Vegetation restoration patterns after rangeland enclosure in arid Tunisia

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Introduction

In Tunisia arid regions, the increase in the rural population density, (Le Floc'h *et al.* 1999) has intensified human pressure on natural resources through ''disturbances'' such as grazing and wood harvesting, land clearing and ploughing, which largely depend on the annual rainfall. About 10% of the steppe area has been taken over by agriculture, shrinking perennial plant cover and a highly degraded vegetation class (Hanafi and Jauffret 2008). This work assesses the vegetation restoration patterns on a protected agricultural field in Tunisian arid rangeland after 15 years of enclosure and protection against plowing.

Material and Methods

Study site

Fieldwork was carried out in an arid region of Sfax (10º42'18"E; 34º45'54") in a private field reserved for almond trees cultivation. Distance between two trees was estimated as 10 m. The area of this field was about 3 hectare. Before enclosure, this field was exposed to ploughing activity during autumn then grazing by sheep during spring, for every year. Climatic data during the study years shows a mean precipitation of 258.8±59.8 and a mean temperature of 20.03±0.20 which were characteristic for this region.

Sampling, index and data analysis

A total of 11 permanent transects, each one 20m long, were randomly located in the study area. The quadrat point method was used to measure the floristic composition and the total plant cover (%). Richness, diversity and dispersion index were calculated. We evaluated the effect of enclosure on vegetation parameters by using one-way ANOVA. We used Canonical Correspondence Analysis (CCA) to examine the influence of environmental variables on species composition in the field.

Results and Discussion

In this study, 72 species were recorded in this protected field with a global density of 5 species/m^2. The specific richness index (Jackknife estimator richness) was about 79.9. Shannon-Winner index of species diversity was 3.35 and Simpson's index was 18.8. Morsita index of dispersion was estimated at 1.22 which indicated an aggregate dispersion of the species in the studied field. For all these values, no significant differences were shown among the three years of studies.

The enclosed field shows 27 families. *Asteraceae*, *Fabaceae* and *Poaceae* with respectively 16, 13 and 11 species were the most abundant families. *Aizoaceae*, *Caryophyllaceae* and *Plantaginaceae* were represented each by 3 species and all the rest of the families (19 families) were represented by only one species for each family (Table 1). The studied field shows equilibrium between two fundamental communities: the restored and native steppic community and the invasive weed community (Table 2). Steppic community was presented by 33 species (45.8%) that contains 15 pasture species. Weed community was presented by 32 species (44.4%) in which 10 were pastoral species. Six species (8.4%) were considered as steppic-weed-pastoral plants. The field also included 1 cultivated species (1.4%). At the density scale, steppic species cover 51.7% of green surface with an absolute density of 8.5 plant/m^2. Weed species cover 29.2% with a density of 4.7 plants/m^2, whereas steppic-pastoral-weed species cover 19.1% with a density of 3.1 plants/m^2.

Table 1. Families and their representative species in the field (27 families and 72 species).

Family	No. spp.	Family	No. Spp.
Aizoaceae	3	*Hyacinthaceae*	1
Amaranthaceae	1	*Malvaceae*	1
Apiaceae	1	*Myrsinaceae*	1
Asparagaceae	1	*Papaveraceae*	2
Asteraceae	16	*plantaginaceae*	3
Boraginaceae	1	*Poaceae*	11
Brassicaceae	1	*Polygonaceae*	1
Caryophyllaceae	3	*Resedaceae*	1
Cleomaceae	1	*Rosaceae*	1
Convolvulaceae	1	*Solanaceae*	1
Dipsacaceae	1	*Urticaceae*	1
Euphorbiaceae	1	*Xanthorrhoeaceae*	1
Fabaceae	13	*Zygophyllaceae*	1
Geraniaceae	2		

Table 2. Vegetation parameters evaluated in the studied field: Types of species: steppic/weed/steppic-weed; Raunkiaer's life form: therophytes and others; Cycles: perennial/ annual; Frequency (%); Relative density (%);Total density/m^2.

Types of sp.			Raunkiaer's LF		Perennnial/ Annual		Frequency (%)			Relative density (%)			Total density (plants/m^2)		
S	W	S/W	Th	Others	P	A	S	W	SW	S	W	SW	S	W	SW
33	32	6	54	16	16	55	52.7	33.9	13.4	51.7	29.2	19.1	8.5	4.7	3.1

This study shows that 19 species that has frequency Fi≥2, were the most frequent and with a clear dominance of steppic over weed species. From this list 11 were forage species. *Bromus madritensis* (Fi=6.29), *Brachypodium distachyon* (Fi=6.12), and *Calendula aegyptiaca* (Fi=5.00) were the most frequent steppic species. *Ononis sicula* (Fi=5.34), *Medicago minima* (Fi=3.36) and *Chrysanthemum coronarium* (Fi=2.84) were the most frequent weeds. However, *Aristida adscensionis* and *Filago germanica* were rare species with a frequency below 1.

Raunkiaer plant-life form classification shows clearly the dominance of herbaceous plants (therophytes) against a regression in shrub-lands which are represented only by some dwarf shrubland species, and the absence of woody species except the cultivated almond tree (*Prunus amygdalus*). Thereby, species distributed in the studied field contain 53 therophytes, 5 chamephytes, 7 hemicryptophytes, 5 geophytes and 2 phanerophytes. Annual plants (76.4%, 55 species) dominated perennial plants (22.2%, 16 species). Perennial Plant Cover (PPC) was about 16.6%, indicating a medium degraded land in the scale of Hanafi (Hanafi & Jauffret 2008).

Spatial distribution pattern of species was recognized by a detrended canonical correspondence analysis (CCA), and the environmental factors were separated into distinct groups along the CCA axis. This reflected the ecological relationships between species and their environments, and the distribution pattern of species in this field. Spatial distribution pattern of species was recognized by a detrended canonical correspondence analysis (CCA), and the environmental factors were separated into distinct groups along the CCA axis. This reflected the ecological relationships between species and their environments, and the distribution pattern of species in this field.

Dispersion of species in CCA analysis described 5 essential groups: (1) Dominant group: represented by steppic species like: *Aegilops geniculata (S/W)*; (2) Soil group: species like *Argyrolobium uniflorum (S/P)* that were very attached to their soil type; (3) Road group: species that can't tolerate activities near road (human disturbance) and grow long away from the road like *Pallenis spinosa* (S); (4) Rare communities: characterized by only 1 species per family and also they have the lower frequency like *Anagallis arvensis* (W); and (5) Homogenous group: containing all of the rest of the species located in the center of the graph. This group was characterized by medium values for all the variables measured and observed.

Discussion and conclusion

Steppe clearing means total biomass destruction, the highest degree of disturbance and degradation (Visser *et al.* 1997). Enclosure strategy was reported to be excellent for the restoration of degrade rangeland and the increase of biodiversity (Abebe *et al.* 2006). In this work, enclosure for 15 years of a degraded rangeland restored about 72 species with a Jackknife index with 79.9. Allred *et al.* (2012) reported that Richness of 70 indicated a very low degraded land. This finding can be proved by perennial plant cover PPC of 16.6% which indicated also a medium degraded land at Hanafi scale (Hanafi and Jauffret 2008).

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