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RESEARCH ARTICLE

Cultural importance, availability and conservation status of Spanish wild medicinal plants: Implications for sustainability

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Abstract

1. The harvest of wild plants with medicinal uses is increasing globally, both for self-treatment and as a source of income. The increasing demand for these remedies could lead to the over-harvest of some species. Despite a recent surge in the number of studies analysing wild medicinal plants management, little is known about the effects of non-commercial harvesting on the conservation status of medicinal plants.
2. We explore the connection between the cultural importance (CI) of medicinal vascular plants traditionally used in Spain for self-treatment and their availability, conservation and legal protection status, and discuss the implications of our results for sustainability. We focus on Spain, located in one of the world's 25 biodiversity hotspots and the most diverse country in Europe regarding vascular plants (7071 species, 1357 endemic), while also being culturally and linguistically diverse.
3. Spain has a rich body of traditional knowledge referring to wild medicinal plants, with 1376 species with medicinal uses, which represents nearly a fourth (22%) of the total autochthonous vascular flora of the country (16% endemic). Species CI is positively correlated with abundance ($\rho = 0.466$) and occupancy area ($\rho = 0.495$). Only 8% of the wild medicinal plants traditionally used in Spain have an endangered conservation status and just 6% are fully or largely affected by protection measures. Most species used for self-treatment in Spain are common, highly available and not threatened. This suggests that domestic use alone does not result in overexploitation and that traditional knowledge systems of plant management might ensure their sustainability.

KEYWORDS
biocultural conservation, ecosystem services, natural resources, pharmaceutical ethnobotany, Spain, wild plants gathering

1 | INTRODUCTION

Around 7% of the 350,000 vascular plant species currently described are considered medicinal (25,791 species; RBG Kew, 2020). The World Health Organization estimates that between 70% and 95% of the population in developing countries relies on traditional medicines, mainly of plant origin, for primary healthcare (Robinson & Zhang, 2011). Medicinal plants are not only used for self-treatment but also as an important source of income (IPBES, 2022). Moreover, the use of medicinal herbs is expanding, especially after the COVID-19 pandemic (Smith et al., 2021; Timoshyna et al., 2020; WHO, 2019), their global trade reaching USD 138 billion in 2019 (Industry Research Biz, 2020), with an average annual growth of 2.4% in volume and 9.2% in value (Vasisht et al., 2016). Although China and India have historically dominated the medicinal plants' market, the increasing global demand has already resulted in the expansion of the sector in other countries (Caporale et al., 2020). The growing demand for medicinal plants has led to unmonitored commercial gathering, which has resulted in the over-harvest of some species (Ganie et al., 2019; Larsen & Olsen, 2007). Indeed, of the 5411 plants with medicinal use assessed by the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species, 723 (13%) are threatened (RBG Kew, 2020). Therefore, there is an urgent need for actionable knowledge that helps avoiding that the increasing use of medicinal plants jeopardizes their sustainability (Kumar et al., 2021).

Over-harvest of plants with medicinal uses is considered a threat to their sustainability. While some tools have been proposed to quantify medicinal plants' vulnerability to overharvest (Castle et al., 2014), a main setback in assessing harvesting impact lies on the lack of a consensual definition of sustainability. In strict sense, sustainable harvesting refers to harvest that does not lead to a population decline and allows for a population growth rate of at least 1.0 (Svenning & Macía, 2002). Under such definition, assessing sustainable harvesting requires in-depth studies that consider the species' life form, growth and extraction rate, population size, part harvested and extraction techniques used, in addition to other environmental variables such as climate (Ticktin, 2015). Given the difficulty of collecting all these empirical data for all medicinal plant species, an alternative operational definition of sustainable harvest refers to the long-term use of a species without exhausting it. Indeed, research shows that many traditional societies have promoted strategies that accommodate the use of a species with its natural growth rate, thus allowing its long-term use (Morales et al., 2011; Turner et al., 2022; Verschuuren et al., 2010). Examples of strategies intended to ensure sustainable harvest include limiting the proportion of individuals gathered to allow reproduction (e.g. *Sideritis raeseri* Heldr. & Boiss; Tomasini, 2019); gathering only the part with active components thus diminishing plant damage (e.g. *Paris polyphylla* var. *yunnanensis* (Franch.) Hand.-Mazz.; Qin et al., 2018); promoting species in their natural environments through seeds dispersal (e.g. *Angelica archangelica* L.; Rautio et al., 2016); or transplanting species into home gardens (e.g. *Limnophila aromatica* Merr.; Cruz-Garcia & Struik, 2015).

While traditional harvest of medicinal plants might be sustainable, the harvest of medicinal plants for commercial purposes may challenge sustainability by increasing extractive pressure and modifying traditional norms that regulate extraction (Ganie et al., 2019; Niu et al., 2021). In that sense, there has been a recent surge in the number of case studies analysing wild medicinal plants management (e.g. Senkoro et al., 2019). These studies have considered elements such as species supply (i.e. availability) and demand (i.e. quantities of plant material being exploited), conservation status and impact of the harvesting method (e.g. harvesting subterranean parts vs. leaves; Benítez et al., 2010; Cunningham et al., 2019). Some studies have analysed the depletion risks of plants traditionally used as medicine, or have proposed strategies to improve coordination between conservation scientists and medicinal plant practitioners (see e.g. Cheung et al., 2021; Gonçalves et al., 2022). Previous studies empirically analysing the impact of harvest of medicinal plants sustainability have focused on small geographical areas, on a single species of particular interest, or on the exploitation of medicinal products for income; moreover, several of them only rely on harvester's perceptions of scarcity as a measure of sustainability (e.g. Chen et al., 2016; Cunningham et al., 2018; Kunwar et al., 2020; Papageorgiou et al., 2020; Timmermann & Smith-Hall, 2019).

While informative, the case study approach predominant so far limits our ability to identify general trends, particularly considering that medicinal plants can be gathered in different places and display functional redundancy. To detect these general trends, national and global level analyses of the impact of harvesting medicinal plants are more informative. For example, in a national study conducted in Indonesia, Cahyaningsih et al. (2021) assessed the species' rarity, occurrence status, and part gathered to recommend the prioritization of several medicinal species for conservation. In the same line, a global assessment of the risks of medicinal plants gathering showed that medicinal plants tend to have larger native ranges than species not reported as medicinal, and therefore have lower mean extinction risks (Howes et al., 2020), something that needs to be analysed in detail at the regional level.

