Ethnobotanical knowledge of two Indian communities in the Monte Desert: the role of age, time outside, and residence isolation

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Ethnobotany Research and Applications 29:28 (2024) - http://dx.doi.org/10.32859/era.29.28.1-15
Manuscript received: 11/06/2024 – Revised manuscript received: 09/08/2024 - Published: 09/08/2024

Research

Abstract

Background: The contributions of ethnobotany are essential for understanding the relationship of local communities with their environment and, therefore, for planning effective conservation and management measures. In this paper, we present the results of the first quantitative approach to the ethnobotany of Indian communities of the Santa María valley, a semiarid region in Tucumán province (Argentina) with marked signs of environmental degradation where people face harsh socioeconomic conditions. This study aimed to evaluate the relevance of a set of plant species for the local communities and to analyze the effects of predictor variables on local people's knowledge about uses of plants.

Methods: We conducted semi-structured ethnobotanical surveys inquiring about the uses of 41 plant species. We analyzed the relevance of each species following consensus and versatility criteria. We searched for patterns in individual knowledge and their relationship with gender, age, time of residence outside the valley, and residence isolation, through ordinations and generalized linear models.

Results: We present a ranking of the species based on their Cultural Importance value. We found that age and residence isolation positively affect knowledge about plant uses, while time outside the valley has a negative effect.

Conclusions: Given the socioeconomic transformations the region has gone through in recent decades, these results highlight the importance of preventing cultural erosion and the loss of its traditional ethnobotanical knowledge.

Key words: plant uses, numerical ethnobotany, cultural importance, age, isolation

Background

As a result of the transformations ethnobotany underwent during the last century (Gaoue *et al.* 2021, Albuquerque *et al.* 2009), it has gained increasing relevance in contributing to conservation and sustainable management (Pei *et al.* 2020, Rodrigues *et al.* 2020). In this sense, quantitative techniques emerged as a useful tool for understanding the management of ecosystems by local people (Sánchez Azofeifa *et al.* 2005). One of the research lines of quantitative ethnobotany evaluates the relative importance of the different plant taxa for human groups, using cultural importance or use value indices (Tardío and Pardo de Santayana 2008). They are usually based on one of the following two concepts: (1) the "consensus among informants", which is the degree of agreement among interviewees (Albuquerque *et al.* 2006). The assumption behind these indices is that the more outstanding a plant or specific use is in the community, the more likely it is to be mentioned (Tardío and Pardo de Santayana 2008); (2) the "versatility" or diversity of uses. Some researchers have developed indices that incorporate both concepts (Tardío and Pardo de Santayana 2008). Both the plant's versatility and its popularity can be suitable as indirect measures of the collecting pressure it is exposed to (Albuquerque *et al.* 2009, Ahoyo *et al.* 2018).

Data quantification is a necessary but not sufficient element for the development of ethnobotany as a scientific discipline (Albuquerque 2009). It is also crucial to advance in the integration of this data within theoretical and conceptual frameworks that guide the formulation of questions and hypotheses (Albuquerque 2009, Gaoue *et al.* 2017). In this work, we addressed three sociological variables that are among the most frequently studied: gender, age, and time of residence in the community and outside of it. The isolation level of the residence was also considered.

The recognition of the gender factor in ethnobotanical studies revealed that, in many cases, there are both quantitative and qualitative differences in the knowledge of men and women from the same community (da Costa *et al.* 2021, Müller *et al.* 2014, Voeks and Leony 2004). In general terms, this happens because the distribution of tasks and responsibilities among community members according to their gender determines unequal access to natural resources and contact with the habitat and affects the transmission and distribution of knowledge (Dan Guimbo *et al.* 2011). Regarding age, several studies indicate that older people have more ethnobiological knowledge than younger ones (Koster *et al.* 2016, Corroto *et al.* 2022, Phillips and Gentry 1993, Voeks and Leony 2004). These results can be interpreted within the framework of the assumption that ethnobotanical knowledge always grows with age (and with residence time, Müller *et al.* 2014). Alternatively, some authors point to them as evidence of knowledge erosion attributed to modernization (Koster *et al.* 2016). Finally, some studies have analyzed the positive relationship between ethnobotanical knowledge and isolation from the community. This relationship would be explained because infrastructure, transportation, and proximity facilitate access to replacements of elements obtained from plants (Corroto *et al.* 2022), for example, to health centers and allopathic medicine in the case of medicinal plants (Weckmüller *et al.* 2019, Vandebroek *et al.* 2004, Merétika *et al.* 2010).

The contribution of ethnobotany to understanding how knowledge is distributed and how the processes of its acquisition and transmission vary is essential for the field of conservation since it provides the necessary foundation for conservation and management strategies grounded in local knowledge (Zent and López Zent 2004). In this context, the present work proposes a quantitative ethnobotanical study in the Monte Desert, a region of Argentina inhabited by numerous human groups and facing various environmental degradation issues (Pol *et al.* 2006). Although there are precedents of ethnobotanical studies in the area, these have been primarily descriptive and focused specifically on the medicinal applications of plants (Simoni and Perea 2016, Ceballos and Perea 2014).

Recognizing that any action aimed at conservation, management, or restoration of natural environments, to be successful, must necessarily incorporate the physical dimension, including biology and ecology, and the human dimension, including social, economic, cultural, and political aspects (Hamilton and Hamilton 2006), we established the following objectives: (1) to evaluate the relevance of a set of plant species for the local people of the Santa María valley (Tucumán province, Argentina), based on consensus and versatility criteria; and (2) to analyze the knowledge about local uses of plants, examining whether factors such as gender, age, time of residence outside the valley, and residence isolation explain the variation in the amount of knowledge. Regarding this last objective, we expect qualitative differences in individual knowledge about the uses of plants linked to gender and age. In addition, we anticipate a positive relationship between the amount of knowledge, age, and isolation, and a negative relationship with the time of residence outside the valley. By examining the interplay of these factors in shaping ethnobotanical knowledge within the Santa María valley, we hope to offer insights that extend beyond this specific community and to enrich ethnobotanical theory, advancing our understanding of how these factors influence knowledge dynamics across diverse cultural landscapes.

Materials and Methods

Study area

The Monte Desert is an arid to semi-arid region spanning 460,000 km2 and ranging from 24°35' S in Salta province to 44°20' S in Chubut province, and from 69°50' W at the foot of the Andes to 62°54' W on the Atlantic coast (Burkart *et al.* 1999).

