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# Ecosystems with the endemic argan tree *Sideroxylon spinosum* L.: their flora and fauna (Algerian Sahara)

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**Abstract.** The Tindouf argan groves in the south-western Algerian Sahara, beside *Sideroxylon spinosum* L. [syn. *Argania spinosa* (L.) Skeels] have a rich flora and fauna. This study was aimed to assess their species composition. During floristic surveys we recorded 79 plant species, 67 genera, and 31 families. Among them, the Brassicaceae and Fabaceae are the most represented families (12.7% and 11.4% of the flora, respectively), followed by the Asteraceae and Zygophyllaceae (8.9% each). The flora includes 18 rare species (23%) and 16 endemic taxa (20.3%). The Saharo-Sindian element dominates, accounting for 24.1%, compared with 11.4% for the Saharo-Mediterranean and the Mediterranean elements each. The argan tree grows in steppe-like plant formations, including pastures, of which 67% are of the desert type. The flora is composed mostly of phanerophytes (19.3%), nanophanerophytes (11.6%), and chamaephytes (35.9%). The argan tree is present in various small facies, along wadi beds, on sandy, rocky, and gravelly substrates. We recorded 25 species of birds, 17 mammals, 9 reptiles, 1 amphibian, and 15 arthropods, mostly insects. Consequently, the remarkable biological richness found within the argan ecosystems of Tindouf in the Algerian Saharan context deserves the attention of international bodies concerned with nature conservation in order to protect it as a biosphere reserve.

**Key words:** *Sideroxylon spinosum*, argan grove, biodiversity, flora, fauna, Sahara, Algeria

## 1. Introduction

The argan tree *Sideroxylon spinosum* L. [syn. *Argania spinosa* (L.) Skeels] is a major tree component of pre-steppe forests, with xeric determinism on the southern margins of the Mediterranean region (Dupont 1993; Quézel 1999). Unfortunately, the species is currently threatened with extinction (Chouaki *et al.* 2006). Abundant argan trees grow naturally in some arid and semi-arid zones, where it plays an irreplaceable role in the ecological balance and in the preservation of biodiversity (Charrouf 1998). It is the northernmost representative of a family that includes hardly any tropical species (Seigue 1985). In many places, it is reduced to mediocre, overgrazed bushes (Msanda *et al.* 2005). The fragility of the ecosystems with *S. spinosum* makes them very vulnerable (Errouati 2005) to 2 major risks: (1) the threat from climate-related disturbances that affect their biotope, which make their survival increasingly difficult; and (2) the increasing human impact, often for socio-economic reasons (Seigue 1985).

From the phytosociological point of view, the argan tree forms several plant associations whose ecological and especially floristic and physiognomic features give

the landscape exceptional originality (Barbero *et al.* 1982; Peltier 1982; Benabid & Fennane 1994; Benabid 2000; Aka Koutoua 2006). The landscape is considerably more complex (Boudy 1950; Feddi *et al.* 2011), containing plant species characteristic of the wooded savannah (Benabid 2000), where the argan tree is part of a pseudo-steppe formation (Zahran 2010).

The argan tree is well adapted to drought conditions in the Algerian western Sahara. The argan groves of Tindouf have a structure of coppice on stumps, with an average height of 4.7 m (Kechairi 2021a). On rocky terrain, the argan plant formation is found in sandy, rocky, and gravelly wadi beds. It covers 56 000 hectares, between 320 and 630 m in altitude (Kechairi & Abdoun 2016). The area of argan groves is characterized by extreme climatic conditions and a dry period that extends all the year round. Under the severe aridity conditions the argan tree adapts well to the hydrography of Hamada of Tindouf in the presence of underflows, where additional water supply is accumulated below the substrate of dry wadi beds (Kechairi 2021b).

The aim of this work in the western Algerian Sahara was to study the previously poorly understood biological diversity within our study area, through floristic and faunistic surveys. Especially the fauna of the argan groves of Tindouf, was mostly not inventoried earlier (Lakhdari & Kechairi 2009).

## 2. Material and methods

### 2.1. Study area

Field research on the biodiversity of argan groves in Tindouf Province in the extreme west of the Algerian Western Sahara was carried out in the north-west of the plateau of Hamada of the river Draa. Taking into account the scattered distribution of groves in the north-west, the area is limited in the north and west by the Moroccan borders, in the south by the Hamada of Tindouf and in the east by the Khebi Wadi (Fig. 1). Our study area is located between 28°17′38.7384″N, 8°40′3.6552″W and 28°45′18.7524″N, 8°2′24.2988″W. The argan groves are situated far from the urban community, about 90 km north-west of the town of Tindouf. It is found between 254 and 634 m above sea level, occupying an area of 50 670 hectares (Kechairi & Abdoun 2016; Kechairi 2018).

Climatic conditions in the study area are generally severe. The maximum temperature reaches 50°C and the dry period extends throughout the year (Kechairi 2009). With annual average precipitation of around 33.5 mm (over a period of 34 years), the argan forest is developing in a particularly precarious climatic context (Kaabèche *et al*. 2010). The hydrographic formation on the desert plateau of the Hamada of the Draa has a mainly alluvial supply, and vegetation generally settles in the beds of wadis.

### 2.2. Methods

In the spring of 2018, during a series of field trips, we investigated 7 representative plots: 5 at the Touaref Bou-aam station, 1 at Merkala, and 1 at Targant. The phytoecological analysis of plant associations with argan trees was carried out through a systematic inventory of quadrats of equal length, forming a regular network (Long 1974). Table 1 presents the survey model adopted in the quadrats. Sampling within the quadrats

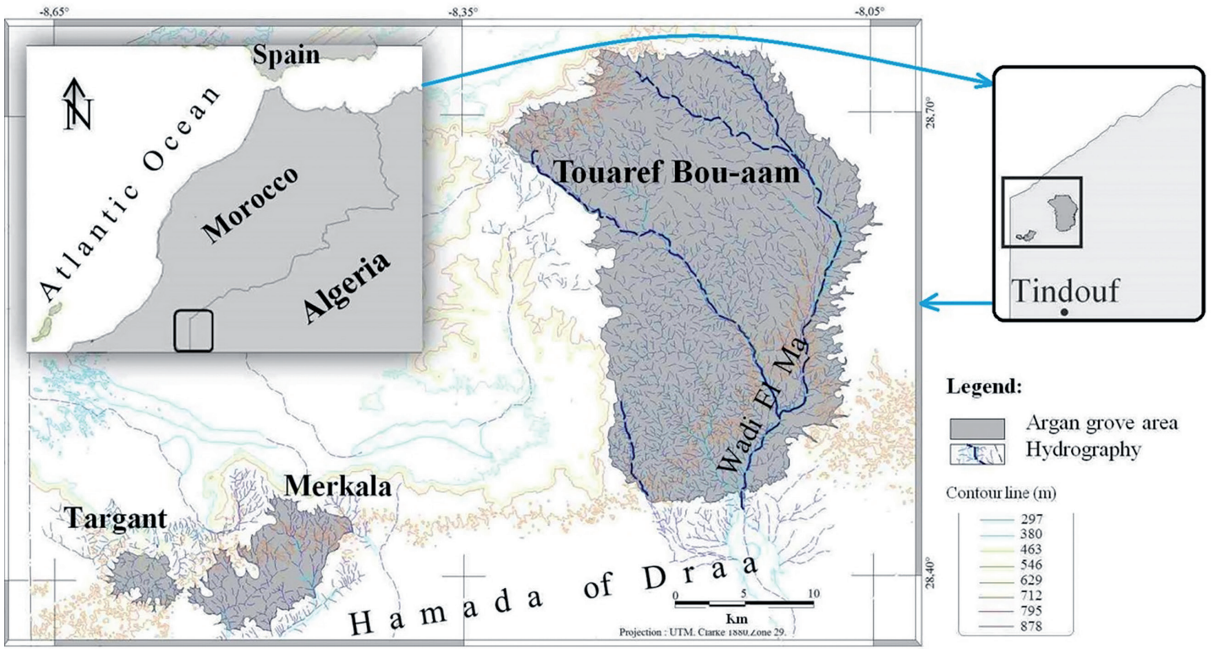


**Fig. 1.** Location of the Tindouf argan groves

**Table 1.** Floristic survey model adopted with R quadrats (meshes) for each plot

| Species | $R_1$ | $R_2$ | $R_3$ | $R_4$ | … | … | $R_{10}$ |
|---|---|---|---|---|---|---|---|
| Species 1 | 1 | 0 | 0 | 1 | - | - | 0 |
| Species 2 | 0 | 0 | 1 | 1 | - | - | 1 |
| Species (n) | 0 | 0 | 1 | 1 | - | - | 0 |

was recorded as species presence/absence, according to Quézel (1965) and Braun-Blanquet (1964). Each plot included 10 quadrats (in total, 70 quadrats) and each quadrat was 100 m long, so the length of each plot was 1 km. However, quadrat width was variable, depending on the width of the wadi beds (Fig. 2).

