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Original article

Analysis of species floristics within the oak forests of Guerrouche (Jijel, Algeria)

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ABSTRACT

The Guerrouche forest is home to a fairly important flora heritage which offers this massif a forest cover by the presence of quite remarkable forest stands, from a floristic point of view by the presence of natural vegetation characterized by a diverse flora. This study aims to quantify the floristic diversity of the vegetation associated with the three main tree species (zeen oak, cork oak and afares oak) that inhabit the Guerrouche forest on the basis of distributed floristic surveys, according to a sampling strategy. stratified and systematic, which took into account the species present in each type of tree stand. The floristic surveys thus carried out, numbering 55, made it possible to establish a list of a floristic list made up of 172 species, which belonged to 69 genera and 45 botanical families. Of these, 42 were endemic species, including 4 specific to the study area. The number of rare and very rare species was 70 taxa. The study also revealed the clear degradation of the genus Erica of this ecosystem. Analysis of the overall chorological spectrum showed a dominance of Mediterranean species (209 species), with a dominance (82.3%) of species that were therophyte species. The forest stands of the genus Quercus inhabiting the Guerrouche massif must be supported by the authorities to preserve and conserve this forest heritage against fires, illegal logging, etc. The results of this study will be the subject of development actions and rational management of these natural forest ecosystems.

KEY WORDS: plant diversity, botanical groups, rare and endemic species, Guerrouche, Algeria

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1. Introduction

Algerian forests form a part of Mediterranean forests and have been severely disturbed over time (QUEZEL & BARBERO, 1990). Different civilizations have strongly contributed to the reduction of forest cover, and disturbances continued throughout the colonial period. In 1830, the forest cover was 5 million ha (BENSAID ET AL., 1998). After independence, the Algerian forest became only 2.4 million ha (LETREUCH, 1995). Faced with this situation, the Algerian Government has initiated various programs to protect and extend the forest heritage through reforestation. The degraded forest ecosystem located largely in the mountains is the priority for the reforestation work. These areas are the most affected by fires and soil erosion. Reforestation activities have particularly focused on promoting higher value-added species such as cork oak *Quercus suber* and Atlas cedar *Cedrus atlantica* (MERDAS ET AL., 2017).

The forests of the Mediterranean area are typically composed of deciduous and evergreen species, such as zeen oak *Quercus canariensis* Willd., cork oak *Quercus suber* L. and afares oak *Quercus afares* Pomel.

A typical feature of Mediterranean forests is that they include both deciduous and evergreen trees. In addition, many forests are mixtures of deciduous and coniferous trees (MANSOURIAN ET AL., 2013).

From the precipitation map established by the National Water Resources Agency (NAWR, 1996), the study area is located in annual sections ranging from 850 mm to 1750 mm. The average minimum temperature for the coldest month (January) varies between 6.1°C and 8.1°C. The maximum temperatures for the hottest month (July) are between 30.2°C and 34.8°C. The dry period varies from 3 to 5 months. The high relative humidity of the air (80%) favours the existence and the maintenance of fairly important plant diversity.

The pluviothermal quotient of Emberger Q2 (EMBERGER, 1955) varies between 110 and 124, placing the Guerrouche Forest in the humid to subhumid bioclimatic stages with variations in mild and warm winters (DAGET & DAVID, 1982). The study area is considered to be the rainiest in Algeria.

The study area presents a very rugged relief comprising several mountain ranges oriented from east to west with an altitude varying from 480 m at the highest point of the region (1121 m). These orographic elements give a general configuration in folds of north-east and south-west orientation. Geologically, the region is dominated by sedimentary sandstone soils and volcanic soils in the northern areas (OBERT, 1970).

Our article describes the significant potential of vegetation within one of the most famous forest ecosystems of north eastern Algeria in the wilaya of Jijel. On a phytogeographic level the study area belongs to the Kabylo-Annabi Sector [K]: District of Djurdjuran Kabylia [K1], district of Baborean Kabylia [K2], and Annabi District [K3].

This sub-sector extends from Bejaia to Skikda, certain localities are quite representative of it such as the mountain and forest areas of the Babors chain, Takoucht, Djebel Tamesguida, the Forest of Guerrouche, the cliffs of Gouraya and El Aouana are near Jijel (MEDDOUR, 2010)

Our study demonstrates the distribution of botanical groups with an important richness of floristic species. It aims to show how this diversity can contribute to the stability and conservation of eco-biological activities within these categories of forest ecosystems in Algeria.

