

# Ethnobotanical Biocultural Diversity by Rural Communities in the Cuatrociénegas Valley, Coahuila; Mexico

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## Research

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# Abstract

## Background

Cuatrociénegas is a region of unique biological, geological, geographical and evolutionary importance. It is part of the Chihuahua Desert, its current population is mestizo; however, it protects a high historical, cultural and tourist relevance. It has been listed as Area of Protection of Flora and Fauna by Mexican law, as well as a site of High Protection by the World Wildlife Fund and UNESCO. Because of its complex biological and sociocultural characteristics, we consider it important to find out, determine, identify and analyze the traditional ethnobotanical knowledge and practices in this region.

## Methods

Between 2016 and 2019, seven field trips were carried out to document and photograph the knowledge and use of the flora by local people. Cuatrociénegas is a protected area, collecting botanical material is regulated, so specimens were collected in communities surrounding the city, and also in public and private gardens; later permission was obtained to complete the collection of specimens (2019-2020). The plants were identified and entered into the flora database of the state of Coahuila, as well as deposited in the Herbarium of the Faculty of Forest Sciences, Autonomous University of Nuevo León, Mexico. One hundred and ten local residents (50 men and 60 women) between the ages of 27 and 91 were interviewed (semi-structured interviews). The cultural importance of ethnobotanical resources (cultural significance index) and its contribution regarding ethnobotany wealth in other Biosphere Reserves (Mann-Whitney test) was evaluated.

## Results

The ethnobotanical information collected from Cuatrociénegas records 158 species and 132 genera in 57 vascular and non-vascular families, registering greater knowledge and use of cultivated species (84) with respect to wild species (74). The diversity of plants reported, compared to other ethnobotanical studies conducted in Biosphere Reserves in Mexico, is notable; the residents pay more attention to medicinal and ornamental plants. The species that presented the highest use values are *Larrea tridentata*, *Jatropha dioica* and *Machaeranthera pinnatifida*, three characteristic species of the desert region.

## Conclusions

The particular diversity of wild flora in Cuatrociénegas and its surroundings, combined with the varied flora introduced, is an important natural resource with multiple ethnobotanical applications. The broad knowledge and use of ethnobotany are an example, that biocultural diversity (at the conceptual level) is strongly associated with mestizo groups and semi-urban rural landscapes, ceasing to be exclusive to indigenous regions.

## Background

Arid lands in Mexico cover 60% of its area; most of them are concentrated in the northern region [1]. These areas harbor a rich flora adapted to these hostile environments [2], which include two large areas, the Chihuahuan Desert (CHD) and the Sonoran Desert. Cuatrociénegas is a region recognized as a living laboratory for the world scientific community, thanks to its historical, biodiversity, geological, geographic and evolutionary components. These characteristics have allowed the development of research in microbial genomics [3], metagenomics [4], genetic variation, diversity and speciation of fishes [5], virus evolution [6], paleoecology [7], paleoclimate [8], limnology [9], microbial endemism [4], endemic algae [10], speleogenesis [11], stratigraphy [12], and flora and vegetation [13, 14]. Cuatrociénegas is one of the few places in the world where stromatolites live, organisms characterized by their antiquity in billions of years [15].

The Cuatrociénegas Basin qualifies as an environment so unique that it has been designated as an “*Área de Protección de Flora y Fauna*” (Flora and Fauna Protected Area) by the Mexican federal government. The area is administered by the Mexican agency SEMARNAT (Secretaría del Medio Ambiente y Recursos Naturales); due to its particular biodiversity, Cuatrociénegas was declared a protected area in 1994 [16]. It is considered a high-priority site for conservation by the Nature Conservancy, the World Wildlife Fund, and UNESCO, and has been listed as a Wetland of International Importance by Ramsar.

The vegetation described for the Cuatrociénegas Valley corresponds mainly to rosetophyllous and microphyllous desert scrub; halophytic vegetation, and aquatic and semiaquatic vegetation of CHD; which is associated with a floristic diversity of approximately 840 species of vascular plants, of which 12 species are considered as species at risk within Mexican legislation.

Cuatrociénegas is located in the center of the CHD, historically important since the Mexican president Venustiano Carranza (1917–1920) was born there [17]. Economically, the area stands out for its alfalfa forage production and the growing of grapes for white and red wine. One of the most profitable activities is tourism, mainly in connection with multiple thermal pools scattered throughout the area, and an area of salt accumulation, consisting mainly of sulphates resulting from high evaporation [18]. Because of its culture, architecture, and traditions, this city is included in the list of Magical Towns, which are places with unique attributes, symbolism, authentic stories, important facts, and daily life, which means that these towns can take advantage of a stronger tourism draw.

Cuatrociénegas was founded approximately in 1760. Its actual population is completely mestizo, so it lacks indigenous population; however, in the past the Valley of Cuatrociénegas had been inhabited by nomadic Coahuiltecos and Borrados groups. In the context of biocultural diversity [19], traditional rural communities also house biocultural heritage, being important in the conservation of biological diversity and in ecosystem services [20]. Biocultural diversity helps lend an understanding of human–nature relationships, not only in cultural areas, but also in urban spaces [21], such as in landscapes or semi-urban areas like Cuatrociénegas.

Based on of the complex biological and sociocultural characteristics of the study area, we set the following objectives: (i) collect knowledge from the residents regarding flora species and their uses; (ii)

determine the main type of use people give to the species; (iii) identify whether the main species used are native or exotic; (iv) contribute to studies in traditional rural regions, as structural elements of biocultural diversity; and (v) contribute to the dissemination of knowledge about traditional ethnobotanical uses as part of preserving the historical cultural heritage of natural resources in semiarid areas of Mexico.

## 2. Methods

### Study site

Cuatrociénegas is a small city located in the central region of the state of Coahuila, 26° 42' 10" to 26° 59' 10" N, 101° 52' 01" to 102° 03' 59" W (Fig. 1). Its population is almost 13,000, it has all the modern services of elementary and basic education, social health care, and media and internet, and all the inhabitants speak Spanish. Physiographically it is located in a valley at 740 m elevation, surrounded by high mountains reaching almost 2,900 m, which belong to the Sierra Madre Oriental range. Its climate is very dry; the most extreme temperatures in the valley reach 44 °C in summer, while in the mountains, the temperature falls below 0 °C in the winter. Annual precipitation is less than 200 mm [22]. Much of the water in the valley comes from groundwater, which emerges in the form of pools and springs; the landscape is characterized by its contrasting wet environments such as wetlands, marshes, underground streams, springs, rivers, lakes, temporary ponds and groundwater [23]. According to its climate, geological, soil, water and biological factors, it is considered one of the three most important desert ecoregions in the world [24].

