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ORIGINAL PAPER

A model to analyse the ecology and diversity of ethnobotanical resources: case study for Granada Province, Spain

Guillermo Benítez[1] · Joaquín Molero-Mesa[1] · M. Reyes González-Tejero[1]

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Abstract In recent decades, a number of ethnobotanical studies have been developed in many territories, but only a few studies deal with the ecology of the botanical resources, apart from those focused on the so-called ethnoecology, i.e., on the local perceptions of the ecological issues of used plants and their environment. Ethnobotanical resources are known by local people and are normally gathered from the wild, therefore altering the environment in which they grow. From a performed database of all ethnobotanical resources used in Granada Province (South Spain), we analysed several botanical issues, such as the main represented botanical families, biological types, and the biological spectrum. Complementing this classical analysis, in order to establish a new model to know which habitats are more visited and therefore altered by plant collections, we performed an ecological study. For this study, an ecological adscription of the botanical resources was made on the basis of the phytosociological method. Some important questions for us developed during our long time field ethnobotanical work are analysed and commented. For example, the fact that generally people do not gather many plants from mountain summits, only a few medicinal plants without a relative-substitute in lowlands. Differences of the visited habitats in order to collect medicinal or edible wild plants are also analysed. A final brief analysis deals with the relation of the ecology of some ethnobotanical resources with their chemical compounds, focusing on alkaloidic plants: most plants with alkaloid generally grow in nitrogen-rich soils in which any type of nitrophilous vegetation is developed.

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✉ Guillermo Benítez
gbcruz@ugr.es

[1] Department of Botany, University of Granada, Campus Universitario de Cartuja, 18071 Granada, Spain

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Introduction

In recent decades, ethnobotany has received increasing attention from researchers, official institutions, and governments. Many significant contributions have been made in recent years in Europe and Spain in both books compiling ethnobotanical data for the general public (for Spain, e.g.: Villar et al. 1992; Verde et al. 2000; Parada et al. 2002; Tardío et al. 2002; Bonet and Vallès 2006; Benítez 2007; Carvalho 2010; Pardo-de-Santayana et al. 2014) and in scientific papers (some of the most recent are Tardío et al. 2006; Rivera et al. 2007; Benítez et al. 2010a, 2012a; Cavero et al. 2011; Carrió and Vallès 2012; Menendez-Baceta et al. 2012, 2014; Alarcón et al. 2015; González and Amich 2015). As a main issue for this discipline, these contributions mainly deal with the correlation of botanical and vernacular names for each plant and the plant-use description, i.e., which plants do people use for a certain ethnobotanical use and, for medicinal plants, which condition(s) are they used against, the part of the plant used, the method of preparation and administration, as well as other ethnographic issues like the cultural significance of each plant, the relation of plants with folklore, religion, and festivities, etc. Ethnobotanical studies are not restricted to the development of catalogues of traditionally used plants commented to a greater or lesser extent and may include the local perception of the environment. Nevertheless, this catalogue can achieve multiple analyses of the results from such diverse perspectives as the different disciplines that take part in these studies, including ethnography, botany, plant ecology, and pharmacology, among others. Resuming our research line, we aim to deepen the analysis of the floristic and ecological issues of ethnobotanical taxa for the province of Granada.

The importance of ethnobotany has been highlighted many times (Schultes 1994; Heinrich et al. 2006; Heywood 2011), even being called “the science of survival” (Prance 2007). Moreover, in the 2003 convention UNESCO declared this kind of local knowledge as part of the known intangible cultural heritage (UNESCO 2003), with ethnobotanical, ethnobiological, ethnoecological, traditional environmental, ethnoveterinary, folk medical, and pharmaceutical knowledge being inextricable components of culture, and therefore worthy of being protected and sustained.

Accordingly, interest in the conservation of ethnobotanical resources has grown together with the general conservationism led by the IUCN and followed by international, national, and regional governments: European Union directives like Habitat Directive (Anon 1992), National and Regional Red Books (Blanca et al. 1999, 2000; Bañares et al. 2004, 2007; Allen et al. 2014), the Convention on Biological Diversity, etc. Nevertheless, only a few papers deal with the ecology of ethnobotanical resources (Díaz González 1986; Albuquerque et al. 2009), with some focused on high mountain plants (Graebherr 2009; Salick et al. 2009). In this direction, the importance of altered environments for collection of ethnobotanical data has been previously highlighted (Santos et al. 2009; Benítez et al. 2010b; Cirujeda et al. 2013). In our opinion, the analysis of the ecological features of the used plants in our study area with regarding these issues can help to understand conservation priorities.

Moreover, many studies have proved that the biosynthesis of some secondary metabolites in plants can be influenced by the habitat (Challis and Hopwood 2003; Alonso-Amelot 2008; Deduke et al. 2011; Ramakrishna and Ravishankar 2011), even analyzing the differences of a specific phytochemical group for the same plant species growing on different plant communities (Gonnet 1983, 1985). Furthermore, some studies show that the concentration of a specific chemical element in the environment can influence the biosynthesis of secondary metabolites in plants (Marten et al. 1973; Kennedy and Bush 1983) as well as in endophytic fungus (Arechavaleta et al. 1992; Markert et al. 2008).