2. Materials and methods

The forest ecosystem of Guerrouche, is composed of formations of cork oak (*Quercus suber* L.), zeen oak (*Quercus canariensis* Willd.), and afares oak (*Quecus afares* Pomel) and is considered to be the most extensive monobloc chain in Algeria (QUEZEL, 1956). It covers an area of over 2896 ha compared to the overall forested area which is estimated to be 3,807 ha (Table 1).

Several development studies have been carried out here in: 1975, 1987, 2004 and 2012 (DGF, 2013), but these studies touched on the essence of the cork oak tree. Ecological studies have made it possible to locate the ecosystem of the forest chain of the Guerrouche Forest in an altitudinal range between 0 m and 1121 m located on the north-eastern facade of Algeria and extends between the geographical coordinates of 36°35' and 36°48' north latitude and between 5°29' and 5°40' west longitude (Fig. 1). The Forest of Guerrouche is part of the Little Kabylia of the Babors and opens onto the Mediterranean Sea in the Gulf of Bejaia. It is located 45 km south-west of Jijel, 80 km east of Béjaïa and 90 km north-east of Setif (OBERT, 1970).

Table 1. Areas for each plant formation type

Plant formation type	Area [ha]	Percentage [%] total forest area
Zeen oak	1670	57.66
Cork oak	756	26.10
Mixed oak grove zeen oak/cork oak	155	5.35
Afares oak	265	9.15
Streamside vegetation	50	1.73
Total forest	2896	76.00

Our study is based on the use of maps such as the plant formations map, the plant groups map and drawn up from satellite images (BOUNAR, 2003; BOUNAR ET AL., 2012; BOULAACHEB ET AL., 2006; KHELIFI, 1987; ZEDAM, 2015). We also used the pre-existing documentation of the Taza Massif (with the master plan that was established within the framework of the forest management of cork stands (DGF, 2004). 57 floristic surveys were carried out in the different plant communities to provide a quantitative description of the richness and diversity floristics of cork oak, zeen oak, afares oak and mixed formations (of zeen oak & cork oak) (Fig. 2). Field visits were carried out over a period of 2016, 2017 and 2018 during the months of March, April and May.

The data collection was undertaken by using a systematic sampling method. The choice of stations was based on the following criteria: altitude, slope, exposure and cover of forest stands of *Quercus suber* L, *Quercus canariensis* Willd and *Quercus afares* Pomel, and surveyed using the plot method with a minimum area recommended by the Braun-Blanquet method. The minimum area was calculated

each time the vegetation formation changed, and was in our case 300 m² for forests and 150 m² for clear and open stands. 9 surveys were carried out in the *Quercus afares* stands, 11 surveys were undertaken in mixed stands of *Quercus suber* & *Quercus canariensis*, 16 in the formation of *Quercus suber* and 19 in the formation of *Quercus canariensis*.

A factorial analysis of correspondences was used to explain the distribution of the large plant formations of the Guerrouche Forest, and included an ascending hierarchical classification which took into account topographic parameters such as altitude, slope and exposure as well as the overall cover of forest vegetation.

