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A. Cuena-Lombraña, M. Fois, G. Calvia & G. Bacchetta

An updated checklist of the vascular flora of Montarbu massif (CE Sardinia, Italy)

Abstract

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The Montarbu (CE Sardinia) is the second highest carbonate massif of Sardinia. This area mainly consists of a group of limestone mountain outcrops named "tonneri" or "tacchi", with a great variety of micro-environmental and topographic conditions that host a high floristic richness. The main aim of this work is to present an updated checklist of the vascular flora of Montarbu to assess its conservation priorities. Based on several field surveys carried out from 2012 to 2023 and integrated by bibliographic and herbaria analyses, the updated checklist of the vascular flora is presented here. The flora amounts to 874 taxa, belonging to 94 families and 425 genera. Regarding the endemic component, we found 126 taxa, of which 44 are exclusive to Sardinia and 40 are shared with Corsica. The alien taxa are 33, but it appears worrying that 20 are recorded for the first time during the last two decades. The analysis of biologic and chorologic data highlighted the peculiarities of this territory and its biogeographic autonomy. Due to the relatively high number of endemics exclusive to Montarbu and its geological and geomorphological peculiarities, despite the already implemented initiatives, we suggest further activities supporting the conservation of this area.

Key words: alien plants, biodiversity hotspot, conservation, endemism, geographical island, Mediterranean flora, native plants.

Introduction

Mountains worldwide represent important areas for biodiversity and endemism (Steinbauer & al. 2016; Hoorn & al. 2018). The high presence of endemic taxa in mountain environments was sometimes explained within the theory of "mountain islands"; in other words, mountains can act as ecological and/or edaphic and climatic islands (Flantua & al. 2020; Lopez-Alvarado & Farris 2022). The concept of islands within islands has also been developed in phylogeny, biogeography, and ecology (Itescu 2019). These island-like systems, though not as considerable as actual islands, can represent essential places for differentiation and speciation for many taxa (Esposito & al. 2015; Steinbauer & al. 2016). Accordingly, many mountains have been identified as centers of endemism or "micro-hotspots" within the Mediterranean islands (Cañadas & al. 2014; Kougioumoutzis & al. 2021).

Sardinia is the second-largest island in the Mediterranean Sea, with 24,090 km^2. The prolonged isolation and its high geological diversity created a wide range of habitats rich in endemic species, particularly on its mountain massifs, where the insularity is strengthened by the elevation and edaphic diversity (Médail & Quézel 1997). The Sardinian vascular flora consists of 2,922 total taxa of which are 2,441 natives (Galasso & al. 2018). Recently, 341 taxa have been reported as endemic to the island and neighbouring islands or small portions of other phylogeographically affine regions, amounting to 12% of the entire native floristic contingent (Fois & al. 2022). Among them, 199 are exclusive endemics, corresponding to about 8% of the native Sardinian flora (Fois & al. 2022). According to the biogeographic classification of the Mediterranean region proposed by Rivas-Martínez & al. (2011), the Italo-Tyrrhenian province includes three subprovinces: the Sardinian, the Corsican and the Tuscano-Calabrian. Later on, the complex of Sardinia, Corsica and the Tuscan Archipelago was proposed as an independent biogeographical province within an Italo-Tyrrhenian superprovince, which extends over the entire western coast of the Italian Peninsula (Bacchetta & al. 2012; Bacchetta & Pontecorvo 2005). Basing their studies on the endemic vascular flora, the Sardinian subprovince was furtherly divided into six sectors and 22 biogeographic subsectors (Fenu & al. 2014).

The present study focused on the updating previous floristic research on the Montarbu massif (Loi & Lai 2001; Loi & al. 2004). This mountain range includes some of the highest carbonate peaks, such as Pizzu Margiani Pubusa and Perda 'e Liana, located in the historical region of Ogliastra, in the central-eastern Sardinia, that constitute an independent biogeographic subsector within the "Barbaricino" sector (Fenu & al. 2014). The geographical position, elevation, isolation, and complex geology of this area contributed to the exceptional plant and animal species richness and to the local variety of unique ecosystems and landscapes. According to the regional law L.R.31/89, about 70% of the Montarbu massif area has been included in the "Golfo di Orosei e del Gennargentu" National Park, established in 1998 but never entered into force. Within this area, the same law L.R.31/89 recognised the calcareous outcrop of Perda 'e Liana as a Regional Natural Monument. These mountains are also included within the Special Areas of Conservation (SAC) "Monti del Gennargentu" (ITB021103; European Commission Habitats Directive 92/43/EEC).

In this paper, we summarised and critically revised both published and unpublished data about the vascular flora of Montarbu and its conservation status. Even though the area has been the focus of numerous botanical studies (e. g., Loi & Lai 2001; Loi & al. 2004; Bacchetta & al. 2004, 2009, 2010, 2014, 2020; Farris & al. 2012; Calvo & Aedo 2015; Brullo & al. 2023) due to its high floristic importance, and considering the recently described and reported species, there is an evident need for further research in the area. Therefore, an update of the Montarbu vascular flora was of critical importance for planning and performing a more effective conservation and management. This checklist, coupled with the analysis of its more relevant components, supports the evaluation of local phytodiversity, highlights its relevance, and sheds light on the conservation status in this area.