#### 2.1 *Vegetation and flora*

Cuatrociénegas is part of the Chihuahuan Desert and its vegetation, like the flora and vegetation of arid environments, is essentially composed of dispersed shrub species [25]. Vegetation of the Cuatrociénegas Valley include rosetophyllous desert scrub, microphyllous desert scrub, halophytic vegetation and aquatic and semiaquatic vegetation, with approximately 840 plant species [26], making up at least 25% of the flora of the state of Coahuila [27]. There are at least 70 species of endemic plants and animals in Cuatrociénegas [28].

#### 2.2 *Ethnobotanical survey*

In order to learn about the diversity of flora and its uses in the Cuatrociénegas region, seven field trips were carried out from 2016 to 2019 in order to photograph and record the plants, as well as to carry out ethnographic work. Since Valle de Cuatrociénegas is a protected area, collecting botanical material is regulated, initially the identification of the plants was through the use of photographs by E. Estrada-Castillón and J.A. Villarreal-Quintanilla, based on a study of the flora of the state of Coahuila [27] and monographs of the genera distributed in this area. Plant specimens were collected from plant communities adjacent to the town, adjacent ejidos, and also from private and public gardens with the owners' consent. Later, permission was obtained to complete the collection of plant specimens (2019–2020). The plants were identified and entered into the flora database of the Coahuila, as well as in the

Herbarium of the Faculty of Forest Sciences, Autonomous University of Nuevo León, Mexico (the collection number belongs to the first author in Supplementary Material). Based on our experience in other studies, we decided to conduct the interviews by selecting people over 25 years of age or older. The ages of the interviewees ranged from 27 to 91. In order to ensure the reliability and homogeneity of the field information, all the interviewees who were selected were native-born or had lived there continuously for at least 25 years. The interviews were semi-structured in order to elicit the greatest amount of information in each interview and allow the free flow of information by the interviewees without limiting the free expression of ideas regarding species and uses. To this end, several key questions were included: What is the name of the plant? What do you use it for (medicinal, timber, food, fodder, seasoning, ritual)? How do you use it (raw, cooked, boiled, ground, battered)? What part of the plant do you use (root, stems, leaves, bracts, inflorescences, flowers, fruits, seeds, sap)? [29]. The interviews were conducted with the prior informed consent of each of the informants (International Society of Ethnobiology 2006; <http://ethnobiology.net/codeofethics/>; [30]). The informants were mainly homemakers, shepherds, and retirees, who knew the flora and its uses due to their custom of daily use of the various plants. During interviews were shown photographs of the species and plant specimens collected in private and public gardens and in areas adjacent to the protected area. We asked for the common names of the plants and the uses they are given (ethnographic technique of visual stimuli; [29]). Informants were also asked about other wild and cultivated plants they knew and about the species they grew in their gardens. All information was recorded in Spanish, the only language spoken in the region.

## 2.3 Data Analysis

To compare the relevance of our study with respect to other ethnobotanical studies carried out in Biosphere Reserves in Mexico with mestizo and indigenous populations, a comparison was made using the Mann Whitney test, calculated in the statistical program Past 3.20 [31]. The test was based on ethnobotanical data corresponding to the number of families, genera and species; also included information such as the extent of the reserve and the types of vegetation. The null hypothesis was rejected when the data of other reserves with respect to ours are similar; when the significance value of the test was less than  $p < 0.05$ . Obtaining information for comparison with other Biosphere Reserves in Mexico was carried out through a systematic review in electronic media, using a set of keywords (ethnobotany, protected natural area, Mexico, use, knowledge, plants). Ethnobotanical data in these protected sites is scarce and nil for the North region, especially Northeast, where our study region is located. Therefore, the compared data are general and not specific to protected sites in areas belonging to the Chihuahuan Desert, where environmental conditions are similar.

In order to obtain and quantify the recorded information, the informant consensus factor (FIC; [32]), fidelity level (FL; [33]) and use value index (IVU; [34]) were calculated. The FIC is an index that measures the relative importance of the different medicinal species for a category of use, and is calculated as  $FIC = \frac{nur - nt}{nur - 1}$ , where  $nur$  = number of uses mentioned, and  $nt$  = number of species used in each category. This quantitative technique enables the homogeneity of the information to be determined. Plants that are effective in treating certain diseases will have higher FIC. The fidelity level (FL) or

Friedman index estimates the relative importance of each of the medicinal species based on the degree of consensus of the informants about the species' use against a given category of use. With this index, the preferred species to cure certain diseases can be identified for certain informants; high FL values indicate that the medicinal species used to cure certain illness is widely used for that purpose. The fidelity level is calculated as  $FL(\%) = lp/lu(100)$ , where  $lp$  = number of informants who independently indicated the use of a plant for the same particular illness;  $lu$  = number of informants who mentioned the species for any illness within a category of use. The IVU is an index that quantifies the local importance of each of the species, and is calculated as  $IVU = \sum Ui / n$  where  $Ui$  = the number of uses mentioned by each informant for a given species, and  $n$  = the total number of informants.

### 3. Results And Discussion

#### 3.1 Species diversity

According to interview records of the ethnobotanical information collected, the useful flora of Cuatrociénegas consists of 158 species and 132 genera in 57 vascular and non-vascular families (Table 1). Most of the species are herbaceous (68 species, 43.1%), followed by shrubs (53 species, 33.5%), and trees (37 species, 23.4%). Of the total species, 84 were cultivated and 74 were wild, which means that the inhabitants of Cuatrociénegas reported in the interviews that they use more cultivated than wild species. This may be associated with the prohibition on collecting flora and fauna in the reserve, so that local people tend to introduce ethnobotanical species that help meet their needs.

Table 1  
Number of families, genera and species of plants known and used by local residents of Cuatrociénegas, Coahuila, Mexico.

	<b>Eudicots</b>	<b>Monocots</b>	<b>Ferns and allies</b>	<b>Conifers</b>	<b>TOTAL</b>
<b>Families</b>	43	7	2	2	57
<b>Genera</b>	116	10	5	3	134
<b>Species</b>	138	11	5	5	159

The richness of ethnobotanical species in Cuatrociénegas is similar to that reported in other works with mestizo communities, showing no significant differences with respect to knowledge and use of flora in Biosphere Reserves in Mexico. For example, there is no significant difference between Cuatrociénegas and the ethnobotanical study in Cumbres de Monterrey National Park ( $U_{d.f. 9}=11$ , n.s.; [35]), the Sierra de Huautla Biosphere Reserve ( $U_{d.f. 9}=12$ , n.s.; [36]) or the El Cielo Biosphere Reserve ( $U_{d.f. 9}=11$ , n.s.; [37]). There is also no significant difference when the results are compared with an ethnobotanical study carried out in the Monarch Butterfly Biosphere Reserve with the Mazahua indigenous group ( $U_{d.f. 9}=11$ , n.s.; [38]). It is also important to consider that the different types of ecosystems among the reserves are completely contrasting, Cuatrociénegas corresponds to characteristics of the Chihuahuan Desert, however, it presents an environmental heterogeneity with different types of vegetation; something similar

for the Cumbres de Monterrey National Park, which may explain why there are no differences. However, when making comparisons with other Biosphere Reserves such as with Sierra de Huahutla; El Cielo; and even more homogeneous sites such as the Monarch Butterfly Biosphere Reserve; no differences are shown either; even when the territorial extension of the reserves has been taken into account (Table 2). Therefore, the ethnobotanical wealth in Cuatrociénegas is highly characteristic, and as significant as in other studies, it represents the importance of ethnobotanical resources in regions of Northeast Mexico where desert vegetation predominates and the majority of the population is mestizo. Cuatrociénegas is an example of the biocultural diversity of traditional rural regions; with ethnobotanical knowledge and use patterns similar to other sites in Mexico, with other environmental characteristics, and even in regions with the presence of indigenous groups.

