Sociocultural and ecological factors influencing management of edible and non-edible plants: the case of Ixcatlán, Mexico

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Abstract

Background: Identifying factors influencing plant management allows understanding how processes of domestication operate. Uncertain availability of resources is a main motivation for managing edible plants, but little is known about management motives of non-edible resources like medicinal and ceremonial plants. We hypothesized that uncertain availability of resources would be a general factor motivating their management, but other motives could operate simultaneously. Uncertainty and risk might be less important motives in medicinal than in edible plants, while for ceremonial plants, symbolic and spiritual values would be more relevant.

Methods: We inventoried edible, medicinal, and ceremonial plants in Ixcatlán, Oaxaca, Mexico, and conducted in-depth studies with 20 native and naturalized species per use type; we documented their cultural importance and abundance by interviewing 25 households and sampling vegetation in 33 sites. Consumption amounts and preferences were studied through surveys and free listings with 38 interviewees. Management intensity and risk indexes were calculated through PCA and their relation analyzed through regression analyses. Canonical methods allowed identifying the main sociocultural and ecological factors influencing management of plants per use type.

Results: Nearly 64, 63, and 55% of all ceremonial, edible, and medicinal wild plants recorded, respectively, are managed in order to maintain or increase their availability, embellishing environments, and because of ethical reasons and curiosity. Management intensity was higher in edible plants under human selection and associated with risk. Management of ceremonial and medicinal plants was not associated with indexes of risk or uncertainty in their availability. Other sociocultural and ecological factors influence management intensity, the most important being reciprocal relations and abundance perception.

Conclusions: Plant management through practices and collectively regulated strategies is strongly related to control of risk and uncertainty in edible plants, compared with medicinal and ceremonial plants, in which reciprocal interchanges, curiosity, and spiritual values are more important factors. Understanding how needs, worries, social relations, and ethical values influence management decisions is important to understand processes of constructing management strategies and how domestication could be started in the past and are operated at the present.

Keywords: Cultural importance, Domestication, Ixcatec, Plant management, Risk management, Reciprocity interchange, Spiritual values and plant management, Tehuacán Valley

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Background
Management of plant resources and traditional ecological knowledge (TEK) are intimately related biocultural aspects that crucially influence the modeling of strategies of multiple use of natural resources in rural communities [1–3]. Understanding how management systems do operate, and identifying the factors influencing and motivating them, is greatly important for analyzing how and why plant management is currently decided, how the ongoing processes of domestication are operating, and how these could have operated in the past [4]. Therefore, studies of these processes may be relevant for designing current strategies of sustainable use of plant resources and ecosystems, as well as for understanding factors that led humans to start domestication and agriculture in the past.

Management can be defined as all practices, interventions, transformations, strategies, or decisions deliberately made by humans on ecosystems, their components, functions, and even their emergent properties, in order to use, conserve, or recover them [5, 6]. In traditional contexts, management practices are based on ancient knowledge transmitted from generation to generation, but innovations are continually constructed influenced by new observations, experimentation, and information from recent sources (information from neighboring villages, schools, communication media, interventions by NGOs, governmental promoters, researchers, among others). Both old and new management practices are organized in dynamic systems of knowledge, beliefs, cultural and spiritual values, and local institutions [7, 8].

For studying domestication, it is particularly interesting to document the morphological and genetic divergences between wild and managed populations directed to maintain or increase the availability of particular phenotypes of managed species. Such aspects provide valuable elements for explaining how processes of domestication currently operate and how these could have operated in the past. The ongoing processes of domestication can be documented in numerous rural communities of the world and are responsible for a continuous mechanism of divergence and generation of a new variation of genetic resources. As a research group, we have focused our attention on domestication processes occurring in Mesoamerica, one of the most active areas of plant management and one of the earliest centers of plant domestication in the World [5, 9, 10]. Numerous studies have documented the consequences of domestication, but relatively few have analyzed what factors motivate people to manage and domesticate plants, animals, and other organisms. In this study, we focus our attention to analyzing the main causes of the process.

Management involves several types of practices, tools, and relations between energy invested and amounts of resources obtained; such aspects reflect different degrees of management intensity [11, 12]. Authors analyzing this topic coincide that management intensity of plants goes from gathering, let standing, special care, protection, and transplanting, to practices procuring increase of desirable plant abundance by enhancing and deliberately propagating them [5, 6]. Some variables have been proposed as relevant for analyzing the degree of management intensity: (1) the number and complexity of practices carried out, (2) the number of people or social units (i.e., persons, households, or communities) participating in such practices, (3) the involvement and level of complexity of planning strategies, (4) social agreements regulating the actions, (5) the occurrence of human selection favoring particular phenotypes and the intensity in which it operates, (6) the deliberate practices favoring human-mediated gene flow and manipulation of plant reproduction, (7) the amounts of fossil or human energy invested in practices, (8) the complexity of tools used, and (9) the amount of products obtained per area unit [11–13].

In several case studies with cacti, agaves, herbs, and trees, mainly with edible use, we have documented that managed plants under higher management intensity are those more consumed or commercialized and whose future availability becomes compromised due to their relatively low availability in relation to the demand on them [11–17]. In other words, plant management is influenced by the amounts of products required by social units (which is in turn influenced by their cultural and economic value) but also by people’s perception of the product quality and their substitutability or not by other resources. In addition, management is influenced by the natural availability of plant products, determined by parameters like distribution and abundance, their resilience capacity after human impact on populations, their vulnerability, and management feasibility [11, 12, 18], as well as the ease of access to resources regulated by land tenure and communitarian agreements. All these relations have allowed proposing that management is a response to the need of facing risks or uncertainty in the current and future availability of resources [12]. In other words, it is a response of people’s worries for ensuring availability of resources [12, 19] or preventing their loss [15].

However, some studies have documented that cultural motives such as relations of reciprocity among persons and communities, some spiritual aspects, and efforts to maintain customs and traditions [20, 21] commonly motivate management practices. In addition, practices such as tolerance or let standing of plants in disturbed areas may be associated with ethical principles like the right of plants to live, whereas enhancing abundance of some species may be associated to favor variants of higher quality to embellish the sites where they occur [22–26]. Transplanting and other forms of propagation may
simply be motivated by the need to have particular plants closer because of their beauty, odor, and role in rituals or simply because of curiosity to know how plants grow and reproduce [19, 23]. These scenarios allow supposing that management type and intensity are not only responses to risk, but also practices related to ethic or esthetic values, symbolism, or curiosity, and all factors may be operating simultaneously. Analyzing how people make management decisions on plants with different purposes may allow visualizing more clearly different motives for managing plants and management intensity [12, 27]. Therefore, this study explores management motives for plants with different use types.

We hypothesized that uncertainty in availability of plant resources is a main factor motivating management of plants, especially those directed to satisfy basic needs. We therefore expected that edible plants would have higher management intensity as the higher the risk or uncertainty in their availability, as similarly documented in previous studies [12, 13]. Uncertainty would be influenced by the scarcity of plant resources and human pressures on them; therefore, scarce species with high cultural value would be more intensely managed. Ecological aspects of plants like survival, vigor, or resprouting capacities, which may be affected by use, and others that influence the ease of management like life cycle length, reproductive systems, ease of propagation, and adaptability to human-made environments would influence management types and intensities. Medicinal plants are generally used in smaller amounts than edible plants (except those that are extracted for commercialization); therefore, we expected that the pattern of management as a response to risk would be less pronounced than in edible plants [12]. Finally, we expected that the management of plants used for rituals and ceremonies, is not necessarily influenced by risk since purposes and amounts of plants used for these purposes follow different rationalities in which reciprocity relations, esthetic and symbolic values could be important.

Summarizing, our study aimed to analyze how management type and intensity are influenced by sociocultural and ecological factors in edible, medicinal, and ceremonial plants among the Ixcatec from Santa María Ixcatlán, Mexico. We analyzed whether or not people’s worries about availability of plants operate similarly in plants with different use type and look for evaluating the weight of different motives for decisions on managing plant resources.

**Methods**

**Study area**

Santa María Ixcatlán belongs to the Tehuacán-Cuicatlán Biosphere Reserve, Central México (Fig. 1). It is located at elevations from 800 to 2600 m, with annual rainfall of 721 mm and average temperature of 17.2 °C. Climate is temperate sub-humid in high zones and semiarid in lowlands [28, 29]. The traditional General Assembly regulates decisions on land, natural resources, and social life [30]. Ixcatlán is inhabited by 171 households [31], almost all of them catholic [26]; 80% of the people
consider themselves to be indigenous, but only 15 persons speak Ixcatel, and this is the only village of the world where the Ixcatel language is spoken [31, 32]. Subsistence of the people is based on the multiple use of natural resources and ecosystems, seasonal agriculture, livestock raising, and forest resource extraction [26]. We previously reported 630 plant species used by local people for satisfying different needs [26], nearly 400 species receiving some type of management in order to increase their abundance [26]. Gathering and management of plants is carried out in 18 types of forests, agroforestry systems, and homegardens over a 41,530-ha territory [26, 31–35].

**Inventory of edible, medicinal, and ceremonial plants**

Ethnobotanical studies by Rangel-Landa et al. [26] documented names, uses, and management of all plant species through semi-structured interviews with 44 persons (see Table 1) in 73 sessions. The information was systematized into the ethnobotanical database of Mexican plants (BADEPLAM), at the Botanical Garden, UNAM, and voucher specimens were deposited in the herbaria MEXU, EBUM, IEB-Bajío, and IBUG. The nomenclature of plant species followed APG III consulted through the site www.theplantlist.org [36].