The herbarium specimens and the photos taken were used for the identification of species collected at the Ecology and Environment Laboratory of the University of Science and Technology Houari Boumediene in Algeria. The identification, classification, rarity assessment, and phytoecological analysis of the species inventoried were based on the works of Quézel and Santa (1962, 1963), Ozenda (1977), Martínez *et al.* (2010), and current updates [https://science.mnhn.fr/institution/mnhn/search]. Floristic diversity was expressed in accordance with Daget and Poissonet (1991).

The faunistic list of argan groves was compiled after having identified what is well observed, based on photos, specimens, niches, footprints and excrements, bird feathers, etc. The inventoried fauna was identified according to Cuzin (1998), Ahmim (2019), and the faunistic identification sheets at the Forest Conservation Department in Tindouf.

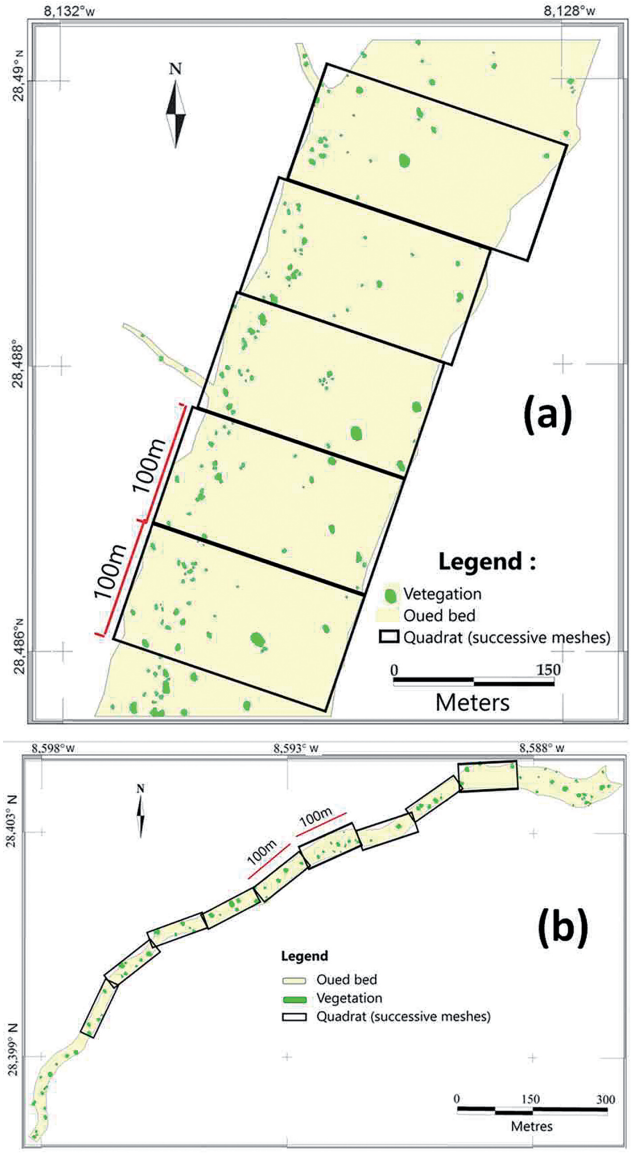


**Fig. 2.** Shapes of sampling quadrats in the wadi beds
Explanations: a – minor wadi bed, b – major wadi bed

## 3. Results

### 3.1. Flora and vegetation

Our study shows that the Tindouf argan groves are home to 79 plant species (Appendix 1). Downstream the acacias dominate the facies. *Acacia tortilis* subsp. *raddiana* and *Faidherbia albida* (syn. *Acacia albida*) are mostly located at the mouth of Touaref Bou-aam, followed by stratified facies, which are found on mounds where some species competing with the argan tree are found, notably *Rhus tripartita* and *Ziziphus lotus* (Fig. 3a).

At mid-slope, on the rocky sand of the wadi beds, the main argan tree groups are found in facies with *Zilla macroptera*, *Farsetia aegyptiaca*, *Echium pycnantum*, and *Foleyola billoti*. On sandy beds, the main competitor affecting the argan tree remains *Cocculus pendulus* (Fig. 3, b1); the plant communities are dominated by *Psoralea plicata* and *Retama retam* (Fig. 3, b2). There are also patches with *Pergularia tomentosa*, *Echium panicum,* and *Launaea arborescens*. In the rocky upstream quadrates, the vegetation is made up of argan tree groups with *Gymnocarpos decander* and *Farsetia aegyptiaca*, while in the lowland oasis of Targant, with *Tamarix* sp., *Nerium oleander, Atriplex halimus, Juncus maritimus,* etc. Interestingly, *Faidherbia albida* in the Tindouf argan grove at the mouth of Touaref Bou-aam reaches a remarkable height of over 25 m (Fig. 3c).

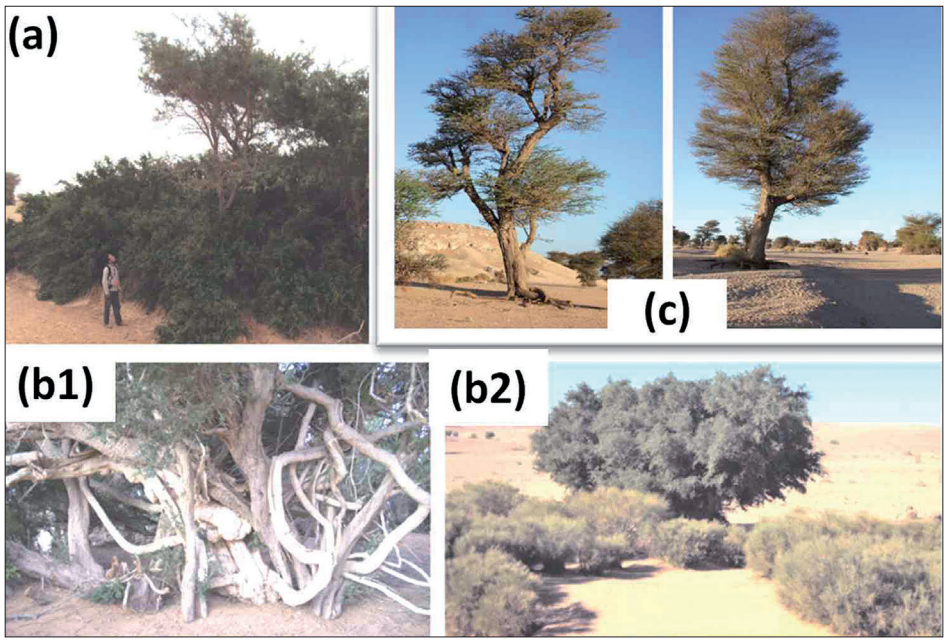


**Fig. 3.** Plant associations with argan trees on sandy beds

Explanations: a – facies with *Faidherbia albida*, *Ziziphus lotus*, and *Rhus tripartita*, b1 – *Cocculus pendulus*, b2 – *Retama retum*, c – tall *Faidherbia albida* trees at the mouth of Touaref Bou-aam

### 3.1.1. Correspondence analysis

The analysis was carried out on the basis of the input matrix formed by 3 columns corresponding to the 3 stations (groves) studied and 79 rows representing the species encountered (Appendix 1). The analysis of the floristic surveys of 3 stations shows their grouping into 6 sets, of which 3 are the main ones, relating to each station (Gr1, Gr2, and Gr3). Two intermediate sets are made up of 15 species shared by Merkala and Touaref Bou-aam (Gr4) and 2 species shared by Touaref Bou-aam and Targant (Gr5). The set shared by all the stations (Gr6) consists of 8 species (Fig. 4). The factorial plane (F1xF2) forms 86.6% of the total inertia, with a