For example, it is known that for the biosynthesis of alkaloids, a concentration of nitrogen in the environment is required. Alkaloids, a group of natural substances with a high therapeutic interest, bioactivity and toxicity, are derived from amino acids (except those derived from terpenes or steroids, which are usually considered pseudoalkaloids). Defined as "basic compounds from natural origin containing one or more nitrogen atoms usually in a heterocyclic ring and usually having a marked physiological action on man or other animals" (Evans 2002), the biological importance of alkaloids is still an unsettled dilemma. Several theories have been postulated: detoxification products; nitrogen reserves for plants; defense role against herbivory, pests, and infections; hormonal function; allelopathic value, etc. (Evans 2002; Bruneton 2001). Nitrogen can be provided from nitrogen-enriched soils, but also from water supplies or even bacteria (as the Rhizobium-Fabaceae symbiosis, for example). In other words, could we stablish some differences when analyzing the proportion of alkaloidic medicinal species regarding the habitat where plants grow up?

When trying to analyse the ecological features of ethnobotanical resources, some other important questions for us are as follows: Where do people use to collect plants for their own use? Which habitats can offer a higher number of resources? Are these habitats truly altered by plant gathering? These are some of the questions we aim to answer in this paper, focusing on the area we know best: Granada Province. The ecology of the ethnobotanical resources is analysed from a researcher standpoint, not from our interviewee's one. Therefore this is not an ethnoecology study (in the sense of Casagrande 2012) dealing with how people perceive their environments, but it focuses on which environments are most frequently manipulated by local inhabitants.

Materials and methods

Study area and ethnobotanical methodology

This paper is focused on the floristic and ecological diversity of the ethnobotanical resources of Granada Province in South Spain (Fig. 1). Granada Province is a rich territory with highly diverse vegetation, from coastal riffs, littoral arid and semi-arid formations, Mediterranean holm oak formations and scrub communities to deciduous forest and diverse and extent orophilous xerophytic vegetation in the summit of Sierra Nevada (3.482 m.a.s.l.). Included in the Mediterranean basin and declared one of the 25 most important biodiversity hotspots in the world (Myers et al. 2000), Sierra Nevada (mostly included in Granada Province but also in Almeria Province) represents the most important plant biodiversity hotspot in the Western Mediterranean basin (Molero-Mesa 1994; Blanca 2001) with a high number of endemic plants (Rivas-Martínez et al. 1991). It was declared National Park in 1999. Four additional natural parks and a natural place, which are lower protection categories, have been stated in the province in order to manage this natural heritage.

For the compilation of the ethnobotanical data of the province, a review of the main ethnobotanical fieldworks carried out in the province was performed, i.e., PhD theses and

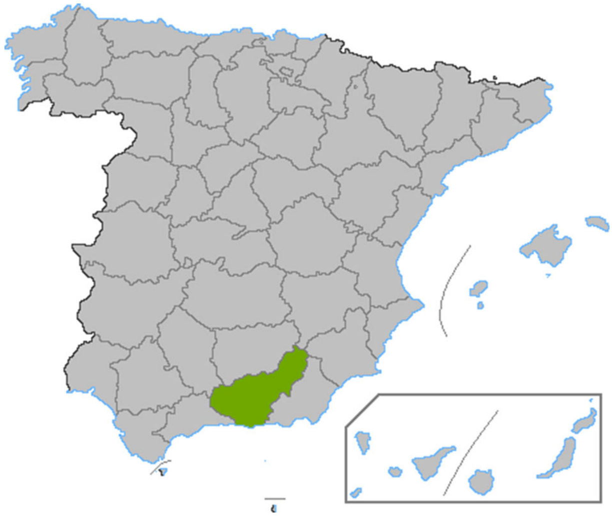


Fig. 1 Study area: Granada Province

Table 1 Bibliographical sources of data and information about the studies

Reference	Study area	Study area (km^2)	Type of work	Main subject	NP	Included information
Benítez (2009)	Western Granada Province	2041	PhD thesis	Ethnobiology	380	U, PU, AF, V, I, R
González-Tejero (1989)	Granada Province	12,531	PhD thesis	Ethnobotany	235	U, PU, AF, V
Muñoz-Leza (1989)	Lecrin Valley, Granada	460	Degree thesis	Ethnobotany	167	U, PU, AF, V

NP number of included plant species (ethnotaxa). Included information: *U* uses, *PU* part used, *AF* administration form, *V* voucher numbers, *I* informant data, *R* number of reports

degree theses. Table 1 shows the main features of the fieldworks, including the extension of the study area, the number of included plant species, and the included information on each work. Although the included fieldworks were performed by different researchers, they were all managed by the same research group at the University of Granada, following the same methodology for the data collection and data treatment (resumed in Benítez et al. 2010a). All data were collected through open and semi-structured interviews (Martin 1995; Cotton 1996) performed in Spanish, with prior informed consent obtained by our informants and following the ethical guidelines of the International Society of Ethnobiology. Interviews were conducted mainly with one person at a time and preferentially in the field, enabling us to locate the species with the help of the interviewee. All included plants were gathered from the field and identified in the botany laboratory of the University of Granada following mainly the regional flora (Blanca et al. 2009) for the botanical nomenclature and classification and considering other major floras such as Castroviejo et al. (1986–2012) and Tutin et al. (1964–1980). Vouchers were prepared and included in the herbarium of the

University (GDA). The voucher numbers of each plant can be found in the original, previously referred fieldworks (see Table 1).

The ethnobotanical uses of each taxon have not been included in this study due to their extension. They can be found in the referred works in Table 1 and in several papers (González-Tejero et al. 1995; Benítez et al. 2010a, 2012a).