Despite the potential contribution of analyses that go beyond the case study and engage in national or global analyses to detect the sustainability of medicinal plant harvest, they are uncommon. To help fill this gap, in this work, we conduct a national-level analysis exploring the relations between the availability and the cultural importance (CI) of wild medicinal vascular plants traditionally used in Spain. We then discuss the implications of this relation for medicinal plant harvesting. In particular, we analyse the association between species' CI and (1) abundance, (2) occupancy area, (3) endemicity and (4) conservation and protection status. We focus on Spain because, being settled in one of the world's 25 biodiversity hotspots, Spain is the most diverse European country regarding vascular plants (CBD, 2020). Nearly a quarter of Spanish flora (7071 species) is endemic: 1823 endemic taxa, 1357 species (Aedo et al., 2013; Buira et al., 2020). Spain is also the European country with the highest number of species threatened with global extinction (Holz et al., 2022). Moreover, from a cultural perspective, Spain has a high cultural and linguistic diversity that has propitiated the constant exchange of plants, knowledge and practices, and a rich ethnobotanical tradition (El-Gharbaoui et al., 2017). Recent research estimates that 3000 vascular plants have traditionally been used in Spain (Pardo-de-Santayana et al., 2014), being medicinal plants the largest use category. Indeed, medicinal plants provided a main pillar for health self-care in Spain until the 1950s, when deep changes in lifestyle associated to industrialization and globalization (Quave et al., 2012) led to a significant loss of this body of knowledge (Gómez-Baggethun et al., 2010). Nowadays, the gathering of wild plant species to treat common illnesses continues to be prevalent in many rural households (Gras et al., 2020; Quave et al., 2012), their collection being generally for self-treatment. In fact, around 15 species with medicinal use (e.g. *Gentiana lutea* L., *Thymus* spp., *Chiliadenus glutinosus* (L.) Fourr., *Chamaemelum nobile* (L.) All.) have been intensively harvested, although the gathering of these species is now in decline (Ministerio del Medio Ambiente, 2000).

2 | MATERIALS AND METHODS

2.1 | Data sources

This study combines ethnobotanical data, botanical data (from online databases), and information from legal and conservation documentation (i.e. current conservation legislation and the Red list of threatened species). Data are available at Zenodo (Mateo-Martín et al., 2023).

Ethnobotanical data used in this work was collected as part of the Spanish Inventory of Traditional Knowledge Related to Biodiversity (IECT) project (Pardo-de-Santayana et al., 2014; Tardío et al., 2018). Through the IECT project, during the last two decades, a team of more than 130 ethnobotanical researchers has created a repository of publications recording ethnobotanical uses documented in Spain. To populate the repository, IECT team members have located books, theses, indexed and non-indexed journal articles that meet two main criteria (1) they report ethnobotanical information that comes from field work and interviews, thus excluding reviews and meta-analyses of pre-existing data, and (2) they are written in English, Spanish, Catalan, Basque or Galician (Pardo-de-Santayana et al., 2014). The repository has also been complemented with the original information contained in the database of the citizen science platform CONECT-e (http://www.conecte.es/; Reyes-García et al., 2021). At the time of conducting this analysis, the IECT repository included more than 500 publications.

Information from the selected publications is collected and organized in a database. Not all the publications selected have already been included in the database. Currently, the database includes a representative portion of the works in the repository, including publications that document the largest number of species and cover the widest geographic area. To minimize repetition, when several publications originate (or partially originate) from the same fieldwork (such as a thesis and subsequent publications), only the initial work and those follow-up papers that add new species or uses have been included. For the work presented here, the database was filtered to obtain only the list of wild autochthonous species for which medicinal uses have been reported (Figure 1).

A total of 158 publications (53 journal articles; 58 books; 30 Ph.D. theses; 16 unpublished academic theses; one online database) appearing during 1982–2020 met the aforementioned requirements. The final list covers all the Spanish territory, as ethnobotanical publications were found for all the autonomous communities (the highest level of territorial organization in Spain; Figure 2; Mateo-Martín et al., 2023: 1. Ethnobotanical references).

To estimate species' abundance, we used the online database of SIVIM (2022), which computerizes the phytosociological inventories carried out in Spain. Currently, the database includes 145,672 inventories. The species distribution area and endemicity was obtained from Anthos (2022), an online platform containing taxonomic and cartographic information (based on bibliographical and herbaria geo-referenced quotations) of the flora of the Iberian Peninsula, the Balearic Islands and the islands of Macaronesia.

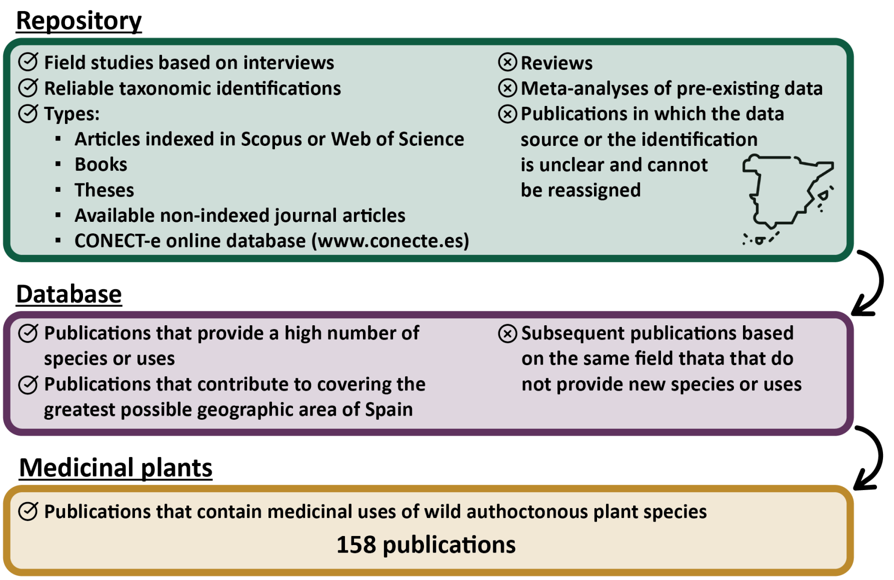

FIGURE 1 Criteria considered for the selection of studies in the analysis of the sustainability of medicinal plant species in Spain. Complete list of final publications selected can be found in Mateo-Martín et al. (2023: 1. Ethnobotanical references).