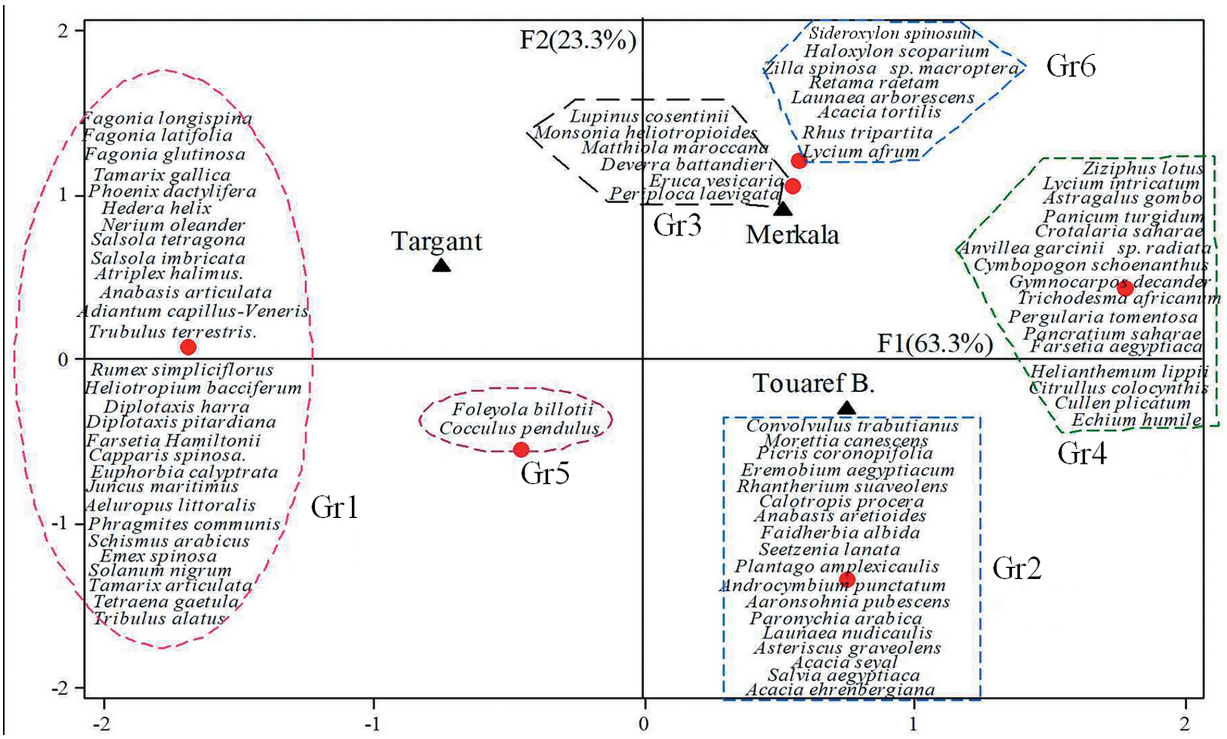


**Fig. 4.** Analysis of the floristic data by projection of the surveys on the factorial plane (F1xF2) of correspondence analysis

**Table 2**. Eigenvalues of the correlation matrix (correspondence analysis) of floristic data from the Tindouf argan groves

| | | | |
|---|---|---|---|
| Own value | 1.9001 | 0.6983 | 0.4015 |
| Proportion | 0.633 | 0.233 | 0.134 |
| Cumulative | 0.633 | 0.866 | 1.000 |

**Table 3.** Specific contributions of the correlation matrix (correspondence analysis) of floristic data from the Tindouf argan groves

| Variable | PC1 | PC2 |
|---|---|---|
| Touaref Bou-aam | 0.616 | -0.314 |
| Merkala | 0.502 | 0.863 |
| Targant | -0.607 | 0.395 |

contribution of 63.3% for axis 1 and 23.3% for axis 2 (Tables 2-3). The point cloud consists of the 6 sets of species. Gr1, marginalized on the negative side of axis 1, is characterized by the floristic composition present in the Targant station, dominated by halophytes due to the halophilic nature of the substrate and the presence of gueltas and springs. The main plant families in this station are the Zygophyllaceae, Salsolaceae, Brassicaceae, and Tamaricaceae, and the main genera: *Salsola* and *Atriplex*. On the negative side of axis 2, the species of Gr2, characteristic of the Touaref Bou-aam station, are generally dominated by the Fabaceae. On the positive side of axis 2, in Gr3, the therophyte species specific to the Merkala station stand out. Gr4, intermediate between Merkala station and Touaref Bou-aam, is formed by alluvial species, dominated by chamaephytes. Gr5, intermediate between the Targant station and Touaref Bou-aam, is formed by 2 species. Gr6 includes the species that are shared by the 3 stations, namely the key species *Sideroxylon spinosum* and *Acacia tortilis* subsp. *raddiana*.

### 3.1.2. Plant families

We assessed contributions of 31 botanical families to the flora of the study area (Fig. 5). The 2 most represented families – Brassicaceae and Fabaceae. The families Asteraceae and Zygophyllaceae contribute 8.9% each, followed by the family Amaranthaceae, Poaceae, Apocynaceae, Solanaceae and Boraginaceae (3.8% each), Tamaricaceae, Polygonaceae, and Caryophyllaceae (2.5% each). The remaining 19 families are represented by single species (1.3% each), which shows the high diversity of botanical taxa in the Tindouf argan groves.

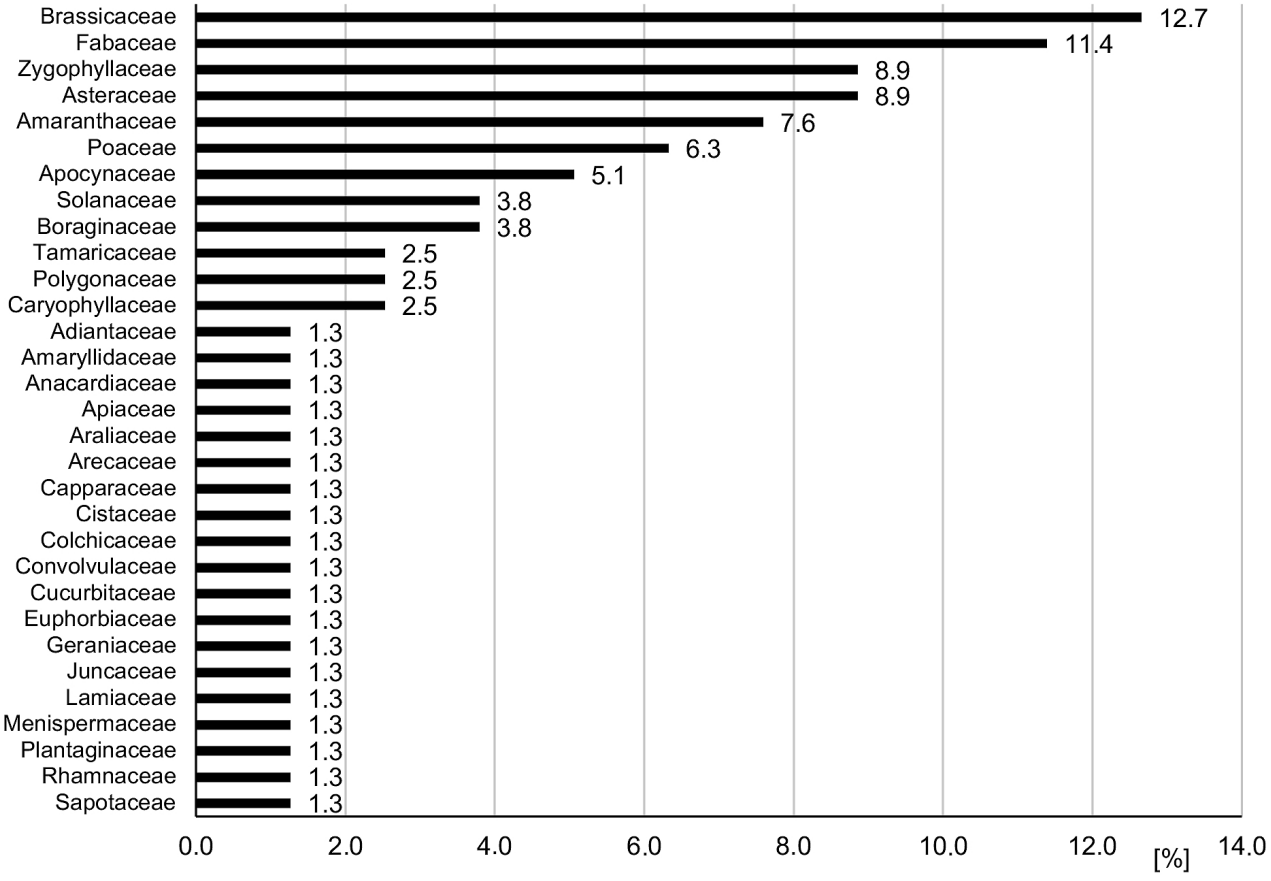


**Fig. 5.** Contributions of botanical families to the flora of the argan groves

### 3.1.3. Degrees of rarity

Out of the 79 plant species recorded in the Tindouf argan groves, 3 taxa are fairly rare (AR) and 11 taxa are rare (R), and 4 taxa are very rare and thus threatened with extinction (RR). In contrast, 37% of species are common (C), 15% very common (CC) and 24% fairly common (AC) (Fig. 6).

