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(RESEARCH ARTICLE)

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Floristic diversity and plant composition of the arid and Saharan zones of southern Tunisia

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Abstract

Spontaneous plants in arid and desert areas of Tunisia are now experiencing a resurgence of interest not only because of the possibilities of their use for multiple economic and ecological purposes, but also because of their great capacity for potential climate change adaptation.

Often considered underused and neglected species, plants in arid and desert areas are of considerable importance.

The purpose of this work is to provide knowledge relating to flora and Tunisian vegetation in arid zones. They are structured around various aspects relating to the characterization of this natural and biological wealth and its impact on the quality of the environment. In this work, we studied the flora of the different regions visited (Tataouine, Medenine, Tozeur, Gabes and Kebeli) in southern Tunisia and we surveyed the botanical composition and species diversity in the governorate of Tataouine region during the spring season of 2018. The flora contained about 279 species belonging to 58 families, with 54% annuals and 46% perennials.

Keywords: South of Tunisia; Flora; Diversity; Species richness; Drylands

1. Introduction

Located in North Africa, Tunisia is situated between longitudes 7° and 12°E and the latitudes 32° and 38°N. It is with the junction of the Western and Eastern Mediterranean, and covers a surface of 164 000 km^2, which is the three quarters of arid and desert regions including in particular the steppe zone in which the northern limit coincides appreciably with the isohyet of 350 mm [1-2].

Climate change and human activity represent a big threat to biodiversity [3-4-5]. In fact, the rangelands have been subjected to intensive anthropogenic and climatic disturbances, such as overgrazing and drought over a long period of time, and their overall condition is deteriorating [4–5]. The continuous damage to biodiversity increases the rate of species extinctions, which undermines our capacity to combat desertification, reduce poverty, increase food security, and exclude invasive species. The ongoing ecosystems degradation and increasing photogenetic erosion justify plans for restoration of arid areas. Loss of biodiversity is a major consideration in the phenomenon of desertification. For restoration activities to be successful, knowledge of local plant species is required because of the significant role their adaptation plays in the ecological context of restoration.

The arid regions are among the most important ecosystems and provide a great variety of services and homes to pastoral and agro-pastoral communities. In particular, they cover diverse habitats and ecological communities. They

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are also economically important given the tremendous richness of edible plant, forage, medicinal, and economic species [3-6].

The effects of any disturbance on the plant biodiversity of Arid areas are more apparent and deeper than in other ecosystems. Several studies have shown the negative effects of biotics and abiotics factors (grazing, drought and other human activities) on biodiversity of dryland plant species [7–8]. In the face of the degradation of natural resources and the progress of desertification, maintenance of biodiversity through active management has recently become an important challenge for biodiversity conservation [9]. Restoration efforts for natural diversity are important and result in high species diversity [9–11]. Some efforts have been made to restore the functions of drylands. Floristic wealth is considered particularly valuable and a prime target for establishing conservation priorities [12-14]. The economic, medicinal and ecological value of desert plants requires knowledge of their botanical composition and their richness in spontaneous species. During the period between 2008 and 2011 the flora of the arid and desert areas of southern Tunisia was assessed (Tataouine, Medenine, Tozeur, Gabes and Kebeli) and the botanical composition of Tataouine region was studied during the spring of 2017-2018, during which the area received an average rainfall (100 mm) and 135 species was recorded. [10].

Under these conditions, arid and desert rangelands show a great resilience illustrated through a very high plant diversity. These rare favorable conditions offer a golden opportunity to record the greatest plant diversity in arid and desert zones and identify key species that can survive in this ecosystem. Specifically, the objectives of our study are to examine the diversity in the flora of the arid and desert areas of southern Tunisia (Tataouine, Medenine, Tozeur, Gabes and Kebeli) and the botanical composition, including plant family, life form, habitat class, palatability, and medicinal and aromatic plants, and to determine the relevance of plant diversity to arid and desert. It is important to understand the significance of these rangelands in terms of providing several ecosystem services of vital importance for the local communities. Our findings could contribute towards developing holistic and sustainable rangelands management practices and finding innovative solutions to protect key natural habitats in southern Tunisia and similar arid environments.

2. Material and methods

2.1. Study Area

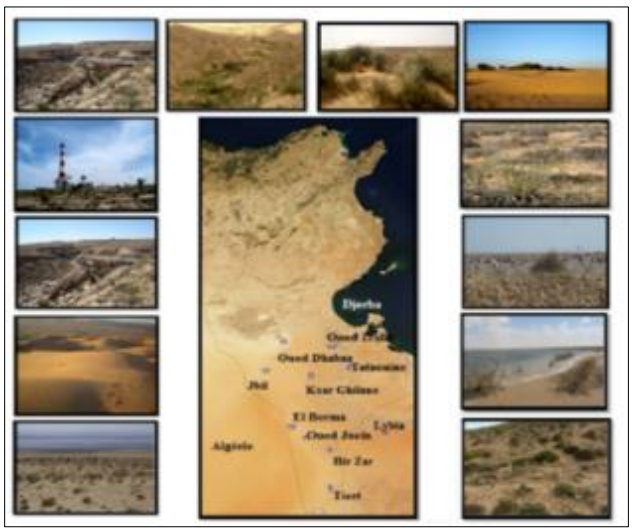

Figure 1 Map of the study sites of the flora of the arid and desert areas of southern Tunisia (Tataouine, Medenine, Tozeur, Gabes and Kebeli).

