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Diversity of desert rangelands of Tunisia

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A B S T R A C T

Plants are important components of any rangeland. However, the importance of desert rangeland plant diversity has often been underestimated. It has been argued that desert rangelands of Tunisia in good ecological condition provide more services than those in poor ecological condition. This is because rangelands in good condition support a more diverse mixture of vegetation with many benefits, such as forage for livestock and medicinal plants.

Nearly one-quarter of Tunisia, covering about 5.5 million hectares, are rangelands, of which 87% are located in the arid and desert areas (45% and 42%, respectively). Here, we provide a brief review of the floristic richness of desert rangelands of Tunisia. Approximately 135 species are specific to desert rangelands. The predominant families are Asteraceae, Poaceae, Brassicaceae, Chenopodiaceae, and Fabaceae. These represent approximately 50% of Tunisian desert flora.

1. Introduction

Rangelands cover about 40% of the world's land area (White et al., 2000) and are as ecologically important as rain forests (Casper, 2009). Arid ecosystems comprise one-third of the global land surface, support 14% of the world's inhabitants, and provide a significant share of the world's agriculture (Nicholson, 2011). Arid environments may not be the most hospitable places on Earth, but the 30% or more of the global land surface that they cover does support an ever-growing human population and has fascinated explorers and scientists for centuries (Thomas, 2011).

Desert rangelands, like other arid rangelands, suffer from severe natural disturbances such as high rates of soil degradation and extremely low rainfall distribution, which, in part, may be caused by the climate due to their geographical location (Le Houérou, 2009). These problems are generally compounded by anthropogenic factors such as overgrazing and wood harvesting (Le Houérou, 2009). Taken together, these factors contribute to decreased biological diversity and rangeland productivity, as well as high rates of erosion, all of which are widespread problems in Tunisia (Gamoun, 2012; Tarhouni et al., 2014).

Tunisia is a small country, yet has highly diverse climatic and edaphic conditions (Floret and Pontanier, 1982). Rangelands constitute the largest use of land in Tunisia, where pastoralism remains vital. Furthermore, rangelands not only provide important goods and services but also represent a tremendous source of biodiversity. Nearly one quarter of Tunisia is rangeland, occupying about 5.5 million hectares, 87% of which are located in the arid and desert areas (45% and 42%, respectively). In Northern Africa, the term “desert” is most properly applied to zones that receive less than 100 mm of average annual rainfall, are little affected by human activity, and possess a very low production potential or likelihood of future evolution (Floret and Pontanier, 1982). The majority of the rangelands of south Tunisia exhibit moderate or severe desertification, and are being damaged and made less productive by mismanagement (Nefzaoui et al., 2011). Desertification includes deterioration of ecosystems and degradation of various forms of vegetation (Le Houérou, 1969).

The causes of desertification are myriad and often interconnected. They include overgrazing and overcutting for firewood and timber, inappropriate farming, poor irrigation, and poor management, which has led to salinity problems, mining, construction of highways and utility corridors, air pollution, recreational activities, particularly off-road vehicle recreation, and climate change (Bainbridge, 2007). The underlying causes of dryland degradation are commonly economic and cultural, rather than ecological (Hallsworth, 1987; Carney and Farrington, 1998; Chambers et al., 1991). The primary causes of current degradation in some arid areas have been identified as intensified and irrational human activities and climate variability (Ouled Belgacem and Louhaichi,

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2013). Overgrazing is the main cause of rangeland degradation and desertification (Le Houérou, 1996; Ibáñez et al., 2007; Gamoun, 2014a, 204b). It may be driven by economic pressure, greed, desperation, and sometimes ignorance (Bainbridge, 2007). For example, Africa as a whole contributes 36% of the world's total land degraded by overgrazing and 49%–90% of the continent's rangelands are believed to already be in the process of long-term degradation (Hudak, 1999).

The primary effects of overgrazing have been reported to be mainly of a biotic nature, resulting in a decrease in plant cover, and in particular, a loss of perennials, which constitutes one of the most significant indicators of desertification (Verstraete and Schwartz, 1991; Aronson et al., 1993). The main consequences of overloading rangelands are summarized as follows: (i) an increase in cultivated land decreases rangeland area; (ii) an increase in livestock number decreases rangeland area; (iii) rangeland is degraded, decreasing both forage yield and carrying capacity (Zhao et al., 1994).

Desertification is largely a response to climatic trends and fluctuations in the availability of resources (Wang et al., 2005). Climate variability (high temperatures and low rainfall distribution) negatively affects rangeland productivity (Peters et al., 2013), and is most severe in dryland areas (Le Houérou, 1996; Darkoh, 1998; Harris, 2010; Reynolds, 2013). Sequences of dry years have been a major climatic force in the degradation of rangelands (Verner, 2013). The unreliable distribution of rainfall is an important component which contributes significantly towards the deterioration of rangeland productivity in the dry areas (Floret et al., 1978; Gamoun, 2013, 2014a, 2014b, 2016a, 2016b). Evidence of this is provided through long term annual rainfall figures in Tunisia, which reveal that desert rangelands are characterized by a dry climate, with hot dry summers and winters and very low levels of precipitation—about 75 mm—from 1997 to 2016 (Figs. 1 and 2).

The flora of desert areas has always attracted ecologists from around the world (Ward, 2016). As a result, the arid zones of Tunisia have been extensively studied over the past fifty years; indeed, the arid zone flora, climate, ecology, hydrogeology, and soils of Tunisia are among the best known in the world.