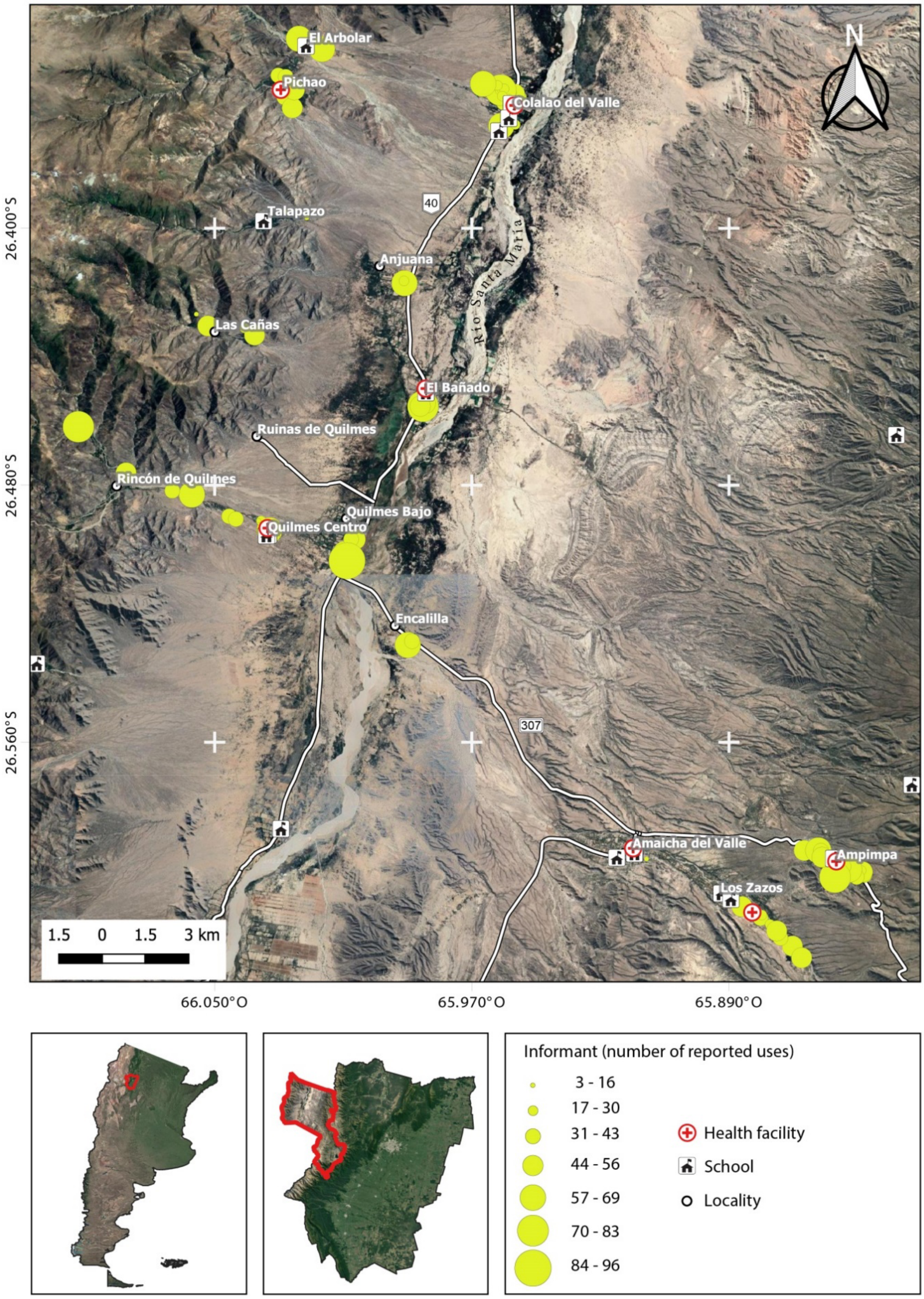

Figure 1. Location map of the study area, in the Tucumán portion of the Santa María valley. The yellow dots mark the informants' residence location. The dot size represents the number of uses reported by the informant during the survey.

It can be classified into two ecoregions based on geomorphological characteristics: The *Monte de Llanuras y Mesetas*, spanning from the south of San Juan to Chubut, and the *Monte de Sierras y Bolsones*, covering the northern region to the south of the province of San Juan (Burkart *et al.* 1999). The northernmost part of the latter includes the Santa María valley, a longitudinal valley approximately 120 km long and 30 km wide, stretching from *Quebrada de las Conchas* in Salta to *Campo del Arenal* in Catamarca. It is bordered to the west by the *Sierra de Quilmes* range (4,700 m a.s.l.) and to the east by the *Cumbres Calchaquíes* range (4,700 m a.s.l.) and the *Sierra de Aconquija* range (4,600 m a.s.l.). Flowing from south to north, the Santa María River collects water from both slopes (Peña Monné and Sampietro Vattuone 2016).

The valley floor ranges from 1,600 to 1,800 m a.s.l., reaching up to 3,000 m a.s.l. at the upper foothills (Peña Monné and Sampietro Vattuone 2016). Characterized by an average annual temperature of 15-16°C, the region experiences rainfall solely in the summer, typically not exceeding 200 mm per year (Peña Monné and Sampietro Vattuone 2016). Vegetation in the region occurs in two main formations: xerophytes and cacti shrub steppes, and carob forests that thrive in areas with permanently available underground water (Morello 1951). Studies by Morello (1951) and Dip *et al.* (2020) have documented variations in vegetation composition across geomorphological units, altitudes, and topographic positions.

The study area is located in the Tucuman portion of the Santa María valley, where the two communities under study are settled: the Comunidad India Quilmes (CIQ) occupies a territory of about 65,000 hectares on the eastern slope of the Sierra de Quilmes, to the west of the Santa María River, and the Comunidad Indígena Amaicha del Valle (CIAV) settles in a territory of 147,000 hectares on the western foothills of the Cumbres Calchaquíes, to the east of the river (Fig. 1). The CIQ is made up of approximately 2,500 people who comprise some 600 families, organized into 14 base communities (Tolosa 2014). The CIAV is made up of 850 families and 5,200 people, of which approximately a third reside in other parts of the country (Arenas and Ataliva 2017). Both communities have a long history of occupation in the area that begins in pre-Hispanic times.