### 3.1.4. Biogeographical elements

In the Tindouf argan groves, endemism is represented by 16 plant taxa (20.3%). The biogeographical distribution of the other species is dominated by the Saharan-Sindian element, which includes 19 taxa (24.1%), characteristic of the Saharan rim (Capot-Rey 1953; Quézel 1965; Barry & Celles 1973). The Saharo-

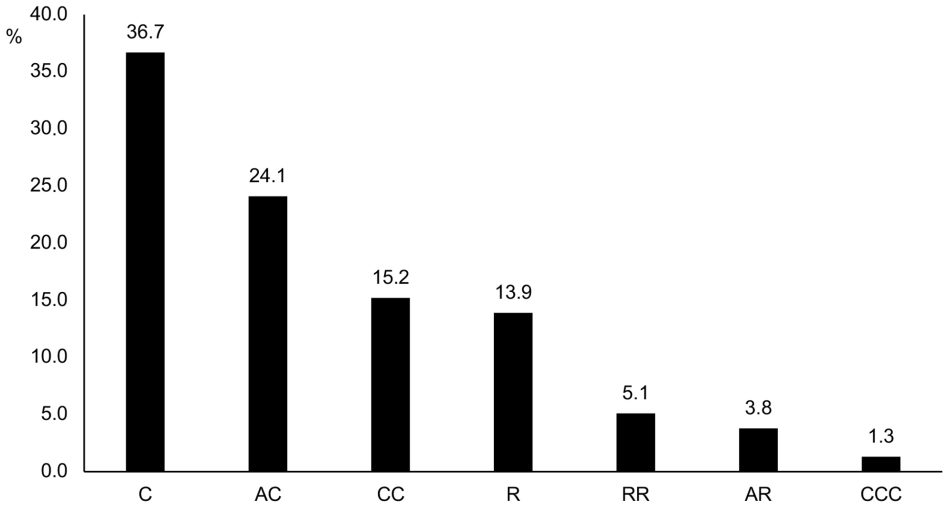


**Fig. 6.** Rarity spectrum of the floristic list

Explanations: C – common, AC – fairly common, CC – very common, R – rare, RR – very rare, AR – fairly rare, CCC – extremely common

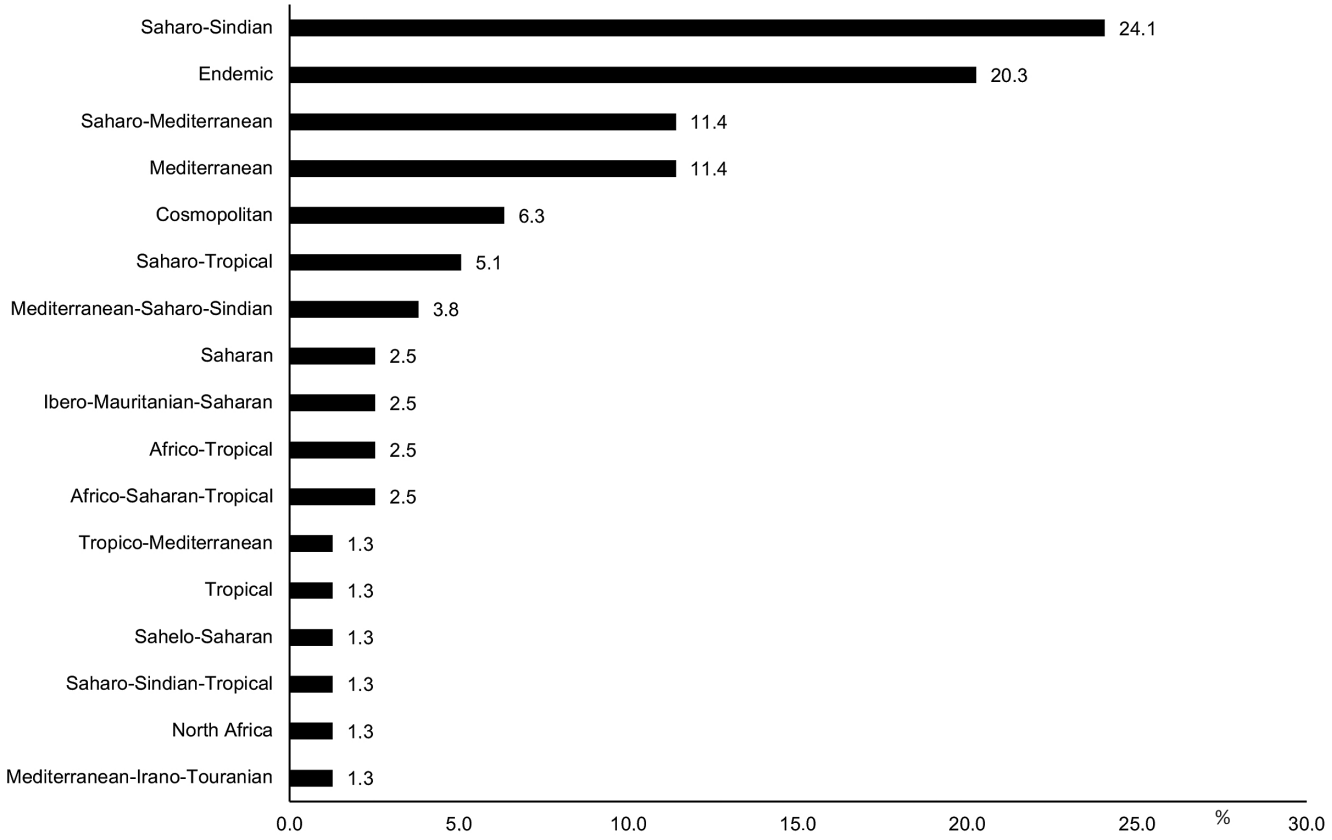


**Fig. 7.** Contributions of biogeographic groups to the total number of plant species identified in the argan groves of Tindouf

Mediterranean and Mediterranean elements constitute 11.4% each. The cosmopolitan element accounts for 6.3%, while the Saharo-tropical and the Saharo-Sindian-Mediterranean for 5.1% and 3.8%, respectively. Contributions of other elements to the flora of Tindouf argan groves are low (Fig. 7).

### 3.1.5. Plant life-forms

Fig. 8 shows the predominance of chamaephytes in Merkala (14 taxa, i.e. 40.4%) and Touaref Bou-aam (19 taxa, i.e. 43.8%). In the Targant station they constituted 23.7% due to the nature of the lowland. The distribution of plant life-forms in the flora of our study region is completely natural. Their average contributions at the 3 sites form the following sequence: chamaephytes (Ch) > therophytes (Th) > phanerophytes (Ph) > nanophanerophytes (NP) > geophytes (Ge) > hemicryptophytes (He).

## 3.2. Types of biotopes

Our argan groves are mainly represented on the rocky plateau reg on 3 wadi bed substrates: sandy, gravelly, and rocky (Fig. 9). The wadi beds are often loaded with alluvial and wind-blown inflow soils. However, the geomorphological nature of the Hamada is characterized by a rocky biotope, which represents 39.1% in Touaref Bou-aam and 30.6% in Merkala. The colluvial deposits which are frequent in Targant (33.3%), are linked to the rugged nature of the cliffs in the resort. The sandy

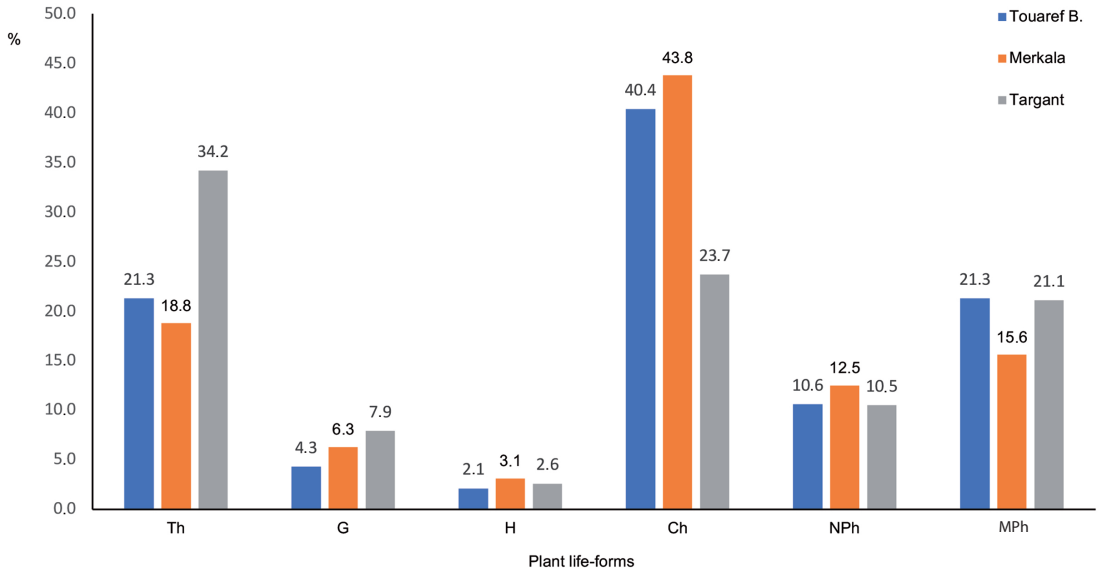


**Fig. 8.** Contributions of plant life-forms to the total number of plant species at the 3 study stations

Explanations: Th – therophyte, G – geophyte, H – hemicryptophyte, Ch – chamaephyte, NPh – nanophanerophyte, MPh – megaphanerophyte