By any measure, the world's arid rangelands qualify as modest repositories of biodiversity (Shachak et al., 2005). The biological diversity of many desert and semi-desert areas continues to be threatened by many different human activities, such as overharvesting of firewood and overgrazing (Bainbridge, 2007). In these areas, where overgrazing and wood collection drive changes in the structure and functioning of rangelands, any decrease in perennial plant cover and plant species diversity leads to changes in floristic composition, soil erosion, and modifications in nutrient, water, and energy flow (Floret et al., 1978; Jauffret and Lavorel, 2003).

In this paper, we provide a brief review of the floristic richness of part of a desert rangeland in Tunisia.

2. Rangeland diversity

Researchers in Tunisia have focused a lot of attention on rangelands as well as on plant diversity and community ecology (Ouled Belgacem et al., 2011; Tarhouni et al., 2015). Tunisia's rangelands span a wide variety of environments from the arid steppe to desert rangelands of southern Tunisia. As in all Mediterranean countries, these steppe zones were previously used mainly for grazing and have been subjected to severe pressure from an increasing population, which has slowly stabilized (Floret and Hadjej, 1977). In response to climatic conditions and grazing, the species composition, diversity and abundance, community structure, and plant life forms also changed (Ouled Belgacem et al., 2011; Tarhouni et al., 2015; Gamoun et al., 2016a, 2016b). Heavy grazing has left

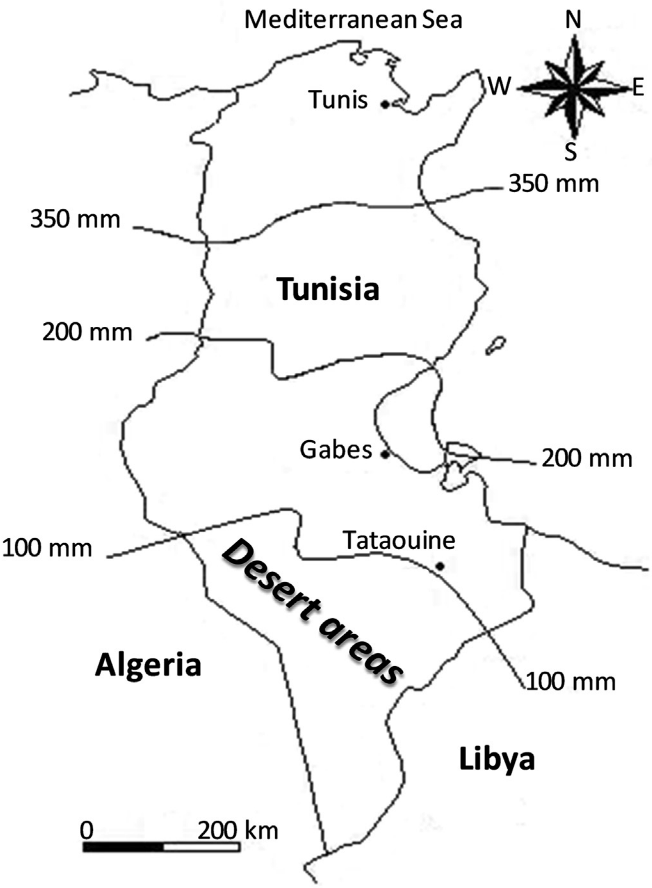

Fig. 1. Isohyetal map of Tunisia (curves with mm values represent mean annual rainfall).

Tunisian ecosystems with a homogenized flora consisting only of species that are unpalatable and highly tolerant to herbivory and other forms of disturbance (Gondard et al., 2003; Jauffret and Lavorel, 2003). Sand deposits due to strong desert winds also further decrease vegetation growth by burying some plant parts, gradually decreasing the floristic variety (Bendali et al., 1990).

Sustainable rangeland management approaches have now been used to protect some sections of these desert rangelands in an effort to reduce the effects of degradation by increasing the vegetation composition, spatial distribution, and structure (Floret, 1981; Ouled Belgacem et al., 2008; Gamoun et al., 2010; Tarhouni et al., 2015). As a result, such sustainable practices have yielded diverse rangeland resources, with an abundant and rich diversity of plant species (Figs. 3 and 4 and Table 1).

Tunisia's rangelands support 2162 species (Le Floc'h et al., 2010). In addition, rangelands in pre-Saharian Tunisia harbor a rich flora which includes about 836 species (Ferchichi, 2000). Approximately 135 of these species are specific to desert rangelands (Gamoun, 2012). Five predominant plant families, Asteraceae, Poaceae, Brassicaceae, Chenopodiaceae, and Fabaceae, represent approximately 50% of Tunisian desert flora (Fig. 5).

In the Tunisian desert rangelands the abundance of plant life forms includes 75 species of Therophyte (49%), 38 species of Chamaephyte (25%), 20 species of Hemicryptophyte (13%), 11 species of Nanophanerophyte (7%), 7 species of Geophytes (5%) and 2 species of Phanerophyte (1%). Anthropogenic disturbances in dry habitats have been shown to generate an increase in micro-scale species richness (Holzaphel et al., 1992). As for Therophytes, their