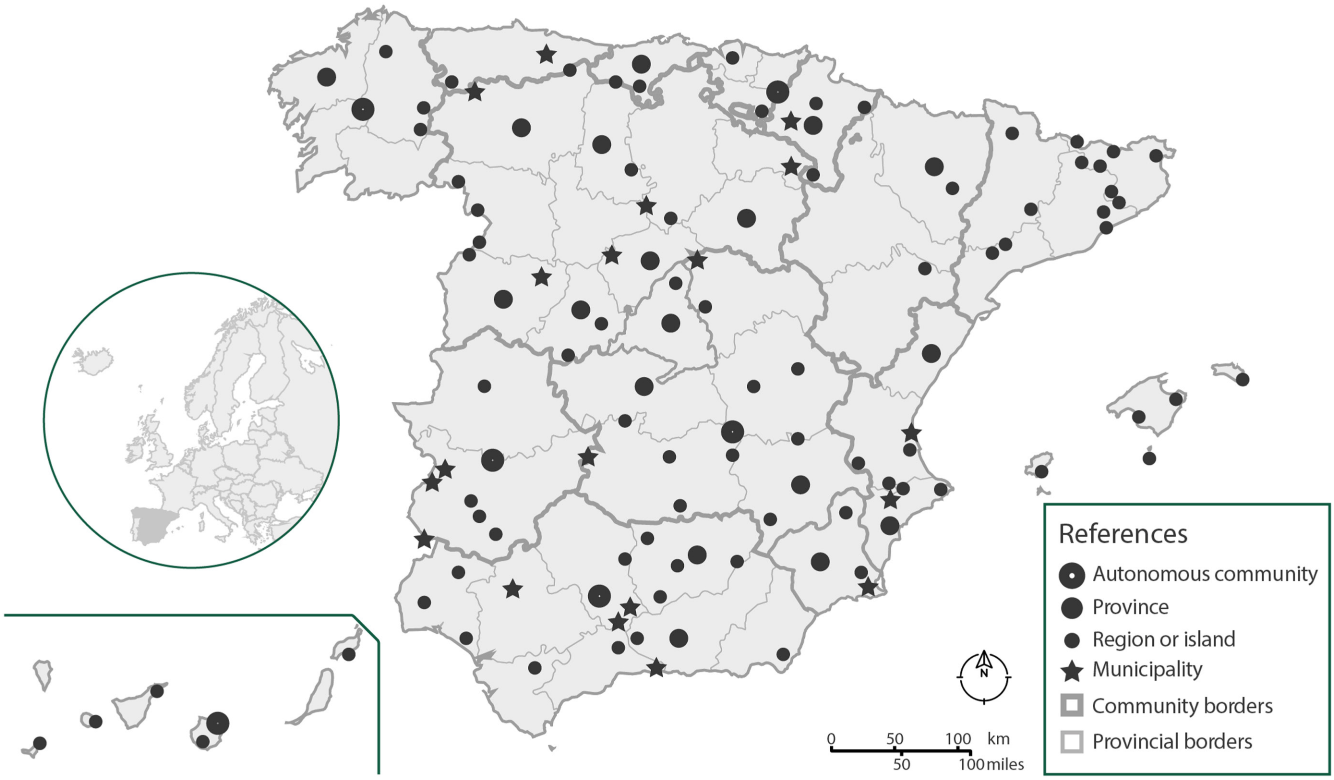

FIGURE 2 Geographical reference of ethnobotanical documents used. The political division of Spain establishes three official levels of territorial organization: autonomous communities, provinces, and municipalities. Regions are traditional divisions of the territory that group several municipalities. The labels indicate the presence of at least one document at the administrative level specified.

Species conservation status was obtained from the Spanish Red List of Vascular Plants (Red Book and Atlas of Endangered Plants, Moreno (2008), and its addendum, the National Red List of Endangered Flora, Bañares et al. (2010)). The document presents the list of threatened wild plants, highlighting the extinction risk they face, and stablishing conservation priorities. The classification of threat levels follows the IUCN threat categories and sometimes refers only to threats at a subspecies level. Species included in the Red List are not necessarily protected, as the list only indicates that the species threat status has been assessed. Protection status was sourced from European, national, and autonomic legislation. For the European level, we used the Habitats Directive (Council Directive 92/43/EEC of 21 May 1992); for the national level, we used the most recent National Catalogue of Endangered Species dating from 2011 (Real Decreto 139/2011); and for the autonomic level, we used the 17 autonomic conservation laws (Mateo-Martín et al., 2023: 3. Legislation).

2.2 | Botanical and taxonomic treatment

From each document, we extracted a list of wild autochthonous plant species used as medicine. For species that are both wild and cultivated (e.g. *Laurus nobilis* L., *Rosmarinus officinalis* L.), we included all citations of medicinal use because it was difficult to distinguish whether the published information referred to wild or cultivated plants. The review was done at the species level because in most cases the original sources did not specify the used subspecies. This approach minimizes potential biases due to taxonomic disagreements.

For the standardization of Iberian and Balearic plant names, we followed *Flora iberica* Castroviejo (1986–2021), and Arechavaleta et al. (2010) for Canarian names not included in *Flora iberica*. This is especially pertinent for the scientific names included in the conservation list and legal protection catalogues consulted, where different taxonomic treatments are used. In Mateo-Martín et al. (2023) we provide the names used in each regulation and its synonyms (when applicable). Moreover, some species complexes, such as *Taraxacum officinale* L., *Alchemilla vulgaris* L. and *Ornithogalum umbellatum* L., are treated *sensu lato* since it was not possible to reassign their citations to currently accepted taxa. For the botanical families, we followed APG IV (APG, 2016).

We used Anthos (2022) to define species endemicity. Species were classified as mainland Spanish, Balearic and Canarian endemisms depending on whether their occupancy area included grids exclusively in the Spanish portion of the Iberian Peninsula, in the Balearic or the Canary Archipelagos.

2.3 | Variables studied

For each medicinal plant in our list, we compiled data for six variables grouped in three categories (i.e. CI, availability, and conservation and protection status).

2.3.1 | Cultural importance

Species CI was defined as the sum of use-reports (UR) of the species divided by the number of informants (Tardío & Pardo-de-Santayana, 2008). As in previous studies, each ethnobotanical reference is treated as an informant (Tardío & Pardo-de-Santayana, 2016). Since we only consider one use category—that is medicinal—a species CI was calculated dividing the number of documents in which the species is mentioned as medicine (i.e. medicinal UR) by the total number of references used ($n=158$), obtaining an index value that ranges from 0 to 1, where 1 means that the species was listed in the 158 documents used.

2.3.2 | Availability

Species availability was assessed through abundance and occupancy area. Species *abundance* was estimated with the number of phytosociological inventories on the online database SIVIM (2022), which registers the presence of the species on a plot. We classified species abundance into four categories: highly abundant (species present >1000 inventories), moderately abundant (500–999), common (50–99) and rare (<50). We followed IUCN (2012) to define *occupancy area* as the area occupied by a taxon within its extent of occurrence. Species occupancy area was estimated using the number of 10×10km UTM grids in which each species was quoted in the Anthos (2022) database. We established four categories for occupancy area: wide (species present >300 grids), moderate (100–299), narrow (10–99) and very narrow (<10 grids).