Outside of the irrigated oases that have allowed for the development of the fruit and wine industries since the last century, the main activity for survival is cattle raising, which the local inhabitants adopted in the 17th century with the arrival of the Spanish, bringing horses, sheep, goats, mules, and cows (Ladio and Lozada 2009). These pastoral societies face harsh socioeconomic and physical conditions (Ladio and Lozada 2009). Additionally, the inhabitants of the Monte have historically utilized plant resources for a wide variety of purposes, and many traditional uses persist in the botanical knowledge of the local inhabitants.

Ethnobotanical survey

To gather data on the local uses of plants, we conducted semi-structured ethnobotanical surveys. We selected a set of 41 plant species, including those frequently cited in previous ethnobotanical studies in the region (e.g., Ceballos and Perea 2014, Simoni and Perea 2016, Crivos *et al.* 2009) and informal conversations with local informants. In addition, we included lesser-known species to capture variation in knowledge. Some of them were cited once in previous references but were not mentioned in informal conversations with local inhabitants, while others were not cited in previous ethnobotanical studies. Samples of these plants were collected, photographed, and preserved for the creation of a field herbarium, which served as a reference during the surveys. These samples were identified in the Fundación Miguel Lillo Phanerogamic Herbarium and deposited in the Laboratorio de Geoarqueología. The field herbarium approach offers the advantage of allowing the participation of people who, for various reasons, may be unable to get involved in field trips. Furthermore, it requires less time per informant, enabling the systematic application of the surveys (de Medeiros *et al.* 2014). The nomenclature in this work followed the criterion established in the Argentinian Flora (Anton and Zuloaga, 2019).

We carried out the surveys between January and March of 2020 in the CIAV and different base communities of the CIQ*: Quilmes Bajo, Quilmes del Centro, Rincón de Quilmes, El Bañado, Las Cañas, Anjuana, Talapazo, Colalao del Valle, Pichao,* and *El Arbolar*. The household sampling technique was systematic: we walked the paths of the village – in several of them, there is a single ascending path along which all the houses are located – and knock on the door. If no one answered or the person didn't agree to participate, we tried the house next door. If the person agreed to participate, we tried the next house 500 meters away. We surveyed one person per household, generally, the person who was willing to answer, which in most cases was the same person who answered the door. The survey involved presenting the informant with the plant species from the field herbarium and inquiring whether they recognized them, as well as whether they knew of any use for each plant (clarifying that all uses, not just medicinal ones, were of interest). Additionally, we recorded age, gender, place of origin, duration of residency outside the valley area, and the altitude of the residence.

Data processing

The uses reported by the informants were classified into three main categories: medicinal, food, and other uses, along with their respective subcategories. Additionally, a second classification of the uses was conducted based on their destructive potential. As the impact on species varies depending on whether the reported uses are destructive (typically involving cutting the trunk or branches of woody plants or uprooting herbaceous plants) or non-destructive, nearly all medicinal uses were categorized as non-destructive, with the exception of *Alternanthera pungens* (**yerba de pollo**), which was reclassified as potentially destructive due to the mention of medicinal use involving its roots.

Analysis

Relevant species detection. The distribution of use reports among the various species and types of use was depicted using chord diagrams. These plots simultaneously represent how the reports for each species are distributed among the different types of use and how the reports for each type of use are distributed among the various species.

We calculated the Cultural Importance Index (CI), as defined by Tardío and Pardo de Santayana (2008), for each species using the formula:

$$CI_s = \sum_{u=u_1}^{u_{NC}} \sum_{i=i_1}^{i_N} UR_{ui}/_N$$

where NC represents the total number of use categories, UR represents a use report (when an informant *i* mentions the use of species *s* in use category *u*), and N represents the total number of informants in the study. Therefore, the index represents the sum of all reports of use for the species divided by the total number of informants, or equivalently, the sum of the proportion of informants that mention each reported use for the species. The theoretical maximum of the CI index is NC (Tardío and Pardo de Santayana 2008).

We calculated the index both for the total number of uses and for each category related to the destructive potential (conservative, non-destructive, and potentially destructive), and used radial bar diagrams for the graphic representation of the results.

Local knowledge of uses. To assess the existence of qualitative differences in knowledge related to gender and age, we performed separate ordination analyses – non-metric multidimensional scaling (nMDS) with Bray-Curtis distance – for food, medicinal, and other uses. We created two-dimensional plots of the nMDS, in which individuals are distinguished by gender – female (F) and male (M) – and by age group: Group 1 includes individuals between 18 and 29 years old; group 2 comprises ages between 30 and 59; and group 3 includes individuals over 60 years old.

To explore the relationship between individual knowledge of uses and the predictor variables gender, age, time lived outside the valley, and altitude, we performed Generalized Linear Models (GLM) following Zuur *et al.* (2009). We also considered the interaction between age and gender, based on trends observed in exploratory analyses. Initially, we fitted a GLM with Poisson distribution and logarithmic link function. Upon confirming overdispersion of the response variable, we switched to a GLM with Negative Binomial distribution. The significance of each variable and its inclusion in the model were assessed using the add1() function, beginning with a null model. This function compares the deviance of a model with the variable to the deviance of a model without it, evaluating the significance of the difference in deviances via a chi-square test.

To assess the model assumptions, we assumed independence between observational units since one survey per household was carried out. We checked for multicollinearity of predictor variables using the variance inflation factor (VIF) and evaluated overdispersion using the testDispersion() function. Additionally, we examined the distribution of residuals vs. predicted values in a scatter plot. Upon identifying outliers, we found that three individuals had above-average knowledge due to unique personal experiences, and thus, they were removed before finalizing the model. All statistical analyzes were performed in *R statistics* software (R Core Team 2021).

Results

A total of 109 people belonging to the CIQ or the CIAV were surveyed, 71 of whom were women and 38 were men. Regarding age, 25 people were in the age group of 18 to 29 years, 54 were in the group of 30 to 59 years, and 30 were in the group of 60 to 90 years. In the case of the CIQ informants, 30 people were from *Colalao*, 19 from *Quilmes*, nine from *El Pichao,* seven from *El Bañado*, four from *Las Cañas*, three from *Anjuana*, three from *El Arbolar*, and two from *Talapazo*. Regarding the CIAV informants, 16 were from *Ampimpa*, 12 were from *Los Zazos*, two were from *Amaicha*, and two were from *Encalilla* (Fig. 1).