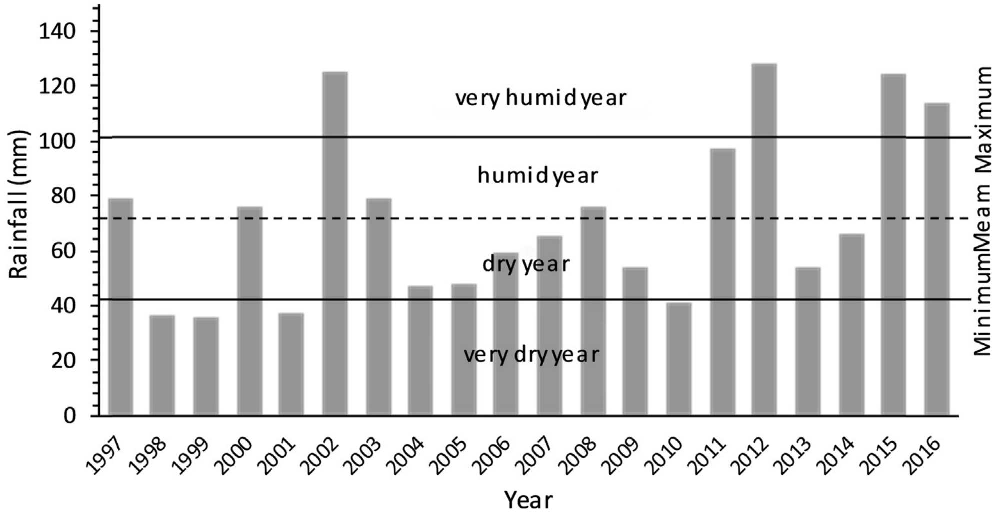

Fig. 2. Rainfall variation between 1997 and 2016 in Southern Tunisia (Remada).

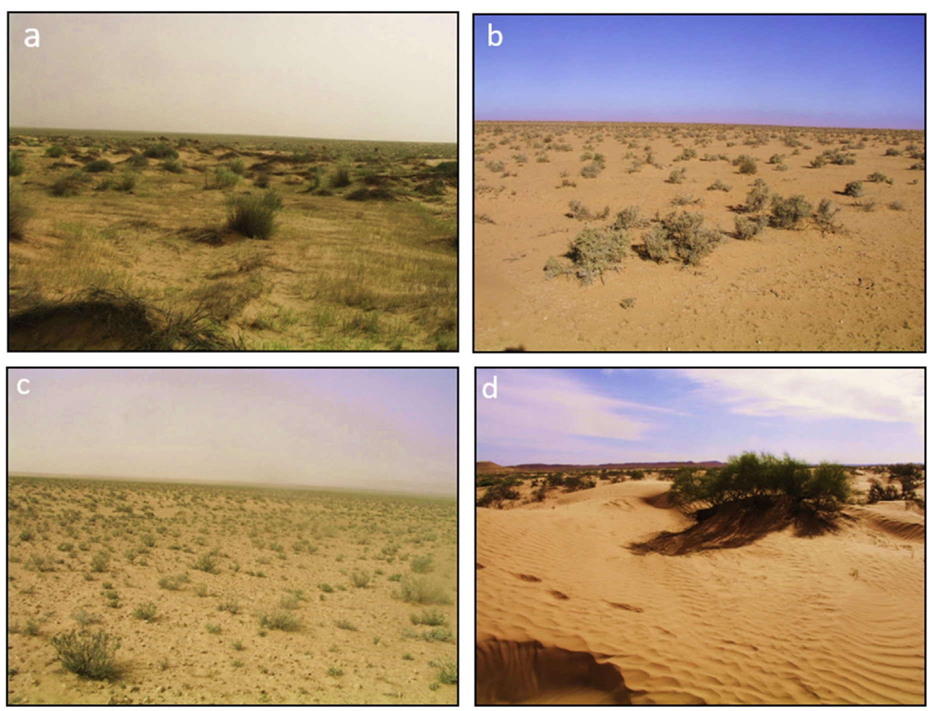

Fig. 3. Photographs showing different rangelands types: (**a**) Psammophytes of *Stipagrostis pungens* on sand accumulation being grazed by camels from the typical desert vegetation site where protecting the vegetation promotes infiltration and minimizes runoff. (**b**) Example of an almost flat, sandy area unit, where the vegetation is dominated by *Haloxylon schmittianum*. (**c**) Good stand of *Anthyllis henoniana* community type in stony terrain showing the spacing of the shrubs. (**d**) *Retama raetam* growing on sand dunes.

presence may be explained in particular by the large number of micro-habitats available to annual plants that have rapid germination and growth, thus increasing their abundance (Gamoun et al., 2011, 2012). Chamaephytes are over-represented in arid rangelands because they are highly adapted to arid conditions (Raunkiaer, 1934; Orshan et al., 1984; Floret et al., 1990; Jauffret and Visser, 2003; Gamoun et al., 2012). The low abundance of Hemicryptophytes reduces competition for soil moisture to the benefit of Chamaephytes (Gamoun et al., 2011) (Fig. 6). On the other hand, the low presence of Geophytes mainly reflects the long period of drought in these arid rangelands (Gamoun et al., 2011, 2012).

Grazing is not the only driver in arid ecosystems. Variable and unpredictable precipitation regimes, as well as limited soil nutrient concentrations are also major factors that determine arid ecosystem features (Noy-Meir, 1985; Walker, 1987). Gamoun et al. (2012) reported changes in the plant community composition in response to grazing and soil texture. In arid rangelands, edaphic factor availability strongly determines vegetation, and soil type has been found to limit arid plant dynamics within rangelands by affecting grazing regimes practices (Gamoun, 2012). Each soil type is characterized by specific vegetation. Range production, cover, and species richness are low and highly irregular in arid zones, and