**In-depth interviews and surveys**

In order to analyze how management is influenced by sociocultural and ecological factors, we selected samples of edible, medicinal, and ceremonial plants. The samples included 20 species of native and naturalized plants per use type, representing the management intensity gradient [26].

In-depth interviews were conducted to obtain deeper and detailed information on uses, values, perception about availability, vulnerability, and management practices (Table 2) for the selected species. These interviews were conducted with 25 persons selected at random (17 women and 8 men, see Table 1). In order to estimate the proportion of families that consume the studied plants in the village, we conducted a survey documenting the role of plant resources in people subsistence [26]. The survey included 20 households selected at random.

**Free listing**

For exploring the use preferences of the plants studied, we included different valuing criteria (utilitarian, symbolic, aesthetic, and emotional) through the free listing technique [37, 38]. We interviewed 38 persons (22 men, 16 women, Table 1) [26], asking them to list plants used: (1) in ceremonies and offerings to Saints and dead people, (2) as food, (3) for health care [26], and (4) for satisfying basic needs, those considered indispensable to live. We estimated their cognitive prominence for each use type through the formula \( S = F/(N \cdot mP) \), where \( F \) is the frequency of each plant species, \( N \) the number of people interviewed, and \( mP \) the average position in which a plant was named [39]. The index was calculated with Flame v1.0 [40].

**Vegetation sampling**

In order to identify the places where the plant species studied are managed, and how abundant they are in forests and agroforestry systems (AFS), we sampled vegetation in 7 agricultural plots, 21 homegardens, and 5 AFS associated to sites of mescal production [26].

**Selection of variables for the analyses**

Socio-ecological and technological variables were selected based on our previous studies [11, 12], which were organized in three main data matrixes. One matrix was with information on indicators of social, cultural, and economic importance of the species studied. A second matrix had information about biological aspects (life cycle length, types of reproduction, growth patterns, among others) and on people’s perception about the availability and vulnerability of each species. The third matrix had information about management practices and management intensity. Information on qualitative variables were categorized assigning numeric values from lower to higher management intensity according to the complexity of strategies and practices, occurrence or not of human selection, and low to high number of persons involved in the management type, among others. We also categorized from lower to higher social, cultural, and economic importance, considering that the higher their importance, the higher the potential risk associated to human pressure. Finally, we categorized from lower to higher vulnerability associated with biological characters considering the impact of human extraction of resources on individual plants and populations (Table 2). We averaged values of different categories, and in variables involving counting or binary records, we calculated the proportions of the states (Table 2). We excluded highly correlated variables, selecting those better representing the importance and management intensity of the plant species analyzed (Table 2).

**Data analyses**

In order to characterize the use and management of plants with edible, medicinal, and ceremonial uses, we used our previous data about all the species recorded [26] and the in-depth interviews for the selected species. We analyzed these data by cross-checking information and using descriptive statistics. We conducted principal component analysis (PCA) with data about management of all the native and naturalized species in order to classify management intensity among use types. The scores of the first principal component were used as management intensity
| ID | Sex | Age | Language | Main activities                  | Participant type | Semistructured interviews | Surveys 2012 | In-depth interviews | Homegarden field | Agricultural field | Mescal factory |
|----|-----|-----|----------|----------------------------------|------------------|---------------------------|---------------|----------------------|------------------|-------------------|----------------|
| 1  | Male| 25  | Spanish  | Mescal production                | Key participant  | Yes                       | Yes           |                      |                  |                   | 2              |
| 2  | Male| 50  | Spanish  | Agriculture, mescal production   | Key participant  | Yes                       | Yes           |                      | 1                |                   |                |
| 3  | Male| 72  | Spanish  | Agriculture, palm weaver         |                  |                           |               |                      |                  |                   | 6              |
| 4  | Male| 66  | Spanish  | Agriculture, palm weaver         |                  |                           |               |                      |                  |                   | 12             |
| 5  | Male| 46  | Spanish  | Agriculture, palm weaver         | Key participant  | Yes                       | Yes           |                      |                  |                   | 2              |
| 6  | Female| 44 | Spanish | Domestic chores, palm weaver     |                  | Yes                       | 15            |                      | 8                |                   |                |
| 9  | Male| 73  | Spanish  | Agriculture, palm weaver         |                  | Yes                       |               |                      | 5                |                   |                |
| 10 | Male| 48  | Spanish  | Agriculture, commerce            | Key participant  | Yes                       | Yes           |                      | 1                |                   |                |
| 11 | Male| 62  | Spanish  | Agriculture, mescal production   | Key participant  | Yes                       |               |                      |                  |                   | 10             |
| 12 | Male| 35  | Spanish  | Agriculture, mescal production, palm weaver |                  |                           |               |                      |                  |                   | 13             |
| 14 | Male| 67  | Spanish  | Agriculture, palm weaver         |                  |                           |               |                      |                  |                   | 3              |
| 16 | Male| 73  | Spanish  | Agriculture, mescal production, palm weaver |                  |                           |               |                      |                  |                   |                |
| 17 | Female| 60 | Spanish | Student                           |                  |                           |               |                      |                  |                   |                |
| 18 | Female| 35 | Spanish | Domestic chores, palm weaver     |                  | Yes                       |               |                      |                  |                   | 13             |
| 19 | Female| 62 | Spanish | Domestic chores, palm weaver     |                  |                           |               |                      |                  |                   | 1              |
| 20 | Female| 62 | Spanish | Domestic chores, palm weaver     | Key participant  | Yes                       | 7             | Yes                  | 15               |                   |                |
| 23 | Male| 72  | Spanish  | Agriculture, palm weaver         |                  | Yes                       |               |                      |                  |                   | 3              |
| 24 | Male| 70  | Spanish  | Agriculture, palm weaver         |                  |                           |               |                      | 14               |                   |                |
| 25 | Male| 51  | Spanish  | Agriculture, mescal production, palm weaver |                  |                           |               |                      | 5                |                   |                |
| 26 | Male| 82  | Spanish, Ixcatec | Agriculture, palm weaver | Key participant  | Yes                       |               |                      |                  |                   | 4              |
| 27 | Male| 68  | Spanish  | Agriculture, palm weaver         |                  |                           |               |                      | 6                |                   |                |
| 30 | Male| 59  | Spanish  | Agriculture, mescal production, palm weaver |                  |                           |               |                      | 4                |                   |                |
| 31 | Male| 57  | Spanish  | Shepherd                          | Key participant  | Yes                       | Yes           | Yes                  |                  |                   |                |
| 34 | Female| 48 | Spanish | Domestic chores, palm weaver     |                  |                           |               |                      |                  |                   | 5              |
| 35 | Male|     | Spanish | Student                           |                  |                           |               | Yes                  |                  |                   |                |
| 36 | Female| 70 | Spanish | Domestic chores, palm weaver     |                  | Yes                       |               |                      | 7                |                   |                |
| 37 | Female| 46 | Spanish | Commerce, domestic chores        |                  |                           |               |                      |                  |                   |                |
| 38 | Female| 18 | Spanish | Student                           |                  |                           |               | Yes                  |                  |                   |                |
| 39 | Female| 59 | Spanish | Domestic chores, palm weaver     |                  | Yes                       | 20            |                      |                  |                   |                |
| 41 | Female| 34 | Spanish | Domestic chores, palm weaver     |                  |                           |               |                      |                  |                   |                |
Table 1 Consultants’ details and the activities in which they collaborated (Continued)