We obtained a total of 3,832 use reports, 1,803 of them being medicinal, 1,172 food, and 857 others (Fig. 2), along with their respective subcategories (Tab. 1 in Supplementary material). When reclassified according to their destructive potential, 2,672 of the use reports were nondestructive, 1,107 were potentially destructive, and 53 were conservative (Fig. 2).

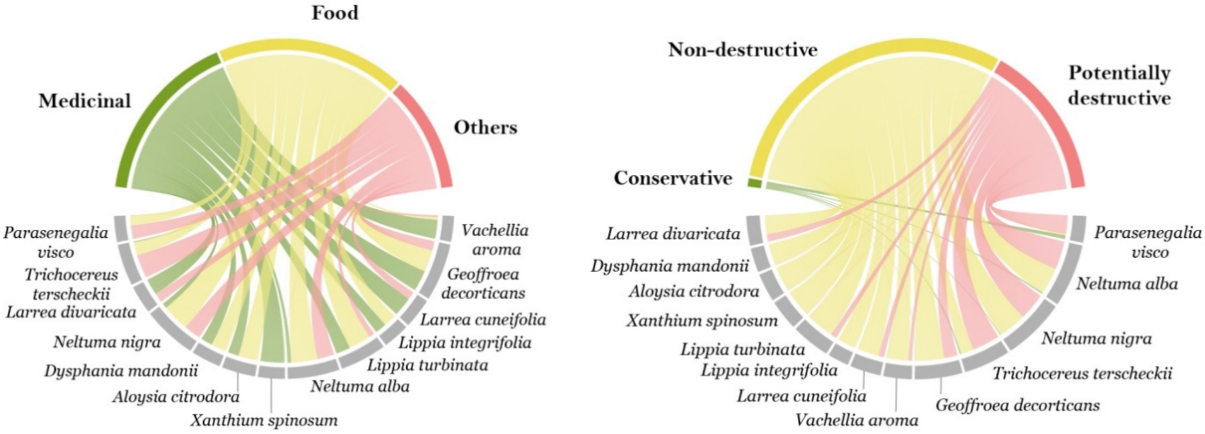

Figure 2. Chord diagrams representing what proportion of the reported uses for each plant are (a) medicinal, food, and others; (b) conservative, non-destructive and potentially destructive. For a better visualization, only the 13 most important species are represented considering their CI value.

Relevant species detection

The species with the greatest cultural importance, considering the CI index computed for all the cited uses, were *Neltuma nigra* (CI=3), *Neltuma alba* (2.881), *Geoffroea decorticans* (2.092), *Larrea cuneifolia* (1.853), *Trichocereus terscheckii* (1.734), *Larrea divaricata* (1.67) and *Lippia turbinata* (1.55). These same species also obtained the highest CI values when considering only the destructive uses, mainly *Neltuma alba* (1,514), *Neltuma nigra* (1,477) and *Trichocereus terscheckii* (1,22). Among them, *Neltuma alba*, *Trichocereus terscheckii*, *Neltuma nigra* and *Geoffroea decorticans*, were cited for conservative uses (Fig. 3; Tab. 1). Some species were cited for various destructive and potentially destructive uses but not for conservative ones, including *Larrea cuneifolia*, *Larrea divaricata*, *Lippia turbinata*, *Salimenaea integrifolia*, *Atamisquea emarginata*, *Ephedra triandra*, *Aloysia citrodora*, *Atriplex lampa*, *Parkinsonia praecox*, and *Suaeda divaricata* (Fig. 3; Tab. 1).

Table 1. Cultural importance index calculated on conservative, non-destructive and potentially destructive uses, and on the total number of uses cited for each species.

Species	Cultural importance index by use type			
	Conservative	Non-destructive	Pot. destructive	Total
Neltuma nigra (Griseb.) C.E. Hughes and G.P. Lewis (Fabaceae)	0	1.505	1.477	3
Neltuma alba (Griseb.) C.E. Hughes and G.P. Lewis (Fabaceae)	0.009	1.33	1.514	2.881
Geoffroea decorticans (Gillies ex Hook. and Arn.) Burkart (Fabaceae)	0.009	1.541	0.541	2.092
Larrea cuneifolia Cav. (Zygophyllaceae)	0	1.587	0.376	1.853
Trichocereus terscheckii (Parm. ex Pfeiff.) Britton and Rose (Cactaceae)	0.037	0.477	1.22	1.734
Larrea divaricata Cav. (Zygophyllaceae)	0	1.376	0.294	1.67
Lippia turbinata Griseb. (Verbenaceae)	0	1.358	0.193	1.55
Aloysia citrodora Palau (Verbenaceae)	0	1.193	0.009	1.202
Vachellia aroma (Gillies ex Hook. and Arn.) Seigler and Ebinger (Fabaceae)	0.009	0.927	0.128	1.064
Parasenegalia visco (Lorentz ex Griseb.) Seigler and Ebinger (Fabaceae)	0.009	0.046	0.872	1.037
Xanthium spinosum L. (Asteraceae)	0	0.982	0.009	0.991