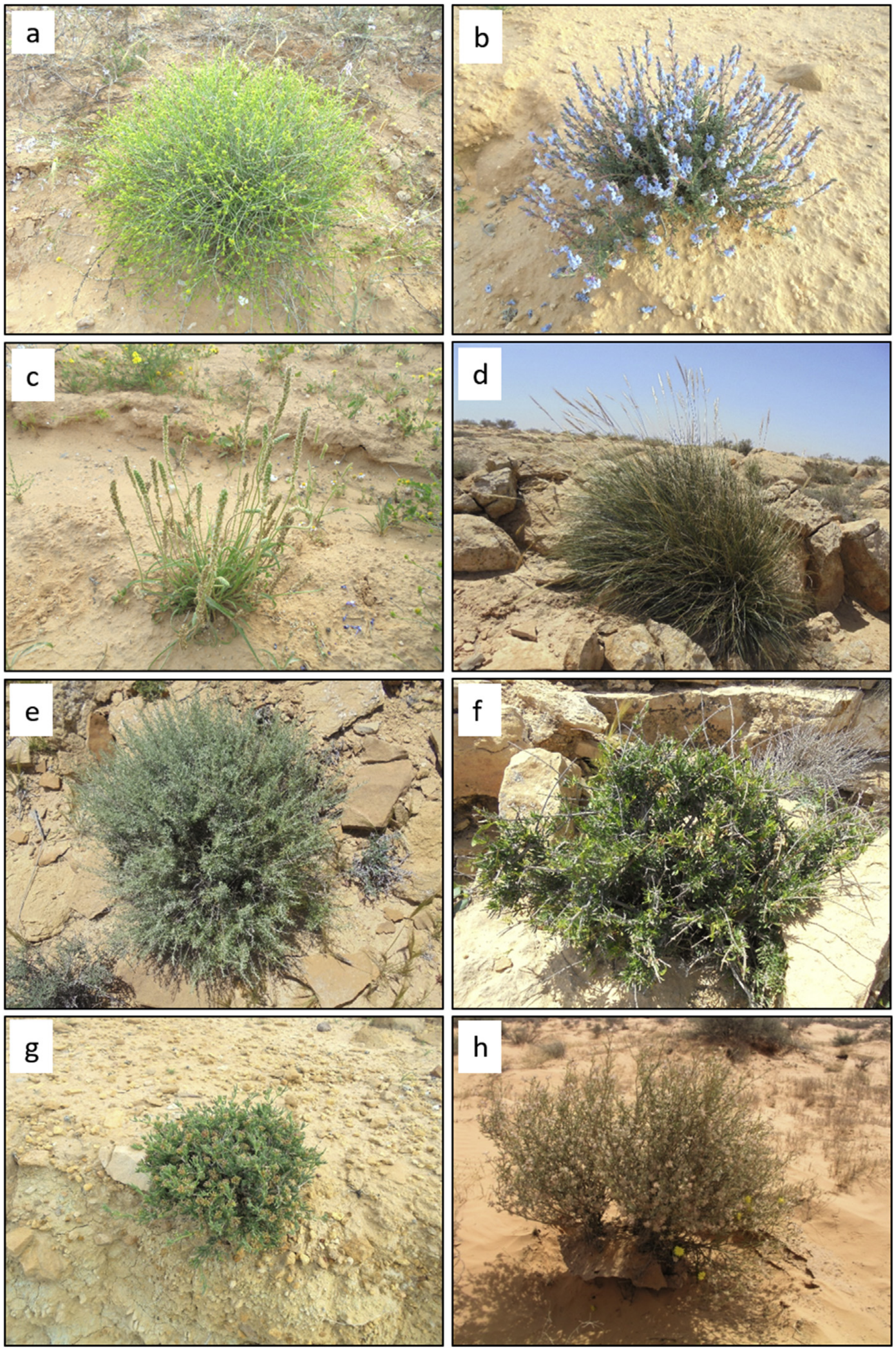

Fig. 4. Some plant species of desert rangelands of Tunisia (photos by Mouldi Gamoun); (**a**) *Rhanterium suaveolens* Desf., (**b**) *Echiochilon fruticosum* Desf., (**c**) *Plantago albicans* L., (**d**) *Stipa tenacissima* L., (**e**) *Artemisa herba-alba* Asso, (**f**) *Periploca angustifolia* Labill., (**g**) *Gymnocarpos decander* Forssk., (**h**) *Anthyllis henoniana* Batt., (**i**) *Stipagrostis ciliata* (Desf.) de Winter (**j**) *Ziziphus lotus* (L.). Lam., (**k**) *Helianthemum kahiricum* Delile, (**l**) *Retama raetam* (Forssk.) Webb & Berthel., (**m**) *Haloxylon scoparium* Pomel., (**n**) *Haloxylon schmittianum* Pomel., (**o**) *Stipagrostis pungens* (Desf.) de Winter, (**p**) *Stipa lagascae* Roem. & Schult.

always spatially limited to sandy and gravelly soils (Gamoun, 2012). The introduction of herbivores is generally believed to reduce plant diversity. Selective grazing by livestock has been shown to negatively affect plant diversity and species composition in arid ecosystems. Heavy grazing of natural rangelands leads to loss of several highly palatable species (Louhaichi et al., 2009). However, the soil type influences the response to grazing. For example, vegetation response on sandy and gravelly soils is more diversified and more productive than on limestone and loamy soil, whereas the latter is more adapted to grazing pressure (Gamoun et al., 2011). On the whole, grazing causes a spatial homogenization of the plant community in areas dominated by Chamaephytes. Under grazed conditions, the vegetation is dominated by perennial species which are generally present in the ungrazed rangelands. These perennial species may benefit from an adaptation caused by drought and grazing (Fensham et al., 2010). The absence of perennial species such as *Echiochilon fruticosum* Desf., *Stipa lagascae* Roem. & Schult., and *Stipagrostis ciliata* (Desf.) de Winter. is due to their high