| ID | Sex | Age | Language          | Main activities                                                                 | Participant type | Semi-structured interviews | Surveys 2012 | In-depth interviews | Homegarden field | Agricultural field | Mescal factory |
|----|-----|-----|-------------------|---------------------------------------------------------------------------------|-----------------|----------------------------|--------------|---------------------|------------------|-------------------|-----------------|
| 42 | Female | 64  | Spanish, Ixcatec | Domestic chores, palm weaver                                                     | Key participant | Yes                        | Yes          |                     |                  |                  |                 |
| 43 | Male   |     | Spanish          | Agriculture, mescal production, palm weaver                                    |                 |                            |              |                     |                  |                  |                 |
| 46 | Male   | 54  | Spanish          | Agriculture, palm weaver                                                          |                 |                            |              | 15                  |                  |                  |                 |
| 47 | Female | 41  | Spanish          | Domestic chores, palm weaver                                                     |                 |                            |              | Yes                 |                  |                  |                 |
| 48 | Female |     | Spanish          | Domestic chores, palm weaver                                                     |                 |                            |              |                     |                  |                  |                 |
| 49 | Male   |     | Spanish          | Commerce                                                                        |                 |                            |              |                     |                  |                  |                 |
| 50 | Female | 41  | Spanish          | Commerce, domestic chores                                                        |                 |                            |              |                     |                  |                  |                 |
| 51 | Female | 35  | Spanish          | Domestic chores, palm weaver                                                     |                 |                            |              |                     |                  |                  |                 |
| 52 | Male   | 76  | Spanish, Ixcatec | Agriculture, palm weaver                                                          | Key participant | Yes                        | Yes          | 9                   |                  |                  |                 |
| 53 | Male   |     | Spanish          | Agriculture, palm weaver                                                          |                 |                            |              |                     |                  |                  |                 |
| 54 | Male   | 32  | Spanish          | Agriculture, construction worker, palm weaver                                   |                 |                            |              |                     |                  |                  |                 |
| 57 | Female |     | Spanish          | Domestic chores, palm weaver                                                     |                 |                            |              |                     |                  |                  |                 |
| 58 | Female | 41  | Spanish          | Domestic chores, palm weaver                                                     | Key participant | Yes                        | Yes          | 16                  |                  |                  |                 |
| 59 | Male   | 38  | Spanish          | Agriculture, palm weaver                                                          |                 |                            |              |                     |                  |                  |                 |
| 60 | Female | 83  | Spanish          | Domestic chores, palm weaver                                                     |                 |                            |              |                     |                  |                  |                 |
| 61 | Female | 88  | Spanish, Ixcatec | Domestic chores, palm weaver                                                     |                 |                            |              |                     |                  |                  |                 |
| 63 | Female | 59  | Spanish          | Domestic chores, palm weaver                                                     |                 |                            |              |                     |                  |                  |                 |
| 64 | Male   |     | Spanish          | Agriculture, mescol production, palm weaver, shepherd                           |                 |                            |              |                     |                  |                  |                 |
| 65 | Male   | 73  | Spanish          | Agriculture, palm weaver                                                          |                 |                            |              |                     |                  |                  |                 |
| 66 | Female | 51  | Spanish, Ixcatec | Domestic chores, palm weaver                                                     | Key participant | Yes                        | Yes          | 2                   |                  |                  |                 |
| 67 | Male   | 20  | Spanish          | Agriculture, palm weaver                                                          |                 |                            |              |                     |                  |                  |                 |
| 68 | Male   | 61  | Spanish          | Agriculture, palm weaver                                                          |                 |                            |              |                     |                  |                  |                 |
| 69 | Female |     | Spanish          | Student                                                                         |                 |                            |              |                     |                  |                  |                 |
| 70 | Female | 71  | Spanish, Ixcatec | Domestic chores, palm weaver                                                     | Key participant | Yes                        | Yes          | 18                  |                  |                  |                 |
| 72 | Male   | 86  | Spanish          | Agriculture, palm weaver                                                          |                 |                            |              |                     |                  |                  |                 |
| 73 | Female | 82  | Spanish, Ixcatec | Domestic chores, palm weaver                                                     | Key participant | Yes                        | Yes          |                     |                  |                  |                 |
| 74 | Male   | 38  | Spanish          | Agriculture, construction worker, palm weaver                                   |                 |                            |              |                     |                  |                  |                 |
| 76 | Female | 65  | Spanish          | Domestic chores, palm weaver                                                     |                 |                            |              |                     |                  |                  |                 |
| 77 | Male   | 38  | Spanish          | Agriculture, palm weaver                                                          |                 |                            |              |                     |                  |                  |                 |
| 78 | Female | 40  | Spanish          | Domestic chores, palm weaver                                                     |                 |                            |              |                     |                  |                  |                 |
| 79 | Male   | 59  | Spanish          | Agriculture, mescal production, palm weaver, construction worker                |                 |                            |              |                     |                  |                  |                 |
| ID  | Sex  | Age | Language       | Main activities                          | Participant type            | Semi-structured interviews | Surveys 2012 | In-depth interviews | Homegarden | Agricultural field | Mescal factory |
|-----|------|-----|----------------|------------------------------------------|----------------------------|----------------------------|---------------|--------------------|-------------|--------------------|----------------|
| 81  | Female | 62  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        |               |                    |             |                    |                |
| 82  | Female | 33  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        |               |                    |             |                    |                |
| 83  | Female | 14  | Spanish, Ixcatec| Domestic chores, palm weaver             | Key participant            | Yes                        |               |                    |             |                    |                |
| 84  | Male   | 26  | Spanish        | Palm weaver, student                     | Key participant            | Yes                        |               |                    |             |                    |                |
| 85  | Male   | 80  | Spanish        | Agriculture, palm weaver                 |                            | Yes                        |               |                    |             |                    |                |
| 88  | Female | 66  | Spanish, Ixcatec| Domestic chores, palm weaver, shepherdess| Key participant            | Yes                        | Yes           |                    |             |                    |                |
| 89  | Female | 64  | Spanish        | Agriculture, mescal production, palm weaver | Key participant           | Yes                        | Yes           |                    |             |                    |                |
| 90  | Male   | 79  | Spanish, Ixcatec| Domestic chores, palm weaver             | Key participant            | Yes                        | Yes           |                    |             |                    |                |
| 92  | Male   | 88  | Spanish, Ixcatec| Palm weaver                              | Key participant            | Yes                        | Yes           |                    |             |                    |                |
| 93  | Female | 84  | Spanish        | Domestic chores, palm weaver             | Key participant            | Yes                        | Yes           |                    |             |                    |                |
| 94  | Female | 94  | Spanish        | Domestic chores, palm weaver             | Key participant            | Yes                        | Yes           |                    |             |                    |                |
| 95  | Female | 33  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        |             |                    |             |                    |                |
| 96  | Male   | 25  | Spanish        | Agriculture, shepherd                    | Key participant            | Yes                        | Yes           |                    |             |                    |                |
| 97  | Female | 39  | Spanish        | Domestic chores, palm weaver             | Key participant            | Yes                        | Yes           |                    |             |                    |                |
| 98  | Female | 55  | Spanish        | Agriculture, mescal production, palm weaver |                            | Yes                        |             |                    |             |                    |                |
| 99  | Male   | 57  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        |             |                    |             |                    |                |
| 100 | Female | 64  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        |             |                    |             |                    |                |
| 101 | Female | 88  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        |             |                    |             |                    |                |
| 102 | Male   | 79  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        |             |                    |             |                    |                |
| 103 | Male   | 84  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        |             |                    |             |                    |                |
| 104 | Female | 94  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        |             |                    |             |                    |                |
| 105 | Female | 33  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        |             |                    |             |                    |                |
| 106 | Male   | 25  | Spanish        | Agriculture, mescal production, palm weaver |                            | Yes                        |             |                    |             |                    |                |
| 107 | Male   | 39  | Spanish        | Agriculture                              |                            | Yes                        |             |                    |             |                    |                |
| 108 | Female | 55  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        |             |                    |             |                    |                |
| 109 | Female | 48  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        | Yes          |                    |             |                    |                |
| 110 | Female | 50  | Spanish        | Domestic chores, palm weaver             |                            | Yes                        | Yes          |                    |             |                    |                |
| 111 | Female | 57  | Spanish        | Agriculture, palm weaver                 |                            | Yes                        | Yes          |                    |             |                    |                |
We performed Kruskal-Wallis tests in order to identify differences among scores of management intensity of plants with ceremonial, edible, and medicinal uses. With the data of selected species, we performed two PCA per use type, one with the variables of the management type matrix and the other with the sociocultural and ecological variables (Table 2); the scores were used as an index of management intensity and a risk index, respectively. The relationships between risk and management intensity were analyzed through regression analyses.

Partial canonical analyses were performed using canonical correspondence analysis (CCA) per use type, in order to identify which fraction of the variation in plant management is explained by sociocultural and ecological factors and the effect of the interaction between the two types of variables [12, 15, 16, 41]. For each analysis, the sum of all canonical eigenvalues divided by the sum of all canonical eigenvalues of the CA with management data allowed calculating the corresponding fraction of variation explained by the analysis. The significance of the models was estimated by permutation tests. All analyses were conducted through the R software [42]. In the PCA and CCA analyses of medicinal plants, *Agave potatorum* and *Quercus acutifolia* were excluded since these species were outliers.