Ecological data and analysis

A database in Microsoft Access (c) was compiled with these data, containing all the information about the local uses of the plants (including the part of the plant used, the method of preparation and administration, the number of references for each use, etc.) and the plants themselves (botanical name, distribution, ecology, etc.). Information on chemical compounds was mainly taken from pharmacognosy and phytotherapy general books (Evans 2002; Bruneton 2001; Arteche et al. 2000).

For the ecological characterisation of the botanical taxa for which some ethnobotanical information has been collected (i.e., the ethnotaxa), we mainly considered three aspects: general distribution of the plant, biotype, and the habitat where the plant can grow up based on the synecology of the plant. For this ecological characterisation, the phytosociological method of classification of the vegetation established by Braun-Blanquet (1918) was followed, as we agree with Pott (2011) that "collecting information on plant communities outdoors by following the combined evaluation method devised by Braun-Blanquet is probably the most standardised of the many different recording methods". Because the phytosociological method is complex and includes a hierarchical classification regarding different syntaxa, we performed the classification to the level of phytosociological class (Pignatti et al. 1995) without considering lower levels of community, alliance, or order so as to simplify the results in a small number of categories (see Braun-Blanquet 1928).

To associate each ethnotaxa with a phytosociological class, we followed Rivas-Martínez (2002a), who provides an extended list of the characteristic species of all syntaxa in Spain. When any species is considered characteristic of any syntaxon, it means that the species grows specifically in the ecological unit defined by this syntaxon, i.e., it is not considered a preferred ecology but an exclusive ecology circumscription. In our approach, most of the ethnotaxa were characteristic species of a given syntaxon. In these cases, we only assigned the syntaxon to the plant. For the rest of the plants which were not characteristic of any syntaxon, we ascribed the plant to the most probable syntaxon (only at the class level) in which the plant can grow in Granada Province according to our own fieldwork. As the list of syntaxa from the province is highly extended due to the ecological diversity of the province, each syntaxon was associated with the phytosociological class in which it is included to reduce the number of categories for the analysis. The precise description of each class can be seen in Rivas-Martínez (2002a). It is known that the ecological characterisation of a syntaxon is not necessarily the same as the ecological demands for one plant associated with it, and generally plants can also grow in different places and even with different associations. Issues such as bioclimatology and biogeography are also taken into account in the ecological characterisation of a syntaxon. However, in our opinion, the adscription of plants to a syntaxon can express the most frequent environment where it can grow.

To simplify the statistical analysis and to promote better comprehension of the final results, we grouped the phytosociological classes into "wide vegetation groups" following the classification of Rivas-Martínez et al. (2001, 2002b), i.e., anthropogenic altered vegetation (including four phytosociological classes), potential forestall vegetation, etc. Some precedents of these ecological studies can be found in Díaz González (1986) and Benítez et al. (2010b).

Results

The main database fields for this paper's purposes, such as botanical (scientific name, family) and ecological data (origin, distribution, ecological circumscription) and main ethnobotanical uses (medicinal or wild-edible), are compiled in the supplementary material table for the included plants.

Ethnobotanical data

Information for 478 plants (439 species and 39 subspecies) with local ethnobotanical value is compiled in this database. Highlighting the main use categories, we recorded 325 medicinal plants and 160 food plants, including not only edibles but also seasonings, wild candies, and non-medicinal beverages. Main data on ethnobotanical uses are included in the supplementary material table but the referenced works should be consulted in order to deep in the local uses of the included plants. Other use categories include ethnoveterinary plants, for which an extensive study has been previously published (Benítez et al. 2012a), handicraft plants, culturally important plants (used in local games, religious or cultural festivities, etc.), and industrial plants.

It should be noted that 478 taxa represent approximately 13.65 % of the estimated 3500 plant taxa in the province (Hernández-Bermejo and Clemente-Muñoz 1994), the most diverse Andalusian province in plant species number. This percentage, defined as the Porteres index (Porteres 1970), expresses the ethnobotanical richness of a territory and the level of knowledge that a society has of its flora, and it is not far from data for other Iberian territories of similar extensions (i.e., provincial studies), such as Castellón or Huesca provinces (17.2 and 22 %, respectively; Mulet 1991; Villar et al. 1992).

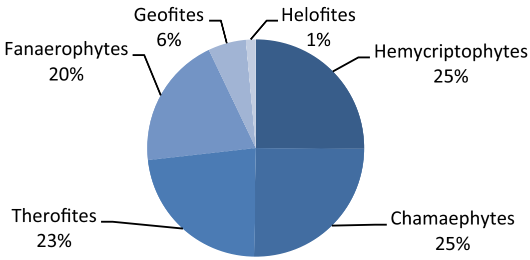
Botanical issues

The botanical diversity of the included plants covers 91 botanical families, 88 of which are vascular plant families. Families Asteraceae (68), Lamiaceae (53), Fabaceae (32), and Poaceae (32) stand out in the number of included species, which is not surprising when comparing with other ethnobotanical works in other southern Spanish territories (Martínez-Lirola et al. 1997; Fernández 2000; Verde 2002).

Considering the classical biotype classification of Raunkiaer (1934), the biological spectrum of the ethnoflora was analysed and is represented on Graph 1. The most significant result is that none of the biotypes stand out above the rest, and the use of therofites, chamaephytes hemicryptophytes, and phanaerophytes is similar in proportion.