Materials and methods

Study area

Montarbu (Fig. 1) consists of a group of limestone mountains and small tablelands, which are commonly called "tonneri" or "tacchi" (Loi & Lai 2001). The study area has a total surface of 42 km^2 and is located in central-eastern Sardinia, in the municipalities of Seui and Gairo (Nuoro). The highest mountain peaks, some of which with elevations higher than 1,200 m a.s.l., are in the northern part of the investigated territory: Pizzu Margiani Pubusa (1,324 m a.s.l.), Perda 'e Liana (1,293 m a.s.l.), Pizzu Andriottu (1,232 m a.s.l.), Accu Linnaru (1,193 m a.s.l.), Bruncu Arrascialei (1,178 m a.s.l.), and Pizzu Is Abis (1,102 m a.s.l.). The peaks of the southern sector reach lower altitudes, rarely exceeding 1,000 m

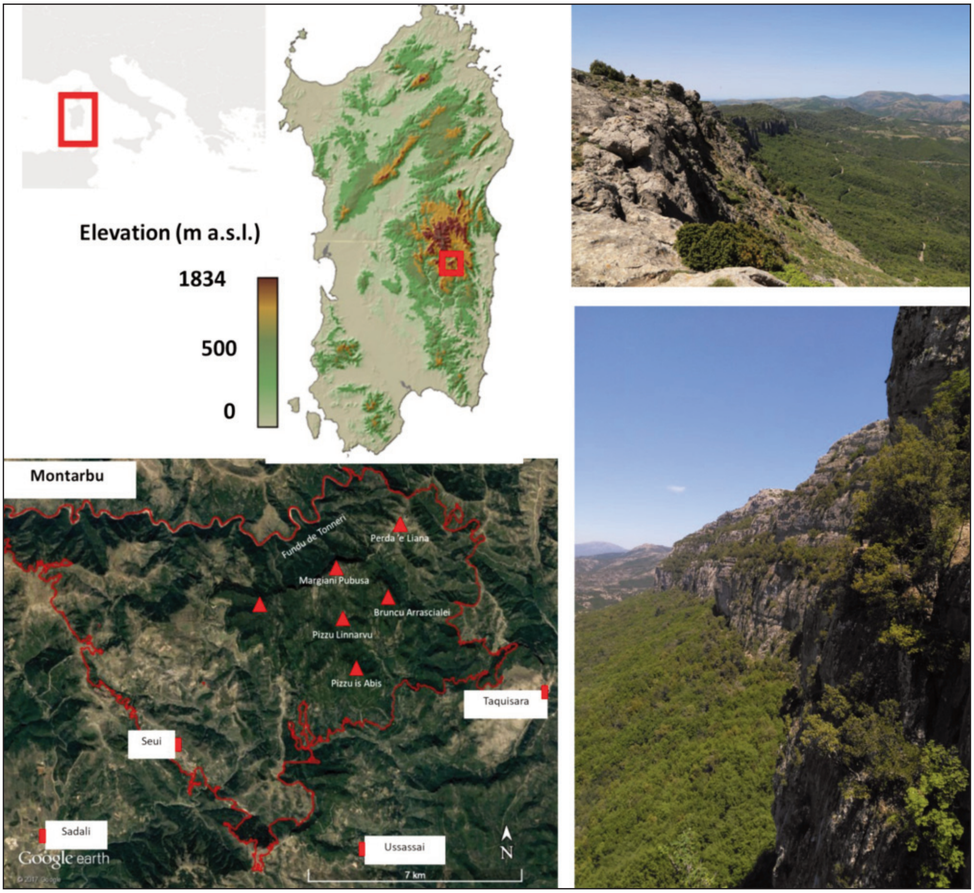


Fig. 1. The study area of Montarbu massif (central-eastern Sardinia) with some typical landscapes: "Pizzu Margiani Pubusa", photo taken from the upper, westwards (top right) and "Fundu de Tonneri", taken from the West to the East (bottom right).

a.s.l. Different environments, such as steep cliffs and gorges (even more than 100 m deep), small wetlands, vast scrublands and woodlands constitute other relevant landmarks scattered over the whole area. Moreover, there are restricted vegetation types of high biogeographic and conservation interests, such as the relict formations with temperate trees like the woods with *Taxus baccata* L., *Ilex aquifolium* L., *Acer monspessulanum* L. and *Ostrya carpinifolia* Scop. (Bacchetta & al. 2004, 2009; Farris & al. 2012).

Apart from some specific studies (e.g., Arrigoni 1965, 1973), the flora of part of this area was published in a relatively recent past (Loi & Lai 2001; Loi & al. 2004). Due to its difficult accessibility, especially to the high cliffs, new endemic plant species were only been described or found in recent years, such as *Senecio morisii* J.Calvo & Bacch., *Pinguicula sehuensis* Bacch., Cannas & Peruzzi, *Hypericum scruglii* Bacch., Brullo & Salmeri, *Genista nuragica* Bacch., Brullo & Giusso, *Solenopsis bacchettae* Brullo, C.Brullo, Tavilla, Siracusa & Cambria and *Siler montanum* subsp. *ogliastrinum* Bacch., F.Conti & Bartolucci (Bacchetta & al. 2010, 2014, 2020; Calvo & Aedo 2015; Conti & al. 2021; Brullo & al. 2023). Moreover, it should be noted that the flora of some marginal crystalline environments, which include part of the Flumendosa valley bordering the study area with the Gennargentu massif and home to some species of particular conservation interest, such as the endemic *Rhamnus persicifolia* Moris, were not included in any previous flora. According to its high endemicity rate, this area has also been identified as a "micro-hotspot" of biodiversity (Fois & al. 2018a). Moreover, part of its peculiar flora has recently been the object of studies concerning several aspects, such as ethnobotany (Sanna & al. 2020), spatial ecology (Fois & al. 2018b) or seed ecophysiology of threatened taxa (Mattana & al. 2012; Cuena-Lombraña & al. 2020; Porceddu & al. 2020).