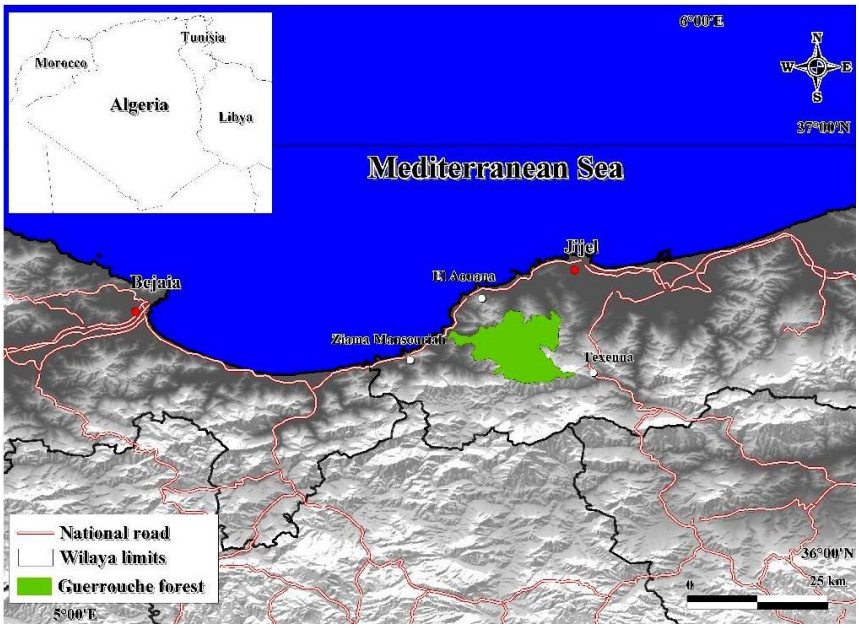

Fig. 1. Geographical location of the study area of the Guerrouche Forest

Bioclimatic floors / Vegetation stage	Sub- humid 600 < P < 900 mm/an	Humid and Perhumid P > 900 mm/an
Supra-Mediterranean - 3 < m < 0 300 < Alt < 900 m 1200 < Alt < 1800 m	*Quercus canariensis* and *Quercus afares*	
Meso- Mediterranean 0 < m < 3 600 < Alt < 1200 m	*Quercus suber* and *Quercus canariensis*	*Quercus canariensis*
Thermo mediterranean 0 < m < 5 200< Alt < 1200 m	*Quercus suber*	*Quercus canariensis* *Erica arborea* and *Quercus suber*

Fig. 2. Simplified diagram of the distribution of forest formations in the Guerrouche Forest Jijel

3. Results and discussion

3.1. Plant species richness

Field trips and surveys led to the development of the floristic list, which clearly shows the floristic richness within the protected area with 172 taxons classified by the family. Very rare taxa (RR), rare taxa (R), endemic taxa (E), taxa newly inventoried in the study area (N) and (C) common taxa. This richness has been demonstrated in the form of a floristic catalogue.

The interpretation of the results of the factorial analysis included 55 floristic records and 172 species which allowed the identification of four plant groups. Each grouping was individualized by the analysis and corresponded to the typical formations of cork oak, zeen oak, afares oak and the mixed formation of zeen and cork oak.

The shrub layers of the *Quercus canariensis* and *Quercus suber* formations were dominated by *Cytisus triflorus*. The results obtained in Table 2 clearly show the floristic species richness of the study site with 45 botanical families and the number of species within each of them.

Table 2. Distribution of species in the Guerrouche Forest by botanical families

Botanical families	Number of species	Botanical families	Number of species	Botanical families	Number of species
Brassicaceae	18	Aceraceae	3	Papaveraceae	1
Caryophylaceae	14	Thymelaeaceae	3	Anacardiaceae	1
Lamiaceae	13	Cistaceae	3	Plumbaginaceae	1
Asteraceae	12	Violaceae	3	Oleaceae	1
Fabaceae	10	Caprifoliaceae	3	Apocynaceae	1
Poaceae	9	Crassulaceae	2	Orobanchaceae	1
Apiaceae	7	Berberidaceae	2	Ericaceae	1
Rubiaceae	7	Salicaceaea	2	Anacardiaceae	1
Polypodiaceae	6	Euphorbiaceae	2	Aquifoliaceae	1
Geraniaceae	6	Rhamnaceae	2	Pteridaceae	1
Scrofulariaceae	5	Convolvulaceae	2	Dryopteridaceae	1
Orchidaceae	5	Plantaginaceae	2	Smilacaceae	1
Fagaceae	4	Gentianaceae	2	Araliaceae	1
Linaceae	4	Cupressaceae	1	Iridaceae	1
Boraginaceae	4	Liliaceae	1	Anacardiaceae	1

Within this research we counted 172 taxa including 42 endemic species and subspecies for the study region. The highest rate of endemism was recorded at the level of the mixed formation located in the north-east of the study area bordering the Babors Range with 24 taxa, followed by the formations of cork oak with 14 taxa and the formation of afares oak with 3 taxa (Table 4). The families with the most endemic species were: Asteraceae – 7, Caryophylaceae – 6, Brassicacea – 5, Ranunculacea – 4, Fabaceae – 4, Geraniaceae – 3, Cistaceae – 3, the other botanical families have 2 or 1 species (Table 3).

There were 70 taxa of rare species distributed across all plant formations of cork oak, zeen oak, afares oak and the mixed formation of zeen and cork oak with 13, 21, 16 and 20 species respectively. The study area was also home to several rare and endangered species to which special attention should be paid (Table 4). Some of these rare species deserve to have their conservation status revised and should therefore be placed on the Red List of the International Union for the Conservation of Nature (IUCN). Fig. 3 shows some photos of the species to be protected and which are endangered. The choice of axes is given by the eigenvalues and the percentage of inertia obtained from the analysis (Table 5).