Table 2

Comparison information for Biosphere Reserves in Mexico where ethnobotanical studies have been carried out. The data was obtained from the publications and from the catalog of the Priority Terrestrial Regions for Mexico, CONABIO.

	<b>Ethnobotanical data</b>	<b>Extension (km<sup>2</sup>)</b>	<b>Vegetation types</b>
Cuatrociénegas	Family	57	843 halophilic, aquatic and semi-aquatic vegetation, grassland, undergrowth scrub, submontane scrub, chaparral, pine and oak forests
	Genus	132	
	Species	158	
El Cielo	Family	62	1,445 deciduous lowland forest, submontane scrub, cold forest, pine forest, medium sub-deciduous forest
	Genus	117	
	Species	69	
Cumbres de Monterrey	Family	69	4,290 pine forest, chaparral, submontane scrub, rosetophile desert scrub, oak forest, oyamel forest
	Genus	170	
	Species	240	
Sierra de Huahutla	Family	69	2,959 deciduous lowland forest, oak forest
	Genus	149	
	Species	185	
Monarch Butterfly	Family	66	4,130 pine forest
	Genus	142	
	Species	213	

More species were native (95) than exotic (63). Within the native species, a total of 21 (22%) cultivated species were registered. Several of these species are economically profitable, such as *Phaseolus vulgaris*,

*Carya illinoensis*, *Persea americana*, *Zea mays* and *Solanum lycopersicon* in northeastern Mexico [35, 39, 40]. Compared to the useful flora from four different areas, Cumbres de Monterrey National Park (240 species, 170 genera, 69 families; [35]), Southern Nuevo León (163 species, 136 genera, 58 families; [39]), Rayones (252 species, 228 genera, 91 families; [40]), and Bustamante (218 species, 176 genera, 66 families; [41]) in the adjacent state, Nuevo León, Cuatrociénegas has a lower diversity of all taxa. This lower species diversity is undoubtedly related to several factors, mainly the homogeneity of the landscape, consisting of a flat valley with a relatively homogeneous climate and soil with a high salt content [42], homogeneous vegetation, at least in the basin, as well as a much smaller area. Except for ornamental trees grown in the urban area, Cuatrociénegas practically lacks wild tree flora, except for several species of *Yucca*, *Prosopis*, and *Acacia*. Of the total species recorded, 95 are native and 61 are exotic (Supplementary Material). Ten main types of uses with their variants were registered, including ornamental (105 species), medicinal (98 species), food (52 species), forage (34 species), and construction (20 species); the remaining uses are given in Fig. 2 (Supplementary Material). The parts most used by the local residents of Cuatrociénegas for different purposes are leaves, stems, fruits, inflorescences, and flowers; the remaining uses are given in Fig. 3 (Supplementary Material).

### 3.2.1 Multifunctionality of ethnobotanical diversity

The diversity of ethnobotanical taxa (native and introduced) are used efficiently, satisfying a number of harvesting categories [43]. Because the collection of native species in the reserve is controlled and, in some cases, prohibited, a high inclusion of introduced species was observed. Plants have a pattern of multifunctional use; for example, it is observed that different parts of plants (fruits, flowers and inflorescences) have different modes of use. This ethnobotanical multifunctionality, the number of reported species ( $n = 158$ ), the type of ecosystem (Chihuahuan Desert), the mestizo communities and the study area under the different protection categories all provide elements to support biocultural diversity in a broad sense, not restricted to the spatial correlation of the cultural, biological and linguistic components [44]. Rather, it is made locally by the diversity of species (in this case, ethnobotany) included in the different socio-ecological systems [19]. In addition, traditional mestizo rural landscapes house biocultural heritage and play an important role in biodiversity conservation [20]. Moreover, the persistence of these rural landscapes depends directly on their maintenance and management, and traditional uses by the local population [45]. The importance of extrapolating the concept of biocultural diversity in urban sites as an explanation of the nature–society relationship must also be taken into account [21]; in this case the relationship between traditional and semi-urban rural societies.

### 3.2.2 Ornamental

The 105 ornamental species, 64 native and 41 exotics, had the highest number of mentions of use in Cuatrociénegas. These plants play an important role in beautification of the regional landscape, mainly along streets and in public and private properties; the role of these cultivated plants in emerging countries has been reported [46]; they are commonly used as germoplasm reservoirs [47] and are found in multipurpose gardens [48], including medicinal, aesthetic and edible [49]. Most ornamental species

recorded are shrubs (39 species) and trees (37 species), while herbaceous plants account for 29 species. According to the interviewees, these elements were selected for one or several morphological, phenological or phenotypic characteristics, highlighting the leaves (33 species), stems (28 species), inflorescences (20 species), or flowers (22 species), or a combination of several of these features (Supplementary Material); however, quantitatively, the tree species were the most commonly used and most frequently planted in many public squares and along sidewalks. *Fraxinus americana* was the most frequent species in streets, gardens and public squares, followed by *Morus celtidifolia*, especially the male plant since the female trees are not as preferred because when the fruits mature, they fall and stain the sidewalks when they are stepped on. Other common cultivated species are *Casuarina cunninghamiana*, *Platanus occidentalis*, *Carya illinoensis*, *Eriobotrya japonica*, *Cupressus sempervirens*, and *Ligustrum japonicum*. In private gardens, the most frequent ornamental tree species were those that are also used as a source of food, for their edible fruits. Among these species are *Prunus persica*, *Persea americana*, *Prunus armeniaca*, *Punica granatum*, *Citrus sinensis*, *C. × limon*, *Populus alba*, and *Ficus carica*. Most of these species are also grown in southern Nuevo León, Mexico [39], and southern Mexico, including species of *Cucurbita* and *Citrus* as well as *Carica* and *Zea*. Some shrubby species are locally abundant in private gardens, notably *Nerium oleander* and *Casacabela thevetia*. Even empirically, people know about the toxicity of *Nerium oleander*, since it is known that two of its components, the cardiac glycosides olenadrine and neriine [50], could be deadly if ingested or even smoked. It is widely planted in many private gardens in Cuatrociénegas, and also in the south of Mexico. The toxic properties of *Casacabela thevetia* are also well known, being due to the cardenolides thevetin A and B [51]. There are no reported cases of poisoning caused by these species in the area. These two genera are used for the same purposes in Pakistan [52]. Accompanying these two species, the ornamental presence of several species and cultivars of *Rosa* is evident in gardens and along sidewalks.