Geology and geomorphology

From a geological point of view, the studied area comprehends metamorphic, volcanic, and sedimentary outcrops of the Palaeozoic and the Mesozoic. Chronologically, Palaeozoic phyllitic schists and micaschists, which were intensely corrugated and metamorphosed during the Hercynian orogeny (Silurian, approximately 443–419 Ma ago, extending from the close of the Ordovician to the beginning of the Devonian), constitute the basement. Therefore, surface erosion agents swiftly disassembled the mountain range that had risen during the Hercynian orogeny. The detritus from higher elevations was then deposited into depressions, frequently occupied by lacustrine basins. This sedimentation process persisted until the conclusion of the Permian period (298–252 million years ago), spanning from the end of the Carboniferous to the beginning of the Triassic. It was during this time that post-orogenic volcanic activity commenced, leading to the formation of effusive eruptive rock covers (Carmignani & al. 2016). In the Mesozoic, other events affected the geologic formation of this area. Currently, the calcareous succession is characterised by the "Dorgali formation" of the middle-late Jurassic Period (c.a. 170-150 Ma), which here reaches a thickness of about two hundred meters and has a slightly southward-inclined pattern, comprising grey or yellowish limestones, sometimes oolithic, dolomites and dolomitic limestones (Agnesi & al. 1990; Carmignani & al. 2016). The predominant soils in the study area are lithosols (lithic and typic xerorthents) supporting vegetation represented by a very sparse maquis, red soil (lithic and typic rhodexeralfs) with a clayey horizon more than 15 cm in thickness, with a very scarce cover represented by forms of degradation of maquis and garrigue, and the inceptisols (lithic and typic xerochrepts) with forest vegetation or evolved maquis (Loi & Lai 2001).

The hydrography of the area is mainly characterised by the course of the Flumendosa River, which is the most extensive hydrographic system of Sardinia and defines the entire northern border of Montarbu, flowing mostly westwards along this stretch. A system of smaller tributaries flows northwards from the highest peaks, feeding the main watercourse through the northern sector. The streams that flow mostly southwards are larger than those flowing in the northern part and are rich in interesting habitats and plant communities (e.g., Rio Ermolinus) and often host rare or endemic taxa.

From a bioclimatic point of view, these territories have a Mediterranean Pluviseasonal Oceanic bioclimate. The observed thermotype and ombrotype indices are comprised between the Euoceanic lower Mesomediterranean and lower subhumid in the basal areas and Semicontinental lower Supramediterranean and lower humid among the peaks (Bacchetta & al. 2009; Canu & al. 2015).

Data collection and analysis

The floristic list presented here issues from field surveys carried out from 2012 to 2023 and extensive analysis of relevant literature, implemented with the data from CAG, SASSA, and SS herbaria.

Collected specimens had been identified using the most relevant and updated floras: Tutin & al. (1964-1980, 1993), Castroviejo & al. (1986-2019), Arrigoni (2006-2015), Jeanmonod & Gamisans (2013), and Pignatti & al. (2017-2019).

The nomenclature follows the most recent checklists of the Italian native (Bartolucci & al. 2018) and alien (Galasso & al. 2018) vascular flora, updated taking into account some floristic and taxonomic novelties (e.g., Bartolucci & al. 2019; Bacchetta & al. 2020). Family names follow PPG I (2016) for Pteridophytes, Pignatti & al. (2017-2019) for Gymnosperms, and APG IV (2016) for Angiosperms.

Life forms had been determined in the field following the classification of Raunkiaer (1934). Chorology follows the abbreviations proposed by Pignatti & al. (2017-2019). Doubtful taxa previously recorded were considered in the checklist as *taxa inquirenda* or *taxa excludenda* and enlisted in different tables (see Electronic Supplementary File 1, ESF1 - Table S2 and S3, respectively).

Details and characteristics regarding the alien flora were based on the national standardised system presented in the study of Galasso & al. (2018). Alien: plants occurring in a specific area, whose presence in Sardinia can be attributed either to intentional or unintentional human activities, or that naturally spread from a non-native region. Casual: alien plants that may flourish and occasionally produce offspring beyond cultivation or unintentional dissemination. However, they usually fade away as they are unable to establish self-sustaining populations. Their persistence is contingent on recurrent introductions. Naturalized: alien plants that occur with self-maintaining populations without direct human intervention. Invasive: alien plants that occur with self-maintaining populations without direct human intervention, produce fertile offspring at considerable distances from the parent individuals, thus being able to spread over a large area. Furthermore, in our classification, archaeophyte taxa pertain to alien plants introduced to Sardinia before 1492, while neophytes refer to those introduced after this date. The term 'cultivated' is used to differentiate taxa exclusively found under cultivation (based on visual data from the authors) from those that have become more or less established within the local ecosystems.