Dysphania mandonii (S. Watson) Mosyakin and Clemants (Chenopodiaceae)	0	0.817	0.009	0.972
Salimenaea integrifolia (Griseb.) N. O'Leary and P. Moroni (Verbenaceae)	0	0.972	0	0.972
Dysphania ambrosioides (L.) Mosyakin and Clemants (Chenopodiaceae)	0	0.963	0.009	0.826
Schinus areira L. (Anacardiaceae)	0.119	0.404	0.294	0.817
Ligaria cuneifolia (Ruiz and Pav.) Tiegh. (Loranthaceae)	0	0.422	0.376	0.798
Plantago sp.	0.018	0.716	0.009	0.725
Schinus sp.	0	0.477	0.248	0.725
Senna aphylla (Cav.) H.S. Irwin and Barneby (Fabaceae)	0.028	0.431	0.229	0.688
Maytenus viscifolia Griseb. (Celastraceae)	0.009	0.404	0.257	0.67
Nicotiana glauca Graham (Solanaceae)	0.046	0.606	0.046	0.661
Atamisquea emarginata Miers ex Hook. and Arn. (Capparaceae)	0	0.532	0.083	0.615
Parkinsonia praecox (Ruiz and Pav. ex Hook.) Hawkins (Fabaceae)	0	0.257	0.349	0.606
Marrubium vulgare L. (Lamiaceae)	0	0.578	0	0.578
Celtis pallida Torr. (Cannabaceae)	0.018	0.211	0.33	0.56
Cestrum lorentzianum Griseb. (Solanaceae)	0	0.514	0.046	0.56
Opuntia sulphurea Gillies ex Salm-Dyck (Cactaceae)	0	0.22	0.284	0.55
Sphaeralcea bonariensis (Cav.) Griseb. (Malvaceae)	0	0.505	0.028	0.532
Ephedra triandra Tul. emend. J.H. Hunz. (Ephedraceae)	0	0.468	0.046	0.514
Clematis campestris A. St.-Hil. (Ranunculaceae)	0	0.349	0.128	0.477
Atriplex lampa (Moq.) D. Dietr. (Chenopodiaceae)	0	0.165	0.266	0.431
Suaeda divaricata Moq. (Chenopodiaceae)	0	0.22	0.193	0.413
Salpichroa origanifolia (Lam.) Baill. (Solanaceae)	0	0.376	0.018	0.394
Cyclolepis genistoides Gillies ex D. Don (Asteraceae)	0	0.367	0.018	0.385
Passiflora caerulea L. (Passifloraceae)	0.037	0.284	0.037	0.33
Alternanthera pungens Kunth (Amaranthaceae)	0	0.257	0.064	0.321
Araujia odorata (Hook. and Arn.) Fontella and Goyder (Apocynaceae)	0	0.294	0.018	0.312
Solanum palitans C.V. Morton (Solanaceae)	0	0.193	0.018	0.211
Oenothera affinis Cambess. (Onagraceae)	0.119	0.119	0.073	0.193
Justicia tweediana (Nees) Griseb. (Acanthaceae)	0.009	0.037	0.092	0.138
Justicia xylosteoides Griseb. (Acanthaceae)	0.009	0.037	0.064	0.11

The **algarrobo negro** (*Neltuma nigra*) was cited in 203 instances for food, 101 instances for other uses, and 23 instances for medicinal purposes. The most frequently mentioned uses included various forms of food (94 reports), fodder (62), drinks - primarily *aloja*, but also beer - (47), firewood (45), and wood for construction, fences, furniture, crafts, and tools (54). Medicinal uses included the use of *algarroba* syrup, to treat respiratory (14) and intestinal ailments (3), to enhance bone strength in children (1), improve memory (1), alleviate *puna* (1), and treat *tembladera* in horses (1). Additionally, two individuals mentioned its use for shade.

For the **algarrobo blanco** (*Neltuma alba*) we documented 196 food, 104 other uses, and 14 medicinal use records. The reported uses were similar to those of *Neltuma nigra*, as many informants considered both species equivalent in this regard. Reported uses encompassed food (75), fodder (65), drinks (56), firewood (45), and wood for various purposes (55). Medicinal uses mirrored those of *Neltuma nigra*, with an additional mention of its use for shade (4).

The **chañar** (*Geoffroea decorticans*) got 99 reports of food use, 85 of medicinal use, and 44 of other uses. Its most reported application was the production of **chañar** syrup from its fruit (79), utilized both as food and throat medicine. It was also documented as fodder (22), firewood (17), wood for various purposes (24) – including handles for pickaxes and shovels, fences, furniture and construction – dyeing (2), and shade (1). Among other medicinal uses, it was cited for its role in a ritual to heal the baby's navel (2) and for baths (1).

The **jarillas** *Larrea cuneifolia* and *Larrea divaricata* were reported 159 and 136 times respectively for medicinal purposes, and 44 and 45 times for other purposes. In general, people cited the same uses for both species. Medicinal uses include those related to diseases of the respiratory system (41 and 28), foot affections, mainly fungus, perspiration, and bad smell (41 and 34), uses for the circulatory system, including baths to give heat (22 and 23) and blood circulation (3 and 2). Also, they were cited for head washing (11 and 9) and dandruff (3 and 2), joint and bone pain (11 and 8), intestinal problems (2), skin conditions (4), muscular pain (2), and various uses that were reported only once.

The **cardón** (*Trichocereus terscheckii*) was recorded for 125 other uses, 60 food uses, and 4 medicinal uses. The various references to its wood (106) include uses for construction and crafts. It is also used to purify water (9), as firewood (31), as an ornamental plant (3), to dry peaches by nailing them to the **cardón** thorns (1), and the thorns as toothpicks (1). One person mentioned its ecological function of soil containment. Forty-three people mentioned the use of its fruit as food, 14 as fodder, and 2 as a drink. The medicinal uses cited include those linked to respiratory (1) and intestinal (1) conditions, taking the heat out of the body (1), and headaches (1).