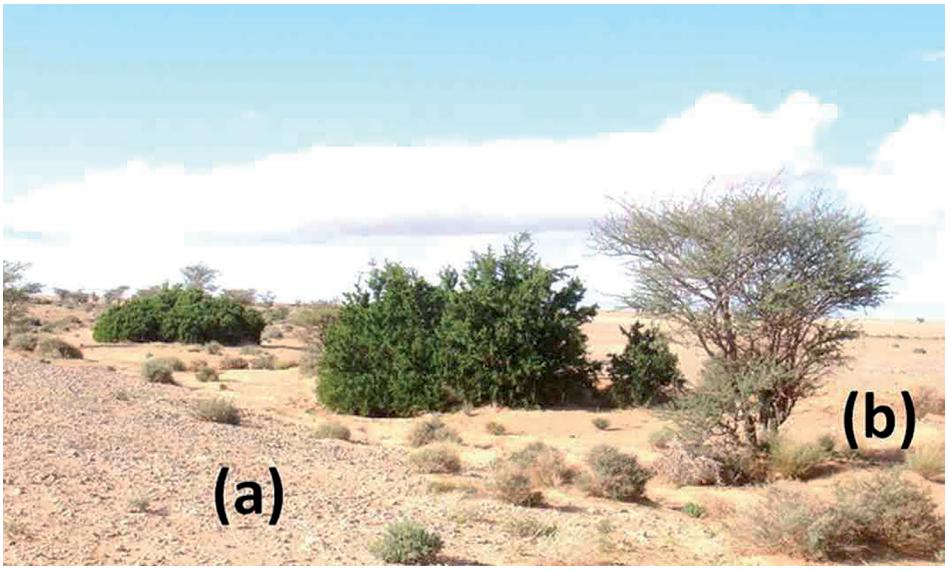


**Fig. 9.** Plant succession on (a) pebble reg substrate; (b) sandy wadi bed

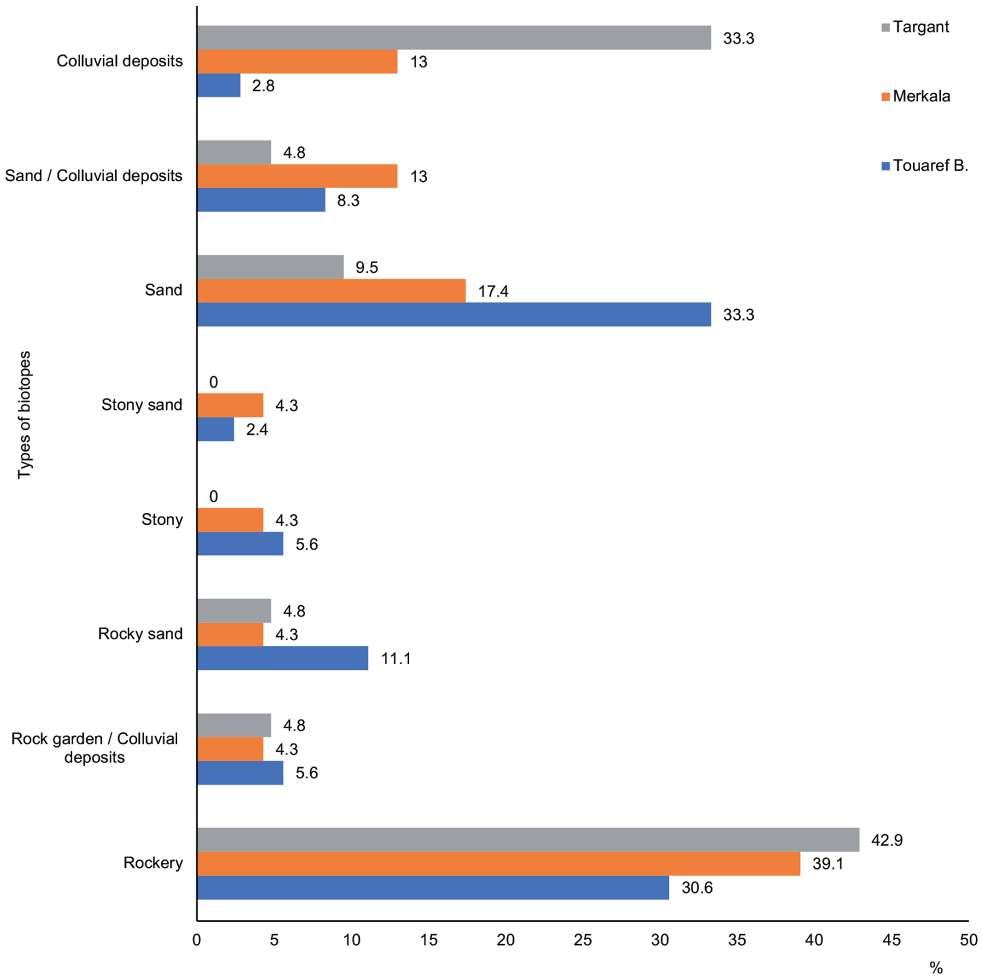


**Fig. 10.** Contributions of various biotopes to the total area of the 3 argan groves

substrate is more common in Touaref Bou-aam (33.3%) than in the other stations (Fig. 10).

### 3.3. Types of pasture

The distribution of species by geographical types increases the diversity of pasture types, both for herbivorous wild animals and for nomadic herds. Desert grazing represents 67% in our study region (Fig. 11).

### 3.4. Animal diversity

The argan tree is home to a great diversity of animals and plants, including nearly 300 invertebrate taxa (Naamani 2004). Thus the Tindouf nature reserve not only protects *Sideroxylon spinosum* but also provides a favourable shelter for many vertebrates and invertebrates (Fig. 12). As a result, the fauna as a whole benefits from the protection offered by the tree (Er-Rafia 1975), which