Results

The floristic checklist consists of 874 taxa, belonging to 94 families and 425 genera (see ESF1 - Table S1 for further details). The taxa at species level are 678, and 196 are considered at the subspecies level. Pteridophytes are 17, which represent 1.97% of the total flora; Gymnosperms consist of 10 taxa, representing 1.14%, of which only the genera *Juniperus* and *Taxus* are native; Angiosperms are 846 taxa, with a percentage equal to 96.90%. The *taxa inquirenda* are 26 (ESF1 - Table S2) and *taxa excludenda* are 18 (ESF1 - Table S3).

Considering families (Fig. 2), the most represented are *Asteraceae* (97 taxa, 11.11%), *Fabaceae* (95, 10.88%), *Poaceae* (83, 9.50%), and *Orchidaceae* (38, 4.35%). The richest genera are *Trifolium* (19 taxa), *Ranunculus* (17 taxa), *Carex* (14 taxa), and *Medicago* (13 taxa).

Biological life forms highlight a substantial richness in therophytes (T = 35.62%), followed by hemicryptophytes (H = 31.73%), geophytes (G = 13.52%), trees and shrubs (P = 7.90% and NP = 2.98%, respectively) and hydrophytes (I = 1.49%) (Fig. 3).

Chorological data (Fig. 4) show a prevalence of Mediterranean (*s.l.*) taxa (30%), followed by European (*s.l.*) ones (28%) and by a further 14% of endemic elements (Fig. 4). The endemic contingent consists of 126 taxa, belonging to 36 families and 96 genera. The

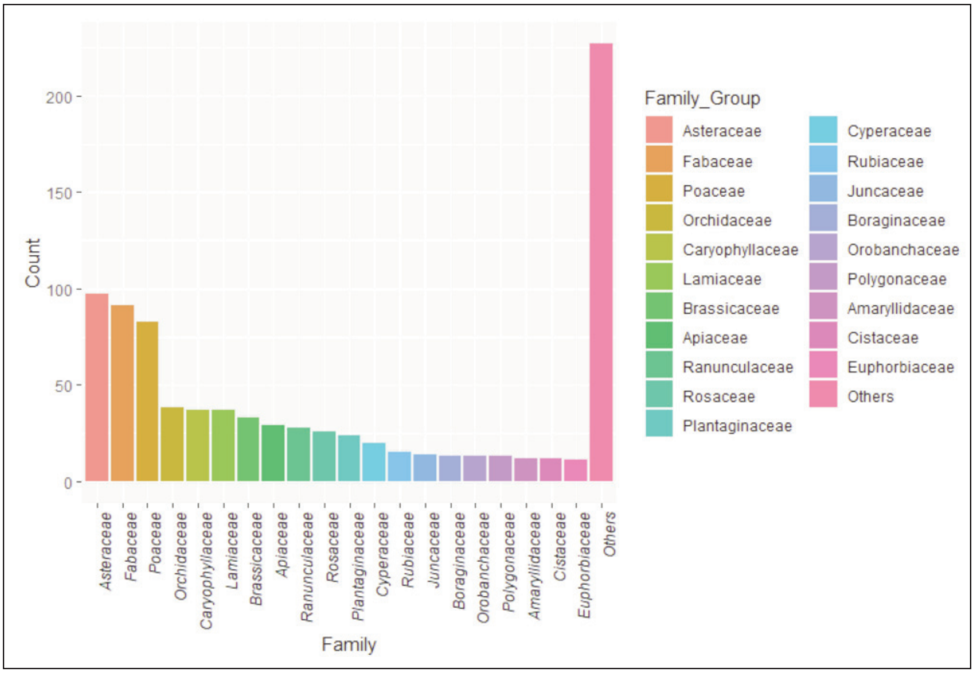


Fig. 2. Number of taxa of the flora of Montarbu by family. Here only the top 20 families are reported.

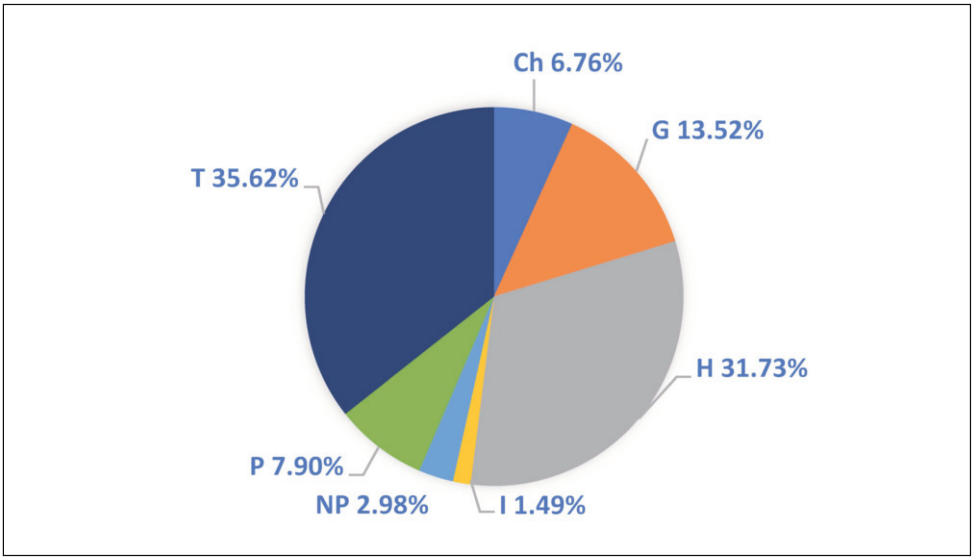


Fig. 3. Biological spectrum of the vascular flora of Montarbu. Life forms: H = hemicryptophytes; Ch = chamaephytes; G = geophytes; NP = nanophanerophytes; P = phanerophytes; T = therophytes and I = hydrophytes.