The study of the flora of the arid and Saharan zones of Tunisia was carried out directly by several field visits during the period between 2008-2011 (Figure 1). All species were photographed using a digital camera, showing structure, leaf, stem, flower, and fruit, if existing. All recorded plants were then identified with the help of available Tunisian flora of Pottier-Alapetite [14-15] and by collaboration with botanists. The coordinates of the study sites are determined by a GPS device (Table 1). The five sites of the region of Tataouine (Bir zar, ElBorma, Tiert, Oued Jnein, El Ouera) were chosen to determine the floristic composition during the year 2008 which was very rainy. The total annual average rainfall in

the area is below 100 mm, with cold, dry, and windy winters and hot and arid summers. Sand dunes and sandy, limestone, and gypsum soils are the most common soils in the desert area.

Table 1 Geographical distribution of study sites in southern Tunisia

Sites	Altitude (m)	regions	Coordinates GPS
Jbil	169	kebeli	33°141'020''N/09°250'508''E
Bir zar	334	Tataouine	31°293'535''N/10°004'597''E
ElBorma	242	Tataouine	32°033'006''N/09°072'698''E
Tiert	392	Tataouine	30°464'235''N/10°111'545''E
ElFjé	15	Medenine	33°295'905''N/10°382'999''E
Oued Jnein	280	Tataouine	31°482'265''N/10°161'592''E
Oued Dhabaa	249	kebeli	36°776'793''N/03°253'147''E
Ksar Ghilane	240	kebeli	32°593'606''N/09°390'184''E
Oued Zridib	369	Medenine	33°151'601''N/09°584'911''E
El Ouera	188	Tataouine	32°562'928''N/10°274'946''E
Djerba	3	Medenine	33°807'600''N/ 10°845'200"E
Nefta	52	Tozeur	33°550'100''N/08°080'00''E
Matmata	380	Gabes	33°320'400''N/09°580'170''E

2.2. Data Collection

As a consequence of the favorable rainfall conditions recorded in southern Tunisia during 2008-2009 (Figure 2), vast rangeland areas were covered by hundreds of bloomed plant species. The present inventory represents the highest species richness recorded in the regions of (Tataouine, Medenine, Tozeur, Gabes and Kebeli) and in the five sites of Tataouine. The inventory was conducted through frequent field visits made to various rangeland sites from March 2008 to April 2008 to identify different plant species (Figure 3 and table 2).

Since the areas is huge, we had to rely on expert knowledge, including herders who practice transhumance, as well as elderly pastoralists, to guide us to the exact locations where certain species were resurfacing during such an exceptional favorable year. All recorded plants were then identified with the help of available Tunisian flora of Pottier-Alapetite [14-15]. The nomenclature for inventoried species was updated using the synonymic index of the flora of North Africa by [16] and POWO (Plants of the World Online) [17] and by collaboration with botanists. Once plants were identified, family, life form, habitat and class of each species were determined.

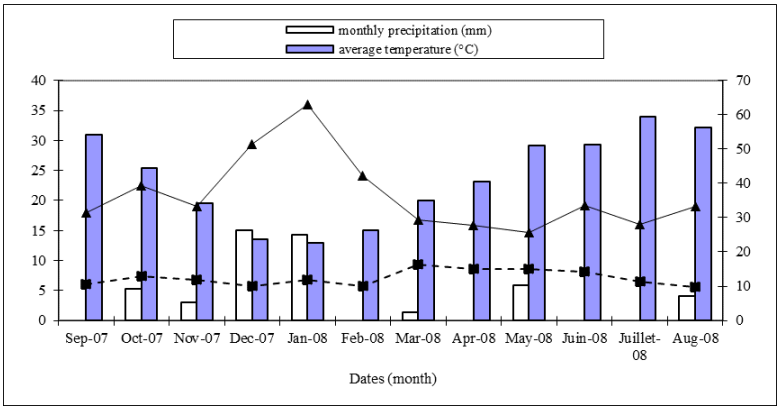

Figure 2 Variation of monthly precipitation (mm), the average monthly temperature (° C), humidity of the monthly average air (%) and the average monthly wind speed (Km / h) during the season of 2008 in Tataouine, southern Tunisia [18]