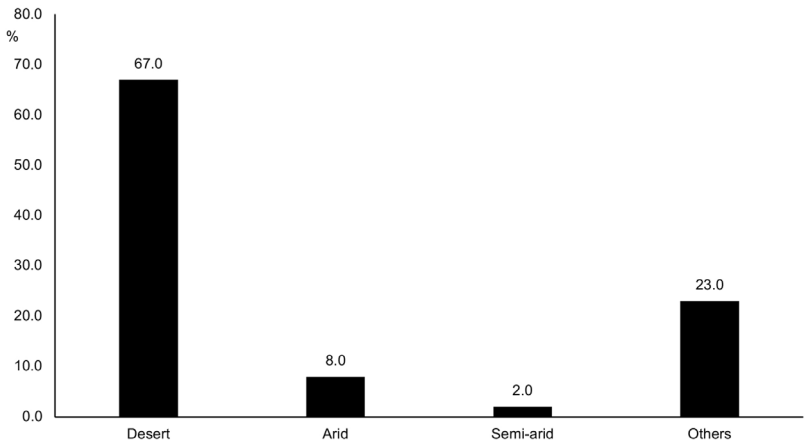


**Fig. 11.** Spectrum of the various types of pastures in the study region

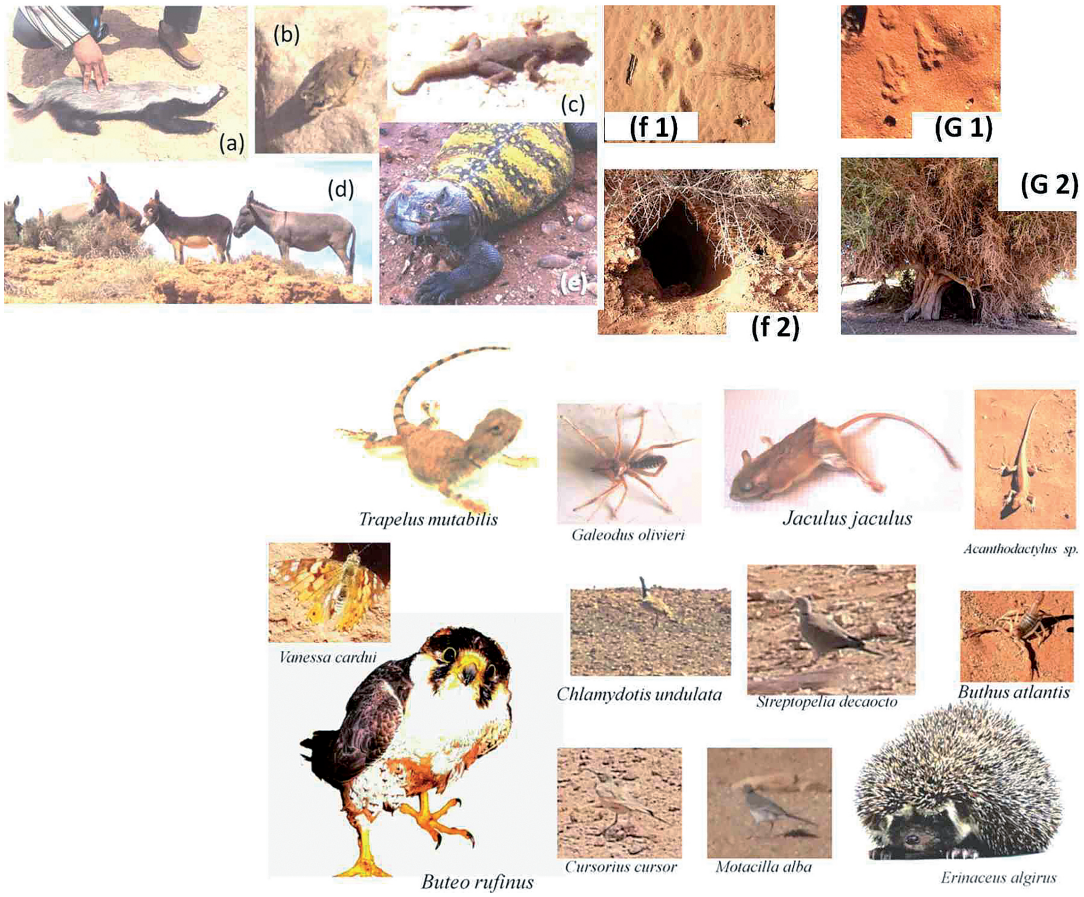


**Fig. 12.** Some animal species of the Tindouf argan groves

Explanations: a – *Mellivora capensis leucanota*, b – *Pelophylax saharicus*, c – *Ptyodactylus oudrii*, d – *Equus asinus*, e – *Uromastyx acanthinurus*, and mammal footprints or shelters under argan trees: (f1, f2) *Vulpes vulpes* footprints and its shelter, G1 – squirrel footprints, G2 – wild rabbit shelter (original photos by R. Kechairi taken in the Tindouf argan groves)

is also an important habitat for birds (Vernon *et al.* 2005). We recorded 25 species of birds, 17 mammals, 9 reptiles, 1 amphibian, and 15 arthropods, mostly insects (Table 4).

The environmental importance of this landscape is remarkable. Firstly, it is a breeding area for endangered wildlife species. Secondly, the groves accumulate and restore the soils. Thirdly, the area is a transition station for migratory birds through the small marshes north of the argan groves (Tafegoumet and Oum El-Achar). Fourthly, it allows safe passage of dorcas gazelles and Barbary sheep away from the villagers and the haters along the southern slope of the river Draa and the north of Ouarkziz crater.

## 4. Discussion

This paper presents the first study of the floristic and faunistic richness of argan groves in the west of the Algerian Sahara. The delimitation of the distribution of *Sideroxylon spinosum* and the comprehensive inventory of plant and animal species were launched by Kechairi (2009). In the same circumstances, an ecological description, presentation of the physical environment, and an imprecise delimitation of its distribution area were carried out by Benkheira (2009). Subsequently, Kaabèche *et al*. (2010) focused on a phytosociological analysis. However, Kechebar *et al*. (2013) detailed the distribution of argan trees in the main wadi beds.

Through subjective sampling we compiled a floristic list of 79 species divided into 31 botanical families. Based on the scale of Daget and Poissonet (1991), the flora of the region is very rich. The argan tree is found in various plant associations in the form of small facies along the El-Ma wadi and its tributaries. The distribution of the facies is influenced by the nature of the lithological substrate of the wadi beds.

The basic structure of the argan grove is a coppice forest, with a dominance of dense and thorny bushes (Kechairi 2021a), in a desert savannah-type plant formation with acacias and *Panicum turgidum*, characteristic of the Sahara in North-West Africa (Quézel & Barbero 1993) and used for grazing (Boughani *et al.* 2009). On alluvial beds, we have essentially the same formation observed in south-western Morocco: *Periploco laevigatae-Agranietum spinosae*, which grows on limestone and dolomite (Msanda 1993; Peltier & Msanda 1995).

The argan ecosystem is distinguished from the surrounding desert environment by the presence of vigorous

**Table 4.** List of animal species recorded in the Tindouf argan groves

| Animal group | Species |
|---|---|
| Birds | *Accipiter nisus* (Linnaeus, 1758) Eurasian Sparrowhawk; *Alaemon alaudipes* (Desfontaines, 1789) Greater Hoopoe-lark; *Ammomanes deserti* (Lichtenstein, 1823) Desert Lark; *Ammomanes cinctura* (Gould, 1839) Bar-tailed Lark; *Buteo rufinus* (Cretzschmar, 1827) Long-legged Buzzard; *Calandrella brachydactyla* (Leisler, 1814) Greater Short-toed Lark; *Caprimulgus aegyptius* (Lichtenstein, 1823) Egyptian Nightjar; *Chlamydotis undulate* (Jacquin, 1784) African houbara; *Ciconia ciconia* (Linnaeus, 1758) White stork; *Corvus ruficollis* (Lesson, 1831) Brown-necked Raven; *Cursorius cursor* (Latham, 1787) Cream-coloured Courser; *Galerida cristata* (Linnaeus, 1758) Crested Lark; *Gyps fulvus* (Hablizl, 1783) Griffon Vulture; *Hirundo rustica* (Linnaeus, 1758) Barn Swallow; *Leiothlypis peregrina* (Wilson, 1811) Tennessee Warbler; *Motacilla alba* (Linnaeus, 1758) White Wagtail; *Neophron percnopterus* (Linnaeus, 1758) Egyptian vulture; *Oenanthe leucopyga* (Brehm, 1855) White-crowned; *Phoenicurus moussieri* (Olphe-Galliard, 1852) Moussier's Redstart; *Phylloscopus humei* (Brooks, 1878) Hume's Leaf-warbler; *Pterocles alchata* (Linnaeus, 1766) Pin-tailed Sandgrouse; *Scotocerca inquieta* (Cretzschmar, 1827) Streaked Scrub-warbler; *Streptopelia decaocto* (Frivaldszky, 1838) Eurasian Collared-dove; *Turdoides fulvus* (Desfontaines, 1789) *Fulvous Babbler*; *Upupa epops* (Linnaeus, 1758) Common Hoopoe |
| Mammals | *Ammotragus lervia* subsp. *sahariensis* (Rothschild, 1913) Barbary sheep (observed on Ouarkziz crater and in Targant); *Atelerix algirus* (Lereboullet, 1842) Algerian hedgehog; *Atlantoxerus getulus* (Linnaeus, 1758) Barbary ground squirrel (major pest of argan seeds); *Camelus dromedarius* (Linnaeus, 1758) Arabian camel; *Canis anthus* (F.Cuvier, 1820) African Golden Wolf; *Equus asinus* (Linnaeus, 1758) Wild Donkey; *Felis sylvestris* (Schreber, 1777) Wild Cat; *Gazella dorcas* (Linnaeus, 1758) Dorcas Gazelle; *Gerbillus campestris* (Loche, 1867) North African gerbil; *Hystrix cristata* (Linnaeus, 1758) Crested porcupine; *Jaculus jaculus* (Linnaeus, 1758) Lesser jerboa; *Lepus capensis* (Linnaeus, 1758) Cape hare; *Mellivora capensis* (Schreber, 1776) Honey badger; *Meriones crassus* (Sundevall, 1842) Sundevall's jird; *Psammomys obesus* (Cretzschmar, 1828) Fat sand rat; *Vulpes vulpes* (Linnaeus, 1758) Red fox; *Vulpes zerda* (Zimmermann, 1780) Fennec fox |
| Reptiles | *Acanthodactylus boskianus* (Daudin, 1802) Bosc's Acanthodactyl; *Agama impalearis* (Boettger, 1874 ) Bibron's agama; *Cerastes cerastes* (Linnaeus, 1758) Desert Horned Viper; *Macrovipera mauritanica* (Duméril & Bibron, 1848) Sahara Rock Viper; *Mesalina olivieri* (Audouin, 1829) Olivier's Sand Lizard; *Ptyodactylus oudrii* (Lataste, 1880) Algerian Fan-fingered Gecko (observed in small water bodies in Targant valley); *Trapelus mutabilis* (Merrem, 1820) Desert agama; *Uromastyx acanthinura* (Bell, 1825) Bell's Dabb Lizard; *Varanus griseus* (Daudin, 1803) Desert monitor |
| Amphibians | *Pelophylax saharicus* (Boulenger, 1913) syn. *Rana saharica* (Sahara frog) |
| Arthropods (arachnids and insects) | *Androctonus liouvillei* (Pallary, 1924) Black Scorpion; *Anthophila* sp. (Bee); *Buthus atlantis* (Pocock, 1889) Atlas Scorpion; *Ceratitis capitata* (Wiedemann, 1824) Mediterranean fruit fly; *Dociostaurus maroccanus* (Thunberg, 1815) Moroccan locust; *Galeodes olivieri* (Simon, 1879) Sun spider; *Harmonia* sp. (Ladybird); *Hottentotta gentili* (Pallary, 1924) black Scorpion; *Heteronychus arator* (Fabricius, 1775) African Black Beetle; *Odonata* (Fabricius, 1793) Dragonfly; *Messor* sp. (Forel, 1890) Harvester ant; *Reticulitermes* sp. (Holmgren, 1913) Termite; *Schistocerca gregaria* (Forskål, 1775) Desert locust; *Trithemis pallidinervis* (Kirby, 1889) Dragonfly; *Vanessa cardui* (Linnaeus, 1758) Butterfly; *Vespula* (Thomson, 1869) Ground Yellowjackets |