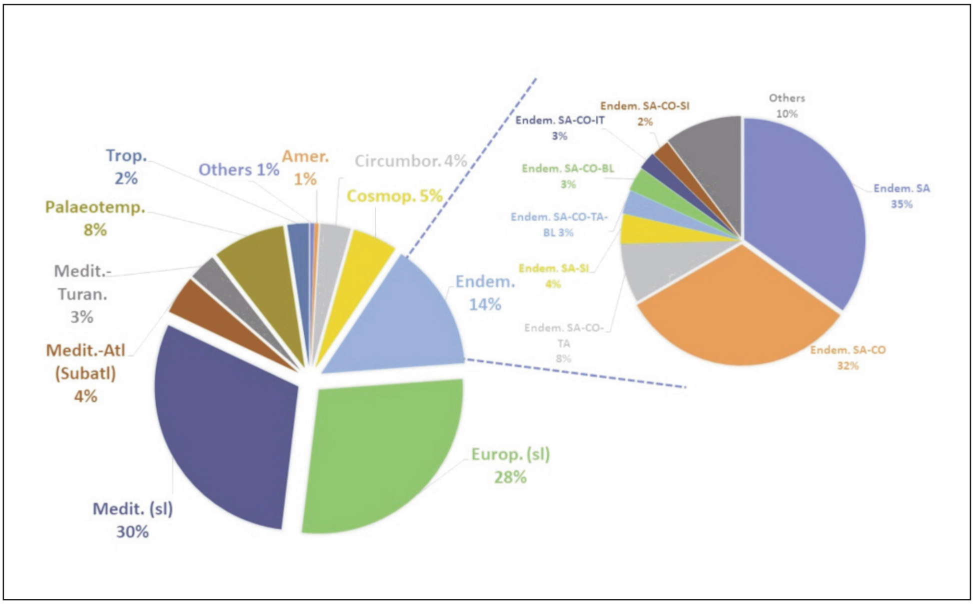


Fig. 4 Chorological spectrum and details regarding the endemic contingent of the flora of Montarbu. SA = Sardinia; CO = Corsica; BL = Balearic Islands; IT = Italian peninsula; SI = Sicily; and TA = Tuscan Archipelago.

families with the highest numbers of endemic taxa were *Asteraceae* (16), *Lamiaceae* (11) *Caryophyllaceae* (10), and *Orchidaceae* (9). The chorology of endemics showed the prevalence of Sardinian (35%) and Sardo-Corsican taxa (32%), that together reach 67% of the total, followed by taxa endemic to Sardinia, Corsica and Tuscan Archipelago (8%), and by the Sardinian and Sicilian endemics (4%). Among the endemic taxa, four only occur in the study area (*Genista nuragica*, *Pinguicula sehuensis*, *Siler montanum* subsp. *ogliastrinum* and *Solenopsis bacchettae*).

We found 33 alien taxa (3.78% of the total flora) (Fig. 5), of which nine are considered invasive, 13 are naturalised and one is a casual alien. Another component of the alien taxa regards the cultivated (8) or cryptogenic (2) taxa. The biological spectrum of the alien flora showed a prevalence of phanerophytes (19 taxa), followed by therophytes (9 taxa), hemicryptophytes and chamaephytes (two taxa both) and one geophyte. From a chorological perspective, the alien taxa were primarily of European or Euro-Mediterranean origin, with a notable prevalence attributed to the cultivated component (e.g. *Corylus avellana* L., *Castanea sativa* Mill., *Juglans regia* L. *Olea europaea* L.). Regarding the invasive taxa, they were primarily of American and Tropical origin, each represented by four taxa. Additionally, there was one taxon each from New Zealand, Macaronesia, and Africa.

Over the taxa included in the most recent Italian Red List (Rossi & al. 2020; Fois & al. 2022), we found 15 Endangered (EN), six Vulnerable (VU), 23 Near Threatened (NT), five Data Deficient (DD) and 67 Least Concern (LC) taxa (Fig. 6).

A total of 325 taxa are here reported for the first time. Twenty of them are alien taxa, accounting for 60.6% of all alien taxa found in the study area, and 40 are endemic, representing 31.7% of the 126 endemic taxa (ESF1 - Table S1).