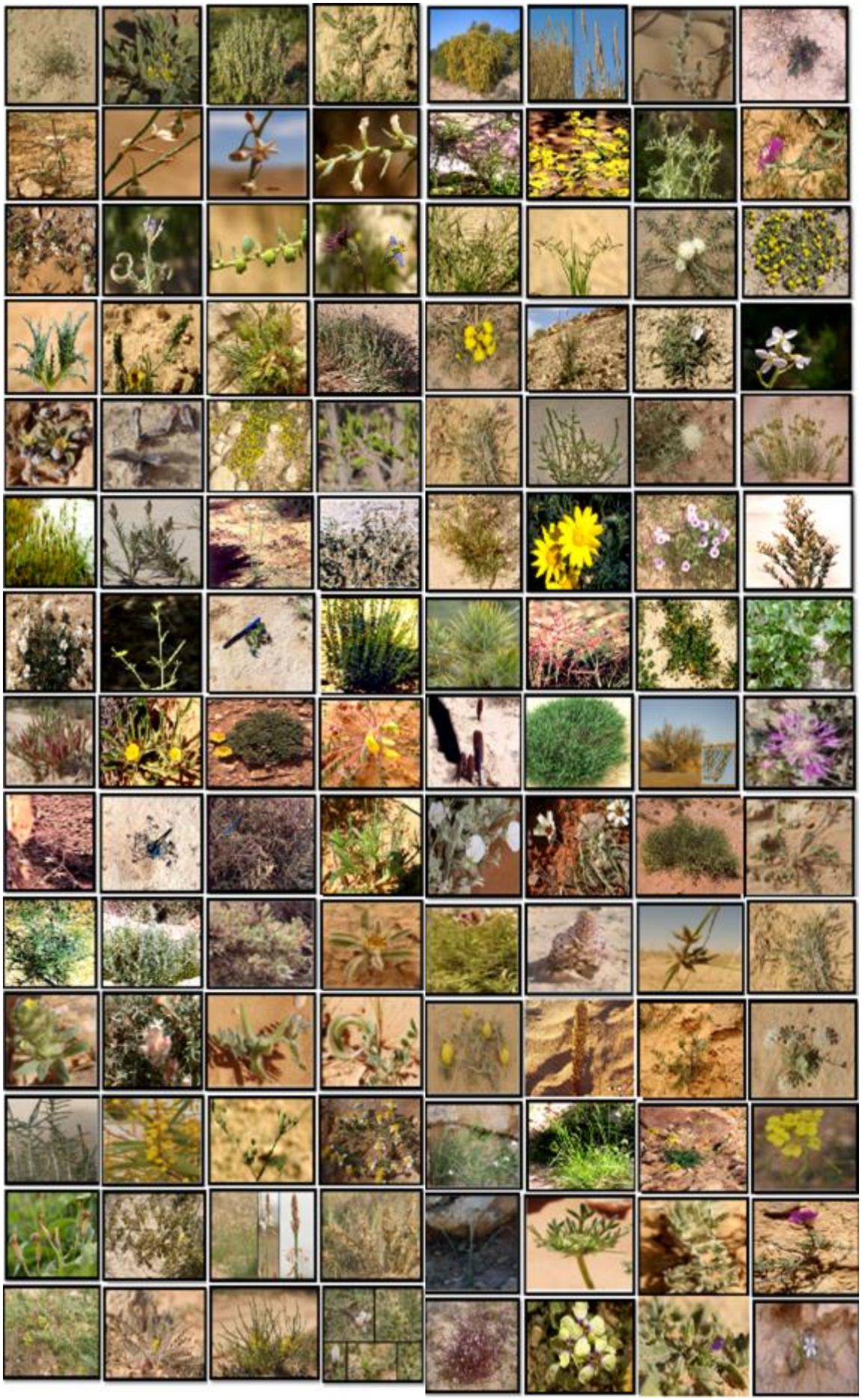

Figure 3 The Flora identified during the visits to the study sites of the southern Tunisia.

Table 2 The list of species identified during visits to study sites in southern Tunisia

Halophilic vegetation
Aeluropus littoralis
Anacyclus monanthos subsp. *cyrtolepidioides*
Artemisia herba-alba
Arthrocnemum macrostachyum [= *indicum*]
Atriplex glauca subsp. *mauritanica*
Atriplex halimus (planté)
Atriplex lindleyi subsp. *inflata*
Atriplex mollis
Bromus madritensis
Casuarina cf. equisetifolia
Diplotaxis simplex
Erodium glaucophyllum,
Filago mareotica
Frankenia thymifolia
Halocnemum strobilaceum
Hyparrhenia hirta
Plantago coronopifolium
Launaea resedifolia
Limoniastrum monopetalum
Limonium pruinosum
Lycium shawii [= *L. Arabicum*]
Lygeum spartum
Medicago minima
Mesembryanthemum cristallinum
Nitraria retusa
Ononis angustissima subsp. *filifolia*
Peganum harmala
Picris coronopifolia
Plantago albicans
Polygonum equisetiforme
Reichardia tingitana
Retama raetam
Rostraria salzmannii [= *Koeleria salzmannii*]
Salsola tetrandra
Sueda vermiculata [= *mollis*]

Trigonella maritima
Zygophyllum album [= *Tetraena alba*]
Aeluropus littoralis
Arthrocnemum macrostachyum [= *glaucum*]
Juncus acutus
Limoniastrum monopetalum
Limonium tunetanum
Lycium shawii
Reaumuria vermiculata
Salsola tetrandra
Tamarix africana
Zygophyllum album
Gypsophyl steppe with *Erodium arborescens*
Anabasis oropediorum
Anarrhinum brevifolium
Argyrolobium uniflorum
Asparagus albus
Asparagus stipularis [= *horridus*]
Asphodelus tenuifolius
Asteriscus hierochunticus
(= *Odontospermum pygmaeum*)
Atractylis cancellata
Atractylis serratuloides
Coris monspeliensis
Deverra chlorantha [= *Pituranthos chloranthus*]
Didesmus bipinnatus
Diplotaxis harra
Erodium arborescens
Fagonia cretica
Fagonia glutinosa
Globularia alypum
Gymnocarpos decander
Hammada scoparium
Hedysarum spinosissimum
Helianthemum crassifolium
Helianthemum intricatum
Helianthemum lippii
Helianthemum sessiliflorum