### Results

#### Ceremonial plants

We recorded 128 ceremonial plant species, 78 of them native or naturalized (Table 3); 22 species are considered by people to be basic for their life (Table 4). We recorded 48 species used for altars at homes for venerating Saints (Fig. 2). The most valuable species are those appreciated for their beauty and odor of their flowers (Table 5). As part of the communitarian celebrations, local people use 33 species as incense-like resin called copal (*Bursera* spp.), in the religious processions (*Litsea glaucescens*), and as ornaments offered to Saints (orchids, *Dasyliirion serratifolium*, *Tillandsia grandis*, *Beaucarnea stricta*) (Fig. 2).
| Matrix          | Variables              | Description                                                                 | Criterion and values                                                                 |
|-----------------|------------------------|-----------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| Sociocultural   | Uses number           | Total number of registered uses                                              | 1 per use                                                                            |
| (matrix X)      | SI basic plants       | Sutrop's cognitive prominence index of plants considered as basic to live in Ixcatlán | 0–1; 0 is a value assigned when no consultant mentioned the plant, and 1 is a theoretical value that a plant could have if all consultants mentioned it at first rank [39] |
|                 | SI by use type        | Sutrop's cognitive prominence index of plants by category (edible, medicinal, ceremonial) | 0–1; 0 is a value assigned when no consultant mentioned the plant, and 1 is a theoretical value that a plant could have if all consultants mentioned it at first rank [39] |
| Consumption     | Proportion of families that have consumed the species for the analyzed use in the last 2 years |                                                                                   | 0–1                                                                                  |
| Use frequency   | Frequency of consumption per availability season/year for analyzed use (2) |                                                                                   | 0 = never been consumed; 1 ≤ 5 times in their life; 2 ≥ 5 times in their life but not regularly; 3 = 1 time every 2 availability seasons; 4 = 1 a 2 times by availability season; 5 = 3 a 10 times by availability season |
| Recognized variants | Types or varieties recognized (1) |                                                                                   | 0 = no varieties are recognized; 1 = varieties are recognized for a plant, but each variety is a different species; 2 = varieties are recognized for a species but are used equally; 3 = varieties are recognized and have specialized use |
| Economic interchange | Type of commercial exchange (1) |                                                                                   | 1 = direct consumption; 2 = bartering; 3 = sold inside the village by collectors of the community or corners who obtain it in other places; 4 = harvested inside the village and are marketed outside (plants or products) |
| Reciprocity interchange | Type of exchange of reciprocity (1) |                                                                                   | 1 = direct consumption; 2 = it is given and received as a gift to/from others; 3 = it is offered in communal celebrations (harvested by sponsors celebration or families who offer the plants to sponsor celebration) |
| Sociocultural strategies | Strategies to obtain the plant when scarce or unavailable (1) |                                                                                   | 0 = nothing; 1 = mobility, look elsewhere; 2 = substitution for other species or products; 3 = store them; 4 = ask someone to give them; 5 = seek to obtain it by barter; 6 = buy them |
| Useful parts²   | Number of useful parts |                                                                                   | 1 per used part                                                                      |
| Harvest effort³ | Invested effort in harvest in a journey (1) |                                                                                   | 1 = opportunist; 2 = journey dedicated to harvest the species |
| Tools for harvest³ | Use of tools, supplies, and vehicles in harvest (1) | | None, only hands are used; 1 = objects obtained at harvest site; 2 = knife, machete; 2 = Arundo donax pole, baskets, bags; 3 = load animals, vehicles, chainsaws |
| Ecological      | Abundance perception  | Abundance perception in the territory (2)                                     | 1 = very abundant; 2 = abundant; 3 = regular abundance; 4 = scarce; 5 = rare        |
| (Matrix W)      | Vulnerability          | Plant vulnerability to factors affecting productivity, quality, and survival (2) | 1 = nothing affects and always produces the same; 2 = plague, drought, steady harvest, others |
|                 | Life cycle             | Life cycle type of the species                                                 | 1 = annual; 2 = perennial                                                          |
|                 | Reproduction           | Reproduction type of the species                                               | 1 = sexual and asexual; 2 = sexual                                                  |
|                 | Harvested parts        | Harvested parts for all use types of the plant in function of survival, resprouting, and reproductive capacity after useful part harvest (1) | 1 = living individual; 1 = dry branches; 2 = exudates, thorns; 3 = leaves; 4 = sprout; 5 = mature branches (lignified tissue/flowers); 6 = fruits, seeds; 7 = bark; 8 = all flowers/fruits of the season; 9 = main stalk; 9 = roots; 10 = complete individuals |
Brahea spp. leaves blessed are used for weaving shoes for dead people. The copal resin is used in praying, altars, processions, masses, and funerary rites and for protecting against “aires” (negative feelings, dangerous situations that may cause illnesses or accidents).

Commercialization of ceremonial wild plants is uncommon, except the resin of Bursera spp., which is used for celebrating the day of the dead. People used to share part of flowers collected in forests or managed in homegardens (mainly Chiococca alba, Lindleya mespiloides, orchids, and copal resin (Bursera spp.)) and give them as presents to people who organize the communitarian feasts. Dasylirion serratifolium, Beaucarnea stricta, and Tillandsia grandis are involved in practices of reciprocity among most of the local households in communitarian feasts (Table 5).

Table 2 Criteria of variables considered for analyzing sociocultural and ecologic factors that influence management intensity (Continued)

| Matrix               | Variables                  | Description                                               | Criterion and values                        |
|----------------------|-----------------------------|-----------------------------------------------------------|---------------------------------------------|
| Nearness to harvest site<sup>a</sup> | Closeness perception of harvest sites to consumption site (2) | 1 = far away; 2 = far; 3 = not too far; 4 = near; 5 = at hand |
| Temporal availability<sup>b</sup> | Temporal availability of the useful part for the analyzed use (2) | 1 = all year; 2 = months; 3 = weeks; 5 = days |
| Collective regulations | Type of regulation for the harvest (1) | 0 = without restrictions; 1 = there are “costumbres” traditions that indicate the techniques, quantity, and occasions of harvest; 2 = In addition to communal agreements aimed at regulating the access, they are aware that external institutions protect the species; 3 = complaints have been made or penalties imposed |
| Management practices | Management practice type (1) | 1 = gathering, forage; 2 = gathering with care to avoid damaging the plant; 3 = tolerance; 4 = enhancement; 5 = protection; 6 = transplanting of individuals; 7 = propagation |
| Artificial selection | Selection of individuals and propagules (1) | 0 = without selection; 1 = selection of individuals or parts that are collected for consumption; 2 = selection of tolerated, protected or enhanced individuals; 3 = selection of individuals from which seeds or cuttings are obtained to propagate |

Management in AFS Species presence proportion in homegardens, agricultural fields, and mescal factories 0–3

Practices number<sup>a</sup> Number of management practices carried out 1 by type of practices

Maintaining labors<sup>a</sup> Type of labors carried out to protect, enhance, and cultivate 1 = prepare soil; fix to hosts; exclusion of predators with fences, cages; removal of competitors; pruning, removing dried or diseased leaves; mechanical support; addition of forest soil, sand, ash, residues of organic matter; addition of lime 2 = irrigation 3 = infrastructure and special equipment for maintenance

Management system type<sup>a</sup> System type where plant is managed with respect to species natural distribution (1) 1 = wild vegetation where plants are distributed naturally; 2 = homegardens, gardens in mescal factories or “palenques,” and agricultural fields, where plants are naturally distributed; 3 = homegardens, mescal factories, and agricultural fields, where plants have been carried; 4 = greenhouses and nurseries

Numbers in variable description indicate the following: (1) addition of the different values registered for the species; (2) average of category values mentioned by consultants

<sup>a</sup>Variables not included in principal component analysis and partial canonical analysis

Table 3 Management of native and naturalized species of Santa María Ixcatlán by use type

| Use Type          | Ceremonial | Edible | Medicinal |
|-------------------|------------|--------|-----------|
| Only gathered     | 28         | 30     | 81        |
| Tolerated         | 21         | 40     | 79        |
| Enhancement       | 6          | 7      | 9         |
| Protection        | 37         | 28     | 31        |
| Transplanting     | 26         | 20     | 15        |
| Propagation       | 18         | 11     | 12        |
| Total             | 77         | 80     | 178       |
Table 4 Native and naturalized plants of Santa María Ixcatlán with ceremonial, edible, and medicinal use

| Family         | Species                                      | Voucher number | Common name                  | Ceremonial use | Edible use | Medicinal use | Basic plant | Voucher type | Origin     | Management practices                        | Management site with respect to natural distribution |
|----------------|----------------------------------------------|----------------|------------------------------|----------------|------------|---------------|-------------|--------------|------------|--------------------------------------------|-----------------------------------------------------|
| Amaranthaceae  | Alternanthera ocuaoa Kunitz                  | ERL-21, SRL-93 | Maravilla                    | Yes            | 0          | Bal, Sol      | icatlan     | In situ      |                         |                                                     |
| Amaranthaceae  | Amaranthus hybridus L.                     | SRL-79, SRL-80, SRL-1122, SRL-1141, ERL-74, ERL-102 | Quelilte tintonil | Yes            | Yes        | 0.024         | Bal, Sol, TS | icatlan      |                         |                                                     |
| Amaranthaceae  | Chenopodium berlandieri Moq.              | SRL-1139       | Quelilte de manteca, flor de huizomte | Yes            | 0.006      | Sol           | icatlan     | In situ      |                         |                                                     |
| Amaranthaceae  | Chenopodium ambrosioides (L.) Mosyakin & Clemants | ERL-32, ERL-33, ERL-168, RLF-89, SRL-1136 | Epazote         | Yes            | Yes        | 0.065         | Bal, Sol    | icatlan      |                         |                                                     |
| Amaranthaceae  | Gomphrena serrata L.                       | RLF-60, RLF-242, SRL-90, SRL-378, SRL-1175 | Gallitos        | Yes            | 0          | Bal, BEA, BN, Iz, Me, Pal            | icatlan     | In situ      |                         |                                                     |
| Anacardiaceae  | Actinocheita potentillifolia (Turcz.) Bullock | RLF-109, RLF-274, SRL-1183, SRL-1368 | Tefate          | Yes            | 0          | CaCe, Me, Iz, Palm                  | icatlan     | In situ      |                         |                                                     |
| Anacardiaceae  | Cyrtocarpa procera Kunth                | SRL-1358       | Chupandio                    | Yes            | 0          | CaCe           | icatlan     | In situ      |                         |                                                     |
| Anacardiaceae  | Pistacia mexicana Kunth                | RLF-326, SRL-1211, SRL-1340, SRL-1523 | Socoya          | Yes            | 0          | BG, CaCe, Iz, SB, Pal, Sol              | icatlan     | In situ      |                         |                                                     |
| Anacardiaceae  | Rhus chondroloma Standll                   | RLF-282, SRL-1222, SRL-1460 | Zumaque         | Yes            | Yes        | 0.007         | BEA, BC, Me, Pal, SB, TS               | icatlan     | In situ      |                         |                                                     |
| Anacardiaceae  | Rhus standleyi F.A.Bakley                | RLF-59, RLF-255, SRL-269, SRL-472, SRL-1248, SRL-1470 | Encino chaparro, zumaque grueso | Yes            | Yes        | 0.007         | BEA, BC, Iz, Me, Pal, Palm, Sol, TS    | icatlan     | In situ      |                         |                                                     |
| Anacardiaceae  | Rhus virens Lindl. ex A.Gray              | RLF-58, RLF-219, SRL-275, SRL-468, SRL-1218 | Zumaque         | Yes            | Yes        | 0.007         | BEA, BN, Iz, Me, BB, BS, TS            | icatlan     | In situ      |                         |                                                     |
| Apiaceae       | Eryngium bonplandii F.Delaroche            | RLF-6, SRL-132, SRL-384, SRL-1247 | Ojo de gallo     | Yes            | 0          | BEA, Paz        | icatlan     | In situ      |                         |                                                     |
| Apiaceae       | Eryngium comosus F.Delaroche              | RLF-127        | espinuda                     | Yes            | 0          | Me             | icatlan     | In situ      |                         |                                                     |
| Apiaceae       | Eryngium pectinatum CPres ex DC.          | RLF-52, SRL-315 |                               | Yes            | 0          | BEA, Bc          | icatlan     | In situ      |                         |                                                     |
| Apocynaceae    | Cascabela thevetia (L.) Lippold            | SRL-1336       |                               | Yes            | 0          | CaCe           | icatlan     | In situ      |                         |                                                     |
| Apocynaceae    | Matelea purpusi Woodson                  | SRL-1123       | Teacacholo                   | Yes            | Yes        | 0             | BEA, Pal, Sol           | icatlan     | In situ      |                         |                                                     |
| Apocynaceae    | Plumeria rubra L.  Photo record            |                          | Gacalsuschi                 | Yes            | 0          | CaMy, Sol      | icatlan     | In situ      |                         |                                                     |
| Araceae        | Brahea dulcis (Kunitz) Mart.              | RLF-155, RLF-1915, SRL-462, SRL-463, SRL-1192, SRL-1193 | Palma orilla     | Yes            | Yes        | 0.106         | BEA, Bc, BG, BN, Iz, Me, Pal, Pal, Palm, Sol, TS | icatlan     | In situ      |                         |                                                     |
| Araceae        | Brahea dulcis x B. calcarea Mart x Liebm    | SRL-1229       | Palma media sierra           | Yes            | 0          | BEA            | icatlan     | In situ      |                         |                                                     |