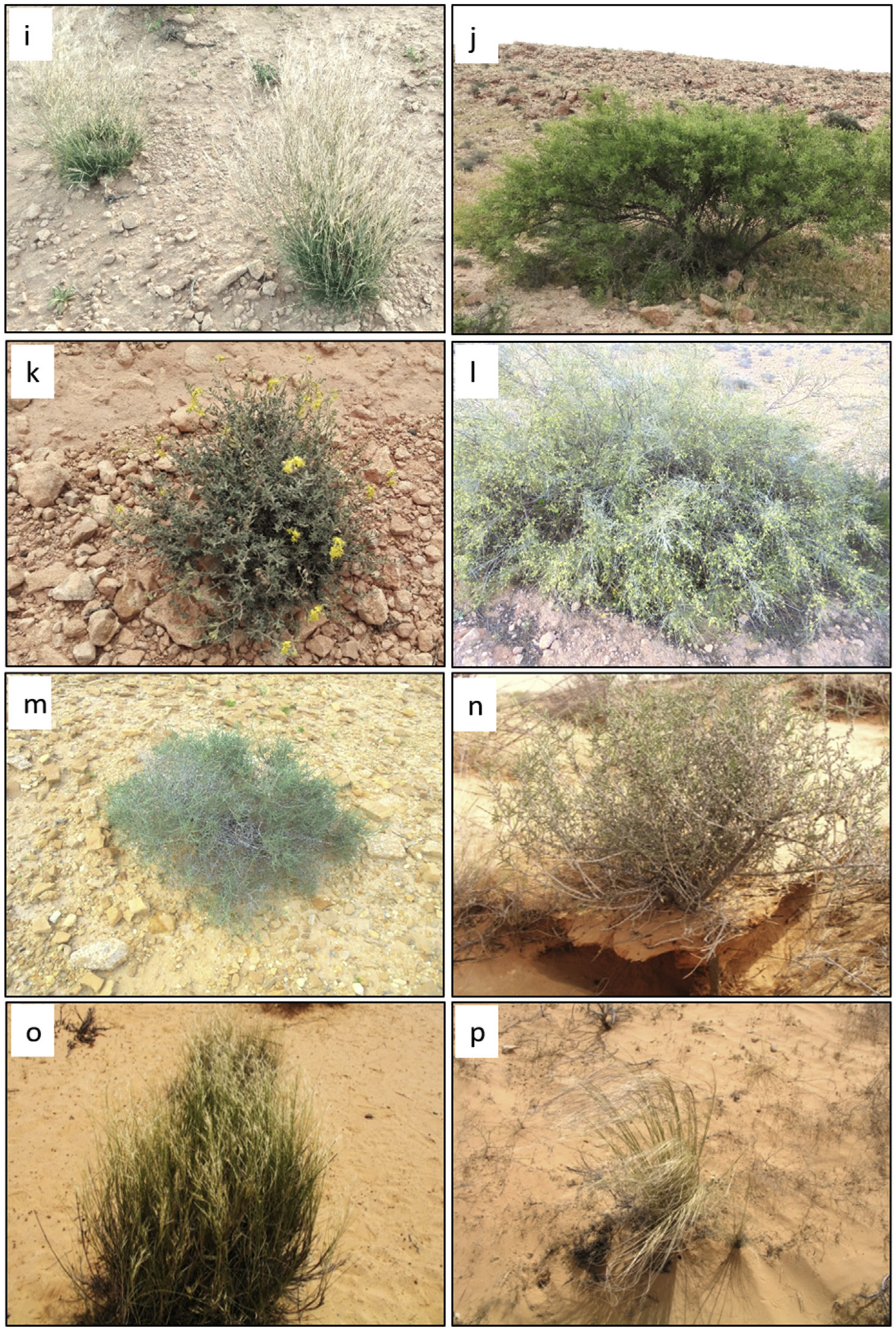

Fig. 4. (*continued*).

palatability. Alternatively, perennial species may have decreased because of intensive grazing and possibly from a trampling effect from livestock in the sandy and gravelly soils of such rangelands (Gamoun et al., 2011). Otherwise, on ideal grazing land, there is a greater variety of plant species available for selective grazing and grazing animals are highly selective when given the opportunity. Thus, positive manipulation of the soil-forage plant-grazing animal complex should play a central role in any grazing management strategy for arid rangelands (Vallentine, 2001).

Few studies have evaluated the effects of controlled grazing on plant diversity in arid areas. Gamoun (2014) reported that vegetation diversity was higher in protected areas than in heavily grazed areas in the desert rangeland of southern Tunisia. In contrast, moderate grazing did not significantly affect species richness, diversity index, or species composition. In another study in the same area, Gamoun and Hanchi (2014) found that plant diversity increased as grazing intensity decreased. Ward et al. (2000) and Jauffret and Lavorel (2003), among others, have shown that palatability may play an important role in determining the effects of grazing on arid ecosystems. For these studies, however, the differences in plant diversity between the ungrazed and lightly grazed areas were small. The largest difference between the ungrazed and heavily-grazed sites was the disappearance of very palatable species under a heavy grazing treatment, including *Anabasis*

Table 1
Family, life form, and livestock acceptability index of main desert species of Tunisia. 0: Refusal or Toxic; 1: Occasionally palatable; 2: Few palatable; 3: Palatable; 4: Very palatable; 5: Extremely palatable.