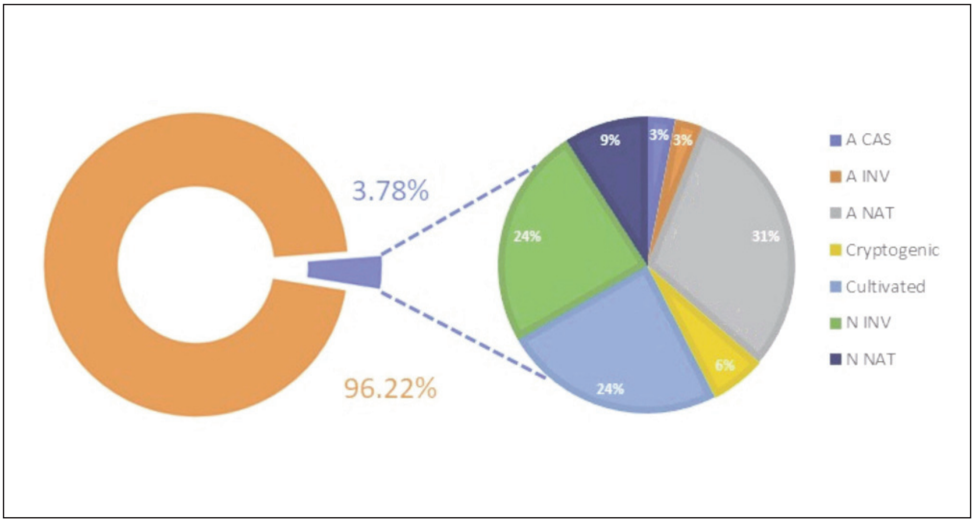
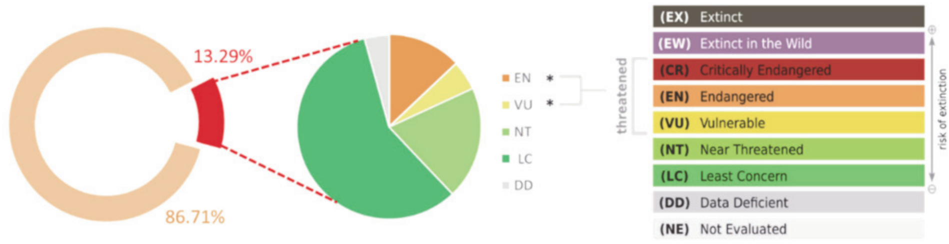


Fig. 5 Native and alien flora details of the flora of Montarbu: A = archaeophytes; N = neophytes; CAS = casual; INV = invasive; NAT = naturalised.

Fig. 6 Vascular plants of Montarbu subject to IUCN assessment and details on their risk categories.



Discussion

The vascular flora of Montarbu includes 841 native taxa, equal to 36.5% (Table 1) of the total flora of Sardinia in less than 0.2% of the whole island surface. These values of species richness appear remarkably high if compared, among others, even with the plant-rich Gennargentu and Limbara massifs, which host more than 30% and 41% of the regional flora, respectively, both in an area near to 1% of the island (Bacchetta & al. 2013; Calvia & Ruggero 2020, 2023).

When evaluating the native taxa richness(n)-to-area ratios (Table 1), Montarbu stood out with a notably high ratio (20.02 n/km^2), followed by the other calcareous chain of Monte Albo (9.51 n/km^2). This suggests a significant influence of lithology in shaping the phytodiversity of Sardinia. This is also confirmed by the lower ratio found for the metamorphic and igneous Gennargentu (1.82 n/km^2) and Limbara (3.85 n/km^2) massifs. Base-rich substrates, and especially limestones, have been observed to be richer than other substrates in various contexts, such as in Sicily or Crete (Sciandrello & al. 2020; Kougioumoutzis & al. 2021). A hypothesis of such higher species richness on calcareous soils in Sardinia and, more generally in Europe, is that carbonate substrates were widely distributed during the Quaternary period and that this influenced the evolution of many plant species on high pH soils (Djordjević & Tsiftsis 2019).

All the aforementioned mountainous areas show a higher density of plant taxa than Sardinia as a whole, which suffers from higher levels of unsustainable land use, habitat degradation and a higher frequency of exotic flora and fauna. In other words, the phytodiversity in mountain areas, apart from the phylogeographical reasons, mainly related to isolation and habitat specificity, is favoured by a lower accessibility and pressure from humans compared to coastal areas and inland plains, which are more impacted, mainly by extensive and long-standing agriculture and urbanization.

Among the most recent floristic novelties for this area, those taxa recently described for the Sardinian flora, such as *Pinguicula sehuensis*, exclusive to the North-Western part of

Table 1. Some information on the vascular floras of other mountain massifs in Sardinia and the whole flora of the island.

Characteristics	Montarbu	Gennargentu	Limbara	Monte Albo	Sardinia
Total taxa	874	948	1,147	659	2,922*
Native taxa	841 (96.22%)	910 (95.99%)	1,010 (88.10%)	647 (98.17%)	2,441 (83.54%)*
Alien taxa	33 (3.70%)	38 (4.01%)	137 (11.90%)	12 (1.83%)	481 (16.46%)*
No. families	94	97	120	82	152*
No. genera	425	427	486	393	730*
No. endemic taxa	126	141	86	49	341**
Area (km^2)	42	500	262	68	24,090
Native taxa/total island native taxa	36.5%	30.0%	41.0%	28.1%	-
Ratio native taxa richness/area	20.02	1.82	3.85	9.51	0.10
References	This work	Bacchetta & al. (2013)	Calvia & Ruggero (2020)	Camarda (1984)	*Galasso & al. (2018) **Fois & al. (2022)