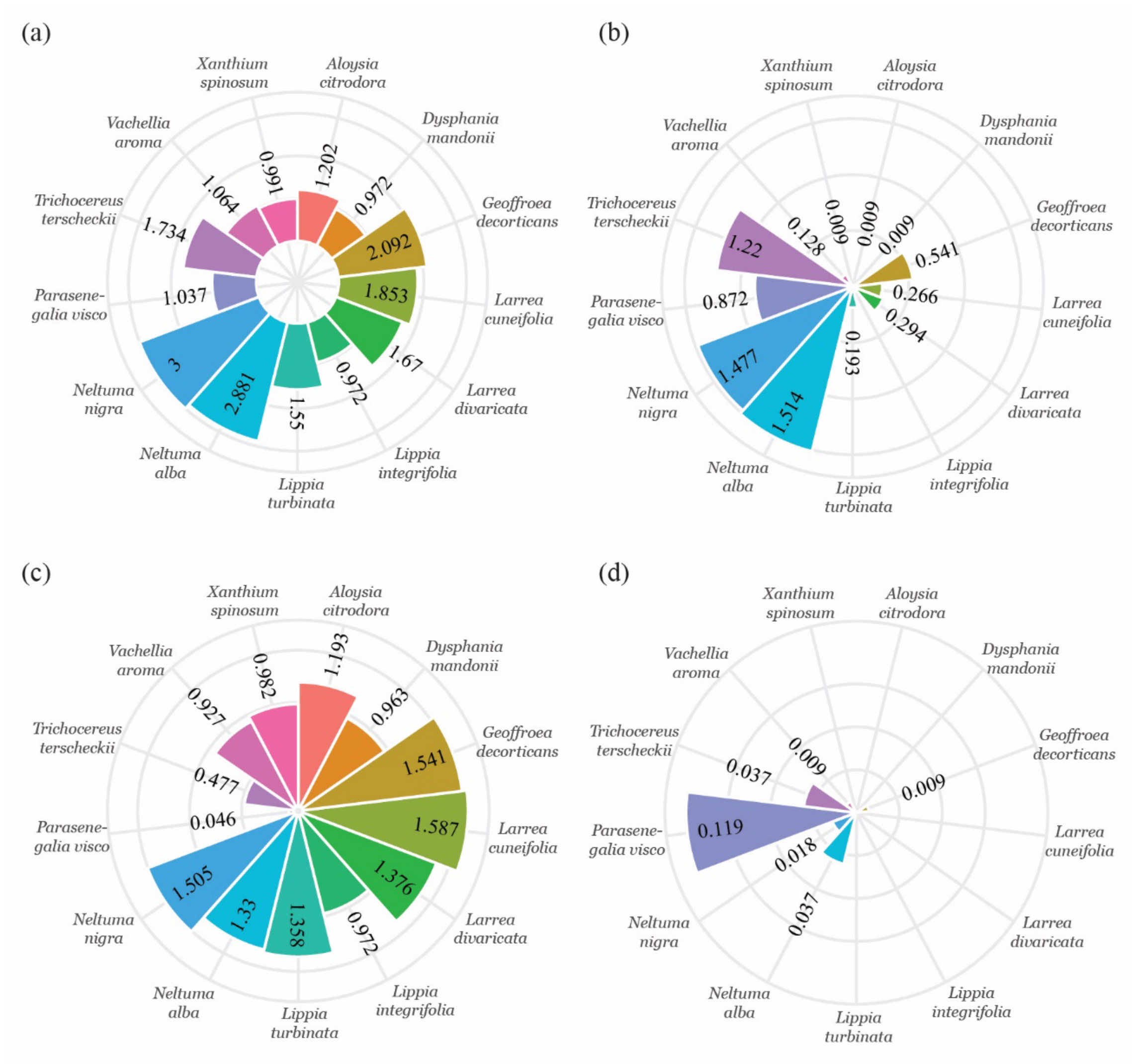

Fig. 3. Circular bar plots comparing the value of Cultural Importance index (CI) obtained by each of the 13 best-scored species, considering (a) all uses; (b) potentially destructive uses; (c) non-destructive uses; and (d) conservative uses.

The **poleo** (*Lippia turbinata*) obtained 88 records of use for food (87 for tea and mate, and 1 as fodder), 60 for medicinal purposes, and 21 for other uses. Medicinal uses included digestive issues (53), treating colds (3), heart conditions (2), and menstrual pain (1). Additionally, it was mentioned as an input for basket making (20) and as a dye (1).

Variations in individual knowledge

The ordination analysis did not allow the visualization of qualitative differences (that is, regarding the uses mentioned by the informants) in individual knowledge linked to gender or age, as evidenced by the fact that the informants all appeared as a unique cloud of points in the two-dimensional space formed by the two axes of the nMDS (Fig. 4). The variation seems even smaller in the case of food uses, except for some informants, particularly from groups 1F and 2M, who are further away from the cloud. The knowledge about medicinal uses reported by the informants of the 3F and 3M groups, as well as the other uses mentioned by the 3M group, were more similar to one another, which is observed in the small distances among the points representing them. The answers of younger informants, for their part, differed more from each other.

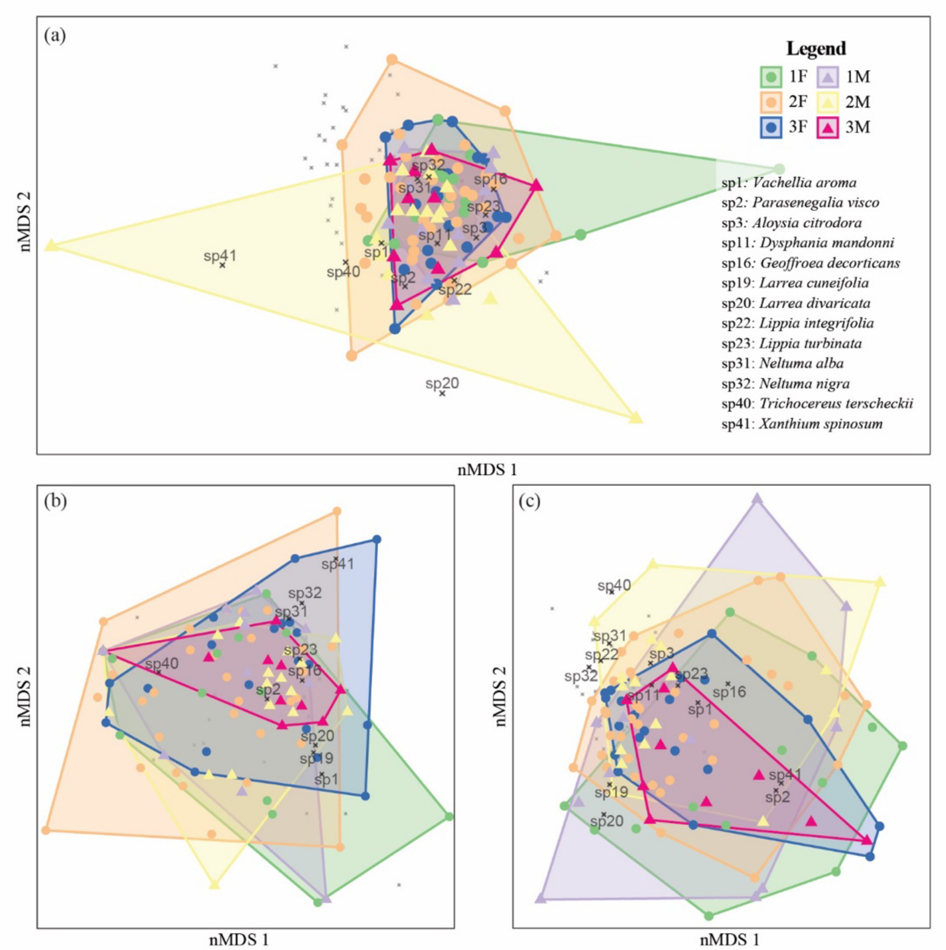

Figure 4. Ordination plots (nMDS) showing how informants distribute along the two-dimensional space according to the uses they cited for each plant, considering (a) Food uses (stress: 0.192); (b) other uses (stress: 0.185); (c) Medicinal uses (stress: 0.21).