Species	Family	Life form	Acceptability index
Anthyllis henoniana Batt.	Fabaceae	Chamaephyte	4
Ajuga iva (L.) Schreb.	Lamiaceae	Therophyte	3
Allium roseum L.	Alliaceae	Geophyte	2
Anabasis oropediorum Maire.	Chenopodiaceae	Chamaephyte	5
Anacyclus clavatus (Desf.) Pers.	Asteraceae	Therophyte	4
Anacyclus monanthos ssp *cyrtolepidioides* (Pomel)	Asteraceae	Therophyte	4
Anarrhinum fruticosum Desf. subsp. *Brevifolium*	Scrophulariaceae	Chamaephyte	1
Argyrolobium uniflorum (Deene.) Jaub. & Spach.	Fabaceae	Chamaephyte	5
Arnebia decumbens (Vent.) Coss. & Kralik	Boraginaceae	Therophyte	2
Artemisia campestris L.	Asteraceae	Chamaephyte	2
Artemisia herba-alba Asso	Asteraceae	Chamaephyte	2
Asphodelus refractus Boiss.	Asphodelaceae	Therophyte	1
Asphodelus tenuifolius Cav.	Asphodelaceae	Therophyte	0
Astragalus armatus Willd.	Fabaceae	Chamaephyte	2
Astragalus asterias Steven.	Fabaceae	Therophyte	2
Astragalus corrugatus Bertol.	Fabaceae	Therophyte	2
Atractylis cancellata L.	Asteraceae	Therophyte	1
Atractylis carduus (Forssk.) C. Chr.	Asteraceae	Chamaephyte	0
Atractylis prolifera Boiss.	Asteraceae	Therophyte	1
Atractylis serratuloides Sieber ex Cass.	Asteraceae	Hemicryptophyte	2
Atriplex halimus L.	Chenopodiaceae	Nanophanerophyte	3
Bassia muricata (L.) Asc.	Chenopodiaceae	Therophyte	2
Brassica tournefortii Gouan.	Brassicaceae	Therophyte	3
Calendula tripterocarpa Rupr.	Asteraceae	Therophyte	1
Calicotome villosa (Poir.) Link.	Fabaceae	Nanophanerophyte	3
Calligonum azel Maire	Polygonaceae	Nanophanerophyte	3
Calligonum polygonoides L.	Polygonaceae	Nanophanerophyte	4
Carthamus eriocephalus (Boiss.) Greuter	Asteraceae	Therophyte	1
Centaurea furfuracea Coss. & Durieu.	Asteraceae	Therophyte	3
Citrullus colocynthis (L.) Schrad.	Cucurbitaceae	Hemicryptophyte	0
Cleome amblyocarpa Barratte & Murb.	Cleomaceae	Hemicryptophyte	0
Convolvulus supinus Coss. & Kralik.	Convolvulaceae	Therophyte	2
Cuscuta epithymum (L.) L.	Cuscutaceae	Therophyte	0
Cutandia dichotoma (Forssk.) Batt. & Trab.	Poaceae	Therophyte	4
Cynara cardunculus L. subsp. *Cardunculus*	Asteraceae	Hemicryptophyte	0
Cynodon dactylon (L.) Pers.	Poaceae	Geophyte	5
Cynomorium coccineum L.	Cynomoriaceae	Geophyte	0
Daucus sahariensis Murb.	Apiaceae	Therophyte	3
Deverra denudata (Viv.) R. Pfiesterer & Podlech.	Apiaceae	Chamaephyte	2
Deverra tortuosa (Desf.) DC.	Apiaceae	Chamaephyte	2
Dipcadi serotinum (L.) Medik.	Hyacinthaceae	Geophyte	0
Diplotaxis harra (Forssk.) Boiss.	Brassicaceae	Therophyte	2
Diplotaxis simplex Spreng.	Brassicaceae	Therophyte	3
Echinops spinosus L.	Asteraceae	Therophyte	0
Echiochilon fruticosum Desf.	Boraginaceae	Chamaephyte	5
Enarthrocarpus clavatus Godr.	Brassicaceae	Therophyte	2
Ephedra altissima Desf.	Ephedraceae	Nanophanerophyte	2
Erodium crassifolium L'Hér.	Geraniaceae	Therophyte	3
Erodium glaucophyllum (L.) L'Hér.	Geraniaceae	Therophyte	1
Erucaria pinnata (Viv.) Täckh. & Boulos	Brassicaceae	Therophyte	3
Eryngium ilicifolium Lam.	Apiaceae	Therophyte	0
Euphorbia retusa Forssk.	Euphorbiaceae	Therophyte	0
Euphorbia terracina L.	Euphorbiaceae	Therophyte	0
Fagonia cretica L.	Zygophyllaceae	Therophyte	0
Fagonia glutinosa Delile.	Zygophyllaceae	Therophyte	0
Farsetia aegyptia Turra.	Brassicaceae	Chamaephyte	3
Filago germanica L.	Asteraceae	Therophyte	1
Gagea fibrosa (Desf.) Schult. & Schult. f.	Liliaceae	Geophyte	0
Gymnarrhena micrantha Desf.	Asteraceae	Therophyte	2
Gymnocarpos decander Forssk.	Caryophyllaceae	Chamaephyte	5
Halocnemum strobilaceum (Pall.) M. Bieb.	Plumbaginaceae	Hemicryptophyte	2
Haloxylon schmittianum Pomel.	Chenopodiaceae	Chamaephyte	1
Haloxylon scoparium Pomel.	Chenopodiaceae	Chamaephyte	1
Haplophyllum tuberculatum (Forssk.) Juss.	Rutaceae	Chamaephyte	0
Helianthemum kahiricum Delile.	Cistaceae	Chamaephyte	4
Helianthemum sessiliflorum (Desf.)	Cistaceae	Chamaephyte	5
Herniaria fontanesii J. Gay.	Caryophyllaceae	Chamaephyte	3
Hippocrepis areolata Desv.	Fabaceae	Therophyte	4
Ifloga spicata (Forssk.) Sch. Bip.,	Asteraceae	Therophyte	1
Kickxia aegyptiaca (L.) Nábelek.	Scrophulariaceae	Chamaephyte	2
Koelpinia linearis Pall.	Asteraceae	Therophyte	4
Launaea angustifolia (Desf.) Muschl.	Asteraceae	Therophyte	4
Launaea capitata (Spreng.) Dandy	Asteraceae	Therophyte	3