Herniaria fontanesii
Kickxia aegyptiaca
Lygeum spartum
Plantago albicans
Reichardia tingitana
Retama raetam
Salsola tetrandra
Thymelaea hirsuta
Thymelaea microphylla
Steppe with *Rhantherium suaveolens*
Acacia saligna
Anacyclus monanthos subsp. *Cyrtolepidioides*
Apteranthes europaea [= *Caralluma*]
Artemisia campestris subsp. *cinerea*
Asparagus stipularis
Astragalus armatus subsp. *tragacanthoides*
Atractylis serratuloides
Cenchrus ciliaris
Centaurea dimorpha
Cistanche phelypaea
Deverra chlorantha [= *Pituranthos tortuosa*]
Echiochilon fruticosum
Eragrostis papposa
Kickxia aegyptiaca
Launaea mucronata [= *L. resedifolia*]
Lycium shawii
Lygeum spartum
Opuntia ficus-indica subsp. *inermis*
Peganum harmala
Picris coronopifolius
Polygonum equisetiforme
Reaumuria vermiculata
Retama raetam
Rhantherium suaveolens
Salsola villosa
Stipagrostis ciliata [= *Aristida*]
Vegetation of the Oases and beaches
Cakile maritima subsp. *aegyptiaca*

Centaurea contracta
Erodium arborescens
Frankenia pulverulenta
Globionis [= *Chrysanthemum*] *coronarium*
Hyoscyamus albus
Launaea resedifolia
Lotus creticus s. l.
Posidonia oceanica
Senecio glaucus subsp. *coronopifolius*
Silene succulenta
Tamarix sp.
White Sagebrush Steppe: (*Artemisia herba-alba*)
Ajuga iva subsp. *pseudoiva*
Anabasis oropediorum (2 pts poils)
Anacyclus monanthos subsp. *cyrtolepidioides*
Argyrolobium uniflorum [= *Genista uniflora*]
Artemisia campestris
Astragalus armatus
Astragalus caprinus
Atractylis carduus (Forssk.) C. Christ [= *A. flava*],
Calendula aegyptiaca [= *C. sancta*]
Caralluma europaea
Carrichtera annua [= *Vella annua*]
Catananche arenaria
Convolvulus supinus
Cuscuta sp. sur *Argyrolobium uniflorum*
Deverra tortuosa
Didesmus bipinnatus Del.
Diplotaxis harra
Echium humile subsp. *pycnanthos*
Echium trygorrhizum
Erodium crassifolium [= *E. hirtum*]
Erodium glaucophyllum
Erodium pulverulentum
Fagonia cretica
Gymnocarpos decander Forssk.
Haloxylon scoparium Pomel [= *Hammada scoparia*]
Helianthemum kahiricum

Helianthemum virgatum
Herniaria fontanesii
Kickxia aegyptiaca [= *Linaria*]
Launaea resedifolia
Limonium pruinosum, accidental presence here!
Lycium shawii Roem. & Schult. [= *L. arabicum*]
Lygeum spartum
Matthiola longipetala
Muricaria prostrata
Pallenis hierochuntica [= *Odontospermum pygmeum*]
Paronychia arabica
Pistacia vera, roadside, planted, ground beetles are planted on the thorns, it is a "shrike" "lardoir"!
Plantago ovata
Polygonum equisetiforme
Pteranthus dichotomus
Reaumuria vermiculata
Reichardia tingitana
Retama raetam
Rumex vesicarius
Salsola brevifolia
Salvia verbenaca
Seriphium herba-album [= *Artemisia herba-alba*].
Stipa capensis (= *S. tortilis*)
Volutaria crupinoides
Volutaria lippii [= *Amberboa lippii*]
Vegetation of the Matmatas Mountains
Anagallis arvensis
Astragalus armatus
Bromus madritensis
Calicotome villosa .
Coris monspeliensis
Coronilla scorpioides
Dactylus glomerata subsp. *hispanica*
Deverra chloranthus
Didesmus bipinnatus
Ephedra altissima
Euphorbia cornuta

Gymnocarpos decander
Helianthemum intricatum
Helianthemum sessiliflorum
Helianthemum virgatum
Helichrysum stoechas
Hippocrepis ciliata ?
Rhus tripartita
Koelpinia linearis
Kickxia aegyptiaca
Lycium shawii
Lygeum spartum
Marrubium vulgare
Medicago minima
Moricandia arvensis
Onopordon espinae
Piptatherum miliaceum
Phagnalon rupestre
Pallenis hierochuntica
Pallenis spinosa
Papaver hybridum
Paronychia chlorothyrsa
Peganum harmala
Plantago albicans
Plantago ovata
Plantago psyllium
Pteranthus dichotomus
Reseda decursiva
Retama raetam
Rhus tripartita
Rosmarinus officinalis var. *troglodytorum*
Scandix pecten-veneris
Scilla peruviana
Scorzonera undulate
Seriphium herba-album
Sisymbrium erysimoides
Stipa tenacissima
Teucrium alopecurus
Thymelea hirsuta