2.3.3 | Conservation and protection status

To determine a species *conservation status*, we analysed the presence of medicinal plant species in the Spanish conservation list (Bañares et al., 2010; Moreno, 2008). As we worked at the species level, when a threat category was documented for one or several subspecies present in Spain, we applied that threat category to the whole species. Infraspecific taxa not accepted by Castroviejo (1986–2021) were not considered. To measure a species' *protection status*, we considered three levels of regulation: European, national and autonomic. Some species are protected only in certain autonomous communities, or the protection affects only one of its infraspecific taxa (e.g. *Senecio pyrenaicus* L. in Loefl. subsp. *carpetanus* (Willk.) Rivas Mart. (regulation EX 2001)). To reflect this diversity, species were classified into three categories based on how the aforementioned legislations affects gathering: (a) gathering always allowed, when the species do not appear in any documents; (b) gathering allowed where used, when the autonomic legislation protects them in a small portion of the areas where medicinal uses had been documented, or when species are documented as medicinal in autonomous communities where they are not subject to legal protection; and (c) gathering restricted where used, when species were mentioned by the European and national legislation, and when the regional legislation protected them in most or all areas where medicinal uses are documented.

2.4 | Limitations of the study

Despite our efforts, compiling, standardizing, and using data from three different databases and several projects might have introduced some bias, as each of our data sources has its own limitations. Ethnobotanical research in Spain shows a geographical bias in data collection, with some areas having received more scholar attention than others. As a consequence, some species may show higher frequency of citations, for example if their occupancy area overlaps with better prospected areas (Reyes-García et al., 2021). We tried to minimize this bias by selecting works that encompass the whole territory and are representative of the country. Regarding abundance, researchers tend to focus on areas of higher botanical interest, or closer to research centres (Izco, 1981). Lack of homogeneity in the distribution of the botanical information across the territory might bias our measure of both species' abundance and occupancy areas. Besides, as this information was not available, we only analysed the number of inventories for each plant, without regarding the phytosociological index associated with the plant in each inventory (from + and 1 to 5, different in each inventory; Braun-Blanquet, 1928), which more accurately reflects its abundance in the inventoried space.

Dealing with species' protection categories can also be challenging, since autonomous communities legislation is not always founded on the assessment of species conservation status. Moreover, regulations are highly diverse and do not have homogeneous criteria for protection as they are based on different conservation status categories. Thus, some laws refer to categories equivalent to the IUCN threat categories (e.g. AN 2012; CN 2010; Mateo-Martín et al., 2023: 3. Legislation, 4. Protection), while others include categories such as 'special interest species' (e.g. MC 2003; CT 2008), 'sensitive to habitat alteration' (e.g. NC 1997; MD 1992), 'regulated achievement' or 'preferential attention' (e.g. CL 2007; Mateo-Martín et al., 2023: 5. Protection categories). Regional protection laws also largely differ in the number of protected species (e.g. 188 species in Murcia, but only one in La Rioja and Cantabria). Some categories allow the collection of specific quantities (e.g. a licence is required for collecting more than 2kg of *Santolina oblongifolia* Boiss. in Castile and Leon, where the species is considered under the category 'regulated achievement') while other categories restrict the collection of the species in specific locations (e.g. the gathering of *Digitalis obscura* L. is strictly forbidden in the area of Cerros de Almatret, Lérida, where the species is considered a 'special interest species'). These specifications may indicate that a species is not genuinely protected in the area where medicinal uses are documented or that a certain amount of it may be legally harvested, although the species is considered protected, which may have led to an overestimation of the number of protected species.

2.5 | Data analysis

Information was compiled in a Microsoft Excel datasheet (Mateo-Martín et al., 2023). Here we provide a descriptive summary of the six variables studied, highlighting examples of representative medicinal wild species. We also test the level of correlation among three of the variables, that is, CI, abundance and occupancy area. We performed a Kolmogorov–Smirnov test (with significance correction of Lilliefors) that showed that none of the variables followed a normal distribution. Therefore, to assess the correlation between pairs of variables, we used a bilateral Spearman correlation test with a 99% of confidence level ($\alpha=0.01$). As the CI variable followed a gamma distribution, we performed a gamma generalized linear model to compare CI averages between the protected species and the whole dataset. All the statistical analyses were conducted in R v.4.1.1 (R Core Team, 2021).

2.6 | Ethics statement

We followed the code of ethics of the International Society of Ethnobiology (ISE, 2006).

3 | RESULTS

3.1 | Wild species used as medicine

The analysis of the 158 documents resulted in a list of 1376 autochthonous wild vascular plant species traditionally used as medicine in Spain (Mateo-Martín et al., 2023: 2. Medicinal species). These species belong to 120 botanical families: 38 ferns (13 families), 20 gymnosperms (four) and 1318 angiosperms (103). Asteraceae (202 species, 15% of the medicinal species) and Lamiaceae (151, 11%) are the botanical families with a higher number of species (Figure 3).

A total of 160 (14%) medicinal species are considered endemic to the study area. Six species in our list are endemic to the Balearic Islands, 82 to the Canary Islands and 72 to mainland Spain (Figure 4; Mateo-Martín et al., 2023: 2. Medicinal species).

3.2 | CI of medicinal wild species

On average, each species was mentioned in 5.4% of the documents (avg. CI = 0.054), with a great disparity in species' CI (standard deviation