Table 1 (*continued*)

Species	Family	Life form	Acceptability index
Launaea fragilis (Asso) Pau.	Asteraceae	Therophyte	2
Launaea nudicaulis (Linn.) Hook. f.	Asteraceae	Therophyte	4
Lavandula multifida L.	Lamiaceae	Chamaephyte	0
Limoniastrum guyonianum Boiss.	Plumbaginaceae	Hemicryptophyte	3
Limoniastrum monopetalum (L.) Boiss.	Plumbaginaceae	Hemicryptophyte	3
Limonium pruinosum (L.) Chaz.	Plumbaginaceae	Hemicryptophyte	1
Linaria laxiflora Desf.	Scrophulariaceae	Therophyte	1
Lobularia libyca (Viv.) Meissn.	Brassicaceae	Therophyte	3
Lotus halophilus Boiss. & Spruner	Asteraceae	Therophyte	3
Lycium shawii Roem. & Schult.	Solanaceae	Nanophanerophyte	2
Lygeum spartum Loefl. ex L.	Poaceae	Hemicryptophyte	2
Matthiola longipetala (Vent.) DC.	Brassicaceae	Therophyte	2
Medicago minima (L.) L.	Fabaceae	Therophyte	3
Moricandia arvensis (L.) DC.	Brassicaceae	Chamaephyte	2
Muricaria prostrata (Desf.) Desv.	Brassicaceae	Therophyte	3
Neurada procumbens L.	Neuradaceae	Therophyte	2
Nitraria retusa (Forssk.) Asch.	Nitrariaceae	Nanophanerophyte	2
Nolletia chrysocomoides (Desf.) Cass. ex Less.	Asteraceae	Chamaephyte	2
Nonea calycina (Roem. & Schult.) Selvi	Boraginaceae	Therophyte	2
Pallenis hierochuntica (Michon) Greuter.	Asteraceae	Therophyte	2
Paronychia arabica (L.) DC.	Caryophyllaceae	Therophyte	1
Peganum harmala L.	Zygophyllaceae	Chamaephyte	0
Pennisetum divisum (Forssk. ex J.F. Gmel.) Henrard	Poaceae	Hemicryptophyte	3
Periploca angustifolia subsp. *angustifolia* (Labill.)	Asclepediaceae	Nanophanerophyte	3
Plantago albicans L.	Plantaginaceae	Hemicryptophyte	5
Plantago ovata Forssk.	Plantaginaceae	Therophyte	3
Polygonum equisetiforme Sibth. et Sm.	Polygonaceae	Hemicryptophyte	4
Reaumuria vermiculata L.	Tamaricaceae	Chamaephyte	0
Reichardia tingitana (L.) Roth	Asteraceae	Therophyte	2
Reseda alba L. subsp. *Alba*	Resedaceae	Therophyte	1
Retama raetam (Forssk.) Webb & Berthel.	Fabaceae	Nanophanerophyte	3
Rhanterium suaveolens Desf.	Asteraceae	Chamaephyte	2
Rhus tripartita (Ucria) Grande	Anacardiaceae	Nanophanerophyte	2
Salsola tetragona Delile	Chenopodiaceae	Phanerophyte	2
Salsola tetrandra Forssk.	Chenopodiaceae	Phanerophyte	2
Salsola vermiculata L.	Chenopodiaceae	Chamaephyte	3
Salvia aegyptiaca L.	Lamiaceae	Chamaephyte	3
Salvia verbenaca L.	Lamiaceae	Chamaephyte	3
Savignya parviflora (Delile) Webb.	Brassicaceae	Therophyte	3
Scabiosa arenaria Forssk.	Dipsacaceae	Therophyte	2
Schismus barbatus (L.) Thell.	Poaceae	Therophyte	4
Scorzonera undulata Vahl.	Asteraceae	Geophyte	4
Senecio gallicus L.	Asteraceae	Therophyte	1
Stipa capensis Thunb.	Poaceae	Therophyte	2
Stipa lagascae Roem. & Schult.	Poaceae	Hemicryptophyte	4
Stipa parviflora Desf.	Poaceae	Hemicryptophyte	4
Stipa tenacissima L.	Poaceae	Hemicryptophyte	3
Stipagrostis ciliata (Desf.) de Winter.	Poaceae	Hemicryptophyte	4
Stipagrostis obtusa (Delile) Nees.	Poaceae	Hemicryptophyte	4
Stipagrostis plumosa (L.) Munro.	Poaceae	Hemicryptophyte	4
Stipagrostis pungens (Desf.) de Winter.	Poaceae	Hemicryptophyte	3
Suaeda vermiculata Forssk. ex J.F. Gmel.	Chenopodiaceae	Chamaephyte	3
Tamarix gallica L.	Tamaricaceae	Nanophanerophyte	2
Teucrium alopecurus De Noé	Primulaceae	Chamaephyte	1
Teucrium polium L.	Lamiaceae	Chamaephyte	2
Thesium humile Vahl, Symb.	Santalaceae	Therophyte	1
Thymelaea hirsuta (L.) Endl.	Thymelaeaceae	Chamaephyte	0
Thymelaea microphylla Coss. & Durieu.	Thymelaeaceae	Chamaephyte	2
Traganum nudatum Delile.	Chenopodiaceae	Chamaephyte	3
Tribulus terrestris L.	Zygophyllaceae	Therophyte	1
Ziziphus lotus (L.) Lam.	Rhamnaceae	Nanophanerophyte	2
Zygophyllum album L. f.	Zygophyllaceae	Chamaephyte	0