Thymus capitatus
Thymus hirtus subsp. *algeriensis*
Trigonella stellata
Vaillantia sp.
Valerianella sp.
Steppe at *Genista microcephala*, near Tougène
Anabasis oropediorum
Astragalus armatus
Dittrichia viscosa [= *Inula viscosa*]
Genista microcephala
Plantago albicans
Plantago ovata
Ruta chalepensis
Stipa parviflora
Teucrium alopecurus
Vegetation of Foum Tatouine
Anacyclus clavatus
Anacyclus cyrtolepidioides
Anchusa hispida [= *Gastrocotyle hispida*]
Andrachne telephioides
Arnebia decumbens
Artemisia herba-alba
Asteriscus hierochuntica
Astragalus falciformis ?
Astragalus pseudosinaicus ?
Carrichtera annua
Cenchrus ciliaris [= *Pennisetum*]
Convolvulus supinus
Cuscuta sp.
Daucus sp.
Deverra chlorantha
Dipcadi serotinum
Diplotaxis harra
Echinops spinosus
Ephedra altissima
Erodium arborescens
Erodium crassifolium
Erodium pulverulentum var. *tunetanum*

Fagonia cretica
Filago germanica s. l.
Gymnarrhena micrantha
Gymnocarpos decander
Hammada scoparia
Helianthemum kahiricum
Lamarckia aurea
Lappula spinocarpos [= *Sclerocaryopsis*]
Matthiola kralikii
Moricandia arvensis
Papaver hybridum
Peganum harmala
Picris coronopifolia
Pinus halepensis
Plantago ovata
Pteranthus dichantomus
Rhanterium suaveolens
Reseda decursiva
Retama raetam
Rhus tripartita
Richardia tingitana
Scilla peruviana
Scorzonera undulata
S. glaucus subsp. *coronopifolius*
Sinapis alba
Stipa capensis
Stipa parviflora
Stipagrostis plumosa
Thesium humile
Trigonella polyceratia
Volutaria lippii
Steppe to *Anthyllis henoniana*, from Chenini
Aegilops triaristata
Allium roseum subsp.*odoratissimum*
Anthyllis sericea subsp.*henoniana*
Argylobium uniflorum
Artemisia herba-alba
Astragalus caprinus

Atractylis serratuloides
Bromus madritensis
Calendula arvensis
Convolvulus supinus
Cutandia dichotoma
Deverra chorantha
Diplotaxis harrra
Diplotaxis simplex
Echium trygorrhizum
Enarthrocarpus clavatus
Echiochilon fruticosum
Fagonia glutinosa
Gagea fibrosa
Gymnocarpos decander
Hedypnois cretica
Helianthemum crassifolium subsp. *glaucum*
Helianthemum intricatum
Helianthemum ledifolium
Herniaria fontanesii
Matthiola longipetala subsp. *kralikii*
Morea sisyrinchium [= *Gynandriris*]
Paronychia arabica subsp. *cossoniana*
Paronychia gr. kapela
Picris coronopifolia
Plantago albicans
Reaumuria vermiculata
Rostraria salzmannii
Scabiosa arenaria [= *Sixalix arenaria*]
Schismus barbatus
Scilla peruviana
Scorzonera undulata
Stipa capensis
Stipa parviflora
Stipa tenacissima
Tetrapogon villosus
Asparagus refractus
Asphodelus refractus
Calligonum polygonoides subsp. *comosum*

Cutandia dichotoma
Daucus sahariensis
Haloxylon schmittianum
Ifloga spicata
Koelpinia linearis
Salsola brevifolia
Stipagrostis pungens
Steppe to *Stipagrostis pungens*, by Ksar Ghilane
Anthyllis sericea subsp. *henoniana*
Asphodelus refractus
Centaurea furfuracea
Cutantia dichotoma
Daucus sahariensis
Gymnocarpos decander
Rhanterium suaveolens
Savigna parviflora subsp. *longistyla*
Stipagrostis pungens – Psammophile whose roots clump together and fix the sand. These lateral ramifications can follow the prevailing winds. They thus promote the development of *Rhanterium*
Anthemis stiparum
Asphodelus tenuifolius
Atractylis carduus [= *A. flava*]
Cleome amblyocarpa
Helianthemum lippii var. *sessiliflorum*
Henophyton deserti [= *Oudneya africana*]
Koelpinia linearis
Matthiola longipetala
Nolletia chrysocomoides
Savignya parviflora subsp. *longistyla*
Stipagrostis pungens
Steppe to *Euphorbia guyoniana*, by Ksar Ghilane
Anthemis stiparum
Asphodelus tenuifolius
Astragalus hamosus
Astragalus saharae
Centaurea purpurea
Cutandia divaricata
Erodium chevallieri Guitt. [= *E. glaucophyllum* var. *cinerascens* Chevallier]