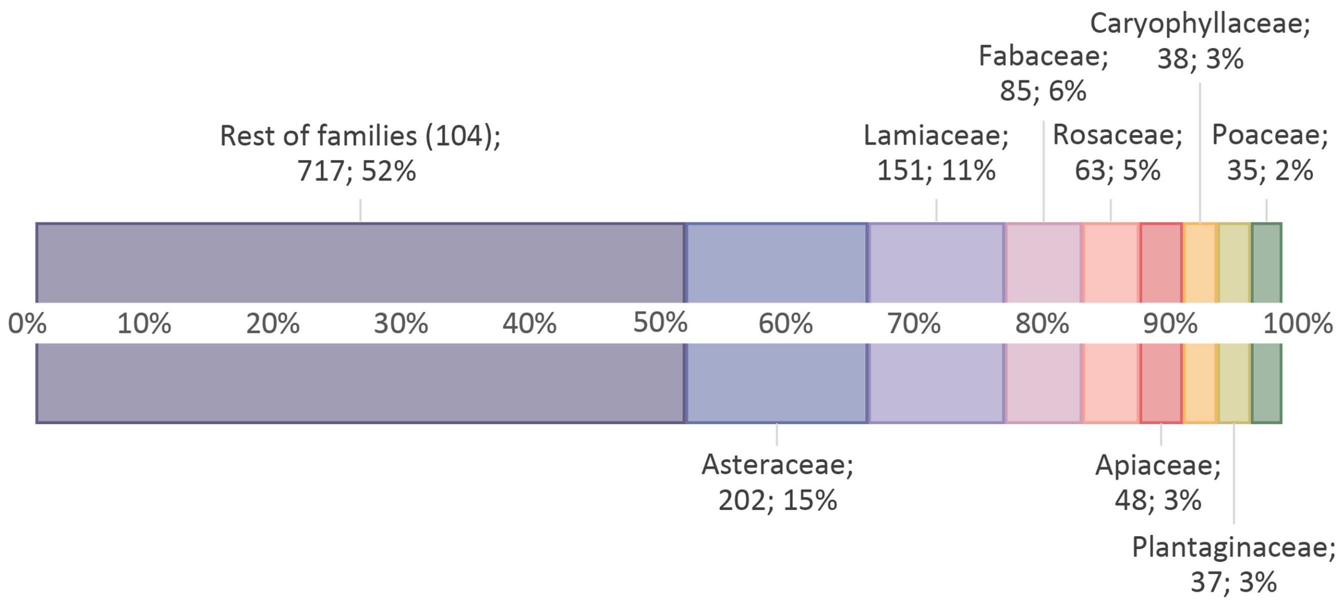

FIGURE 3 Number and percentage of wild species used as medicine in Spain, per family ($n=1376$).

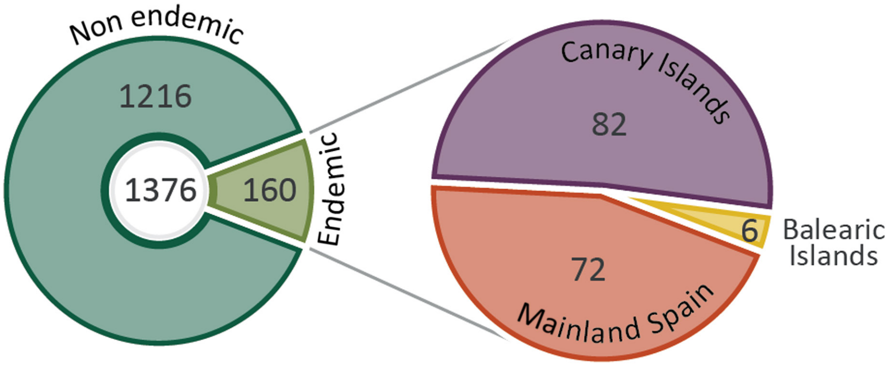

FIGURE 4 Distribution of endemic plant species with medicinal use.

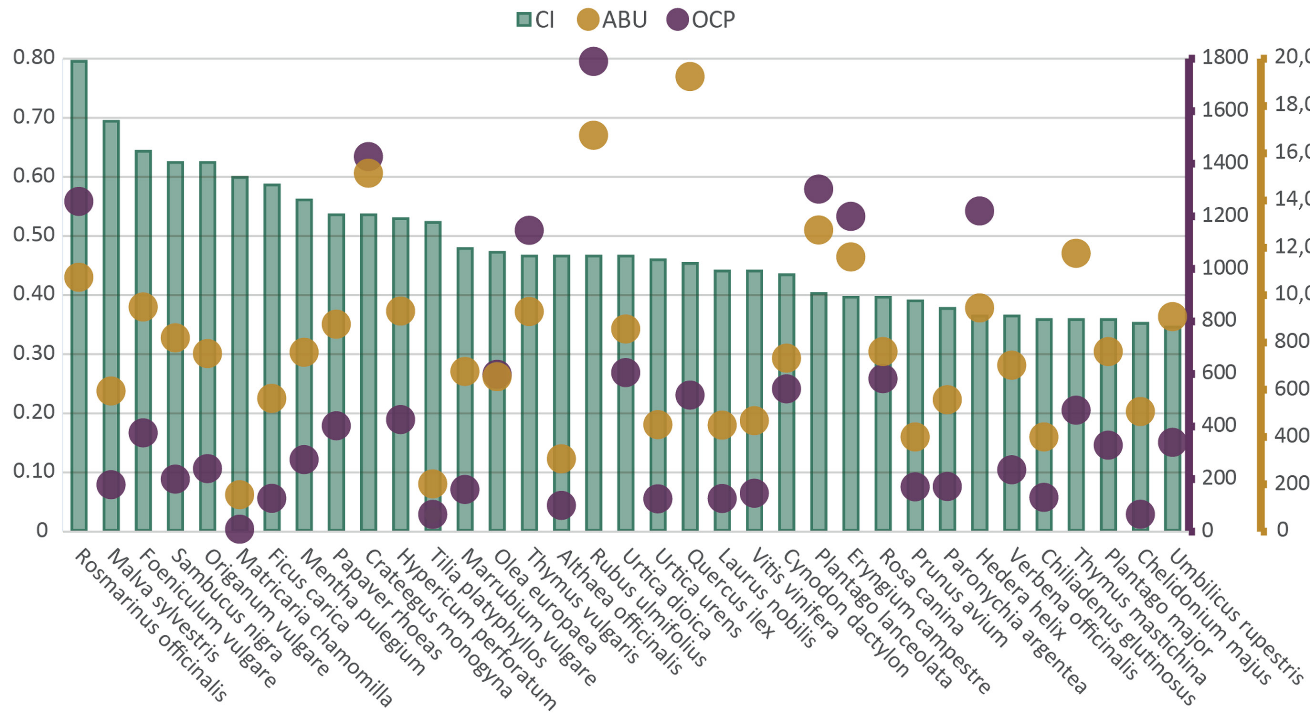

FIGURE 5 Cultural importance (CI, green bar), abundance (ABU, yellow dot) and occupancy area (OCP, purple dot) of the 35 wild species with medicinal use with CI > 0.35.

0.093; max = 0.80, min = 0.01). The five species with the highest CI are *Rosmarinus officinalis* (CI = 0.80), *Malva sylvestris* L. (0.70), *Foeniculum vulgare* Mill. (0.65), *Origanum vulgare* L. (0.63), and *Sambucus nigra* L. (0.63). Only 35 species (3% of the total) appear in more than 35% of the documents (CI > 0.35; Figure 5), whereas 332 species (24%) appear in more than 5% (CI > 0.05). The less quoted 665 species (48%) had a CI of 0.01 (i.e. were cited in less than 1% of the references).