### 3.2.3 Medicinal

Medicinal use was the second most important use of the species reported in Cuatrociénegas, with 98 species, of which 39 are herbaceous, 43 shrubs and 15 trees. There were 62 native and 36 introduced species. Similar percentages of growth forms, herbaceous and shrub medicinal species were found in Ethiopia [53]. The families with the greater number of genera and species were Lamiaceae (10 genera and 11 species), Asteraceae (9 and 9), Cactaceae (8 and 15), and Lauraceae (3 and 4). Nine categories of use following the World Health Organization (WHO; [54]) and 57 ailments or diseases treated were reported (Table 2). The main categories were digestive, integumentary, endocrine, respiratory, and circulatory (Table 3).

Species used to alleviate digestive ailments stand out from the rest of the other uses, and almost 60% of the species are used exclusively for this purpose. The boiled leaves of 24 of these plants are used to alleviate ailments in a similar way to those reported in central Mexico [55], Bolivia [56], Ethiopia and Morocco [57–58], and India [59]. Several native and exotic plants used in Mexico to alleviate digestive disorders such as *Tragia ramosa*, *Poliomintha glabrescens*, *Rosmarinus officinalis*, *Salvia officinalis*, *Peumus boldus*, and *Moringa oleifera* are used to alleviate these disorders around the world, for example

in Turkey [60], Algeria [61], Serbia [62], and Nepal [63]. Among these medicinal species several exotic species in Lamiaceae which have aromatic glands are notable, such as *Marrubium vulgare*, *Melissa officinalis*, *Mentha piperita*, *Mentha spicata*, *Ocimum basilicum*, as well as *Symphytum officinale*, *Citrus × limon*, *Citrus × sinensis*, and few autochthonous species such as *Artemisia ludoviciana*, *Poliomintha glabrescens*, *Persea americana*, and *Vachellia farnesiana*. Most of the exotic species are commonly used for medicinal purposes in southern Mexico [64], Colombia [65], Europe (Serbia [66], Spain [67], and Bosnia-Herzegovina [68]). Almost half of the species used to alleviate digestive ailments (23) are exotic. The ancestral traditions about the use of these aromatic medicinal species for the cure of certain symptoms has been perpetuated by the pilgrimage of species, whose uses are repeated in different cultures and continents, as stated by Leonti and Casu [69]. This reinforces the hypothesis of transference between cultures, and ethnobotanical globalization and its ethnopharmacological knowledge.

The majority of dermal conditions or those related to the integumentary system are cured with at least 23 different species. Most of these species are native, mainly several genera such as *Cylindropuntia*, *Echinocactus*, *Echinocereus*, *Epithelantha*, *Ferocactus* and *Opuntia*. These genera have a common use among the inhabitants of the area since the pulp of all of these plant species is used as a poultice to heal external wounds. These genera are of New World origin, but their traditional use is also found in other cultures where these species are introduced, such as in India [70]. These and other cactus genera are used for the same purposes in other countries. Some of these genera and species include *Opuntia* and *Melocactus* [71], *Opuntia* [72], *Opuntia ficus-indica* [73]. Other important native species commonly used for these purposes are *Agave lechuguilla* (ground raw root); *Flourensia cernua* (boiled leaves), *Machaeranthera pinnatifida* (boiled leaves), and *Jatropha dioica* (raw root). *Agave lechuguilla* has a long tradition of use for the control of skin diseases [39]. It is known that the stems of *Jatropha dioica* are boiled and the resulting infusion is applied in the form of a poultice or used in baths to relieve infection from blows or external or internal wounds after washing with soap [40], and in Cuatrociénegas people use this plant in the same way. Similarly, the traditional medicinal uses of exotic species are the same or similar to those applied in their place of origin. Among these species noted for their widespread and multipurpose use to cure wounds are *Matricaria chamomilla*, *Aloe vera*, and *Punica granatum* [74, 75]. The treatments essentially involve the application of poultices with the solution obtained from the boiled, crushed or fresh plant parts.

The third place in importance as ranked by the number of mentions for medicinal uses is the use of plants to alleviate ailments of the endocrine system. There were 19 species in this category, 12 native and 7 exotics. The most common uses are the stems of the five *Opuntia* species, in addition to *Arctostaphylos pungens*, *Anemopsis californica*, *Solanum rostratum*, *Capsicum annum*, *Turnera diffusa*, *Lippia graveolens*, *Larrea tridentata*, and *Urtica chamedryoides*. Branches (14 species) and leaves (11 species), both boiled, and inflorescences (6 species) are the main plant parts used. These uses and species also occur in Bolivia [76].

Respiratory diseases are mainly treated with 13 species, half of which are native. Regardless of the part of the plant used, all these treatments involve the use of the boiled plant part and are taken as an

infusion. The leaves are among the main plant parts used (*Rosmarinus*, *Eucaliptus*, *Citrus*, *Leucophyllum*, and *Poliomintha*), as well as stems (*Opuntia*) and bracts (*Bougainvillea*). It is often found that essential oils of *Citrus* are used to control cough [77], and the leaf tea and lemon juice of several genera of Rutaceae are good for eliminating cough [78]. *Eucalyptus* leaf tea is used in several countries to control respiratory ailments [79], commonly used in Cuatrociénegas.

Circulatory ailments are essentially treated with seven plants, five natives (*Ibervillea sonorae*, *Croton suaveolens*, *Portulaca oleracea*, *Leucophyllum frutescens* and *Turnera diffusa*) and two exotic species (*Olea europea* and *Salvia officinalis*). The leaves, stems, and roots are the plant parts most used for these effects. The leaves and stems of these last two exotic species are boiled and drunk as an infusion. The dried root of *Ibervillea sonorae* (brought from the state of Sonora by plant sellers), cut into pieces and then added to water for later consumption, or the leaves, stems and flowers of *Portulaca oleracea*, *Croton suaveolens*, and *Turnera diffusa* are commonly boiled and the infusion is drunk. These latter species are widely used in other areas of northeastern Mexico to purify the blood and increase physical strength [39–41]. *Croton* species have active alkaloids [80], and some species even produce red latex, which is culturally associated with certain medicinal properties [81]. The pink tones that the boiled water acquires when the branches of some species are added are considered an indicator that these plants are medicinal and they are frequently taken daily at lunchtime. This is the case for *Croton suaveolens*; when pieces of branches are added to boiling water, it acquires a pink hue, and is used as hot or iced tea as a daily drink instead of soft drinks as a way to purify the blood. Popular knowledge recognizes aphrodisiac properties of *Turnera diffusa* [40, 82]. Some interviewees mentioned that they use it daily to obtain better physical performance at work in the fields. Both virtues of this plant have been detailed in studies where at least twenty different chemical compounds have been detected [82]; however, it is still unknown which compound is responsible for the aphrodisiac activity [83], although the aphrodisiac effect has been demonstrated in rats [84].