Table 3. Number of endemic and rare species per family within the Guerrouche forest

Botanical families	Number of endemic species	Botanical families	Number of rare species	Botanical families	Number of rare species
Asteraceae	7	Asteraceae	7	Fagaceae	1
Poaceae	2	Poaceae	6	Ranunculaceae	1
Caryophylaceae	6	Lamiaceae	6	Berberidaceae	1
Ranunculaceae	4	Brassicaceae	5	Cistaceae	1
Brassicaceae	5	Orchidaceae	4	Plumbaginaceae	1
Crassulaceae	1	Caryophylaceae	4	Gentianaceae	1
Fabaceae	4	Rosaceae	4	Ericaceae	1
Geraniaceae	3	Aceraceae	3	Pteridaceae	1
Linaceae	2	Apiaceae	3	Smilacaceae	1
Apiaceae	1	Boraginaceae	3	Araliaceae	1
Cistaceae	3	Salicaceaea	2	Orobanchaceae	1
Scrofulariaceae	1	Crassulaceae	2	Plantaginaceae	1
Rubiaceae	1	Fabaceae	2	Fagaceae	1
Campanulaceae	1	Rhamnaceae	2	Ranunculaceae	1
Violaceae	1	Thymelaeaceae	2	Berberidaceae	1

Table 4. Rare and threatened species of the Guerrouche Forest

Species not included in the IUCN Red List	Species on the IUCN Red List
Asperula odorata L.	*Arabis doumetii* Coss.
Satureja juliana L.	*Saxifraga numidica* Maire
Hieracium ernesti Maire	*Teucrium kabylicum* Batt.
Viburnum lantana L.	*Fedia sulcata* Pomel.
Convolvulus dryadum Maire	*Carum montanum* (Coss & Dur.) Benth. et Hook.
Stellaria holostea L.	*Lonicera kabylica* Rehder.
Chrysanthemum fontanesii (B. & R.) Q. & S.	*Teucrium atratum* Pomel.
Bupleurum montanum Coss.	*Epidemium perralderianum* Coss.
Quercus afares Pomel	*Phlomis bovei* de Noé.
Sedum pubescens Vahl.	*Sedum multiceps* Coss & Dur.
	Pimpinella battandieri Chabert
	Moehringia stellarioides Coss.

Table 5. Eigenvalues from factorial correspondence analysis

	Factorial axis F1	Factorial axis F2
Own value	26,817	14,669
Variability (%)	42,566	23,284