Euphorbia guyoniana
Herniaria fontanesii
Koelpinia linearis
Launaea capitata [= *L. glomerata*]
Lotus pusillus [= *L. halophilus*]
Plantago ciliata
Savignya parviflora subsp. *longistyla* Boiss
Vulpiella stipoides
Dunes in *Ephedra alata*, south of Douz
Anabasis articulata
Bassia muricata
Cistanche violacea
Ephedra alata subsp. *alenda*
The presence of this chlamydosperm species is the main feature of the resort. For the alenda subspecies, the fruiting cones are 10-16 mm, with bracts without tab at the base, male flowers with 6-7 anthers are grouped into a dense head (Ozenda, 2004). It is common throughout Western Sahara.
Halocnenum strobilaceum
Haloxylon schmittianum Pomel
Helianthemum confertum Dun.
Ifloga spicata
Limoniastrum guyonianum
Lotus pusillus
Maresia nana
Moltkiopsis ciliata
Retama raetam
Senecio gallicus
Traganum nudatum
Zygophyllum album
et à 4 km au sud de Douz :
Calligonum polygonoides subsp. *comosum*
Casuarina equisetifolia
Salsola brevifolia
Suaeda mollis
Tamarix africana
Planting of "saxoul" *Haploxylon persicum*
Acacia karroo
Anabasis articulata
Arnebia decumbens

Diplotaxis harra
Erucaria vesicaria
Haloxylon persicum (introduit en 1969 par
Schoenenberger to fix the dunes: currently in the process of invasive expansion.
Ifloga spicata
Launaea resedifolia
Maresia nana
Matthiola longipetala subsp. *kralickii*
Plantago albicans subsp. *laniginosa*
Reaumuria vermiculata
Senecio gallicus subsp. *coronopifolius*
Tamarix amplexicaulis [= *T. pauciovulata*]
Traganum nudatum
Zygophyllum album
Vegetation of the Edge of the Chotts (chott El Djerid, de Douz)
Cistanche violacea
Halocnemum strobilaceum
Limoniastrum guyonianum
Salsola tetragona
Tamarix africana
Zygophyllum album
Vegetation of the north-east of Tozeur
Aizoon canariense
Anabasis articulata
Asteriscus pygmaeus
Citrillus colocynthis [= *Colocynthis vulgaris*]
Echiochilon fruticosum
Filago pygmaea [= *Evax pygmea*]
Hammada schmittiana
Linaria laxiflora
Neurada procumbens
Peganum harmala
Polycarpaea repens
Retama raetam
Stipagrostis pungens
Tamarix gallica (cultivé)
Volutaria lippii

Other species of flora have been observed
Atriplex suberecta
Bassia indica
Bromus catharticus
Caesalpinia gilesii
Casuarina stricta [= *quadrivalvis*]
Cionura erecta
Fumaria capreolata
Fumaria mirabilis
Heliotropium currassavicum
Hordeum murinum
Hornungia procumbens
[= *Hymenolobus procumbens*]
Lawsonia inermis, le henné
Malva parviflora
Nicotiana glauca
Ocymum basilicum
Rubia tinctoria
Sphenopus divaricatus
Dunes in *Calligonum arich* (Grand Erg Oriental)
Calligonum arich
Astragalus gombiformis,
Calligonum. azel,
Cleome arabica,
Cornulaca monocantha,
Euphorbia gugoniana,
Helianthemum confertum,
Retama raetam,
Spartium saharae
Stipagrostis pungens

3. Results and discussion

The plant species identified during the visits to the study sites in the southern of Tunisia are represented by Figure 3.

Several studies have claimed that precipitation has a significant impact on the vegetation dynamics of arid zones [19-20]. More particularly, rainfall variability has a great impact on plant phenology [21–22], plant life cycles [23–24], and therefore species richness [25–26]. Rainfall distribution and quantity play important roles in encountering the maximum number of plant species that can grow in arid and desert zones.

The favourable conditions of 2009/2008 resulted in a large number of plant species. Many of which were not recorded in recent decades, such as *Helianthemum crassifolium, Helianthemum ruficomum, Helianthemum virgatum subsp. africanum, Plantago afra, Dactylis glomerata, Andrachne telephioides, Catananche arenaria, Coris monspeliensis, and Teucrium alopecurus.*

Concerning the floristic composition of the five chosen sites of tataouine, the altered climate conditions in the south of Tunisia were associated with increased species richness. a total of 558 species were recorded, belonging to 58 families (Table 2). The families with the highest number of species were *Asteraceae* with 86 species (30.70%), *Poaceae* with 60 (22%), *Fabaceae* with 48 (17.14%), *Amaranthaceae* with 32 (11.42%), *Brassicaceae* with 32 (11.42%), and *Boraginaceae*, *Caryophyllaceae*, and *Lamiaceae* with 24species each (8% each). These families were the most diverse of the flora in the arid zones of Tunisia. Overall, 54% of the species were annual (301 species) and 46% were perennial (257). Several annual plant species can be found exclusively in improved microsite conditions (e.g., lower temperatures, reduced solar radiation, or increased organic matter) in Rocky Mountains and benefit from higher rainfall. For example, the presence of *Lamarckia aurea* and *Umbilicus rupestris* indicates favorable environmental conditions, which may be the result of available microsites for plant establishment under higher rainfall conditions.

During the extremely wet year, the arid and desert rangelands, with all their different habitats (mountain, plain, wadi, dune), tended to be dominated by therophytes (ephemerals and annuals) [27].

These species germinate on conditions that are favorable and thrive under heavy rainfall.

The life-form spectrum of these recorded species showed that 48% were therophytes, 20% were chamaephytes, 20% were hemicryptophytes, 5% were nanophanerophytes, 3% were geophytes, 2% were macrophanerophytes, 1% were phanerophytes, and 1% were parasites (Figure 4). The dominance of therophytes can be attributed to the large number of microsites suitable to annual plants that have rapid germination and growth, thus increasing their abundance [46–48]. Chamaephytes can survive in arid zones because they are highly adapted to arid conditions [28–29].