Regarding the biogeographical spectrum of the included flora (Graph 2), chorology shows a major group of taxa distributed throughout the Mediterranean region sensu lato (i.e., including the so-called late-Mediterranean and circum-Mediterranean elements and even those which reach the Middle East, Central Europe, or the European Atlantic Islands). The second big group includes taxa with a great area of distribution (including cosmopolitan, holarctic, and highly distributed species). On the other hand, 17 % of the ethnotaxa have a low distribution, being endemic from North Africa and the Iberian

Graph 1 Biological spectrum of the ethnoflora



Peninsula, or Iberian, South-Iberian, or Baetic endemism. This relatively important percentage gives an idea of the ethnobotanical originality of this territory.

Ecological issues and diversity

Twenty-five percent of the included species are not autochthonous to the study area (118 taxa). Some are introduced, cultivated in orchards or gardens, or purchased in local markets and not gathered from the wild, and in these cases it was not possible to associate the species with a syntaxon. Even some of the native flora could not be associated with a syntaxon (e.g., the parasite *Orobanche crenata*). On the other hand, some of the naturalised species in the area have a well-defined ecology, so they were associated to a syntaxon (e.g., *Arundo donax*).

Therefore, 116 plant species were excluded from this synecological characterisation and marked as “undefined” in the supplementary material table. The remaining 362 plants (75 % of the total) were grouped into 35 categories, corresponding to a phytosociological class. The number of species in each of the classes and the classification of classes in wide groups of vegetation can be seen in Table 2.

It is noteworthy that 294 (81 %) of these plants are characteristic species of a syntaxon according to Rivas-Martínez (2002a), as they have a very concise ecological definition. Moreover, it is not surprising that the classes which include a higher number of ethnotaxa represent frequent and extended ecosystems in the province: *Stellarietea mediae*, *Rosmarinetea officinalis*, and *Quercetea ilicis*, which are discussed below. When classes are grouped into wide vegetation groups, the anthropogenic vegetation (including the forest boundary vegetation and megaphorbic formations, named “synanthropic, fringe and megaforbic vegetation”) clearly stands out among other categories. This category represents altered environments.

Graph 2 Biogeographical spectrum of the ethnoflora

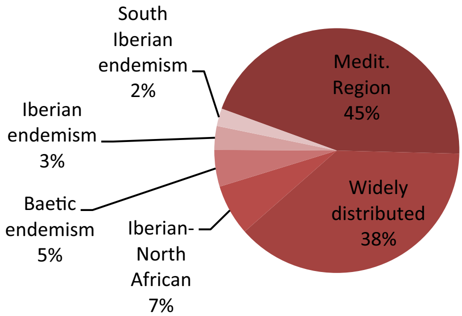


Table 2 Number of ethnotaxa per phytosociological class, sorted by major vegetation groups

Vegetation groups	Ethnotaxa
I. Amphibious vegetation of fresh-waters, springs, and fens	13
ISOETO-NANOJUNCETEA	1
PHRAGMITO-MAGNOCARICETEA	11
SCHEUCHZERIO PALUSTRIS-CARICETEA NIGRAE	1
II. Coastal and continental halophilous and sand dune vegetation	3
AMMOPHILETEA	1
JUNCETEA MARITIMI	2
III. Chasmophyte, epiphyte, and scree vegetation	23
ADIANTETEA	2
ASPLENIETEA TRICHOMANIS	3
PARIETARIETEA	9
PHAGNALO-RUMICETEA INDURATI	5
THLASPIETEA ROTUNDIFOLII	4
IV. Synanthropic, fringe, and megaforbic vegetation	125
ARTEMISIETEA VULGARIS	23
PEGANO-SALSOLETEA	23
POLYGONO-POETEA ANNUAE	2
STELLARIETEA MEDIAE	68
GALIO-URTICETEA	5
CARDAMINO HIRSUTAE-GERANIETEA PURPUREI	1
TRIFOLIO-GERANIETEA	1
MULGEDIO-ACONITETEA	2
V. Supratimberline climactical zonal vegetation in cryophilous geliturbated soils	5
FESTUCETEA INDIGESTAE	5
VI. Grassland and meadow vegetation	74
TUBERARIETEA GUTTATAE	8
FESTUCO-BROMETEA	18
POETEA BULBOSAE	5
SEDO-SCLERANTHETEA	1
LYGEO-STIPETEA	15
MOLINIO-ARRHENATHERETEA	25
FESTUCO HYSTRICIS-ONONIDETEA STRIATAE	2
VII. Heathland, dwarf scrub, and scrub vegetation	65
CISTO-LAVANDULETEA	3
ROSMARINETEA OFFICINALIS	44
CYTISETEA SCOPARIO-STRIATI	5
RHAMNO-PRUNETEA	13
VIII. Forest, woodland, semidesert and desert potential natural vegetation	54
NERIO-TAMARICETEA	1
SALICI PURPUREAE-POPULETEA NIGRAE	10
JUNIPERO SABINAE-PINETEA SYLVESTRIS	2
QUERCETEA ILICIS	31
QUERCO-FAGETEA	10

Table 2 continued

Vegetation groups	Ethnotaxa
Subtotal	362
Undefined	116
Total	478

Discussion

Plants per phytosociological class

Why classes *Stellarietea mediae*, *Rosmarinetea officinalis*, and *Quercetea ilicis* are the most visited in order to gather ethnobotanical resources in our study area?