### 3.2.4 Food

The food category was the third most important group of plant species, accounting for 54 species. The plant parts used were fleshy and dry fruits (32), leaves (10), and seeds (9). There were 24 native species and 30 exotic species. Over half (51%) of the species were herbaceous and the rest shrubs or trees. The most commonly used were three natives (*Carya*, *Juglans*, *Persea*) and seven exotic species (*Ficus*, *Punica*, *Ziziphus*, *Cydonia*, *Eriobotrya*, *Prunus*, and *Citrus*). All these species are used with a dual purpose; on the one hand as a shade of fruit while the fruits are edible, or cooked to make sweets or syrups. At least seven of these double function genera are used in the same way in Morocco [85], and six of them as edible fruits [86]. The fruits of cultivated plants grown in the gardens are mainly for self-consumption, and sometimes fruits of *Ficus* and *Prunus* are sold at local markets. The fruits of native plants that are used the most are from the genera *Opuntia* and *Echinocereus*, which are picked in season to be consumed directly after removing thorns and husks or stored for a few days under refrigeration and later sold as seasonal fruit. Their sweet-sour pulp is used to make flavored ice pops or milk pops. There is a high demand for their seasonal consumption because they are products of a single season. Edible fruits

of various genera of cacti such as *Opuntia*, *Hylocereus* and *Stenocereus* are notable in the State of Mexico for being used much more than other families of native plants [87]. Our informants reported having a greater preference for these genera due to their presence most of the year or because they can store them dehydrated. This is partly consistent with the fact that people choose products that provide security, selecting species (products) present throughout the year [88], in addition to being a response to the availability of ethnobotanical resources present in the Cuatrociénegas region.

### 3.2.5 Forage

There were 21 forage species recorded; two exotic species, *Avena sativa* and *Sorghum bicolor*, which were the most important cultivated species used to feed domestic livestock, and 19 native wild species. The fruits and stems of all members of Cactaceae, and inflorescences and fruits of Asparagaceae (*Yucca*, *Dasylyrion* and *Agave*) are the most important wild species for forage. Except for *O. ficus-indica*, all the *Opuntia* fleshy stems are seared before feeding them to cattle, and the inflorescences, flowers and edible fruits of all Asparagaceae are eaten raw. *Opuntia ficus-indica* is common in the area and grown in many gardens. This species was domesticated in Mexico [89], and grows in human-modified environments [90]. It is common to find it in abandoned farming areas close to human settlements. It is used as fodder by cutting the stems with a machete to feed the cattle.

### 3.2.6 Construction and fuel

Twelve of the most common native genera in the regional landscape, including *Prosopis*, *Juniperus*, *Vachellia*, *Quercus*, *Cupressus*, *Fouquieria*, *Pinus*, *Fraxinus* and *Larrea*, are the most common plants used for fuel and construction. They are used to build pens for cattle, attic, roofs, and columns for rural houses. Several of these genera are used similarly in southern Mexico [91] and North Africa [92]. Although the use of these woods is frequent, the areas bordering the natural protected area are not threatened, as the main source of fuel in the area is natural gas, sold in cylinders; however, from the point of view of economic botany, mesquite wood stands out as being economically important as it is sold for firewood and for the manufacture of handicrafts. It provides part of the income of a good number of inhabitants. Wooden crafts are sold mainly to domestic and foreign tourists. The prices of these items range from 30 pesos (about \$1.60 USD) to 500 pesos (about \$25.00 USD), according to the quality of the woodworking. The wood of the other species, *Vachellia*, *Quercus*, *Cupressus*, and *Pinus*, is regularly stored dry for cooking at gatherings of family and friends and it is used to roast goat, lamb or pork.

### 3.2.7 Condiments

The native and exotic cultivated species used as condiments are an important part of traditional foods in Cuatrociénegas. In total, 14 species with seasoning properties were registered, 10 of them exotic, and four natives. Two plant families, Apiaceae and Lamiaceae, contain almost 77 percent of these species. Of the exotic species, the most notable for their multiple uses are *Mentha piperita*, *M. spicata*, *Coriandrum sativum*, *Petroselinum crispum*, *Ocimum basilicum*, *Rosmarinus officinalis*, and *Cuminum cyminum*. All of them are used daily in the preparation of various traditional dishes. Several of these species as well as

many other different genera and species of this family are also used as medicinal plants to heal digestive disorders [93], or even to alleviate types of ailments such as respiratory and endocrine diseases [94]. Two of the most common native species used as condiments in the study area are *Capsicum annum* (to prepare spicy food) and *Lippia graveolens*. Both are also commonly present in many regional dishes; the latter is frequently used to prepare a heavily spiced dish (called menudo) considered to relieve hangovers. Although it is mentioned in few interviews, a boiled solution of the *Capsicum annum* fruit is used as an anti-inflammatory. Some components of Capsaicinoides and capsinoids have anti-inflammatory activity [95]. An infusion of *Lippia graveolens* is often used in Cautrocieneegas to alleviate phlegm produced by bacterial infections of the throat or sore throat, and it has been shown that this plant possesses antibacterial activity [96].

### 3.2.8 Living fences

A distinctive feature in rural homes in northern Mexico is the presence of live fences as a means of delimiting private property, especially small areas. Given the presence of a large number of shrub species with lateral or terminal spines, thorny fleshy stems or hardwood, they are useful species for keeping cattle, native fauna and humans away. These morphological characteristics are widely used for this purpose, and their attractive appearance, colorful and aromatic flowers, leaf size and shape give them an additional aesthetic appeal, which also fulfills the function of beautifying an area as well as protecting it. The most common species used for these purposes are of the genera *Agave*, *Yucca*, *Fouquieria*, *Opuntia*, *Vachellia*, and *Prosopis*. *Agave* is the most effective due to its vegetative reproduction, producing young individuals adjacent to each other that make it very difficult for intruders to cross these fences.

### 3.2.9 Fibers

The production of fiber, which was once highly lucrative, today is a craft, which still survives; however, there are few people who are engaged in this activity, due to the low prices of crafts made from natural fiber. People say that it is not worth working so hard. This activity is less and less frequent in northern Mexico, even in the poorest communities [97]. The loss of this activity is a reflection of the transculturization processes.