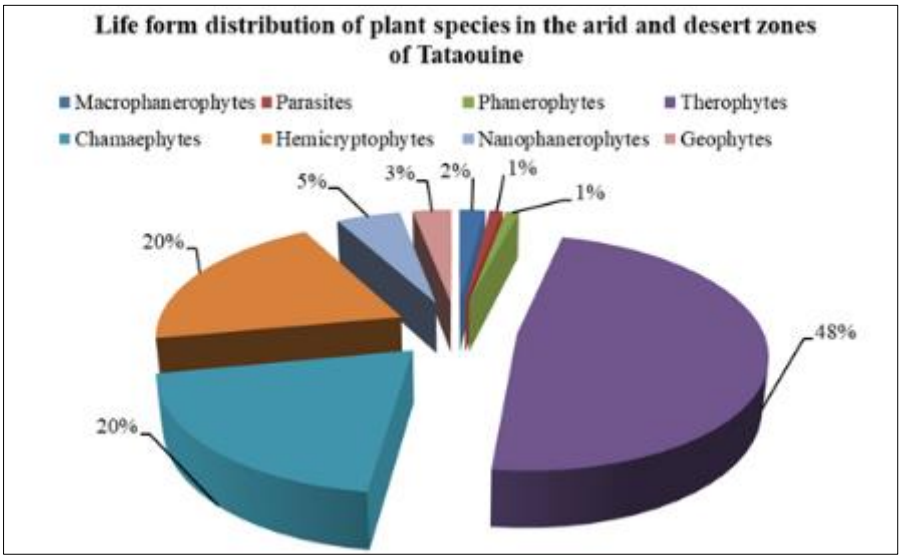

Figure 4 Life form distribution of plant species in the arid and desert zones of Tataouine, Tunisia (spring 2008).

The perennial shrubs were mainly chamaephytes, such as *Haloxylon schmittianum*, *Haloxylon scoparium*, *Helianthemum kahiricum*, *Helianthemum lippii*, *Rhanterium suaveolens*, and *Gymnocarpos decander*, which characterize the dry and desert rangelands. Hemicryptophytes were very common plants in large areas of arid rangelands, with more than some species, most of which were *Poaceae* that emerge from seeds and propagate vegetatively from plant parts [30].

During the rainy season, the growth of herbaceous plants in the rangelands of Tataouine was very important (Figure 5). Herbaceous vegetation was dominant, with 73% of species, followed by shrubs 25%, and trees 2%, with climbers represented by only one species: *Convolvulus supinus*. Not surprisingly, herbaceous species were very abundant because the majority of herbaceous species are therophytes and hemicryptophytes, which dominate the rangelands.

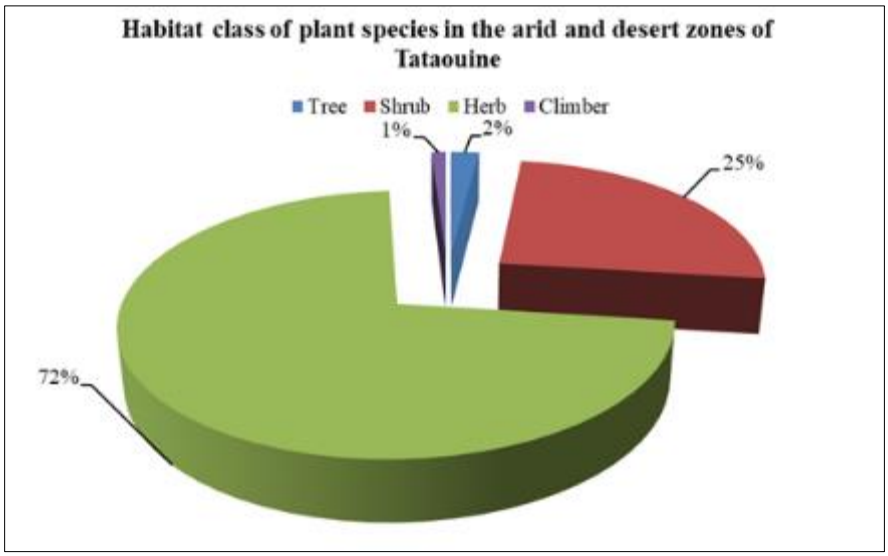

Figure 5 Habitat class of plant species in the arid and desert zones of Tataouine, Tunisia (spring 2008).

The inventoried rangelands had a relatively high species richness, due to its diverse plant communities combined with favorable rainfall conditions.