Stellarietea mediae represents the annual vegetation of arable land and ruderal habitats, and it is highly extended in the province, which maintains high agricultural activity. Many medicinal plants can be gathered from these places, such as *Matricaria chamomilla*, *Malva sylvestris*, *Papaver rhoeas*, and *Urtica urens*, which are some of the most employed ones (see for example Benítez et al. 2010a for the number of use reports). These places are also rich in wild food plants like *Allium ampeloprasum*, *Anchusa azurea*, *Borago officinalis*, *Ridolfia segetum*, *Rumex pulcher*, and *Sonchus oleraceus*. Nevertheless, as observed for a long time in the territory, current agricultural practices (including herbicides, deep plowing, etc.) can reduce the availability of these species.

Rosmarinetea officinalis represents the basophilous secondary communities of open shrubs rich in chamaephytes and nanophanerophytes, typical of the western Mediterranean. These formations are rich in aromatic plants, highlighting the Lamiaceae ones such as *Lavandula lanata, L. latifolia*, *Rosmarinus officinalis*, *Salvia lavandulifolia*, *Satureja obovata*, *Sideritis* spp., and *Thymus* spp., used as medicinal and seasonings, but including many other plants from different families, like *Ruta chalepensis, Digitalis obscura*, and *Lithodora fruticosa*. This kind of scrub formation grows in poor and sparse soils and has been favoured by human land management through time by forest degradation, inducing forest fires or cultivating non-productive lands which are later abandoned.

Quercetea ilicis is the Mediterranean sclerophyllous forest and scrub vegetation, dominated by the holm oak (*Quercus rotundifolia*) and with other phanerophytes in determinate microclimatic situations (*Q. coccifera*, *Pistacia terebinthus*, *P. lentiscus*, *Olea europaea* var. *sylvestris*, *Pinus halepensis*, *P. pinaster*, *Arbutus unedo*, *Ceratonia siliqua*, *Juniperus oxycedrus*, *J. phoenicea*) and many shrubs (*Bupleurum gibraltaricum*, *Daphne gnidium*, *Rhamnus lycioides*) and lianoids (*Lonicera etrusca*, *L. implexa*, *Smilax aspera*). *Q. ilicis* represents the potential vegetation which would exist in the main part of the province, and it is related with most of the protection figures in Andalusia. Nevertheless, in general these frequent formations are not in their optimum conservational state.

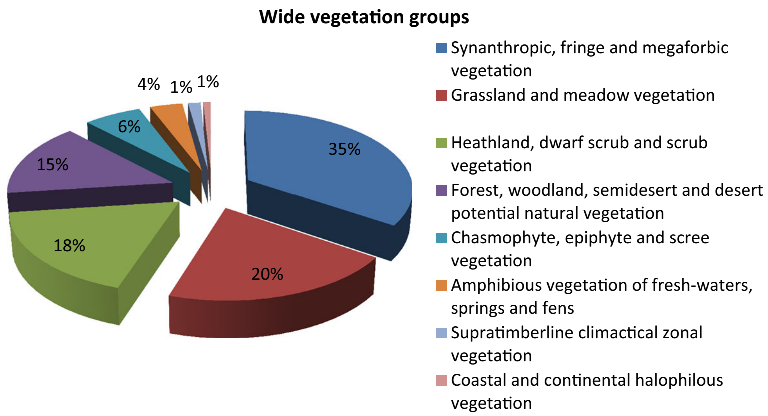
Plants per vegetation group

For a more comprehensive analysis with a small number of categories of vegetation types, we grouped the classes into what we call *wide vegetation groups*, as shown in Table 2.

The obtained results show that the anthropogenic vegetation zones (including the forest boundary vegetation and megaphorbic formations) offer the highest number of ethnobotanical resources, mainly coming from places with communities included in the classes

Stellarietea mediae, *Artemisietea vulgaris*, and *Pegano-Salsoletea* (see Graph 3). This is in concordance with a similar study regarding only the western part of the province (Benítez et al. 2010b). As discussed in this paper, this high occurrence can be caused by the high number of wild food thistles within *Artemisietea vulgaris* (*Cynara cardunculus*, *Cynara humilis*, *Silybum marianum*, *Carduus platypus* subsp. *granatensis*, *Onopordum nervosum*, and *Eryngium campestre*) or the high number of annual nitrophilous herbs of *Stellarietea mediae*, used as medicinal but mostly as food (e.g., *Allium ampeloprasum*, *Anchusa azurea*, *Bifora testiculata*, *Crepis vesicaria* subsp. *haenseleri*, *Leontodon longirrostris*, *Malva sylvestris*, *Ridolfia segetum*, *Scandix pecten-veneris*, and *Urtica urens*). Extending this idea from a local previous study (Benítez et al. 2010b) to this regional one, the hypothesis that a large group of useful plants (mostly medicinal and edible) grows nearby is reinforced. A high number of useful plants are gathered from easily accessible inhabited and altered areas.

The grassland and meadow vegetation areas are also important and offer many resources (mainly the *Molinio-Arrhenatheretea*, *Festuco-Brometea*, and *Lygeo-Stipetea* classes). Considering these grassland formations also as anthropogenic ecosystems, altered by grazing, culture, and abandoned agricultural or farming fields, we can state that more than half (55 %) of the ethnobotanical resources are collected in areas of vegetation disturbed by man, whether nitrophilous communities or in areas of pasture and rangeland, which are also influenced by humans. This is in concordance with analyses from other Spanish studies focused on edible wild plants, such as Pardo de Santayana et al. (2005) and Bonet and Vallès (2002). A reasonable explanation for the high affluence of species collected in these areas of grassland and rangeland vegetation can be the high biodiversity of these areas. As Wilson et al. (2012) showed, semi-dry basophilous grasslands are the maximum species richness communities found in smaller plots worldwide, while the unmanaged and natural tropical lowland rain forest are the maximum species richness communities at larger plots. In addition, apart from being highly diversified, another reason for which semi-dry grasslands can offer many useful resources can be that many of the interviewees in ethnobotanical studies are people with a close relation to these natural environments in their work, i.e., mainly farmers, shepherds, or people living in rural areas inside these environments, who know how to obtain valuable resources from them.