### 3.2.10 Informant consensus factor (Fic), fidelity level (FL) and IVU (use value index)

Four species; three autochthonous, *Lophophora williamsii*, *Arcoarapus fissuratus*, *Cylindrountia imbricata*, and one exotic, *Sansevieria thyrsiflora*, obtained the highest FIC value (0.66). These species represent the osseous-muscular category; there is a high consensus in the use of these plants for the cure of this type of disease. *Lophophora* cut into pieces and dipped in alcohol has long been used as medicine in northeastern Mexico [40] and southern USA [98]. The other two categories of use with the highest FIC were the circulatory (0.5) and integumentary (0.5) categories (Table 3). Together these two categories include 21 species (18 native). This points to the extensive empirical knowledge of the local people that results in continuous use of these species for the cure of certain related diseases; namely cacti to remedy integumentary ailments, and the species *Croton suavelones*, *Ibervillea sonora*, *Portulaca oleracea*, and

*Olaea europaea* to relieve circulatory ailments. Fourteen species with a high fidelity level were the most common species mentioned for healing a specific type of illness, mainly 11 native species, among them *Chenopodium ambrosioides* (antiparasitic, FL = 100%), *Poliomintha glabrescens* (cough, FL = 100%), *Jatropha dioica* (strengthening gums, FL = 85.7%), *Lophophora williamisii* (rheumatism, FL = 85.7%), and *Persea americana* (antiparasitic, FL = 83.3%). *Salvia officinalis* (anemia, FL = 75%) and *Mentha spicata* (stomach pain, FL = 60%) were the most mentioned exotic species (Table 4). The IVU values in this study range from 1.3 (*Matricaria chamomilla*) to 2.72 (*Larrea tridentata*). If it is considered that the IUV reflects the potential use of a particular plant to treat diseases, higher values of IVU indicate that the use of a particular species is more commonly used to alleviate particular illnesses. This the case for the most important native species, such as *Larrea tridentata*, *Flourensia cernua* (IVU = 2.33), *Capsicum annuum* (IVU = 2.3), *Opuntia ficus-indica* (IVU = 2.25), *Opuntia engelmannii* (IVU = 2.23), *Turnera diffusa* (IVU = 2.13), *Hedeoma costata* (IVU = 1.9), and two exotic species, *Rosmarinus officinale* (IVU = 1.95), and *Mentha spicata* (IVU = 1.8), which, according to the information gathered, are considered the most reliable medicinal species in the cure of certain particular diseases (Table 5). Most interviewees who use *Larrea tridentata* as a medicine agree that it is useful for the removal of kidney stones and that the use of *Flouresnia cernua* is suitable for curing stomach pain. Most of the interviewees who know the medicinal use of *Capsicum annuum* apply it to eliminate cough. More than half of the interviewees mention that *Turnera diffusa* is an excellent remedy against body weakness. At least regionally in northeastern Mexico, these species are also used to alleviate the same or related illnesses [35, 39–41].

Table 3

Category of use, number of species, number of uses recorded and FIC of medicinal plants used in Cuatrociénegas, Coahuila, Mexico. The Roman numerals correspond to the WHO International Statistical Classification of Diseases and Related Health Problems [54].

Category of use (system)	Number of species mentioned ( <i>nt</i> )	<i>nur</i>	<i>Fic</i>
Digestive (XI)	48	68	0.29
Endocrine (IV)	18	29	0.39
Respiratory (X)	13	13	0.20
Integumentary (XII)	23	47	0.5
Circulatory (IX)	6	11	0.5
Nervous (VI)	1	2	0.01
Osseous-muscular (XIII)	2	4	0.66
Ocular (VII)	1	2	0.01
Reproductive (XIV)	1	5	0.01

Table 4

Fidelity label (*FL*) values obtained for the main medicinal species mentioned by informants in Cuatrociénegas, Coahuila, Mexico. *Ip* = number of informants who indicated the use of a plant for the same particular illness; *Iu* = number of informants who mentioned the species for any illness within a category of use.

<b>Plant species</b>	<b>Ailment</b>	<b><i>Ip</i></b>	<b><i>Iu</i></b>	<b><i>FL</i></b>
<i>Matricaria chamomilla</i> L., E (25066)	Stomach pain	26	45	57.7
<i>Machaeranthera pinnatifida</i> (Hook.) Shinnars, N (25065)	Stomach pain	10	46	21.7
<i>Opuntia ficus-indica</i> (L.) Mill., N (25070)	Diabetes	7	13	53.8
<i>Turnera diffusa</i> Willd. ex Schult., N (25076)	Physical strength	6	11	54.5
<i>Litsea pringlei</i> Bartlett, N (24995)	Stomach pain	4	5	80
<i>Lophophora williamsii</i> (Lam. ex Salm-Dyck) J.M. Coult., N (25030)	Rheumatism	6	7	85.7
<i>Mentha spicata</i> L., E (25022)	Stomach pain	9	15	60
<i>Salvia officinalis</i> L., E (25020)	Anemia	3	4	75
<i>Jatropha dioica</i> Sessé, N (25059)	Strengthening gums	12	14	85.7
<i>Poliomintha glabrescens</i> A. Gray ex Hemsl., N (25053)	Cough	3	3	100
<i>Opuntia engelmannii</i> Salm-Dyck ex Engelm., N (25003)	Diabetes	18	27	66.6
<i>Persea americana</i> Mill., N (24978)	Antiparasitic	5	6	83.3
<i>Bougainvillea glabra</i> Choisy, N (25105)	Cough	26	36	72.2

Table 5

Medicinal species with the greatest number of different uses in Cuatrociénegas, Coahuila, Mexico and their respective IVU.

Species (number of uses)	IVU	Species (number of uses)	IVU
<i>Larrea tridentata</i> (Sessé & Moc. ex DC.) Coville, N (6; 24999)	2.72	<i>Flourensia cernua</i> DC., N (3; 25035))	2.33
<i>Jatropha dioica</i> Sessé, N (4; 25059)	1.88	<i>Hedeoma costata</i> Hemsl., N (3; 25104))	1.9
<i>Machaeranthera pinnatifida</i> (Hook.) Shinnars, N (4; 25065)	1.68	<i>Mentha spicata</i> L., E (3; 25022)	1.31
<i>Rosmarinus officinalis</i> L., E (4; 25021)	1.95	<i>Ruta graveolens</i> L., E (3; 24983)	1.44
<i>Artemisia ludoviciana</i> Nutt., N (3; 24097)	1.40	<i>Turnera diffusa</i> Willd. ex Schult., N (3; 25076)	2.13
<i>Opuntia engelmannii</i> Salm-Dyck ex Engelm., N (3; 25003)	2.23	<i>Aloe vera</i> L., E (3; 25041)	1.58
<i>Opuntia ficus-indica</i> (L.) Mill., N (3; 25070)	2.25	<i>Capsicum annum</i> L., N (3; 25043)	2.3