oropediorum (Maire), *Cutandia dichotoma* (Forssk.) Batt. & Trab., *E. fruticosum* (Desf.), *Helianthemum kahiricum* (Delile), *Helianthemum sessiliflorum* (Desf.), *Hippocrepis areolata* Desv., *Launaea nudicaulis* (Linn.) Hook. f., *Launaea angustifolia* (Desf.) Muschl., *Koelpinia linearis* Pall., *Polygonum equisetiforme* S. & Sm., *Scorzonera undulata* Vahl. and *S. lagascae* Roem. & Schult., (Gamoun, 2014a, 2014b). Jauffret and Lavorel (2003) note that long-spine species such as *Astragalus armatus* Willd., and unpalatable, highly fibrous species such as *Thymelaea hirsuta* (L.) Endl., are dominant in arid Tunisian rangelands, and suggest this is a consequence of long grazing history. Similarly, unpalatable shrubs such as *Haloxylon scoparium* Pomel., *T. hirsuta* (L.) Endl., and *Anabasis articulata* (Forssk.) Moq., are often dominant in heavily grazed arid regions of the Middle East (Ward, 2004).

Deserts are biologically stressful environments and plants have acquired two principal strategies to cope with the harsh arid conditions and herbivory: avoidance and tolerance (Laity, 2008). These strategies allow plants to cope with heat and drought to ensure that

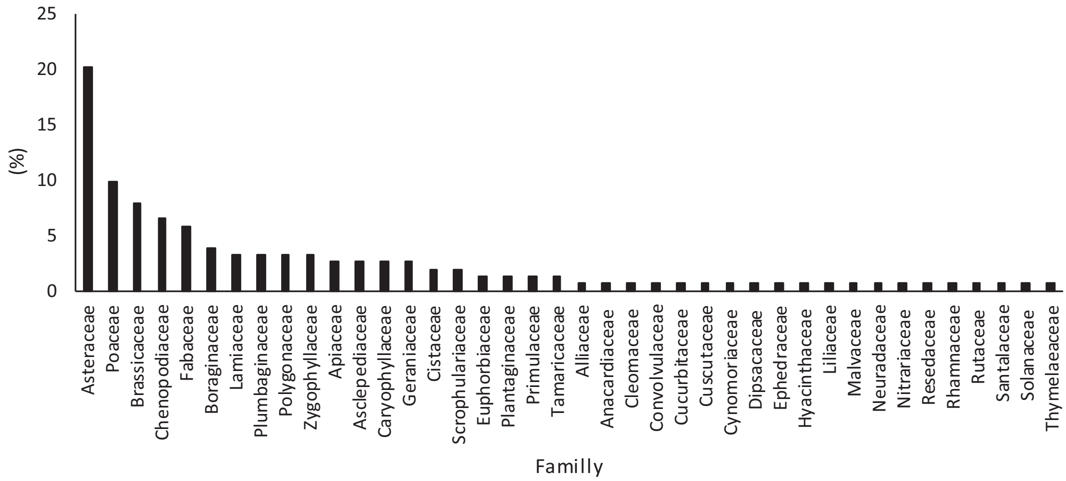

Fig. 5. Family distribution of plant species of desert rangelands of southern Tunisia (%).

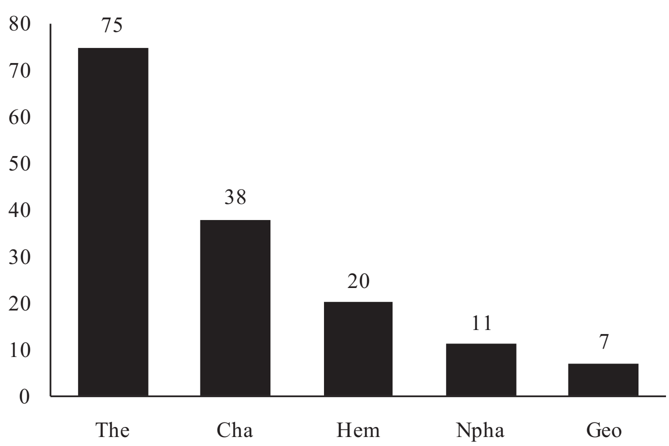

Fig. 6. Life form distribution of plant species of desert rangelands of southern Tunisia (%). The: Therophyte; Cha: Chamaephyte; Hem: Hemicryptophyte; Npha: Nanophanerophyte; Geo: Geophyte.

neither internal temperatures nor tissue dehydration reach deadly levels. The majority of the flora in deserts are evaders, surviving stressful periods by living permanently or temporarily in cooler and/or moister microhabitats (Laity, 2008).

3. Conclusion

Many plants live in deserts, but it is only xerophytes that can withstand and live under long-term dry conditions. Asteraceae, Poaceae, Brassicaceae, Chenopodiaceae, and Fabaceae represent approximately 50% of Tunisian desert flora. This diversity provides many benefits that can meet the demands of both the local people for medicinal plants and fruits, as well as livestock requirements through providing forage. Mismanagement and climate change have gradually destroyed previously productive ecosystems. To reverse the degradation and desertification of these natural resources, restoration and improved management is essential.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.pld.2018.06.004.

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