Rangel-Landa et al. Journal of Ethnobiology and Ethnomedicine (2017) 13:59
| Family | Species | Voucher number | Common name | Ceremonial use | Edible use | Medicinal use | Basic plant | Vegetation type | Origin | Management practices | Management site with respect to natural distribution |
|--------|---------|----------------|-------------|---------------|------------|--------------|-------------|---------------|--------|----------------------|-----------------------------------------------|
| Aristolochiaceae | Aristolochia teretifolia | SRL-1130 | Orejita de ratón | Yes | 0 | Sol, TS | icatlán | Gathering, tolerance, uproot | In situ |
| Asparagaceae | Agave kouchelvii Lem. | Photo record | Maguey rabo de león | Yes | 0 | Iz, Pal | icatlán | Forage, gathering | In situ |
| Asparagaceae | Agave potatorum Zucc. | RLF-285, SRL-403, SRL-1209 | Maguey papalome | Yes | Yes | 0.057 | BEA, Iz, Me, Pal, Palm, SB, Sol, TS | icatlán | Enhancement, forage, gathering, protection, propagation, tolerance, transplanting of individuals | Ex situ, in situ |
| Asparagaceae | Agave salmiana Otto ex Salm-Dyck subsp. tehuacanensis (Karw. ex Salm-Dyck) Garcia-Mend. | Photo record | Maguey cimarrón | Yes | Yes | 0 | BEA, BN, Pal, Palm, Sol, TS | icatlán | Forage, gathering, protection, tolerance, transplanting of individuals | Ex situ, in situ |
| Asparagaceae | Agave scoposa Gentry | Photo record | Maguey potrero | Yes | 0.006 | BEM, Sol | icatlán | Gathering, protection | Ex situ, in situ |
| Asparagaceae | Agave trianota Gentry | SRL-404 | Maguey tiesto | Yes | 0 | Iz | icatlán | Forage, gathering | In situ |
| Asparagaceae | Agave triangularis Jacobi | SRL-437 | Maguey rabo de león, maguey tiesto | Yes | 0 | Iz | icatlán | Forage, gathering | In situ |
| Asparagaceae | Agave vivipara L. | SRL-235, SRL-1353, SRL-1309 | Maguey espadín | Yes | 0 | CaCe, Iz, Pal, SB, Sol, TS | icatlán | Gathering, protection, propagation | Ex situ, in situ |
| Asparagaceae | Beaucarnea stricta Lem. | RLF-149 | Sotol | Yes | 0.005 | Iz | icatlán | Gathering, protection | In situ |
| Asparagaceae | Dasylirion serratifolium (Karw. ex Schult. & Schult.f.) Zucc. | RLF-156, SRL-420, SRL-1473, SRL-1521 | Cucharilla, manita | Yes | Yes | 0.010 | BG, Me | icatlán | Forage, gathering | In situ |
| Asparagaceae | Echeandia paniculata | SRL-442, SRL-1114 | Cebolla de cacalote | Yes | Yes | 0 | BEA, Iz, Me | icatlán | Gathering | In situ |
| Asparagaceae | Echeandia paniculata | SRL-228 | Sotol | Yes | Yes | 0 | BEA, Me | icatlán | Gathering | In situ |
| Asparagaceae | Echeandia paniculata | RLF-1505 | Toluca | Yes | 0 | AA | icatlán | Gathering | In situ |
| Bignoniaceae | Tecoma stans (L.) Juss. ex Kunth | RLF-13, RLF-56, RLF-249, SRL-438, SRL-465, SRL-1307 | Tronadora | Yes | 0 | BEA, BN, Iz, Me | icatlán | Forage, gathering | In situ |
| Boraginaceae | Antiphytum senectifolium (Karw. ex Schult. & Schult.f.) Hemsl. | SRL-35 | Mostaza | Yes | 0 | BN, Me, Palm | icatlán | Gathering | In situ |
| Brassicaceae | Brassica rapa L. | SRL-1536 | Mostaza | Yes | 0 | Bal, Sol, TS | Naturalized, from other continents | Gathering, tolerance, uproot | Ex situ |
| Brassicaceae | Capsella bursa-pastoris (L.) Medik. | SRL-182, SRL-1324 | Lentejilla | Yes | 0 | Bal, Sol | Naturalized, from other continents | Gathering, tolerance, uproot | Ex situ |
| Brassicaceae | Descurainia villosa (E.Fourn.) O.E.Schulz | SRL-35 | Mostaza | Yes | 0 | Bal, Sol | icatlán | Forage, gathering | In situ |
| Brassicaceae | Enca vesicaria (L.) Cav. | RLF-309, SRL-39, SRL-1131 | Jaramón | Yes | 0 | Bal, Sol, TS | Naturalized, from other continents | Forage, gathering, tolerance, uproot | Ex situ |
| Family         | Species | Voucher number | Common name | Ceremonial use | Edible use | Medicinal use | Basic plant | Sunop index | Vegetation type | Origin | Management practices                                                                 | Management site with respect to natural distribution |
|---------------|---------|----------------|-------------|----------------|------------|---------------|--------------|-------------|----------------|---------|-------------------------------------------------------------------------------------|------------------------------------------------------|
| Brassicaceae  | Lepidium virginicum L. | ERL-109, RLF-70, RLF-103, RLF-179, SRL-1320 | Lentejilla | Yes | 0 | Bal, B, B, S, Ixcatlán | Forage, gathering, protection, tolerance | In situ |
| Brassicaceae  | Nasturtium officinale R.Br. | SRL-199 | Bero | Yes | 0 | 00 | VR | Naturalized, from other continents | Gathering | In situ |
| Bromeliaceae  | Caesalpinia pulcherrima | RLF-335, SRL-1253 | Soluche de jarrata | Yes | 0 | BEA, B, I, S, S, | Ixcatlán | Gathering, forage, transplanting of individuals | Ex situ, in situ |
| Bromeliaceae  | Tillandsia floribunda | SRL-1492 | Jarrilén | Yes | 0 | CaCe, Me, S, Ixcatlán | Gathering, forage, transplanting of individuals | In situ |
| Bromeliaceae  | Tillandsia neomexicana | SRL-1201, SRL-1435 | Soluche blanco, soluche de flor colorada | Yes | 0 | BEM | Ixcatlán | Gathering | In situ |
| Bromeliaceae  | Tillandsia sp. | RLF-81, SRL-1246, SRL-1254 | Soluche | Yes | 0 | BEA, B, S, Ixcatlán | Gathering | In situ |
| Bromeliaceae  | Tillandsia sp. | RLF-84, SRL-224, SRL-1242, SRL-1250 | Soluche | Yes | 0 | BEA, B, P, S, V | Ixcatlán | Gathering, forage, transplanting of individuals | Ex situ, in situ |
| Bromeliaceae  | Tillandsia recurvata | SRL-211 | Soluchito | Yes | 0 | Palm, S, Ixcatlán | Gathering, forage, transplanting of individuals | In situ |
| Bromeliaceae  | Tillandsia usneoides | SRL-1243 | Soluche | Yes | 0 | BA | Ixcatlán | Gathering | In situ |
| Buddlejaceae  | Buddleja pavoniana Kunth | ERL-197, SRL-371, SRL-1207, SRL-1522 | Lengua de vaca, tepozol | Yes | 0 | BEA, B, P, S, Ixcatlán | Gathering, forage, transplanting of individuals | Ex situ, in situ |
| Burseraceae   | Bursera biflora (Rose) Standl. | RUS-11, RLF-122, SRL-1219 | Copal colorado, copal amarrillo, copal criollo | Yes | 0 | Iz, Me, S, S, Ixcatlán | Gathering, forage, transplanting of individuals | Ex situ, in situ |
| Burseraceae   | Bursera fagaroides (Kunth) Engl. | SRL-349 | Copallillo | Yes | 0 | Me | Ixcatlán | Gathering, forage, transplanting of individuals | Ex situ, in situ |
| Burseraceae   | Bursera ponceaensis Rand, Calderón & Medina | SRL-1271 | Copallillo blanco | Yes | 0 | Me | Ixcatlán | Gathering, forage, transplanting of individuals | Ex situ, in situ |
| Burseraceae   | Bursera schéchenardii Engl. | SRL-1367 | Acreceño | Yes | 0 | CaCe | Ixcatlán | Gathering, forage, transplanting of individuals | Ex situ, in situ |
| Cactaceae     | Ferocactus recurvus (MIR) Borg | SRL-1419 | Biznaga grande | Yes | 0 | Paz, B, S, TS | Ixcatlán | Gathering, forage, transplanting of individuals | Ex situ, in situ |
| Cactaceae     | Ferocactus macrodiscus (Mart.) Britton & Rose | SRL-402 | Biznaga | Yes | 0 | Paz, S, S, Ixcatlán | Gathering, forage, transplanting of individuals | Ex situ, in situ |