3.3 | Wild species availability

On average, each species appears on 1157 inventories, although there is a very high variation among species abundance (standard deviation = 1719; max = 19,229; min = 1). About one third of the species (34%) appeared in more than 1000 inventories and are thus categorized as "highly abundant", 18% of the species are "moderately abundant" and 34% are "common". Only 13% of the species with medicinal use were cited in less than 50 inventories and are considered "rare". Of the 35 species with CI > 0.35, 28 (80%) are "highly abundant", 6 (17%) are moderately abundant and only one species (3%) is common (see Figure 5; Mateo-Martín et al., 2023: 2. Medicinal species). Some very abundant plants have high CI (e.g. *Crataegus monogyna* Jacq.; 11,201 inventories; CI = 0.54), whereas others have low (e.g. *Dactylis glomerata* L.; 19,299; CI = 0.01).

Regarding occupancy area, a medicinal wild plant species was found in an average of 274 UTM grids (standard deviation = 253.8; max = 1732; min = 1). Overall, 494 species (36%) had a wide occupancy area, 461 (34%) a moderate, 386 (28%) a narrow, and only 35 (3%) a very narrow occupancy area. Within the 35 species with CI > 0.35, 32 (91%) have a wide distribution and the remaining three (9%) have a moderate distribution (Figure 5). While some widely distributed species are very frequently used as medicine (e.g. *Rubus ulmifolius* Schott.; 1508 grids; CI = 0.47), for others, the medicinal use is uncommon (e.g. *Briza maxima* L.; 975; CI = 0.01).

Compared to the full sample, endemic species have a lower CI (0.014 vs. 0.054). Also, most endemic medicinal species have a narrow (78% vs. 28%) or very narrow (12% vs. 3%) occupancy area, and according to their abundance, most can be considered common (42% vs. 34%) or rare (50% vs. 13%).

3.4 | Wild species conservation and protection status

Only 8% (89 species) of the medicinal plant species were found in the Spanish Red List of Endangered Flora (Moreno, 2008). Among them, 12 are considered critically endangered, eight endangered, 45 vulnerable and 24 belong to less threatened categories. For about half of the species in the list (41 species), the threatened conservation status specifically pertains only to one of the various infraspecific taxa present in Spain. An example of this is *Centaurea aspera* L. that was considered as endangered, although only the subspecies *scorpiurifolia* (Dufour) Nyman appeared in the Red List (see Mateo-Martín et al., 2023: 4. Protection, for further details).

Only about one third of the medicinal plant species ($n = 430$, 31%) have some type of protection status, being found in the consulted legal catalogues (Figure 6; Mateo-Martín et al., 2023: 4. Protection). From these catalogues, 15 species are mentioned in the European legislation, 17 in the National Catalogue, and 425 in autonomous communities' catalogues. There are only six species listed at the three levels, 15 species at two and 409 species at one level, mostly the autonomous community (Mateo-Martín et al., 2023: 4. Protection).

The level of protection of the species listed in the catalogues varies greatly across autonomous communities. About half of the 430 species with legal protection status are solely monitored for their uniqueness, scientific, ecological or cultural value, and belong to categories such as "regulated management", which allows the gathering of specific amounts of plant material under certain circumstances. However, 211 species (15% of the sample) fall into highly restrictive protection. These include three species in our list that are considered as "locally extinct" (*Buxus balearica* Lam. and *Taxus baccata* L. in Murcia and *Glaucium flavum* Crantz in Cantabria); 46 species that are regarded as "endangered" (e.g. *Laserpitium latifolium* subsp. *nevadense* Mart. Lirola, Molero Mesa & Blanca in Andalusia); and 164 species considered "vulnerable" (e.g. *Aconitum napellus* L. in Castile-La Mancha and Community of Madrid; see Mateo-Martín et al., 2023: 4. Protection, and 5. Protection categories, for further details). In some cases, these categories imply the creation of restoration plans or species or habitat conservation plans.

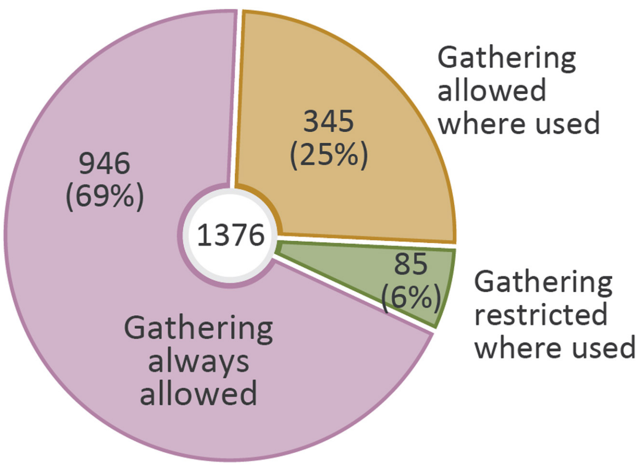

FIGURE 6 Protection status of Spanish medicinal plants (n = 1376).

However, out of the 430 protected species, only 85 species (6% of the total sample) receive some level of protection in the specific area where medicinal uses have been documented. This situation occurs either because they are included in the European or national legislation (five species), because their use-area overlaps with the provinces where regional laws protect them (63), or both (17). Regional legislation does not restrict the gathering of the remaining 345 plants, which are mostly documented as medicinal in areas where they are not subject to legal protection. Thus, when considering species that are not listed in the consulted catalogues and species whose gathering is not restricted in areas where medicinal uses are documented, we find that 1291 species (94%) are not affected by any protection measure (Figure 6).

The 85 medicinal species affected by some level of protection were only mentioned in 2.7% of the ethnobotanical references, thus their CI was lower than that of the total list (average protected species CI = 0.027 vs. 0.054; standard deviation = 0.046 vs. 0.093; maximum = 0.32 vs. 0.80, minimum = 0.01).

3.5 | CI, availability and protection status of wild medicinal species

Species' CI bears a positive and statistically significant association, although moderate, with both species' abundance ($\rho = 0.466$; $p < 0.01$; Figure 7a) and occupancy area ($\rho = 0.495$; $p < 0.01$; Figure 7b). The highest correlation was found between species' occupancy area and abundance ($\rho = 0.830$; $p < 0.01$; Figure 7c), probably because both variables reflect the species' availability. This correlation was statistically significant and strong.

The average CI of the protected species is significantly lower than that of the total list of medicinal species, as proved by the generalized linear model performed (Pr(>F) = 0.0006).