argan trees over 10 m high and *Faidherbia albida* over 25 m high in Wadi El-Ma (Kechairi 2021a). This confirms what Ozenda said (1991), that trees are far from being absent from the Saharan flora and that there are at least 20 arborescent species in the north and centre of the Sahara. Most of them can reach a size comparable to those of trees of temperate zones (Quézel & Barbero 1993).

The most continental in the whole biogeographic classification of North-West Africa, the floristic elements in our study area are made up of similar types already cited by Peltier (1982): tropical, Saharan, and Mediterranean, but the Macaronesian element is absent. The Mediterranean element confirms that the region has a great floristic originality (Chevalier 1943).

The majority of Saharan trees are of tropical origin (Quézel & Barbero 1993), but in our study *Sideroxylon spinosum*, *Acacia* spp., and *Ziziphus lotus* dominate in the canopy. Where the argan tree is present, endemism is high (Zahran 2010) and indeed endemic species constitute 20.3% of the flora of the studied plant formation.

Considering plant life-forms, chamaephytes dominate with a frequency of around 40% in Touaref Bou-aam and Merkala. Unfortunately, these sites are currently considered an open field for the herds of Sahrawi nomads. Therophytes, which are a sign of aridity of the environment (Négre 1966), have a frequency of 34.2% in the border region of Targant, not accessible to herds (Kechairi 2021a).

It is alarming that the increase in anthropogenic and environmental disturbances, including climate change (Moukrim *et al.* 2019), negatively affect argan forest ecosystems. Therefore, long-term efforts must be taken within the framework of sustainable development to protect these ecosystems, threatened with extinction if they do not receive enough attention, not only at the national level, but also at the global level.

## 5. Conclusions

The possible disappearance of the argan groves could lead to a great decrease in biodiversity, including

a reduction in genetic heritage. The ecosystems with argan trees play an irreplaceable role in the ecological balance, with many living organisms (fauna, flora and microflora) directly linked to its presence. Its natural environment at the Hamada of the Draa includes valuable vegetation, occupying the ecological niches on the wadi beds, with specific biological diversity that must be preserved in order to maintain the authentic habitat for threatened animal species, such as the fennec fox, spiny-tailed lizard, and houbara bustard. Unfortunately the ostrich has already completely disappeared.

Our floristic analysis has shown that the Brassicaceae and Fabaceae are the most represented families (12.7% and 11.4% of the flora, respectively), followed by and the Asteraceae and Zygophyllaceae (8.9% each), while 18 species (23%) are rare and 16 are endemic (20.3%). The Saharo-Sindian element is the major biogeographical group (24.1% of the flora), compared with 11.4% for the Saharo-Mediterranean and the Mediterranean elements each.

In the Algerian Sahara, the Tindouf argan groves are valuable ecosystems, which serve as shelters for wildlife. Indeed, the argan ecosystem is characterized by a rich flora, represented by 31 families, 67 genera, and 79 species, and we recorded 25 species of birds, 17 mammals, 9 reptiles, 1 amphibian, and 15 arthropods, mostly insects. The argan groves need better protection and conservation. Their degradation could have a considerable impact on biodiversity, inducing its reduction and a drift of the genetic heritage for the tree as well as for other animal, plant or microbial species.

Our argan heritage, which constitutes a valuable ecosystem within the Sahara desert, requires long-term conservation management within the framework of sustainable development. Firstly, by local authorities and services concerned with nature protection at the national level, but also by seeking the support of NGOs through international cooperation.

**Author Contributions:**

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**Appendix 1.** Floristic list of the Tindouf argan groves