Montarbu, are worthy of attention. Currently, only one population is known, with seven subpopulations occurring in vertical cliffs (chasmophytic habitat), and one linked to small terraces among cliffs (Bacchetta & al. 2014). Another species recently described is *Senecio morisii* (Calvo & Aedo 2015), previously reported as *S. doria* L. (Arrigoni 2006-2015). This species grows only in CE Sardinia, on saturated calcareous soils along the banks of streams and springs, under woods of *Ostrya carpinifolia,* often accompanied by *Taxus baccata* and *Ilex aquifolium*, at elevations between 700–1,200 m a.s.l. (Calvo & Aedo 2015). Another taxon with a similar distribution and ecology is *Hypericum scruglii*, an endemism recently described (Bacchetta & al. 2010) and previously reported as *H. tomentosum* L. (Loi & Lai 2001). More recently, the new species *Genista nuragica* within the *G. salzmannii* group has been described (Bacchetta & al. 2020). It is a dwarf shrub exclusively growing on the windy ridges of Montarbu di Seui, at an elevation of 1,250–1,310 m a.s.l. Recent studies on the *Siler montanum* group (Conti & al. 2022) have also allowed to describe *S. montanum* subsp. *ogliastrinum*, a subspecies endemic to the limestone cliffs of Ogliastra. Finally, the most recent taxon described for this area is *Solenopsis bacchettae*, an exclusive species of CE Sardinia, typical of calcareous substrates in wet habitats such as springs and small streams (Brullo & al. 2023).

The remaining newly reported taxa mainly concerned alien introductions or colonisations, such as *Ailanthus altissima* (Mill.) Swingle or *Erigeron canadensis* L., or neglected, cryptic and rare taxa, such as *Bivonaea lutea* (Biv.) DC., *Monotropa hypopitys* L., or *Hypericum aegypticum* subsp. *webbii* (Spach) N.Robson. For the reasons mentioned above, it is essential to highlight the need to keep on updating the floras to incorporate new records/taxa, their nomenclature, and their conservation status.

Overall, *Asteraceae*, *Fabaceae* and *Poaceae* are usually the most represented families of the vascular flora (e.g., Bacchetta & al. 2013; Cannucci & al. 2019; Calvia & Ruggero 2020; Nikolić & al. 2020). However, the flora of Montarbu di Seui also shows a high presence of *Orchidaceae*, including several taxa exclusive to Mesozoic limestones (Lussu & al. 2020). This apparently surprising result is not an uncommon feature; in fact, numerous studies have highlighted that - especially in the European countries under Mediterranean bioclimatic conditions - calcareous substrates (limestone-dolomite, in particular) are the most favourable for the growth and survival of orchids (Landi & al. 2009; Pierce & al. 2014; Djordjević & Tsiftsis 2019; Tsiftsis & al. 2019).

Data relating to the biological spectrum underline the Mediterranean character of the area, a pattern that is confirmed by the H/T index = 0.88 (T = 35.62%; H = 31.52%). According to Cannucci & al. (2019), typical Mediterranean conditions occur if H/T = <1, while under continental bioclimatic conditions H/T > 1. Compared to the flora of Gennargentu (H/T index = 1.05: Bacchetta & al. 2013), Montarbu hosts a higher number of Mediterranean vascular plants. The rate of woody taxa (P/NP = 10.8%) is similar to Monte Albo (P = 9.7%: Camarda 1984) and Genneragentu Massif (ca. P/NP = 11.6%: Bacchetta & al. 2013), but lower than the one recorded for Mount Limbara (P/NP = 12.7%: Calvia & Ruggero 2020). The high percentage of hemicryptophytes and chamaephytes (31.52% and 6.75%, respectively) can be correlated to the abundance of natural rocky crevices and Mediterranean climatic conditions. The percentage of geophytes (G = 13.52%) results higher than that of Gennargentu (12.13%: Bacchetta & al. 2013) and Limbara (12.90%: Calvia & Ruggero 2020) massifs and seems to be more related to the high presence of *Orchidaceae*. This richness can also be related to land use, especially in relation to the practice of setting fires and other sylvo-pastoral activities shared with other Sardinian mountain systems, which favoured the formation of different environmental types, thus allowing better conditions for geophytes and orchids as well. The percentage of hydrophytes, mainly located along watercourses and around springs, is significant (I = 1.49%), due to the geological nature of the territory that facilitates infiltration and percolation processes. These are mainly located in the lower parts, where the Hercynian basement is in contact with the overlying limestone outcrops and where the waters of the upper parts flow out, giving rise to numerous springs, rivulets and streams, which are also of high faunistic interest due to the presence, among others, of the Mediterranean brown trout *Salmo cettii* and the endemic Sardinian newt *Euproctus platycephalus* (Lecis & Norris 2003; Sabatini & al. 2018). The percentage of hydrophytes is more similar to that of the Limbara Massif (1.9%: Calvia & Ruggero 2020) than the closer mountains of the Gennargentu Massif (0.53%: Bacchetta & al. 2013).

Chorological data show a dominance of Mediterranean and endemic taxa; their total amounts correspond to 51% of the entire local vascular flora. Nonetheless, the remarkable importance of this area is increased by those chorological elements, such as Palaeotemperate (8%) and Circumboreal (4%) taxa, testifying past different climatic conditions, that can still be observed in the relic *Taxus baccata* and *Ostrya carpinifolia* communities, confirming the complex geological history and prolonged insularity leading to the inclusion of Montarbu massif as a putative Mediterranean refugium and micro hotspot (Fenu & al. 2014).

The richness of endemic taxa is among the most relevant elements highlighted in this study, although in line with the general proportion of endemics in Sardinia (approx. 14% of its total native flora, Fois & al. 2022). The presence of endemics in the study area is facilitated by its high biological and ecological diversity. Simultaneously, this underscores the robust association between limestone mountain environments, especially cliffs, and endemism. This connection has been previously highlighted by Fenu & al. (2010) for the Supramontes area and by Bacchetta & al. (2013) for the Gennargentu in Sardinia. Similar patterns have been observed in various locations throughout the Mediterranean, as highlighted by Thompson (2020) and references therein.