4 | DISCUSSION

Spain has a rich traditional knowledge referring to medicinal plants. The 1376 wild plants with medicinal use reported in this

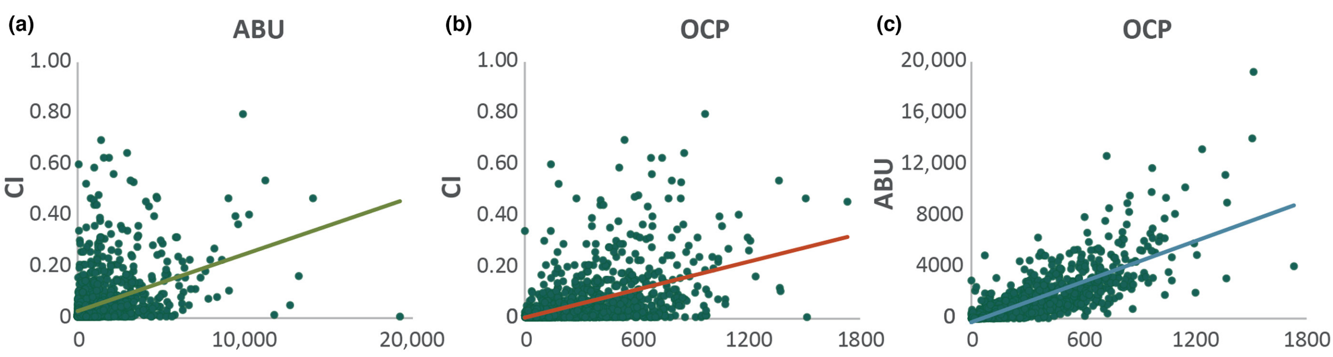

FIGURE 7 Scatterplots and correlation coefficient of cultural importance (CI), abundance (ABU) and occupancy area (OCP). (a) Correlation of CI and ABU. (b) Correlation of CI and OCP. (c) Correlation of ABU and OCP.

work represent nearly one-fourth (22%) of the total autochthonous vascular flora of Spain (Aedo et al., 2013). This percentage is comparable to data from countries like Nepal (21%), smaller than in countries with richer medicinal ethnofloras (e.g. India 44%; Kunwar & Bussmann, 2008) but considerably higher than the global estimation of 7% plant species with medicinal uses (RBG Kew, 2020). The botanical families with a higher proportion of wild medicinal plants in Spain correspond to those dominant in the medicinal floras of the world (Moerman et al., 1999) and belong to the most relevant families in the Spanish flora: Asteraceae, Lamiaceae, Fabaceae, Rosaceae and Apiaceae (Buira et al., 2017). The medicinal use of the species with the highest CI (e.g., *Rosmarinus officinalis*, *Malva sylvestris*, *Foeniculum vulgare*, *Sambucus nigra* or *Matricaria chamomilla* L.) has been documented since ancient times (El-Gharbaoui et al., 2017; Quave et al., 2012). The chemical compounds and main pharmacological properties of these species have been largely studied (Barnes et al., 2007) and many of these species, or their derivates, are nowadays used in basic healthcare (Carvalho & Morales, 2010) as they are easily available, gathered from the wild, cultivated in home gardens, or purchased from herbal shops or supermarkets (Quave et al., 2012).

Culturally important species with medicinal uses are generally available, as defined by their abundance and occupancy area. The 35 species with the highest CI had wide or moderate occupancy area, and just one (*Matricaria chamomilla*, a species that is commonly cultivated or obtained from markets) was classified as common. We venture to guess that several of them would qualify as Cultural Keystone Species, due to their high CI, versatility and symbolism in society (Cristancho & Vining, 2004; Garibaldi & Turner, 2004), although—so far—only one, *Urtica dioica* L., has been documented in the latest compilation of cultural keystone species (Reyes-García et al., 2023). Among the species with highest CI there is an Iberian endemism, *Thymus mastichina* (L.) L., widespread in the territory and that has even been locally cultivated (Blanco, 1998a). The overlap between species CI and availability dovetails with previous research suggesting that most plant species used as traditional medicines are abundant (Gaoue et al., 2017), including weeds or plants present in disturbed habitats (Stepp & Moerman, 2001). However, as the positive correlations between CI, abundance, and occupancy area are not very strong and many widely available plants have low CI, our findings also suggest that, besides availability, other criteria are relevant in the selection of wild plants as medicines. Beyond species' pharmacological properties, such criteria might include aspects such as aromatic or visual qualities (Leonti et al., 2020).

While the correlation found in our data between CI and availability does not explicitly imply causality, in the reviewed references we found several examples signalling that, in Spain, local populations engage in care and management practices that might actively maintain medicinal plants' populations stable over time. For instance, *Osmunda regalis* L. collectors keep its location secret, harvest only a part of the rhizome or even transplant it into their home gardens (Molina et al., 2009): all practices that protect the species. Other practices documented in the references that might contribute to protect medicinal species include gathering a part of the inflorescences of *Sideritis hyssopifolia* L. to encourage reproduction, planting cuttings of *Sambucus nigra* (authors' personal obsesrvation) or cultivating species such as *Thymus moroderi* Pau ex Martínez at small scales (Marco-Medina, 2010). A list of these and other examples is provided (Table 1: Examples of documented medicinal plants management practices that might contribute to the long-term viability of the species). Indeed, at least some evidence suggest that the abandonment of traditional landscape management practices may have potentially resulted in the population decline of some species with medicinal uses. For example, the population of bitter chamomile (*Chamaemelum nobile*) has declined as a result of the meadows no longer being grazed, which encourages the growth of other species (Pardo-de-Santayana & Morales, 2006).

The finding that a species CI correlates with its availability aligns well with the premise that care and management practices of useful wild species often ensure the long term viability of the resource (Fisher et al., 2019; IPBES, 2022; Turner et al., 2022). Prior research has shown that individuals place a higher value on species that are used in everyday life than on species that are gathered for commercial purposes. When a species is emotionally valued, as opposed to just being collected for profit, it is more likely that it will be managed for long term viability (Freitas et al., 2020; Pardo-de-Santayana & Macía, 2015; Quave & Pieroni, 2015; Senkoro et al., 2019). In fact, only 8% of the documented medicinal plants have an endangered conservation status, and have been included in the Spanish conservation list. Furthermore, as in many cases the endangered status refers only to infraspecific taxa, the share of medicinal plant species with endangered conservation status might be even smaller. Most (69%) of the wild species with medicinal uses do not appear in any legal protection catalogues, and only 6% have a restrictive protection category that affects gathering in the area where they are used as medicines. Many medicinal plants seem to be used in areas where they are common and abundant, and therefore not protected. While current availability might be partly explained by decreasing use, the fact that most wild species with medicinal uses are highly available and not protected seems to suggest that the current harvesting of such species is regulated by management practices that ensure their long term viability, as it has also been documented in other areas (Morales et al., 2011; Senkoro et al., 2019; Turner et al., 2022; Verschuuren et al., 2010). Similar conclusions were found in a study that reviews the medicinal plants used globally (Howes et al., 2020).