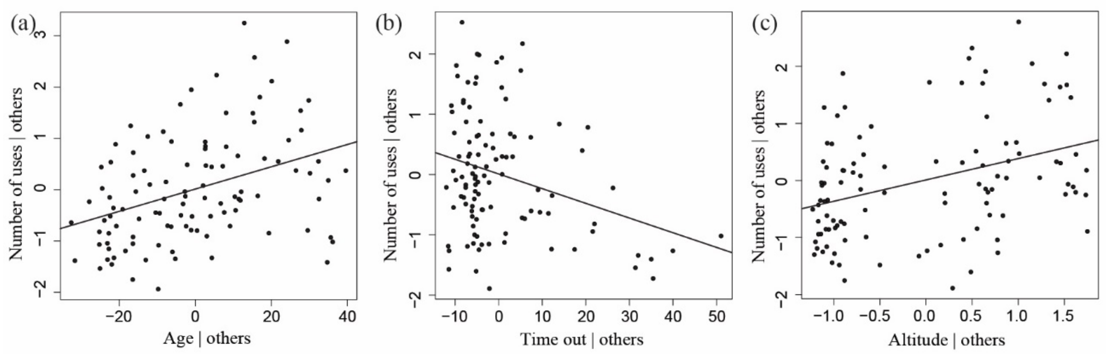

Figure 5. Partial regression plots (also called added variables plots) illustrating the partial relationship between the response variable “number of uses” and each focal predictor – (a) age, (b) time out of the valley, and (c) altitude – adjusted for all other predictors in the model.

Table 2. Estimated regression parameters at the model scale (m) and at the response variable (rv), standard errors, z values, and p values of the negative binomial GLM describing the relationship between individual knowledge and the response variables time out of the valley, age, and altitude.

Coefficients	Estimate (m)	Estimate (rv)	Standard error	Z value	P value
Intercept	3.067	21.490	0.126	24.303	$2e^{-16}$
Time out	-0.155	-0.984	0.003	-3.978	$7e^{-06}$
Age	0.011	1.011	0.002	4.488	$6e^{-05}$
Altitude	0.178	1.194	0.046	3.813	$1e^{-04}$

The model that included the variables age, time outside the valley, and altitude turned out to be the best model (Fig. 5 and Tab. 2). Both gender and the interaction between age and gender were ruled out. All three covariates added to the model had a significant effect on knowledge, measured as the number of use records. The model selection process showed that the best model is the one that includes the three covariates since the deviance is significantly reduced by adding each of them. However, the magnitude of the change in deviance is very small. The pseudo-R2, a measure of data fit to the model, was 37.6. Thereby, there was a high percentage of variation that the model did not explain. The estimated coefficients on the scale of the model and the response variable are presented in Tab. 2.

Discussion

The surveys yielded a total of 1,803 reports of medicinal uses, 1,172 of food uses, and 857 of other uses. The reports of medicinal uses, which vastly outnumbered those of other types, also presented greater dispersion in terms of variety. The variety of food uses was small, several of them being well known and therefore adding a large number of reports (such is the case of the drinks and food produced with *algarrobas*, and the fodder use of various species). The variety of medicinal uses cited could respond to a certain tendency of the interviewees to assume that what was sought with the survey was precisely to record knowledge about these uses (Guber 2019) since many of the previous ethnobotanical studies carried out in the Valles Calchaquíes focused on them (e.g. Ceballos and Perea 2014, Simoni and Perea 2016, Crivos *et al.* 2009).

The species with the highest values in the Cultural Importance Index are those cited for their uses in various other works: *Neltuma nigra* and *Neltuma alba* for their uses as wood, firewood, fodder, food and beverages produced with their fruit, and as cough medicine (e.g. Vilela *et al.* 2009, Ceballos and Perea 2014); *Geoffroea decorticans* for the consumption of its fruit, the medicinal properties of the syrup produced from it, and also for its use as fodder, wood and firewood and for its dyeing properties (Vilela *et al.* 2009, Ladio and Lozada 2009); *Larrea cuneifolia* and *Larrea divaricata* for their medicinal properties and their use in dyeing construction and firewood (Ladio and Lozada 2009, Carabajal et. al 2020); *Trichocereus terscheckii* for its wood and fruits (Kiesling 1978); *Lippia turbinata* and *Salimenaea integrifolia* for their medicinal and aromatic properties and their use as fodder, and *L. turbinata* also for the manufacture of baskets (Catalán *et al.* 2021, Ceballos and Perea 2014, Ledesma *et al.* 2017).

We found no previous records in the literature of some uses reported in this work. Such is the case with the use of *Neltuma nigra* and *Neltuma alba* for intestinal ailments, strengthening bones in children, memory enhancement, and treating *tembladera* in horses; the ritual use of *Geoffroea decorticans* to heal the baby's navel; the use of *Larrea divaricata* for intestinal problems and muscular pain; the use of *Trichocereus terscheckii* as firewood, to dry peaches, for soil containment, for purifying water and also its medicinal applications; and the use of *Lippia turbinata* for menstrual and heart problems. Most of these uses were cited by a few people, so they did not have a major impact on the calculation of the CI index. However, it would be advisable to verify them with qualified informants.

The best model to explain the variation in individual ethnobotanical knowledge was the one that included all the candidate variables, except gender. Although the magnitudes of their effects were small, they all significantly reduce the deviance when added to the model. Time outside the valley negatively affects knowledge. These results agree with previous studies that link residence time with ethnobotanical and/or ethnoecological knowledge (e.g. Wayland and Walker 2014, Guest 2002, Corroto *et al.* 2022). However, Guest (2002) points out that variables such as "residence time" act mainly as proxies, and not as explanatory variables by themselves since, although some aspects of knowledge can be transmitted during general social interaction, what truly increases the rate of knowledge acquisition are activities that increase exposure to the natural world. This is surely one of the reasons why models that incorporate some measure of residence time explain a relatively low percentage of the variation in individual knowledge, such as the one by Wayland and Walker (2014), and also the one we present here. Wayland and Walker (2014) point out that the variable that had a positive effect on the knowledge reported by women in the urban Amazon was the time spent in the *seringal* (rural), while the time spent in colonies (rural) or the city (urban) had no effect. In this sense, the variable considered in the present study is residence time outside the *Valles Calchaquíes* area and may include residence in a variety of rural or urban environments without distinction. This could explain part of the variability in the responses of individuals with similar emigration times out of the valleys. We also observed that, while many years of emigration were always related to low levels of knowledge about plant uses, a few or no years of emigration do not necessarily imply high knowledge, as other possible variables come into play, such as occupation, personal interest in plants, etc.