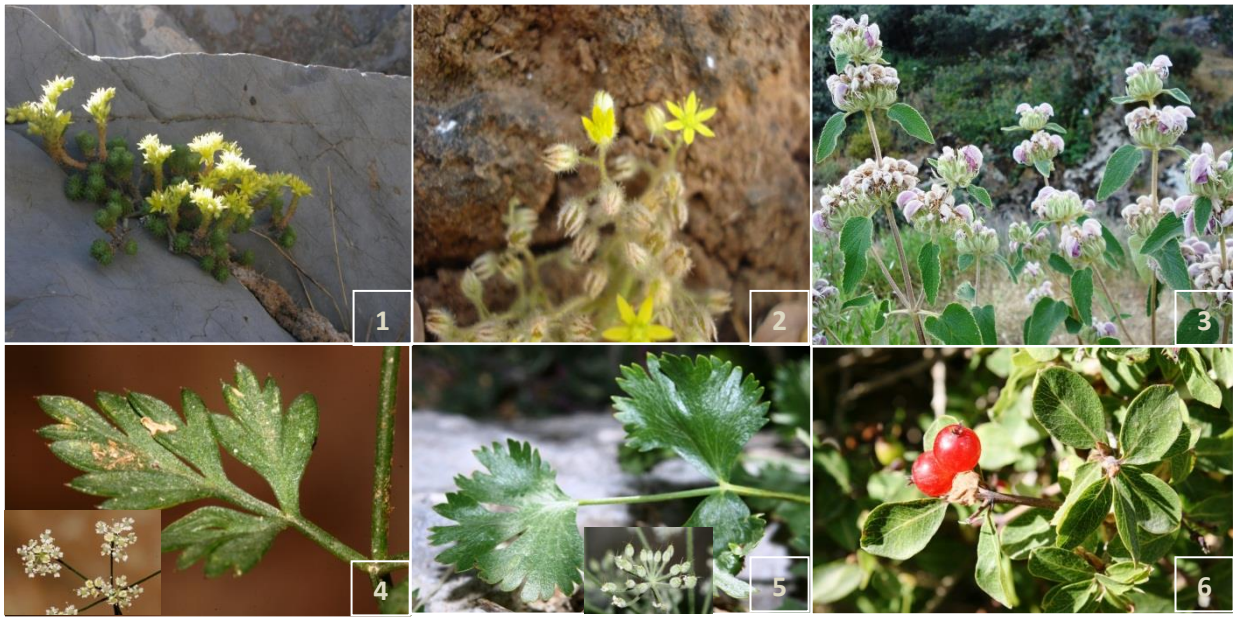

Fig. 3. Other botanical groups with a few numbers of species within the protected area of Guerrouche (Jijel)
1 – *Sedum multiceps* Coss. et Dur., 2 – *Sedum pubescens* Vahl., 3 – *Phlomis bovei* de Noé, 4 – *Carum montanum* (Coss. & Dur.) Benth. et Hook., 5 – *Pimpinella battandieri* Chabert, 6 – *Lonicera kabylica* Rehder

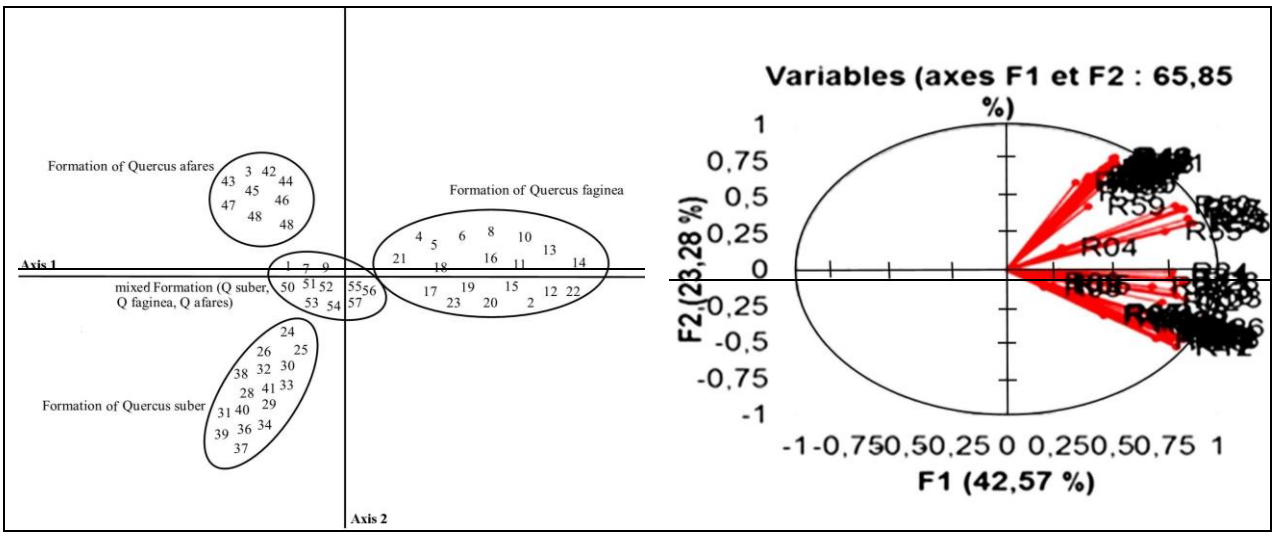

Fig. 4. Floristic analysis of the factorial map of the surveys

3.2. Individualization of forest stands

The analysis of the factorial map relating to the factorial plane 1-2 (Fig. 4), allows to note, the detachment of the floristic records according to their type of formation, one notes 8 (eight) records are attached to the high altitude groupings (*Quercus afares*), opposed to the group of records of (*Quercus suber*) which occupy the low altitudes, 16 (sixteen) records are in the center of the plan focus the records of the mixed formation of *(Quercus suber, Quercus* afares, *Quercus canariensis*) with 10 records floristic, the pure formation of Quercus canariensis is well marked in the positive part of the F1 and F2 axis (Fig. 4). We therefore ended up defining four forest stands according to the variables altitude, exposure, slope, soil depth, and annual precipitation and the minimum temperatures of the coldest month.

In this type of investigation, (AHC) made it possible to define clear classes of grouping records: A (*Quercus suber*), B (*Quercus faginea*), C (*Quercus afrès*) and D (mixed formation *Quercus suber*, *Quercus canariensis*, *Quercus afares*) which was not possible by a simple AFC (Fig. 5). In general, the factors responsible for the diversification of forest stands in the Guerrouche forest are factors which correspond to the climatic gradient, the thermal altitudinal gradient and the rise in vegetation or biological elevation.