Table 4: Native and naturalized plants of Santa María Ixcatlán with ceremonial, edible, and medicinal use (Continued)
| Family       | Species                                      | Voucher number[a] | Common name               | Ceremonial use | Edible use | Medicinal use | Basic plant | Sutrop index | Vegetation type[b] | Origin | Management practices                                      | Management site with respect to natural distribution |
|--------------|----------------------------------------------|-------------------|---------------------------|----------------|------------|---------------|--------------|--------------|---------------------|--------|----------------------------------------------------------|---------------------------------------------------------|
| Cactaceae    | *Mammillaria haageana* Pfeiff.              | SRL-387, SRL-1480 | Biznaga chiquita          | Yes            | Yes        |               | BCA, Iz, Me, Palm, Sol | Ixcatlán     | Gathering, protection, transplanting of individuals | Ex situ, in situ                                       |
| Cactaceae    | *Mammillaria sphacelata* Mart.              | Photo record      | Biznaga                   | Yes            | Yes        |               | BCA, BN, Me, Pal, Sol, TS | Ixcatlán     | Gathering, protection, tolerance, transplanting of individuals | Ex situ, in situ                                       |
| Cactaceae    | *Opuntia depressa* Rose                     | SRL-238           | Nopal de coyote           | Yes            | 0          |               | BEATS        | Solar        | Forage, gathering, tolerance                            | In situ                                                |
| Cactaceae    | *Opuntia lasiacantha* Pfeiff.               | SRL-477           | Nopal pachón              | Yes            | 0.042      |               | Sol, Ixcatlán | Ixcatlán     | Gathering, protection, propagation, tolerance, transplanting of individuals | Ex situ, in situ                                       |
| Cactaceae    | *Opuntia* sp.                               | Photo record      | Nopal de coyote, nopal tuna roja | Yes          | 0          |               | Palm, Sol     | Ixcatlán     | Gathering, forage, propagation, tolerance, transplanting of individuals | Ex situ, in situ                                       |
| Cannabaceae  | *Celtis coudia* Planch.                     | ERL-79, ERL-155, ERL-194, ERL-222, SRL-1475 | Malintze, moralillo      | Yes            | 0          |               | Me, Sol       | Ixcatlán     | Gathering, protection, tolerance                        | In situ                                                |
| Chenopodiaceae | *Chenopodium murale* L.               | RLF-184, SRL-194, SRL-1121, SRL-1140, SRL-1321 | Quelite de guajolote    | Yes            | Yes        |               | Bal, Sol     | Naturalized, from other continents | Forage, gathering, tolerance, uproot | Ex situ |
| Commelinaceae | *Tradescantia cassinifolia* Cav.          | SRL-149           |                           | Yes            | 0          |               | Me           | Ixcatlán     | Gathering                                                   | In situ                                                |
| Compositae   | *Ageratina ephrosorum* (A.Gray) RMK & HRob. | RLF-36, SRL-114, SRL-291, SRL-325, SRL-363, SRL-1279 | Oreganillo          | Yes            | 0          |               | BEA, BC, BN, Iz, Me, Pal, Palm, Sol, TS | Ixcatlán     | Forage, gathering, tolerance                             | In situ                                                |
| Compositae   | *Ageratina moleotiana* (DC.) RMK & HRob.   | SRL-186, SRL-390  | Hiebre de ángel           | Yes            | 0.014      |               | BEA, Pal, Sol | Ixcatlán     | Forage, gathering, protection, tolerance, transplanting of individuals | Ex situ, in situ                                       |
| Compositae   | *Ageratina* sp.                             | RLF-116, SRL-74   | Hiebre de ángel           | Yes            | 0          |               | Me, Sol       | Ixcatlán     | Forage, gathering                                          | In situ                                                |
| Compositae   | *Ageratina* sp.                             | SRL-208           | Oreganillo                | Yes            | 0          |               | Pal, Sol     | Ixcatlán     | Forage, gathering                                          | In situ                                                |
| Compositae   | *Ambrosia palastachya* DC.                  | RLF-9             | Chamizo                   | Yes            | 0          |               | BEA          | Ixcatlán     | Gathering                                                   | In situ                                                |
| Compositae   | *Baccharis salicina* Terr. & A.Gray         | SRL-1151          |                           | Yes            | 0          |               | BEA          | Ixcatlán     | Gathering                                                   | In situ                                                |
| Compositae   | *Bidens pilosa* L.                          | SRL-190, SRL-1531, ERL-27, ERL-63, ERL-190, ERL-218 | Somiate            | Yes            | 0.003      |               | BG, Pal, Palm, Sol | Ixcatlán     | Forage, gathering, tolerance, transplanting of individuals | In situ                                                |
| Compositae   | *Bidens pilosa* L.                          | SRL-4, SRL-1285   | Oaxaqueña                 | Yes            | 0          |               | BG, Pal, Sol, TS | Ixcatlán     | Forage, gathering, tolerance, uproot                     | In situ                                                |
| Compositae   | *Bisnagua veronica* (Kunth) HRob & Brettell | RLF-11, RLF-203, RLF-205, SRL-293, SRL-361, SRL-1276, ERL-101 | Oreganillo, orejita de ratón | Yes          | 0          |               | BEA, BN, Iz, Me, Pal, Palm, Sol, TS | Ixcatlán     | Forage, gathering, tolerance, uproot                     | In situ                                                |
| Compositae   | *Chrysanthemum morifolium* (Kunth) A.Gray   | RLF-154, SRL-1163 | Hiebre de San Nicolás     | Yes            | 0          |               | Palm         | Ixcatlán     | Gathering, protection                                     | In situ                                                |
| Compositae   | *Chrysanthemum mexicanum* AGray             | RLF-154           | Leduga cimarrón           | Yes            | 0          |               | BG, Pal      | Ixcatlán     | Forage, gathering                                          | In situ                                                |
| Compositae   | *Cosmos bipinnatus* Cav.                    | ERL-4, ERL-166, ERL-167, SRL-45, SRL-47 | Jazmín               | Yes            | 0          |               | Sol          | Naturalized-from other parts of Mexico | Gathering, enhancement, protection, propagation, tolerance | Ex situ |
| Family      | Species                                                                 | Voucher number | Common name          | Ceremonial use | Edible use | Medicinal use | Basic plant | Vegetation type | Origin | Management practices                                                                 | Management site with respect to natural distribution |
|------------|-------------------------------------------------------------------------|----------------|----------------------|----------------|------------|---------------|-------------|----------------|--------|--------------------------------------------------------------------------------------|------------------------------------------------------|
| Compositae | Dahlia apiculata (Sherff) P.D.Sorensen                                  | RLF-259, SRL-91, SRL-1199, ERL-133, ERL-148 | Dalia corriente, ticurrichi | Yes            | 0          | BEA, BEM, Pal, Sol | icatlán     |                              | Gathering, protection, propagation, transplanting of individuals | Ex situ, in situ                                      |
| Compositae | Dahlia coccinea Cav.                                                   | RLF-96, RLF-260, SRL-423, SRL-1160, SRL-1186 | Dalia             | Yes            | 0          | BEA, BEM, BG, Me, Pal, Sol | icatlán     |                              | Gathering, protection, propagation, transplanting of individuals | Ex situ, in situ                                      |
| Compositae | Gnaphalium sp.                                                          | SRL-297        |                      |                |            |               |             |                | icatlán | Gathering                                                                            | In situ                                               |
| Compositae | Grindelia inuloides Wildd.                                             | RLF-14, SRL-66, SRL-107, SRL-278, SRL-209, SRL-365, SRL-1547 | Amica            | Yes            | 0.029      | BEM, BN, Palm, Pal, Sol | icatlán     |                              | Gathering, protection, propagation, transplanting of individuals | Ex situ, in situ                                      |
| Compositae | Gymnsea glaucescens (Spreng.) Less.                                     | RLF-72, RLF-121, SRL-75, SRL-290, SRL-1117, SRL-1297, ERL-25 | Cecilia, popote   | Yes            | 0.002      | Bal, BEA, BN, Pal, Palm, Sol, TS | icatlán     |                              | Forage, gathering, tolerance, uproot | In situ                                               |
| Compositae | Helianthus mexicanus Kunth                                             | RLF-25, SRL-1116, SRL-1134 | Chiche de perro   | Yes            | 0          | BEA, Palm | Ixcatlán     | Gathering | In situ                                               |
| Compositae | Montanoa tomentosa Cerv.                                               | RLF-300, SRL-2  | Oaxaqueña           | Yes            | 0          | BEM, BN, Pal, Sol | Ixcatlán     | Gathering | In situ                                               |
| Compositae | Neurobionia lobata (L.) RBr. ex Cass.                                   | SRL-198        | Naranjillo           | Yes            | 0          | VR         | Ixcatlán     | Gathering | In situ                                               |
| Compositae | Panthenium bippinastidum (Ortega) Rollins                              | ERL-9, RLF-87, RLF-178, SRL-34, SRL-82, SRL-445, SRL-1325 | Huerba cenizo    | Yes            | 0          | Sol        | Ixcatlán     | Forage, gathering, tolerance, uproot | In situ                                               |
| Compositae | Parthenium tomentosum D.C.                                              | SRL-1213, SRL-1375 | Palo prieto       | Yes            | 0          | Cacce, SB  | Ixcatlán     | Gathering | In situ                                               |
| Compositae | Porphyllum sp.                                                          | RLF-251        | Cahual              | Yes            | 0          | Iz          | Ixcatlán     | Forage, gathering | In situ                                               |
| Compositae | Pinaropappus roseus (Less.) Less.                                      | RJS-8, SRL-407, SRL-1526 | Chipule            | Yes            | 0          | Bal, BG, Iz, Paz | Ixcatlán     | Gathering | In situ                                               |
| Compositae | Piqueria tirimia Cerv.                                                 | RLF-8          |                      |                |            |             |             |                | Ixcatlán | Forage, gathering                                                                        | In situ                                               |
| Compositae | Porophyllum ineraria (Cav.) D.C.                                       | RLF-18, SRL-158, SRL-357, SRL-1150, ERL-141 | Pepitza           | Yes            | 0          | BEA        | Ixcatlán     | Forage, gathering, protection, propagation, transplanting of individuals | Ex situ, in situ                                      |
| Compositae | Porophyllum radians Raderse subsp. macrophyllum (D.C.) R.R.Johnson      | RLF-318, SRL-1539 | Papaloquelite      | Yes            | 0.004      | Me, Sol     | Ixcatlán     | Forage, gathering, tolerance, transplanting of individuals | Ex situ, in situ                                      |
| Compositae | Psilostachyum paucicapitatum (B.L.Rob & Greenm) H.Rob. & Brettel         | RLF-193, SRL-1159 | Huerba de camote de venado | Yes            | 0          | BEA, Iz     | Ixcatlán     | Gathering, protection, transplanting of individuals | Ex situ, in situ                                      |
| Compositae | Rhodanthe aemuligiosa (Klatt) H.Rob. & Brettel                         | SRL-1152        | Huerba de perro     | Yes            | 0          | BEA        | Ixcatlán     | Gathering | In situ                                               |
| Compositae | Sanvitalia procumbens Lam.                                             | RLF-42, SRL-12, SRL-1179 | Ojo de gallo       | Yes            | 0          | Me, Palm, Sol, TS | Ixcatlán     | Forage, gathering, tolerance, uproot | In situ                                               |
