in W21 and W22.

DISCUSSION

Present study is a good example to study vegetation response to the degree of disturbance simulated by distance from watering points. At the level of the most distant transect from wells (1 and 2 km), the perennial cover is superior to the critical level (20-25%) below which the erosion starts (Le Houérou, 1995). Contrarily, the nearest transects from wells (250 and 500 m), characterized by a strong animal activity, present a richness and a more elevated cover of annual plants. This observation agrees with the results reported by Metzger *et al.* (2005) who noted that areas, characterized by an increasing animal density, present a strong abundance of annuals. We emphasize the therophytization phenomenon discussed by several authors (Floret and Pontanier, 1982; Jauffret, 2001) and we indicate that annualisation is a reality. In general, grazing enhanced species cover. With regard to perennials, it appeared that grazing increase the individual cover (not in density) which was responsible for the increase in species cover and indeed, total vegetation (Le Floc'h *et al*., 1999). In some arid zones, where the evapotranspirative demand is high, controlled grazing reduced the aerial biomass and allowed the root system to meet the water needs (Le Floc'h, 2001). Our result, degradations tend to creep further with time see above, correlate with Heshmatti *et al*. (2002) who show that piospheres expand under continuing grazing pressure for many years after the establishment of the water point.

Despite the small number of sites (four distances on each watering points) in our sample, the results from the PCA confirm our original hypotheses and show the dominance of CS- and S-species in low disturbed sites, CS- and CRS-species at medium disturbance degree and RS-species in the most disturbed sites. Hence three zones are distinguished according to the degree of utilization. The first zone, corresponding to the typical sacrifice area as defined by Graetz and Ludwig (1978), is dominated by annuals. The second zone, moderately grazed, is marked by CRS and CS-species but the third, lightly grazed, is dominated by CS- and S-species. Likely, Van Der Schijff (1959) investigated the rangeland surrounding wells and distinguished five zones according to the degree of utilization. Zones, similar to those of Van Der Schijff (1959), were identified on cattle ranches in the Kalahari of Botswana (Perkins and Thomas, 1993b; Brits *et al*., 2002).

The total variation of the data set can be condensed in two principal components which explain 87.8% of this variation. PC1, that indicates the disturbance degree, is dominated by RS on the negative and CP in the positive side. In contrast to the results reported by Jauffret and Visser (2003) indicating the dominance of CR-species in the most disturbed sites, this study shows a dominance of RS-plants which avoided grazing by rapid development and seed set. Hence it appears that these plants are more resistant to disturbance and stress when the aridity is high. PC2, which focuses on the degree of disturbance around the first watering point, shows a dominance of RS-species in the more disturbed sites (the negative side), a dominance of CRS at medium disturbance and CS- and a dominance of S-species at low disturbance (positive side). This indicates that these stress-tolerant and ruderal taxa (RS) are more adapted to climatic stress and human disruptions (Jauffret and Visser, 2003). Many results already evoked this phenomenon, when they studied the therophytes lawns in the French Mediterranean region (Madon and Médail, 1999 in Jauffret, 2001) when the ruderal and stress tolerant species (RS) are relatively important (in particular annual plants). At the intermediate disturbance, with no or little disturbance, only the competitive dominants can survive (Jauffret and Visser, 2003), while at sufficiently high level of disturbance only fugitive species (annual) can survive (Sagar *et al*., 2003).

The hierarchical classification of 12 distances from watering points according to their floristic characteristics showed that the most disturbed sites are very similar. The exploitation around watering points worsens degradation and leads to homogenisation of the floristic cortege (Jauffret, 2001; Jauffret and Lavorel, 2003). The intense animal activity leads to a notable regression of perennial grasses (significant correlation between W21 and W22). When the duration of exploitation is lower (well 3), however, we cannot observe a significant difference between sites. Knowing that steppes which surround the three wells are dominated mainly by *S. pungens*, a common species between the studied sites, our results indicated that this plant is tolerant to disturbances such as continuous sand movement (Bendali *et al*., 1990) but it cannot tolerate heavy disturbances such as grazing and trampling. The same observation was given by (Fusco *et al*., 1995) which indicated that the perennial grass rate cover increased with distance from water on the good condition range but Soltero *et al*. (1989) reported that grass biomass decreased at a distance of 300 m from water.

The present results, despite the low number of wells and distances away from them, constitute valid hypotheses for future work that considers several wells on skeletal soils and several wells on sandy soils with more number of distances. The importance of such studies is to determine new ecosystem attributes, in order to improve the management of the floristic heritage, guarantee its long-term effectiveness and study the distribution of plant species along a disturbance gradient.

CONCLUSION

In southern Tunisia and especially in its hyper-arid part, the floristic cortege is subjected to several constraints dealing with the climate and soil conditions and human disturbance. The effects of these factors increase the risks of degradation of the natural plant communities. Such degradation leads to changes in the physiognomy and the structure of the vegetation cover, especially in sites submitted to high animal pressures as well as proximity to watering points. The main results of this study highlighted the dominance of RS-species in the more disturbed sites. At medium disturbance CRS-species dominated and CS- appears. Whereas, sites dominated by S- and CS-species could be considered relatively undisturbed because these plants give perennial cover to relatively low disturbed sites. Otherwise, *Stipagrostis pungens* seems to be a species with low tolerance to disturbances and isn't tolerating a very high and long exploitation.

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