Graph 3 Distribution of species in wide vegetation groups: where local people collect ethnobotanical resources

The third position is for the resources gathered in serial vegetation areas coming from the alteration of the main and primary forests, dominated by chamaephytes and shrubs. The most important class is *Rosmarinetea*, which is rich in aromatic plants (e.g., thyme, rosemary, sage, lavender, rue) and plants with striking flowers (e.g., *Cistus albidus, C. clusii*, *Digitalis obscura*). Additionally, these formations are frequent in the province, geographically extended, forming a very typical and locally valuable landscape. There are also noteworthy species from spiny forest fringes included in *Rhamno-Prunetea*, most from the Rosaceae (e.g., from the genera *Rosa*, *Crataegus*, and *Prunus*), that provide mainly food fruits and medicinal resources.

The most natural vegetation, the potential one (including forests, river forests, high mountain formations, etc.), goes to the fourth position due to the high and intense degradation of this potential vegetation throughout the history of the territory, despite offering some widely known resources as *Quercus* acorns (used as food or to feed animals); *Arbutus unedo*, *Ceratonia siliqua*, or *Prunus avium* fruits; and many sources of wood. This is analysed in greater depth in the next section.

Do people prefer to collect plants from mountain summits or well-preserved environments?

In the prologue of the first book of his famous *Materia Medica*, Pedanio Dioscorides wrote *"…there is a difference in collect on dry weather or rainy one, or in perform it in high and windy mountain places, cold and without water, since in this case their virtues are more potent. In return, virtues of those growing on flat lands, wet, shady and not beaten by winds are, mostly, less intense….*" (translated from the Spanish version of Laguna 1555). Since ancient times and, according to our ethnobotancial fieldwork until now, there has been a belief: *the mountain summits or well-preserved environments offer more effective plants for medicinal purposes*. This belief, still alive in our study area, can be extended to a greater territory.

Therefore, plants from closed and preserved forests, from the funds of the ravines or from the summits of the mountains, are popularly said to be more effective. Likewise, people do not use to collect plant specimens developing in different places where they use to grow; for example a thyme which grows in a culture margin. People therefore regard not only the resource identity (the useful plant species) but also its location (ecological issues). In addition, people know that collection of edible plants on preserved environments can avoid the intake of possible toxics and contaminants. However, in our aim to analyse this fairly widespread belief, results show that the number of species collected from these preserved ecosystems is very low. For Granada Province, only 51 species are harvested from potential forest vegetation zones (*Quercetea ilicis*, *Querco-Fagetea*, and *Salici-Populetea*), and only 5 species from climatophilous supraforestal vegetation zones (*Festucetea indigestae*).

Plants collected from potential forest vegetation zones include forest-forming main trees from the genera *Quercus* and *Pinus*, along with trees not forming large forests like *Pistacia* spp., *Juniperus* spp., *Taxus baccata*, *Sorbus aria*, *Acer granatense*, *O. europaea* var. *sylvestris*, *C. siliqua*, and *Chamaerops humilis* in climatophilous zones. Additionally, *Populus* spp. and *Salix* spp. together with *Ulmus minor, Fraxinus angustifolia*, and *Celtis australis* form edaphohygrophilous vegetation communities. We should add a list of non-tree cohabitants in these potential forest vegetation zones which are collected for different purposes (e.g., edible *Asparagus* spp., *Bunium macuca*, or the highly reported medicinal *Bupleurum* spp., *Equisetum telmateia*, and *Hedera helix*).

In the case of high mountain plants, many studies argue that the exposure to cold weather, lower water uptake or water stress, high ultraviolet radiation exposure, and other factors may contribute to higher accumulation of secondary metabolites (Alonso-Amelot et al. 2004; Zhang and Björn 2009; Zidorn 2010; Cuello et al. 2011; Sakalauskaite et al. 2012), because most of the secondary metabolites are considered an outcome of stress response (not only weather, but also disease, pests, etc.; Edreva et al. 2008; Bartwal et al. 2013). However, only five plants are collected from mountain tops in Granada. They are all used for medicinal purposes and, in our interviewees' opinion, with a higher efficacy than lowland plants. Possible reasons for this low number of resources in these environments can be a short flowering period resulting in a short gathering period and a limited distribution not developing extensive formations.