| Compositae | Semecia praecox (Cav.) D.C.                                            | ERL-191, SRL-1487 | Consueida, pata de león | Yes            | 0          | Me, Sol     | Ixcatlán     | Gathering, protection, transplanting of individuals | Ex situ, in situ                                      |
| Family          | Species                      | Voucher number(s) | Common name    | Ceremonial use | Edible use | Medicinal use | Basic plant | Sunop index | Vegetation type | Origin                                      | Management practices                                      | Management site with respect to natural distribution |
|-----------------|------------------------------|-------------------|----------------|----------------|------------|---------------|--------------|-------------|----------------|---------------------------------------------|-----------------------------------------------------------|----------------------------------------------------------|
| **Compositae**  | *Sonchus oleraceus* (L.) L. | ERL-10, SRL-1126  | Chicoria        | Yes            | 0          | Sol           | Naturalized, from other continents | Gathering, tolerance, uproot | Ex situ                                       |
|                 | *Stevia lucida* Lag.        | SRL-332, SRL-339  | Chamalacate     | Yes            | 0          | BN, IZ, Me, Palm, TS | Ixcatlán        | Gathering, forage, tolerance, uproot | In situ                                       |
|                 | *Stevia sp.*               | RLF-170, RLF-183, SRL-32, SRL-97, SRL-1281 | Chahuil delgado | Yes            | 0          | BN, Pal, Sol, TS | Ixcatlán        | Forage, gathering, tolerance | In situ                                       |
|                 | *Stevia sp.*               | RLF-276           | Chahuil prieto  | Yes            | 0          | BEA, Pal      | Ixcatlán        | Gathering                     | In situ                                       |
|                 | *Stevia sp.*               | SRL-1262          | Yes             | 0              | Me        | Ixcatlán        | Forage, gathering | In situ                                       |
|                 | *Stevia sp.*               | SRL-1295          | Yes             | 0              | Pal        | Ixcatlán        | Forage, gathering | In situ                                       |
|                 | *Stevia canacacana* D.C.   | RLF-211, SRL-1289, SRL-1293, SRL-1402 | Yes            | 0              | Iz, Pal, Palm | Ixcatlán        | Gathering, tolerance | In situ                                       |
| **Compositae**  | *Tagetes erecta* L.         | ERL-12, ERL-62, ERL-117, ERL-118, ERL-134, ERL-149, ERL-151, ERL-152, ERL-159, SRL-7, SRL-408, SRL-1142 | Cempasuchí     | Yes            | 0.003       | Sol, TS | Naturalized-from other parts of Mexico | Enhancement, protection, propagation, tolerance, transplanting of individuals | Ex situ                                       |
|                 | *Tagetes lucida* Cav.       | RLF-3, SRL-377, SRL-1232, SRL-1426 | Petición        | Yes            | Yes        | Yes            | 0.003         | BEA, Paz | Ixcatlán        | Gathering                     | In situ                                       |
|                 | *Tagetes lunulato* Ortega  | ERL-137           | Cempasuchí chiquito | Yes            | 0          | Sol           | Ixcatlán        | Gathering, enhancement, forage, protection, tolerance | In situ                                       |
| **Compositae**  | *Tocquea campefладes* G.E.Haglund | ERL-106, SRL-89  | Achicoria       | Yes            | Yes        | 0              | Sol           | Ixcatlán        | Forage, gathering, tolerance, uproot | Ex situ                                       |
| **Compositae**  | *Tridax cosmopófilo* (Kunth) Heerl. | SRL-104          | Yes             | 0              | BN         | Ixcatlán        | Gathering                     | In situ                                       |
| **Compositae**  | *Viguiera dentata* (Cav.) Sprenq. | RLF-227, SRL-164, SRL-1277, SRL-1302 | Chimalacate     | Yes            | Yes        | Yes            | 0              | BEA, BEC, BG, IZ, Me, Pal, Sol, TS | Ixcatlán        | Gathering, forage, tolerance, uproot | In situ                                       |
| **Compositae**  | *Viguiera grammatogloia* DC. | RLF-233, RLF-298, SRL-347, SRL-1286 | Chahuil prieto  | Yes            | 0          | BEG, IZ, Me, Pal, Palm, TS | Ixcatlán        | Forage, gathering, tolerance, uproot | In situ                                       |
| **Convolvulaceae** | *Zinnia peruviana* (L.) L. | SRL-1214          | Galíto          | Yes            | 0          | BEA, BN, IZ, Me, Palm, TS | Ixcatlán        | Forage, gathering, tolerance, uproot | In situ                                       |
| **Compositae**  | *Sutrop index*              | SRL-1214          | Jazmín, cahuil blanco | Yes            | 0          | SB             | Ixcatlán        | Gathering                     | In situ                                       |
| **Convolvulaceae** | *Ipomoea wrightii* House | SRL-1272          | Yes             | 0              | CaCe        | Ixcatlán        | Gathering                     | In situ                                       |
| **Convolvulaceae** | *Ipomoea aff. papulina* House | SRL-1275          | Cahuil prieto   | Yes            | 0          | Pal, Sol, VR | Ixcatlán        | Gathering                     | In situ                                       |
| **Convolvulaceae** | *Ipomoea aff.* | SRL-1478          | Heleba de ángel, oxaxqueña | Yes            | 0          | BEA             | Ixcatlán        | Gathering                     | In situ                                       |
| **Convolvulaceae** | *Ipomoea aff. populinata* House | SRL-1339          | Cempasuchí de motivo de campo | Yes            | 0          | CaCe        | Ixcatlán        | Gathering                     | In situ                                       |
| **Convolvulaceae** | *Dichondra argentea* Humb. & Bonpl. ex Willd. | SRL-1314          | Orejita de ratón | Yes            | 0          | BEA, BN, IZ, Me, Palm, TS | Ixcatlán        | Gathering | In situ                                       |
| **Convolvulaceae** | *Ipomoea wrightii* House | SRL-1306          | Jicara          | Yes            | 0          | Me             | Ixcatlán        | Forage, gathering | In situ                                       |
| Family         | Species                          | Voucher number | Common name                 | Ceremonial use | Edible use | Medicinal use | Basic plant | Suntop index | Vegetation type | Origin       | Management practices                                                                 |
|---------------|----------------------------------|----------------|-----------------------------|----------------|------------|---------------|--------------|--------------|----------------|--------------|----------------------------------------------------------------------------------------|
| Convolvulaceae| Ipomoea conzattii Greenm.        | SRL-1491, SRL-1510 | Jícama de cerro             | Yes            | 0          | CaMy, Me      |              |              | 0              | Ixcatlán     | Forage, gathering                                                                      |
| Convolvulaceae| Ipomoea purpurea (L.) Roth       | ERL-14, RLF-44, RLF-45, SRL-145, SRL-48  | Quebrada platos            | Yes            | 0          | BEA, Me, Paz, Sol, TS |              |              | 0              | Ixcatlán     | Gathering, tolerance, uproot                                                              |
| Convolvulaceae| Echeveria gigantea Rose & Purpus | SRL-1313        | Siempreviva grande, lengua de vaca, oreja de toro | Yes            | 0          | Me, Sol      |              |              | 0              | Ixcatlán     | Gathering, protection, transplanting of individuals                                    |
| Convolvulaceae| Echeveria nodulosa (Baker) Otto   | SRL-356, SRL-1187, SRL-1255, SRL-1436 | Siempreviva chiquita       | Yes            | 0          | BEA, Me, Iz, Palm, Sol, TS |              |              | 0              | Ixcatlán     | Gathering, protection, transplanting of individuals                                    |
| Convolvulaceae| Saturn dendraeum Mac. & Sesse ex DC. | SRL-77, SRL-195, ERL-97, ERL-174 | Siempreviva               | Yes            | 0          | NE, Sol      |              |              | 0              | Ixcatlán     | Gathering, protection, transplanting of individuals                                    |
| Cucurbitaceae | Cucumis pedatifolia L.H.Bailey   | ERL-120, RLF-268, SRL-1135 | Calabacita amarga         | Yes            | 0          | Bal, Pal, Sol |              |              | 0              | Ixcatlán     | Forage, gathering, tolerance, uproot                                                     |
| Cucurbitaceae | Cyclanthera dissecta (Torr. & A.Gray) Arn. | SRL-151 | Chayotillo                  | Yes            | 0          | Me, TS       |              |              | 0              | Ixcatlán     | Forage, gathering, tolerance, uproot                                                     |
| Cucurbitaceae | Schizocarpum filiforme Schrad.   | SRL-1260        | Chayotillo                  | Yes            | 0          | Sol, TS      |              |              | 0              | Ixcatlán     | Forage, gathering, tolerance, uproot                                                     |
| Cucurbitaceae | Sicyos laxivulus L.              | ERL-100, RLF-90, SRL-14 | Chayotillo, pegajosa       | Yes            | 0          | Sol, TS      |              |              | 0              | Ixcatlán     | Forage, gathering, tolerance, uproot                                                     |
| Cupressaceae  | Juniperus fillicula Schidtt.     | ERL-187, RUF-126, RUF-134, SRL-123, SRL-412, SRL-1199 | Nebro               | Yes            | 0.053      | BEA, BEC, BG, BN, Iz, Me, Pal, Palm, Sol, TS |              |              | 0              | Ixcatlán     | Gathering, protection, transplanting of individuals                                    |
| Cupressaceae  | Taxodium huegelii C.Lawson       | SRL-210, SRL-434, SRL-1294 | Sabino                  | Yes            | 0.004      | BG, Pal, Palm, Sol |              |              | 0              | Ixcatlán     | Gathering, protection, transplanting of individuals                                    |
| Cyperaceae    | Carex sp.                        | RLF-133         | Pasto                       | Yes            | 0          | Me           |              |              | 0              | Ixcatlán     | Forage, gathering                                                                      |
| Cyperaceae    | Eleocharis acuticulris (L.) Roem. & Schult. | RLF-138 | Pasto de arroyo             | Yes            | 0          | VR           |              |              | 0              | Ixcatlán     | Gathering                                                              |
| Ebenaceae     | Diospyros oacanensis Standl.     | SRL-1446        | Zapotillo                   | Yes            | 0          | VR           |              |              | 0              | Ixcatlán     | Forage, gathering                                                                      |
| Ericaceae     | Arbutus xalapensis Kunth         | ERL-172, RLF-124, RLF-279, SRL-1477 | Medranha, allita        | Yes            | 0.018      | BEA, BEC, BEM, BN, Me, TS |              |              | 0              | Ixcatlán     | Gathering, tolerance                                                                  |
| Euphorbiaceae | Cnidosculus tehuacanensis Brecinon | Photo record   | Mala mujer                  | Yes            | 0          | Iz, Palm     |              |              | 0              | Ixcatlán     | Gathering                                                              |
| Euphorbiaceae | Euphorbia dioica Kunth           | ERL-107, RLF-7, SRL-359 | Cedronia                 | Yes            | 0          | BEA, Sol     |              |              | 0              | Ixcatlán     | Gathering, tolerance, uproot                                                          |
| Euphorbiaceae | Euphorbia macropus (Klotsch & Garcke) Böiss. | SRL-1120 | Hierba de chicle           | Yes            | 0          | Pal          |              |              | 0              | Ixcatlán     | Gathering                                                              |
| Euphorbiaceae | Jatropha neopacifica Pax         | SRL-1357        | Sangre de grado, aceitillo | Yes            | 0          | CaCe         |              |              | 0              | Ixcatlán     | Forage, gathering                                                                      |
| Euphorbiaceae | Ricinus communis L.              | ERL-116, ERL-144, ERL-145, ERL-243, SRL-23, SRL-1129 | Gria                  | Yes            | 0          | Bal, Sol     | Naturalized, from other continents |              | 0              | Ixcatlán     | Enhancement, gathering, protection, tolerance, transplanting of individuals, uproot |