Our study allows to identify a few wild plants with medicinal uses with threatened status. One of the few cases in Spain in which gathering for medicinal purposes has promoted the species' scarcity and threat of extinction, is the case of *Artemisia granatensis* Boiss., an endemism of Sierra Nevada, highly marketed for its multiple medicinal uses (Molero-Mesa et al., 2014). This species is included in the national and regional catalogues (Mateo-Martín et al., 2023: 3. Legislation), in the European Red List of Vascular Plants (Bilz et al., 2011), and in the European Red List of Medicinal Plants (Allen et al., 2014) as critically endangered. Other medicinal plant species that have suffered from intense gathering exacerbated by their commercialization, include *Arnica montana* L., *Atropa*

TABLE 1 Examples of documented medicinal plants management practices that might contribute to the long-term viability of the species.

Species	Management or harvesting practice	Reference
Arbutus unedo L.	Cultivated in home gardens	Benítez (2009)
Artemisia absinthium L.	Cultivated in home gardens	Benítez (2009)
Artemisia alba Turra	Only aerial parts are collected Informants indicate that they are aware of the scarcity and control its collection	Authors' personal observation (Serranía de Cuenca, Spain)
Centaurium erythraea Rafn	Cultivated in home gardens	Benítez (2009)
Chiliadenus glutinosus (L.) Fourr.	Only aerial parts are harvested Informants indicate that they are aware of the scarcity and control its collection	Authors' personal observation (La Manchuela, Spain)
Crataegus monogyna Jacq.	Cultivated in home gardens	Benítez (2009)
Laurus nobilis L.	Cultivated in home gardens	Benítez (2009)
Matricaria chamomilla L.	Cultivated in home gardens	Benítez (2009)
Origanum vulgare L.	Cultivated in home gardens	Benítez (2009)
Osmunda regalis L.	Keeping the location secret Harvesting only a part of the rhizome Transplanting to home gardens	Molina et al. (2009)
Sambucus nigra L.	Planting cuttings	Authors' personal observation
Sideritis hyssopifolia L.	Gathering a part of the inflorescence	Authors' personal observation
Sideritis spp.	Harvesters use lowland substitutes instead of using species of high summits of these genera. Lowland species are more common. High summit ones are more restricted, less abundant, and mostly grow in protected areas where gathering is not allowed (e.g. *S. glacialis* vs. *S. hirsuta*)	Benítez et al. (2016)
Tilia platyphyllos Scop.	Harvesting only the flowers	Authors' personal observation (Serranía de Cuenca, Spain)
Thymus moroderi Pau ex Martínez	Cultivated in home gardens	Marco-Medina (2010)
Thymys zygis Loefl. ex L.	Cultivated in home gardens	Benítez (2009)
Thymus spp.	Harvesters use lowland substitutes instead of using species of high summits of these genera. Lowland species are more common. High summit ones are more restricted, less abundant, and mostly grow in protected areas where gathering is not allowed (e.g. *T. serpylloides* vs. *T. zygis*)	Benítez et al. (2016)
Valeriana officinalis L.	Cultivated in home gardens	Benítez (2009)

belladonna L., *Ceterach aureum* (Cav.) Buch, *Dictamnus hispanicus* Webb ex Willk., *Gentiana lutea*, *Ruscus aculeatus* L., *Santolina oblongifolia*, *Saxifraga vayredana* Luizet and *Thymus* sp. pl., some of them present in the Habitats Directive. A few of these traditionally used species had entered the pharmaceutical industry, which might explain their high levels of exploitation. For example, *Atropa belladonna*, which pharmacists intensely harvested during the 1950s and 1960s, has currently disappeared from some of the areas where it was collected (Verde et al., 2008). In the case of *Saxifraga vayredana*, a species endemic to a relatively narrow area in Catalonia, its use transitioned from folkloric to industrial (Bonet & Vallès, 2006) as it became an ingredient of a phytomedicine, which increased the pressure on the species (Seoane et al., 1991). Hundreds of tonnes of several species of *Thymus* are harvested, 90% of which are destined for export. Plants are directly uprooted, and although it has not been proven to have harmed their populations, it is considered to accelerate soil erosion in an already particularly dry and arid environment (Blanco, 1998b).

5 | CONCLUSIONS

We present the first comprehensive list of wild plants traditionally used in Spain as medicine and their associated CI, availability and conservation and protection status. Our results suggest that, in Spain, most wild plants with documented medicinal uses are abundant, widely distributed and hold a non-threatened conservation status, for which they largely do not require protection. While determining the sustainability of the harvesting of wild plants with medicinal uses, in the strict sense of the term, would require the use of data that are not available for most species, based on our results showing a correlation between species CI and availability, we argue that—at large—the harvest of wild plants for medicinal use does not pose a threat to their sustainability. Our results also suggest that the situation is different for a few wild and uncommon species used for commercial purposes, which also happen to be protected by the current legislation. Together, the two findings make good ground to support the argument that traditional systems of care and management of important wild plant species do not threaten their long-term viability.

As bodies of local knowledge and associated management practices are rapidly being lost in western societies, the revitalisation and integration of this knowledge could promote the sustainable use of biodiversity. It is imperative that the different stakeholders interested in safeguarding these species, make more efforts to integrate traditional and scientific knowledge for achieving an effective, social, legitimate and sustainable relationship with nature. In many regions, such as Spain, further research is needed to assess the relationship among traditional and commercial gatherers and their attitudes towards the resources.

AUTHOR CONTRIBUTIONS

Jimena Mateo-Martín, Manuel Pardo de Santayana and Guillermo Benítez designed the paper and did the analysis, and Jimena Mateo-Martín wrote the first draft. All authors worked in the ethnobotanical database and Manuel Pardo de Santayana, Jimena Mateo-Martín and Guillermo Benítez reviewed the data. Victoria Reyes-García, Airy Gras, Alonso Verde, Javier Tardío and María Molina reviewed and contributed to the manuscript. All authors worked on the design and development of the IECTB, read, discussed and approved the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data used in this article can be found at https://doi.org/10.5281/zenodo.7808167 (Mateo-Martín et al., 2023).

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