Alien taxa correspond to a low percentage (3.7%, Table 1), which is a further confirmation of the high ecological value of this area. This component was mainly originated by reforestations during the 1970s and 1980s, which have partly modified the original landscape. Only seven of the alien taxa are considered invasive, albeit their impact in the studied territory is still not particularly high. However, more than half of the alien taxa (20 over 33 taxa) were recorded for the first time during the last decades, highlighting the need to pay attention on this potential threat, which is particularly common, especially in islands (Fois & al. 2020). Similarly, another important part of newly reported taxa is consisting of ruderal and synanthropic ones, such as *Dittrichia graveolens* (L.) Greuter or *Hyoscyamus albus* L.

From a conservation point of view, only 13.29% of the flora of Montarbu di Seui has been assessed following the IUCN criteria. In particular, 15 taxa are Endangered (EN), and six are Vulnerable (VU). Five taxa were already assessed as Data Deficient (DD), while other recent discoveries, such as *Genista nuragica*, are not yet assessed, confirming, once again, the need to enhance the current knowledge about conservation statuses. It should be noted that many endangered taxa, such as *Solenopsis bacchettae, Hypericum scruglii, Borago pygmaea* (EN, IUCN category) or *Senecio morisii* (VU, IUCN category) are closely linked to wetlands, and their survival is threatened by anthropogenic alterations of the water regime, such as withdrawals of water from the springs, possible reclamation works or climate change (Bacchetta & al. 2010; Cuena-Lombraña & al. 2021). Moreover, a considerable number of orchid taxa clearly show a preference for moderately humid to wet habitats (Djordjević & Tsiftsis 2019). Given their conservation significance, their recognition is particularly emphasised in multilateral environmental agreements, including the Water Framework Directive (WFD 2000/60/EC). Other endangered (EN) taxa, such as *Centaurea filiformis* Viv. subsp. *filiformis* or *Sesleria insularis* subsp. *barbaricina* Arrigoni, are more closely associated with xeric cliffs and screes. They may be particularly susceptible to stochastic episodes induced by the growing frequency of extreme meteorological events or by tourism, especially the rise in climbers opening new routes. Similar threats may affect chasmo-hygrophilous species living in wet crevices and cliffs, such as the endangered (EN) *Aquilegia nugorensis* Arrigoni & E.Nardi and the vulnerable (VU) *Pinguicula sehuensis*.

These results indicate that Montarbu is one of the most interesting massifs of Sardinia from a botanical point of view. Consistent with the findings of Bacchetta & al. (2013), where regions in Sardinia dominated by limestone and carbonate rocks were examined, the count of exclusive Sardinian endemics appeared to be greater in the limestone reliefs than in the Limbara and Gennargentu massifs, which are considered a putative floristic refuge according to the criteria of Médail & Diadema (2009). Similarly, cliffs – especially limestone cliffs have acted as refuges for many plants which were able to survive there safe from anthropogenic and environmental stress and disturbance factors, resulting in unique habitats with many rare and endemic species that are particularly sensitive to interspecific competition and/or environmental changes (Lorite & al 2017). These habitats have proven to be very useful in addressing a significant number of ecophysiological and evolutionary issues, thereby constituting a priority for biodiversity conservation (Bacchetta & al 2013; Cañadas & al. 2014). Wet habitats, together with cliff habitats, can be considered ecologically or topographically controlled "islands". Due to the high number of endemics, exclusive endemics and peculiarities related to geology and geomorphology, and according to the recent conservation policies at local level (Fenu & al. 2010), Montarbu is a reservoir for plant diversity and already defined as a "micro-hotspot" of biodiversity within the Mediterranean "mega-hotspot", and its protection is of pivotal importance (Bacchetta & al. 2013; Cañadas & al. 2014).

Conclusions

Despite its relatively small extent, Montarbu massif presents a high diversity in vascular plants, being their flora made up of 874 specific and subspecific taxa. Even if comparison with previous floras is difficult, mainly because of the different extent of the examined area, several plant species are reported for the first time in a checklist concerning this area. These new reports contribute to the already extensive list of endemic and exclusive taxa found in this area. An increasing number of non-native vascular taxa has been recorded. Although less representative, European, temperate and circumboreal taxa play a relevant role, and the plant communities where they belong are important from both the ecological and conservation point of view. These taxa and communities are often represented by peripheral and isolated plant populations at the edge of their distribution range, thus particularly sensitive to climate change and global warming. Overall, considering the high endemicity rate, the increasing number of alien taxa and the endangered ones, along with those potentially endangered, we confirm the importance of conserving and pursuing floristic investigations in this area.

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Addresses of the authors:
A. Cuena-Lombraña[1], M. Fois[1*], G. Calvia[1,2] & G. Bacchetta[1],
[1]Centro Conservazione Biodiversità (CCB), Dipartimento di Scienze della Vita e dell'Ambiente (DiSVA). Università degli Studi di Cagliari V.le Sant'Ignazio da Laconi, 13, 09123 Cagliari, Italy.
[2]Free University of Bozen-Bolzano, Faculty of Agricultural, Environmental and Food Sciences. Piazza Università, 5 -39100, Bozen-Bolzano, Italy
*Corresponding author, E-mail: mfois@unica.it