| Family | Species | Plant life-form | Degree of rarity | Biotope | Biogeo-graphical distribution | Stations | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | TFB | MRK | TRG |
| Adiantaceae | *Adiantum capillus-veneris* L. | G | AC | Rocks | Med. | 0 | 0 | 1 |
| Amaranthaceae | *Anabasis aretioides* Moq. & Coss. ex Bunge | Ch | C | Desert pastures | End. | 1 | 0 | 0 |
| | *Anabasis articulata* (Forssk.) Moq. | Ch | C | Desert pastures | Sah.-Sind. | 0 | 0 | 1 |
| | *Atriplex halimus* L. | Ch | C | Rockeries | Cosmop. | 0 | 0 | 1 |
| | *Haloxylon scoparium* Pomel | Ch | AC | Desert pastures | Sah.-Med. | 1 | 1 | 1 |
| | *Salsola imbricata* Forssk. | Ch | R | Desert pastures | Sah.-Sind. | 0 | 0 | 1 |
| | *Salsola tetragona* Delile | Ch | AC | Desert pastures | Sah.-Med. | 0 | 0 | 1 |
| Amaryllidaceae | *Pancratium saharae* Coss. ex Batt. & Trab. var. *chatinianum* Batt. | G | AR | Arid pastures and rockeries | Sah.-trop. | 1 | 1 | 0 |
| Anacardiaceae | *Rhus tripartita* (Ucria) Large | MPh | AR | Arid pastures and rockeries | Sah.-Med. | 1 | 1 | 1 |
| Apiaceae | *Deverra battandieri* (Mayor) Chrtek | Ch | AC | Desert pastures | End. | 0 | 1 | 0 |
| Apocynaceae | *Calotropis procera* (Aiton) Dryand. | MPh | C | Wadi beds | Sahelo-Sah. | 1 | 0 | 0 |
| | *Nerium oleander* L. | NPh | R | Wadi beds, rockeries | Med. | 0 | 0 | 1 |
| | *Pergularia tomentosa* L. var. *schmidtiana* Batt. | Ch | CC | Desert pastures | Sah.-Sind. | 1 | 1 | 0 |
| | *Periploca laevigata* subsp. *angustifolia* (Labill.) Markgr. | NPh | CC | Arid rockeries | Sah.-Med. | 0 | 1 | 0 |
| Araliaceae | *Hedera helix* L. | MPh | CC | Wadi beds | Med. | 0 | 0 | 1 |
| Arecaceae | *Phoenix dactylifera* L. | MPh | C | Wadi beds | End. | 0 | 0 | 1 |
| Asteraceae | *Aaronsohnia pubescens* (Desf.) K. Bremer & Humphries | Th | CC | Desert pastures | N. Afr. | 1 | 0 | 0 |
| | *Anvillea garcinii* subsp. *radiata* (Coss. & Durieu) eterb | Ch | CC | Stony pastures | End. | 1 | 1 | 0 |
| | *Asteriscus graveolens* (Forssk.) Less. | Ch | CCC | Stony pastures | Sah.-Sind. | 1 | 0 | 0 |
| | *Launaea arborescens* (Batt.) Murb. | NPh | C | Desert pastures, rockeries | Ibero.-Maur.-Sah. | 1 | 1 | 1 |
| | *Launaea nudicaulis* (L.) Hook.f. | Th | CC | Desert pastures | Med. Sah.-Sind. | 1 | 0 | 0 |
| | *Picris coronopifolia* (Desf.) DC. sp. *albida* (Ball) M. | Th | AC | Wadi beds, rockeries | Sah.-Med. | 1 | 0 | 0 |
| | *Rhanterium suaveolens* Desf. | Ch | C | Desert pastures | End. | 1 | 0 | 0 |
| Boraginaceae | *Echium humile* Desf. | H | C | Desert pastures | Sah.-Med. | 1 | 1 | 0 |
| | *Heliotropium bacciferum* Forssk. | Ch | C | Variables | Sah.-Sind. | 0 | 0 | 1 |
| | *Trichodesma africanum* (L.) R.Br. | Th | AC | Desert rockeries | Sah.-Trop. | 1 | 1 | 0 |
| Brassicaceae | *Diplotaxis harra* (Forssk.) Boiss. | Th | RR | Wadi beds | Med.-Iran-Tur. | 0 | 0 | 1 |
| | *Diplotaxis pitardiana* Mayor | Th | R | Wadi beds | End. | 0 | 0 | 1 |
| | *Eremobium aegyptiacum* (Spreng.) Asch. ex Boiss. | Th | C | Sands | Sah. Sind.-trop. | 1 | 0 | 0 |
| | *Eruca vesicaria* (L.) Cav. | Th | C | Desert pastures | Med. | 0 | 1 | 0 |
| | *Farsetia aegyptiaca* Turra | Ch | C | Desert regs | Sah.-Sind. | 1 | 1 | 0 |
| | *Farsetia hamiltonii* Royle | Ch | AC | Desert regs | Sah.-Sind. | 0 | 0 | 1 |
| | *Foleyola billotii* Mayor | NPh | R | Wadi beds | End. | 1 | 0 | 1 |
| | *Matthiola maroccana* Coss. var. *puberula* Mayor | Th | R | Desert pastures, rockeries | End. | 0 | 1 | 0 |
| | *Morettia canescens* Boiss. var. *erecta* Mayor | Th | C | Desert pastures | Sah.-Sind. | 1 | 0 | 0 |
| | *Zilla spinosa* subsp. *macroptera* (Coss.) Maire & Weiller | Ch | C | Desert rockeries | End. | 1 | 1 | 1 |
| Capparaceae | *Capparis spinosa* L. | Ch | AC | Rockeries | Med.- Sah.-Sind. | 0 | 0 | 1 |
| Caryophyllaceae | *Gymnocarpos decander* Forssk | Ch | AC | Desert rockeries | Sah.-Sind. | 1 | 1 | 0 |
| | *Paronychia arabica* (L.) DC. subsp. *tibestica* Quézel | Th | AC | Desert pastures | Sah. | 1 | 0 | 0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cistaceae | *Helianthemum lippii* (L.) Dum. Course. | Ch | C | Desert pastures | Sah.-Med. | 1 | 1 | 0 |
| Colchicaceae | *Androcymbium punctatum* (Cav.) *Baker.* var. *saharae* M. | G | AC | Rocky pastures, Sands | Sah.-Sind. | 1 | 0 | 0 |
| Convolvulaceae | *Convolvulus trabutianus* Schw. and Musch. | Ch | R | Desert rockeries | End. | 1 | 0 | 0 |
| Cucurbitaceae | *Citrullus colocynthis* (L.) Schrad. | Th | CC | Sands | Trop. Med. | 1 | 1 | 0 |
| Euphorbiaceae | *Euphorbia calyptrate* Cosson and DR. var. *involucrate* Batt. | Th | C | Desert pastures | End. | 0 | 0 | 1 |
| Fabaceae | *Acacia ehrenbergiana* Hayne | MPh | RR | Wadi beds | Sah.-Med. | 1 | 0 | 0 |
| | *Acacia seyal* Delile | MPh | C | Wadi beds | Afr. Sah.-trop. | 1 | 0 | 0 |
| | *Acacia tortilis* (Forssk.) Hayne | MPh | C | Wadi beds | Afr. Sah.-trop. | 1 | 1 | 1 |
| | *Astragalus gomboeformis* Pomel | Ch | AC | Desert pastures | End. | 1 | 1 | 0 |
| | *Crotalaria saharae* Coss. | Ch | C | Wadi beds | End. | 1 | 1 | 0 |
| | *Cullen plicatum* (Delile) CH Stirt. | Ch | AC | Wadi beds | Afr. trop. | 1 | 1 | 0 |
| | *Faidherbia albida* (Delile) A.Chev | MPh | R | Wadi beds | Afr. trop. | 1 | 0 | 0 |
| | *Lupinus cosentinii* Guss. | Th | R | Wadi beds | Sah.-Med. | 0 | 1 | 0 |
| | *Retama raetam* (Forssk.) Webb | NPh | C | Sands | Sah.-Sind. | 1 | 1 | 1 |
| Geraniaceae | *Monsonia heliotropioides* (Cav.) Boiss. | Th | CC | Rockeries | Sah.-Sind. | 0 | 1 | 0 |
| Juncaceae | *Juncus maritimus* Lam. | G | C | Gueltas | Cosmop. | 0 | 0 | 1 |
| Lamiaceae | *Salvia aegyptiaca* L. | Ch | C | Desert pastures | Sah.-Sind. | 1 | 0 | 0 |
| Menispermaceae | *Cocculus pendulus* (JR Forst. & G. Forst.) Diels | NPh | R | Rockeries | Trop. | 1 | 0 | 1 |
| Plantaginaceae | *Plantago amplexicaulis* Cav. | Th | AR | Sands | Med. | 1 | 0 | 0 |
| Poaceae | *Aeluropus littoralis* (Gouan) Parl. | H | C | Gueltas | Med. | 0 | 0 | 1 |
| | *Cymbopogon schoenanthus* subsp. *schoenanthus* (L.) Spreng. | Ch | C | Wadi beds | Sah.-trop. | 1 | 1 | 0 |
| | *Panicum turgidum* Forssk. | Ch | AC | Saharan pastures | Sah.-trop. | 1 | 1 | 0 |
| | *Phragmites communis* Trin. | G | C | Gueltas | Cosmop. | 0 | 0 | 1 |
| | *Schismus arabicus* Nees | Th | C | Wadi beds | Med. | 0 | 0 | 1 |
| Polygonaceae | *Emex spinosa* (L.) Campd. | Th | RR | Wadi beds | Med. | 0 | 0 | 1 |
| | *Rumex simpliciflorus* Murb. | Th | C | Desert rockeries | Sah.-Sind. | 0 | 0 | 1 |
| Rhamnaceae | *Ziziphus lotus* (L.) Lam. | MPh | CC | Desert pastures | Med. | 1 | 1 | 0 |
| Sapotaceae | *Sideroxylon spinosum* L., syn. *Argania spinosa* (L.) Skeels | MPh | RR | Desert pastures, rockeries | End. | 1 | 1 | 1 |
| Solanaceae | *Lycium afrum* L. | MPh | AC | Desert pastures, rockeries | Sah. | 1 | 1 | 1 |
| | *Lycium intricatum* Boiss. | NPh | R | Rocks | Ibero-Maur.-Sah. | 1 | 1 | 0 |
| | *Solanum nigrum* L. | Th | R | Rockeries | Cosmop. | 0 | 0 | 1 |
| Tamaricaceae | *Tamarix articulata* Vahl. | Ph | C | Wadi beds | Sah.-Sind. | 0 | 0 | 1 |
| | *Tamarix gallica* L. | Ph | CC | Gueltas | Med. Sah.-Sind. | 0 | 0 | 1 |
| Zygophyllaceae | *Fagonia glutinosa* Delile | Th | CC | Desert pastures | Sah.-Sind. | 0 | 0 | 1 |
| | *Fagonia latifolia* Delile | Th | AC | Desert rockeries | Sah.-Sind. | 0 | 0 | 1 |
| | *Fagonia longispina* Batt. | Th | C | Desert pastures, rockeries | End. | 0 | 0 | 1 |
| | *Seetzenia lanata* (Willd.) Bullock | Th | AC | Desert pastures | Sah.-Sind. | 1 | 0 | 0 |
| | *Tetraena gaetula* subsp. *gaetulum* (Emb. & Mayor) Beier & Thulin | Th | AC | Gueltas | End. | 0 | 0 | 1 |
| | *Tribulus alatus* Forssk. | Th | AC | Desert pastures | Sah.-Sind. | 0 | 0 | 1 |
| | *Tribulus terrestris* L. | Th | CC | Desert pastures | Cosmop. | 0 | 0 | 1 |

Explanations: stations, TFB – Touaref Bou-aam, MRK – Merkal, TRG – Targant; plant life-form, Ch – chamaephyte, G – geophyte, H – hemicryptophyte, MPh – megaphanerophyte, NPh – nanophanerophyte, Th – therophyte; degree of rarity, AC – fairly common, AR – fairly rare, C – common, CC – very common, CCC – extremely common, R – rare, RR – very rare