Additionally, rangelands are characterized by a large number of palatable species belonging to *Poaceae*, such as *Oloptum miliaceum*, *Dactylis glomerata*, *Stipagrostis plumosa*, *Cynodon dactylon*, and *Cenchrus ciliaris*. Annual plants that grow mainly in spring are an important component of arid rangelands. They include, for example, many species that are very palatable, such as *Astragalus asterias*, *Astragalus hamosus*, *Astragalus arpilobus*, *Sulla carnosa*, *Hippocrepis areolata*, and *Medicago laciniata* of the *Fabaceae*. Moreover, in addition to its pastoral value, these rangelands have many valuable medicinal and aromatic plants [31]. Many traditional species remedies derived from pastoral plants that originated in natural rangelands have become modern medicines.[32] These species include the following : *Allium roseum, Allium ampeloprasum, Searsia tripartita, Periploca angustifolia, Capparis spinosa, Herniaria fontanesii, Haloxylon scoparium, Artemisia herba-alba, Artemisia campestris, Henophyton deserti, Diplotaxis harra, Citrullus colocynthis,Calligonum comosum, Ephedra alata, Ephedra altissima, Hyparrhenia hirta, Rosmarinus officinalis, Thymus algeriensis, Thymbra capitata, Ajuga iva, Daucus carota, Marrubium deserti, Teucrium polium, Calicotome villosa, Retama raetam, Cymbopogon schoenanthus, Calligonum polygonoides, Polygonum equisetiforme, Ziziphus lotus, Thymelaea hirsuta, Thapsia garganica, Deverra denudata, Deverra tortuosa, Nitraria retusa, Peganum harmala, and Zygophyllum album.* Some species have high culinary value [33], such as *Rosmarinus officinalis, Thymus algeriensis, Capparis spinosa, Allium roseum, and Allium ampeloprasum*. Some species, such as *Ziziphus lotus and Nitraria retusa,* have small edible fruits used by the local population [34]. A few species are poisonous or toxic to animals, such as *Peganum harmala, Euphorbia terracina, Euphorbia retusa, and Adonis microcarpa.*

The floristic survey conducted on the study sites revealed a high number of endangered species. The endangered forage species were *Anabasis oropediorum, Anarrhinum fruticosum, Calligonum comosum, Echiochilon fruticosum, Eragrostis papposa, Sulla carnosa, Stipa parviflora, and Stipa lagasca*e. Likewise, the majority of the medicinal plants are considered seriously threatened due to overuse. For example, *Allium roseum* is threatened with extinction because of overexploitation; the harvesting of this plant is very destructive because the bulbs are torn off during harvesting [35]. Of the medicinal species recorded in our survey, eight are classified as critically endangered: *Allium roseum, Allium ampeloprasum, Ephedra alata, Ephedra altissima, Rosmarinus officinalis, Thymus algeriensis, Thymbra capitata, and Cymbopogon schoenathus.* Out of the 558 species that have been identified, some species are endemic to the country, which are *Anarrhinum fruticosum subsp. brevifolium,Calligonum arich, Helianthemum virgatum subsp. africanum, Limonium tunetanum, Onopordum espinae, and Teucrium Alopecurus* [36]. This inventory has devoted a great deal of attention to the botanical composition and species diversity of arid and desert rangelands in Tataouine that provide important ecosystem services, yet they are still neglected.

Nevertheless, a great number of plant species are still vitally important for human health, as well as livestock and wildlife feeding. The recorded wide range of species reflects the significant resilience and adaptation of these arid rangeland ecosystems. Among the strategies adopted by the arid plants to overcome such harsh conditions is their

ability to go dormant and cope with extreme heat and recurrent drought to ensure that neither internal temperatures nor tissue dehydration reach low levels [36].

The degree of floristic importance varies from one species to another and is based on spatial distribution across the region. Interesting enough, south Tunisia's flora includes some species endemics to the country that are classified as endangered.

There is solid evidence that greater botanical diversity is essential to sustainable land use by increasing forage yield, pollinators, as well as weed and pest suppression [37]. Certainly, high botanical diversity also plays a key role in soil aggregate stability. The root system of the plant improves soil structure and increases the soil organic matter [38-39]. Furthermore, plant diversity and root traits also benefit essential soil physical properties [38-39]. In recent years, advanced research in ecological conservation, combined with greater focus on ecosystem services, have enhanced our understanding of these complex ecosystems but also highlighted several challenges, calling for innovative measures to preserve our natural resources.

4. Conclusion

In addition to the ecological importance of safeguarding the stability of the natural environment, the rich and diverse flora of arid and desert rangelands in Tunisia provide essential ecological services to the livestock and human population. They provide a great variety of native forage and medicinal plants with modern pharmacological uses. Because the rangelands are not protected, a serious threat to floral diversity, caused by human activity, has occurred in a large area of the arid rangelands, while climate conditions are creating significant transformation through favorable years.

Although the rangelands of Tataouine are dry, they are the native habitat of more than 10% of the total flora of Tunisia. The recorded species are mainly annuals and perennials characteristic of dry ecosystems. The main families are the *Asteraceae*, *Poaceae*, *Fabaceae*, *Amaranthaceae*, *Brassicaceae*, *Boraginaceae*, *Caryophyllaceae*, *Lamiaceae*, *Apiaceae*, and *Cistaceae*, which together account for 65% of the flora. Therophytes comprised the highest number of species, followed by chamaephytes and hemicryptophytes. These rangelands are rich in foraging. Species of high nutritional value for livestock feeding and many important plants used in both traditional and modern medicine. Despite this significant floristic richness, certain species remain endangered and must be effectively managed and protected to avoid their extinction. For this, it is necessary to set up a comprehensive biodiversity conservation program. Furthermore, it would be wise to establish botanical gardens or field gene banks as part of a long-term biodiversity conservation program for endangered species.

Compliance with ethical standards

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Conflicts of Interest

The authors declare no conflict of interest References

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