Furthermore, in our opinion, a different plausible reason for the low number of resources in these environments can be the high amount of energy needed to gather these plants, with many hours of walking through difficult pathways, and the fact that this energy expenditure can be decreased by using a similar or relative plant for the same medicinal purpose, i.e., a lowland substituent. Because some plants collected from natural supraforestal vegetation do not have any lowland substituent, they must be collected in mountain summits. This includes plants reputed to treat tumour pain (*Draba hispanica* subsp. *laderoi*), a very specific use not common in ethnobotanical catalogues. Nevertheless in some cases the collection of mountain plants can only be explained according to the previously commented popular idea of a higher effectiveness. This is the case with the famous and highly endangered *Artemisia granatensis*, discussed in Benítez et al. (2012b) which, despite having some lowland substituents such as *Artemisia* spp., *M. chamomilla*, and *Jasonia glutinosa* (all used as digestives), is much more appreciated by local people. The same can be said for *Sideritis glacialis*, *Thymus serpylloides*, and *Arenaria tetraquetra* subsp. *imbricata*, which are more appreciated but used for the same purposes as more accessible relatives from the same genus (*Sideritis hirsuta, S. granatensis*, *S. incana*, different *Thymus* or *Arenaria* species, and other Caryophyllaceae species with the same traditional diuretic and anti-litiasic use as *Arenaria*, such as *Paronychia, Spergularia*, and *Herniaria*).

In summary, the higher local valuation of mountain plants as medicinal resources can be associated with the folk idea: the more effort is needed to collect plants in the mountain, the higher virtues the plant have. Nevertheless, in our opinion the effectiveness can be popularly also associated with the collection in a particular, special, or emblematic place. In the study area, Sierra Nevada represents a high mountain associated with highly preserved environments and flanked by some mysticism of a special place. Collection of botanical resources in this mountain can be a folk reason for an intended higher virtue. This idea was also observed in the markets of Granada, where plants form Sierra Nevada or the Alhambra palace are sold and said to be more effective.

However, an important point to explain the relatively low number of plants collected from mountain summits or potential forest vegetation zones nowadays can be the number of protected areas in the province, which include a national park (Sierra Nevada), five natural parks (Sierra de Baza, Sierra de Castril, Sierra de Huétor, Sierras de Tejeda, Almijara y Alhama, and Sierra Nevada), and other minor conservation figures reaching 293,973 ha of protected areas (Anon 2014, nearly 23.5 % of the province). Collection is generally forbidden in these areas except in certain cases small quantities for familiar use with special permission from the Environmental Government Agency.

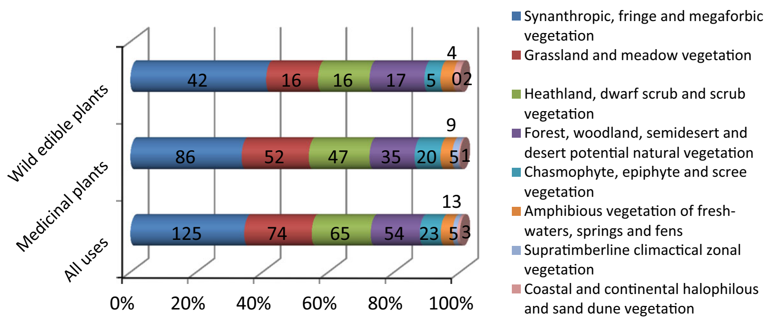
Do people use to collect endangered species?

Only a few of the included taxa are threated. Seven plants are included in both the regional and national red lists of endangered plants or conservation laws: four in the national red list (*Artemisia granatensis, Centaurea aspera* ssp. *scorpiurifolia, Pinguicula nevadensis, Senecio pyrenaicus* ssp. *granatensis*; Moreno 2008) and three in the Andalusian catalogue of protected species (*Aconitum burnatii, Sideritis arborescens*, *Taxus baccata*; Anon 2012). In our opinion, only the case of the collection of *Artemisia granatensis* as an ethnobotanical resource (medicinally used for digestive disorders) can represent a real threat to the species conservation, but fortunately its collection is doubly forbidden: besides being included in both national and regional protection laws (IUCN category "critically endangered", Moreno 2008), all specimens of this endemism grow in the protected area of Sierra Nevada National Park (see Benítez et al. 2012b for more details). Moreover, *Artemisia granatensis* is the only endangered plant in an international context, and it is included in the European Red List of Medicinal Plants (Allen et al. 2014). Considering only the native flora, the proportion of use of protected plants is quite low (7/362).

Do any ecological differences exist when collecting medicinal or edible plants?

Comparing the whole ethnobotanical catalogue with only the gathered species for medicinal purposes (347 in total), the major vegetation groups' distribution does not substantially vary. The most visited ecosystems for gathering plants are the same, with slight variations in the better represented classes (Graph 4). The same situation is found when analysing only the wild gathered food plants. Therefore it seems not to be any substantial difference regarding the visited habitats to collect a certain type of resource or another. Nevertheless, a notable difference is the absence of food species among the climatophilous high mountain siliceous vegetation of *Festucetea indigestae*. As Graph 4 shows, most of the resources are collected in places with anthropogenic vegetation and grassland and meadow zones, and it seems that people collect these resources mostly from nearby places.

According to this fact and to our experience in the Mediterranean mountain ethnobotany, for local people the spent energy in the search for food (walk through the countryside, climb a mountain, etc.) must be less than the energy obtained from its consumption, what has been postulated for animals looking for grazing as a theory: "the



Graph 4 Differences in the visited ecology (wide vegetation groups) when collecting wild edibles or medicinal plants