## 4. Conclusion

The particular diversity of wild flora in Cuatrociénegas Valley, combined with the varied introduced flora, is an important natural resource with multiple applications. Local people have developed an important baggage of ethnobotanical knowledge and practices based on local species and introduced species; adapting at a socio-ecological level to extreme environmental conditions. In these terms, wild and cultivated flora become an important source of food, medicine, ornamentals, wood, and other material goods to be exploited according to the needs of the inhabitants. It is interesting to note the importance and care that the local population gives to ornamental species since, in related studies in other semi-arid areas of northeastern Mexico [35, 39–41], this category of use had never been detected. This special care is especially related to its medicinal use; in addition, this can, in part, be attributed to the ecosystem, an area belonging to the Chihuahua Desert, where the vegetation is mostly shrubby and herbaceous; therefore, local people, at least those in the city, strive to maintain a lush garden that provides more shade for the grounds and houses, which allows them to mitigate part of the solar radiation and the drying of the landscape. However, despite detecting that people give high importance to introduced species due to their ornamental value, the cultural importance indexes put native species and characteristics of the Chihuahuan Desert first. The multifunctionality of ethnobotanical species in Cuatrociénegas is an example that supports that the concept of biocultural diversity not only applies in regions with high biological and cultural diversity [44]; at the local level it is a relationship between traditional knowledge and practices and the different biological groups [19] in this case with the plants. Biocultural diversity also describes the way in which people live and interact with nature, in relation to urban landscapes [21] and to traditional rural landscapes [20]; in this case, with traditional and semi-urban rural landscapes.

## Declarations

Ethics approval and consent to participate

“In each interview, the informant's consent was obtained, including the consent to take photographs and participant observation activities (International Society of Ethnobiology 2006; <http://ethnobiology.net/codeofethics/>)”

Consent for publication (Not applicable)

Availability of data and materials (Not applicable)

Competing interests

“The authors declare that they have no competing interests”

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Authors' information (Not applicable)

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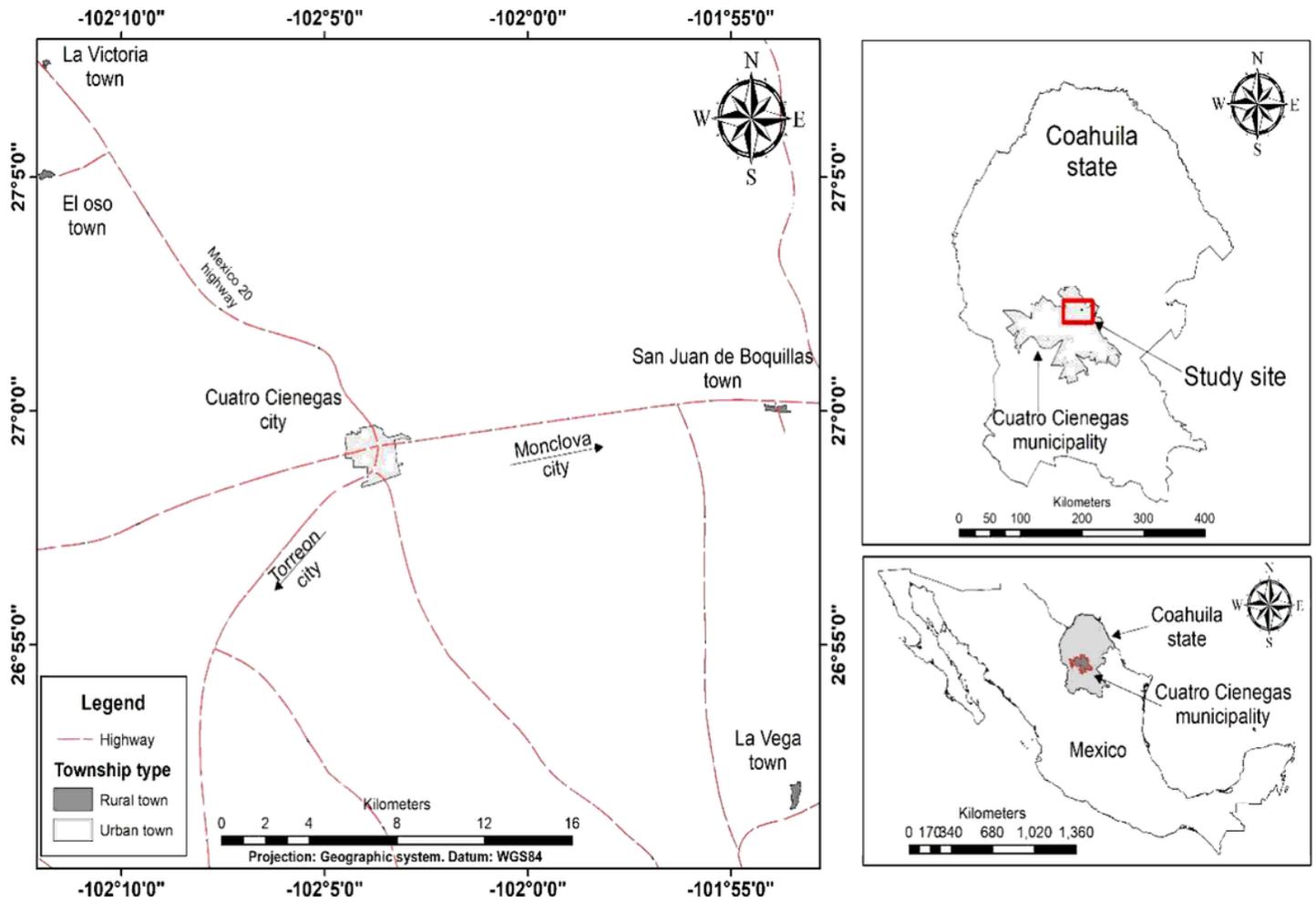
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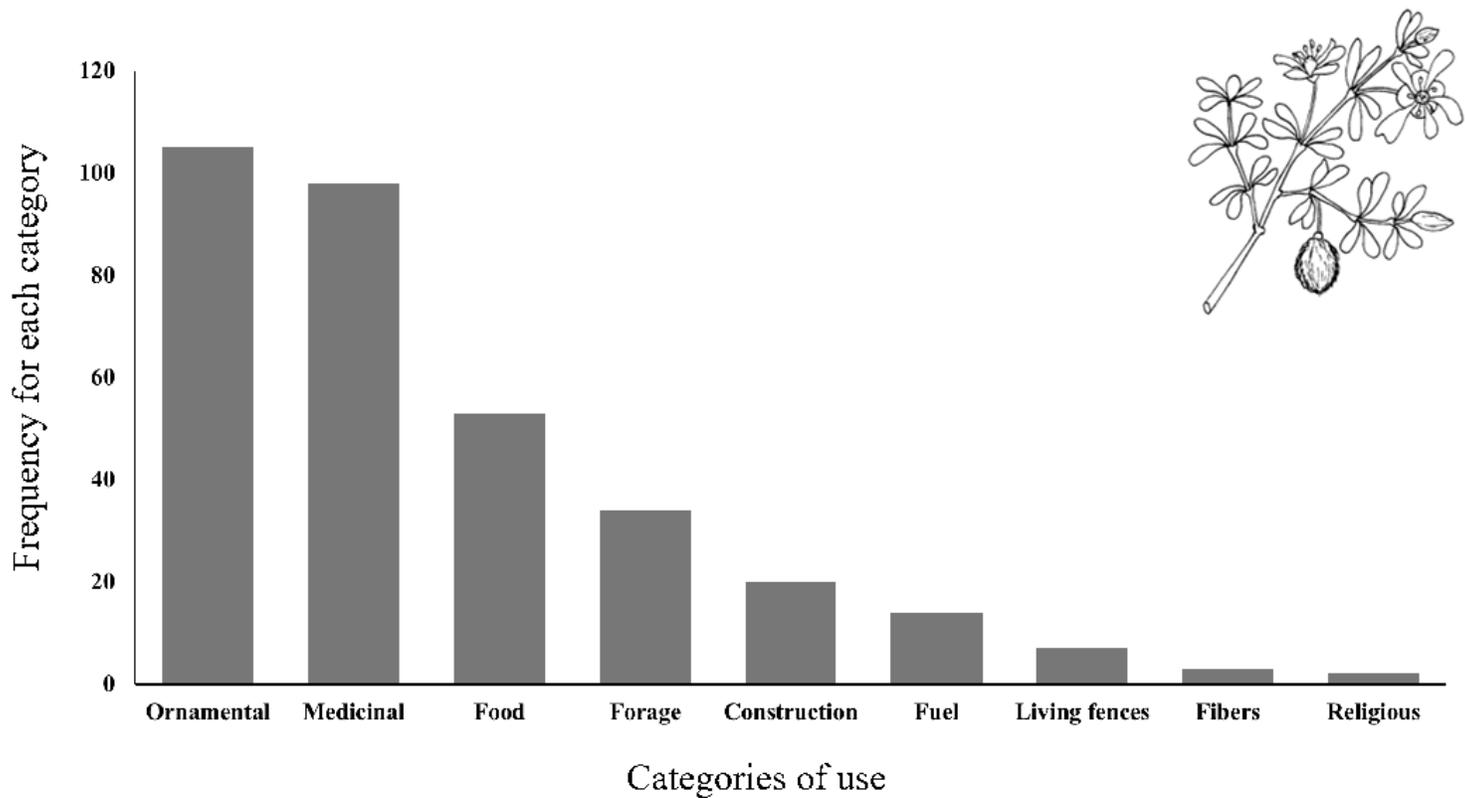
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# Figures