Age had a positive effect on the number of uses reported by the informants, which is consistent with previous ethnobotanical studies (e.g. Corroto *et al.* 2022, Merétika *et al.* 2010, Phillips and Gentry 1993, Voeks and Leony 2004). However, it is not an easy task to distinguish to what extent these results fit the hypothesis that knowledge accumulates continuously with age, and to what extent they reflect a process of knowledge erosion derived from socioeconomic changes in recent decades (Voeks and Leony 2004). For that, longitudinal studies may be necessary. In any case, it is worth noting the contributions of Argañaraz (2022), in which the community members of Amaicha del Valle report some changes in local youth in recent decades, mainly the need to migrate due to what they perceive as a lack of opportunities in their place of origin, which, in turn, changes the dynamics of the transition to adulthood. A community member points out that before when there was no high school, the boys and girls had to start working when they finished school, and they rapidly started their own families (Argañaraz 2022). Work in the communities of the Calchaquíes Valleys includes cultivation, animal husbandry and grazing, gathering, food preparation, cleaning, construction, opening ditches, and handicrafts manufacturing (Barriach and Trebucq 2017), all important activities for the acquisition and application of communal ethnobotanical knowledge.

In this work, we used altitude as a measure of residence isolation, since residences located at the bottom of the valley are in (or close to) the most densely populated areas, near National Route 40 in the case of the CIQ and Provincial Route 307 in the case of the CIAV. This variable showed a positive effect on ethnobotanical knowledge, a result consistent with previous studies in other indigenous or rural communities (Weckmüller *et al.* 2019, Vandebroek *et al.* 2004 Merétika *et al.* 2010, Montanari and Teixidor Toneu 2021).

Studies addressing similar issues – isolation, urbanization, and integration into the market economy – are more often focused on the relationship between knowledge about medicinal plants and different measures of urbanization/integration as they facilitate access to the health system. For example, among the Waorani of the Ecuadorian Amazon, people living in more isolated communities exhibited a higher average number of known medicinal plants than people from more integrated communities, with better access to the health system, markets, and schools (Weckmüller *et al.* 2019). Similarly, in communities of the Bolivian Amazon, Vandebroek *et al.* (2004) found that knowledge of medicinal plants was positively correlated with distance to reference points such as the nearest town, public transport stop, and primary healthcare center. In the Quilmes and Amaicha communities, all the health centers are located at lower altitudes, and the difficulty of accessing them for people who live in more remote places may explain their preference for the use of medicinal plants for the treatment of certain complaints.

To a lesser extent, some studies evaluate knowledge of plant uses in general (Reyes García *et al.* 2005), the explanation of the effect being similar to that of medicinal uses: knowledge is negatively affected by the market economy bringing substitutes for products obtained from plants (Reyes García *et al.* 2005). A case worth mentioning is that of the **jarillas** *Larrea cuneifolia* and *Larrea divaricata*, which were reported 44 times as a material for roof construction. Some respondents emphasized that, currently, the market facilitates access to alternative elements such as tin or reed, which explains the progressive fall into disuse of the **jarillas**. The accessibility provided by the market decreases with the residence's distance from the road, particularly from vehicle-accessible roads. Therefore, in our study area, it decreases with altitude.

Despite altitude's statistical significance, much of the variation in the data remained unexplained by the model. In this sense, it should be considered that other variables not accounted for in the model would modulate the correlation between altitude and isolation, such as the state of the roads, the possession of a vehicle by the family, the interaction networks between community members, etc. In turn, as Reyes García *et al.* (2005) point out, not all forms of market insertion have the same effect on ethnobotanical knowledge. Knowledge could grow through activities that increase the dependence of the inhabitants on the plant environment, such as the sale of products obtained from plants, or decrease due to activities that reduce dependence, such as wage labor.

Conclusions

In the present work, we classified the uses cited by the informants as medicine, food, and others, and according to their destructive potential as non-destructive, potentially destructive, and conservative. We employed numerical methods to analyze ethnobotanical data for the first time in the study area. We calculated the Cultural Importance index of each species following consensus and versatility criteria. In addition, we found evidence supporting the hypotheses that age and residence isolation positively influence individual ethnobotanical knowledge, while residence time outside the area has a negative impact on it. We found no influence of gender or the interaction between gender and age. These results highlight the importance of implementing measures to avoid cultural erosion and the loss of traditional ethnobotanical knowledge by the CIQ and CIAV inhabitants, as well as considering the question of representation both in ethnobotanical research and in projects and actions aimed at the conservation, restoration or sustainable exploitation of plant resources.

Declarations

List of abbreviations: CIQ (Comunidad India Quilmes), CIAV (Comunidad Indígena de Amaicha del Valle), CI (Cultural Importance Index), nMDS (non-metric multidimensional scaling), GLM (Generalized linear models), VIF (variance inflation factor).

Ethics approval and consent to participate: All participants gave their prior informed consent.

Consent for publication: Not applicable.

Availability of data and materials: The raw dataset that support the findings of this study are available from the corresponding author on request.

Competing interests: The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding: This research was supported by grants from ANPCyT (projects PICT2018-1119 and PICT2019-0193).

Authors' contributions: Sampietro MM contributed to the conceptualization, funding acquisition, project administration, and supervision of the study, as well as reviewing and editing the manuscript. Dip AB was responsible for the conceptualization, data curation, formal analysis, investigation, and methodology, and prepared the original draft of the manuscript.

Acknowledgements

We are very grateful to people of the *Comunidad India Quilmes* and *Comunidad Indígena de Amaicha del Valle* for their kind hospitality, particularly to Mr. Juan Mamani from *Las Cañas*.

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