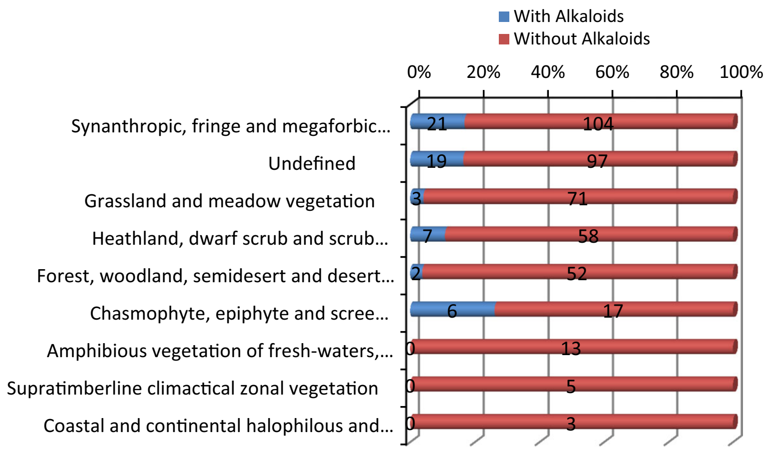
optimal foraging theory" (Pyke 1984; Kelly 1995). This theory has been applied to human foragers with several adaptations (Smith 1983; Sheehan 2004) and is relevant for our study area, as well as in several others (Ladio and Lozada 2000; Aceituno-Mata 2010). Therefore, most of food resources are gathered from areas close to the places of residence (usually anthropogenic environments) and only a few are gathered in remote areas like mountain summits, which are difficult to access. Another significant fact supporting this theory is the absence in the compiled provincial ethnobotanical catalogue of some mountain edible plants known for other mountain territories, even growing in this territory, such as *A. schoenoprassum*, *Vaccinium uliginosum*, *Ribes alpinum*, and *Bunium macuca* ssp. *nivale*—plants that offer low biomass edible parts and which are uncommon in the province.

However, as mentioned before, this is not the case for medicinal species; on many occasions collectors do not mind going up to the summit because of the idea that plants from areas with extreme weather, especially high mountains, have a "better effect" or "higher effectiveness" than those from lowland places.

Relation of the synecology of the gathered plants and their chemical compounds

As commented in the introduction, the biosynthesis of some secondary metabolites in plants can be influenced by the habitat. This raises a logical question: due to the fact that most of the collected species in our study area come from altered environments—mainly nitrophilous or subnitrophilous communities enriched in nitrogen, phosphorous, potassium, and other main plant nutritional constituents—do these altered environments influence a greater biosynthesis of certain active compounds? In attempt to answer this question, medicinal plants from our database containing alkaloids were analysed. Our aim in this sense is to determine if there is a greater alkaloidic species proportion in nitrophilous or subnitrophilous communities.

Considering only the species included in our database, i.e., those which have a cultural interest in the study area, 57 of the 478 species are plants with alkaloids (12 % of the species; see Graph 5). The distribution of these species shows, as expected, that



Graph 5 Distribution of plants with and without alkaloids in the vegetation groups

there is a greater affluence of plants with alkaloids in anthropogenic vegetation zones (21 of the 58 total species). Main classes are *Stellarietea mediae* (12 sp.), *Pegano-Salsoletea* (4 sp.), *Mulgedio-Aconitetea*, and *Artemisietea* (2 sp.). However, considering that this vegetation group (nitrophilous or subnitrophilous communities) includes a higher number of ethnotaxa, the relative proportion of species containing alkaloids (to respect the total number of species in each group) is higher in areas of chasmophytic vegetation. Up to six species from *Adiantetea, Parietarietea* and *Thlaspietea* (26 % of total species in this vegetation group) contains alkaloids: *Trachelium caeruleum*, *Chelidonium majus*, *Fiscus carica*, *Fumaria rupestris*, *Hyoscyamus albus*, *Senecio pyrenaicus* ssp. *granatensis*.

Conclusions

As expected, most of the used plant species in the study area are gathered from frequent and extended ecosystems in the province: places cover with anthropogenic vegetation, easily accessible, inhabited and altered areas, grassland and meadow vegetation favoured by human livestock practices, and areas of serial vegetation derived from the alteration of main and primary forests. The importance of altered environments for the ethnobotanical resources has been highlighted one more time.

Without going into the ecological differences of all the included categories (phytosociological classes), the three classes with the higher species number: *Stellarietea mediae, Rosmarinetea* and *Quercetea ilicis* were representative of three wide vegetation groups.

There is a general perception among the local people that medicinal plants collected in well-preserved environments like mountain summits or forests have higher effectiveness. References to this fact are not unusual when collecting ethnobotanical data through interviews. However, our analysis shows that only a few resources are collected in these places: some reputed plants that only grow in these environments or plants without a more accessible similar substituent (species of the same genus or species with similar properties). Therefore, we think that this popular idea could be more associated with the singularity of the collection place or with the extra effort needed to collect in such places (which were once farther than altered environments).

In general, there are no significant differences in the places visited to collect wild medicinal or edible plants. However, the shortage of used food plants in the high peaks seems to indicate that the commented theory of the optimal foraging theory is fulfilled in the Andalusian Mediterranean mountains but can probably be extended to other mountainous areas, as the close Mediterranean mountains of Central Spain (Aceituno-Mata 2010).

As it could be expected and according to the analysed data for the study area, the higher proportion of plants with alkaloids corresponds to zones with anthropogenic vegetation, usually nitrogen-enriched environments where a greater bioavailability of nitrogen exists for the synthesis of alkaloid precursor amino acids. Nevertheless, chasmophytic and stony place vegetation areas with shallow, decapitated, and stony soils are also rich in species with alkaloids, even more in proportion than those with anthropogenic vegetation. In any case, more in-deep studies apart from this brief analysis are needed in order to establish a possible relation between habitats and the ability of plants to biosynthesize chemical compounds as alkaloids.

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