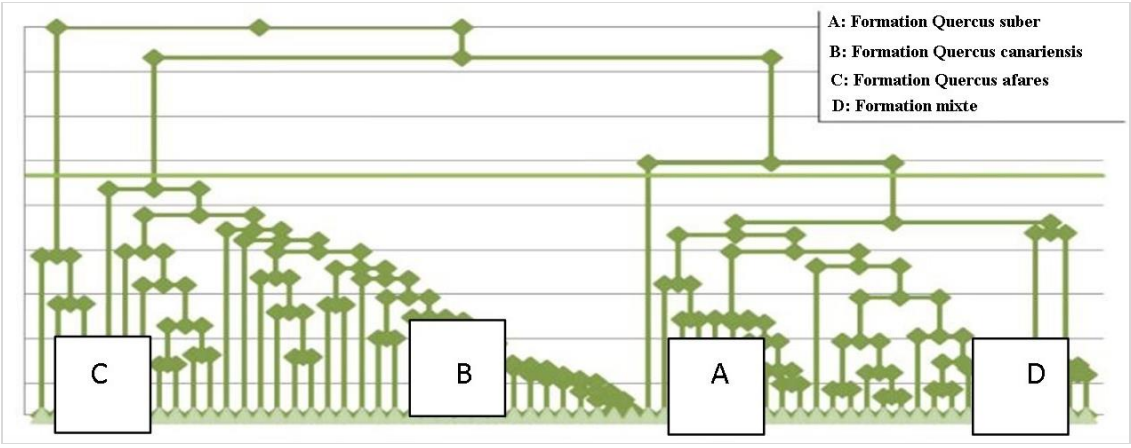

Fig. 5. Hierarchical classification of forest stands in Guerrouche forest (AHC)

This analysis also makes it possible to differentiate the high-altitude groups, represented by *Quercus afares*. These groups are made up of species adapted to a humid bioclimate with cold to very cold winters and medium altitude groups. On the other hand, the mid-altitude groups are better preserved than these high altitude ones. In the same altitudinal range and under the same bioclimate, the thermal altitudinal factor is an important element in the evolution of the Guerrouche Range.

4. Conclusions

The species richness and the floristic diversity analysis of the Guerrouche Forest have found 172 taxa including 42 endemic species. The highest rate of endemism was recorded at the level of mixed stands located to the north-east of the study area bordering the Chain of Babors. Existing data on endemism in Algeria are scarce and fragmentary. The study region by nature of its geographical position and wide pedological variation as well as its great climatic variations has allowed the development of a rich and varied endemic flora, through its ecological and phytogenetic originality. These data justify its classification, with the whole of Little Kabylia, as the nerve center "hot spot" of northern Algerian (VELA & BENHOUHOU, 2007; VALDÉS ET AL., 2002).

However, the Guerrouche Forest, despite the legislative protection that it enjoys, is subject, like most Mediterranean natural ecosystems, to worrying degradation, because of anthropogenic activities (uncontrolled harvesting of wood, exploitation of cork, uprooting of plants of interest, etc.) and uncontrolled grazing it is seriously deteriorating its specific wealth. To address this problem and to maintain the ecological integrity of this ecosystem, an integrated strategy for the conservation of this floristic diversity must be put in place soon. This strategy must first focus on the forest species, which, through their uniqueness, constitute the essential framework of this natural ecosystem, in particular zeen oak *Quercus canariensis* Willd, cork oak *Quecus suber* L. and afares oak *Quercus afares* Pomel which each have a very remarkable economic value (cork, wood, etc.). Indeed, these oak groves constitute the main forest formations of the Guerrouche Forest and include in their floral constitutents several endemic or/and rare species of the genera Cyclamen, Corydalis, etc. The study area is also home to several rare and sometimes endangered species to which special attention should also be paid (Table 4). Some of these rare species deserve to have their conservation status revised and should therefore be placed on the Red List of the International Union for the Conservation of Nature (IUCN). This particularly concerns these species: *Moehringia stellarioides* Coss, *Asperula odorata* L., *Satureja juliana* L., *Viburnum lantana* L., *Hieracium ernesti* Maire, *Convolvulus dryadum* Maire, *Stellaria holostea* L., *Chrysanthemum fontanesii* (B & R.) Q. & S., *Bupleurum montanum* Coss and *Sedum pubescens* Vah. It is therefore time to think seriously about the protection of these species and to urgently establish a management strategy to conserve these habitats and their plant heritage.

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