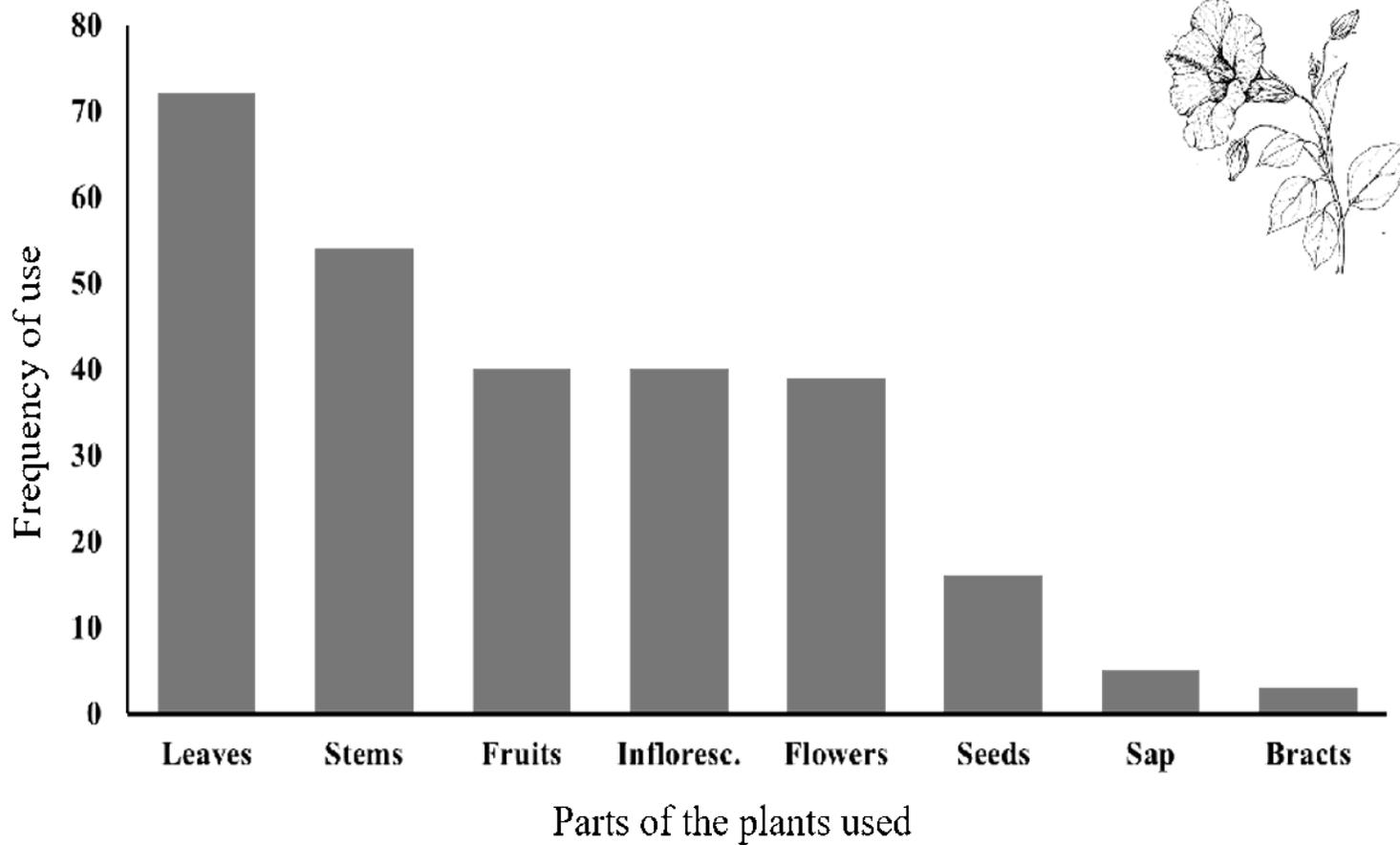
**Figure 1**

Geographic location of Cuatrociénegas, Coahuila, Mexico. Cuatrociénegas is an important region belonging to the Chihuahuan Desert. Due to its biological, geological, historical and cultural characteristics, it is considered a magical town. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



**Figure 2**

Number of plant species mentioned by the interviewees, organized by use categories.



### Figure 3

Parts of the plant most commonly used for all types of uses in Cuatrociénegas, Coahuila, Mexico.