Rangel-Landa et al. Journal of Ethnobiology and Ethnomedicine (2017) 13:59
| Family   | Species                                      | Voucher number(s) | Common name         | Ceremonial use | Edible use | Medicinal use | Basic plant | Vegetation type   | Origin          | Management practices                                                                 | Management site with respect to natural distribution |
|----------|----------------------------------------------|-------------------|---------------------|----------------|------------|---------------|--------------|-----------------|----------------|---------------------------------------------------------------------------------------|--------------------------------------------------------|
| Fagaceae | Quercus acutifolia Née                        | SRL-1226, SRL-1516| Encino colorado     | Yes            | Yes        |               | 0.072        | BEM             | Ixcatlán        | Forage, gathering, protection, transplanting of individuals, propagation               | Ex situ, in situ                                       |
| Fagaceae | Quercus castanea Née                         | RLF-78, SRL-1233, SRL-1408, SRL-1425, SRL-1431 | Encino prieto, encino blanca | Yes            | Yes        |               | 0.056        | BEA, BEM, BN, TS | Ixcatlán        | Forage, gathering, tolerance                                                          | In situ                                                |
| Fagaceae | Quercus grisea Benth.                        | SRL-1156          | Encino colorado     | Yes            | Yes        |               | 0.072        | BEM             | Ixcatlán        | Forage, gathering, protection                                                         | In situ                                                |
| Fagaceae | Quercus irota Liebm.                         | RLF-68, SRL-143, SRL-253, SRL-385, SRL-1230 | Encino prieto, encino amarillo | Yes            |            |               | 0.140        | BEA, BEC, Pal, Sol | Ixcatlán        | Forage, gathering, protection, propagation, tolerance                               | Ex situ, in situ                                       |
| Fagaceae | Quercus kahmanni Oemt. ex Trel.              | SRL-1107, SRL-1514| Encino amarillo     | Yes            |            |               | 0.140        | BEA, Me, Palm, TS | Ixcatlán        | Forage, gathering, protection, propagation, tolerance, transplanting of individuals | Ex situ, in situ                                       |
| Fagaceae | Quercus obnita Bonpl.                        | SRL-1423          | Encino prieto       | Yes            |            |               | 0.056        | BEM             | Ixcatlán        | Forage, gathering, protection                                                         | In situ                                                |
| Fagaceae | Quercus polyantha Schidt. & Cham.            | SRL-1503          | Encino prieto       |                |            |               |              |                 | Ixcatlán        | Forage, gathering, protection                                                         | In situ                                                |
| Fagaceae | Quercus urbanii Trel.                        | RLF-161, SRL-252, SRL-475, SRL-1228 | Encino cucharilla   | Yes            |            |               | 0.074        | BEA, BEC, TS    | Ixcatlán        | Forage, gathering, protection, tolerance                                              | In situ                                                |
| Iridaceae| Tigridia pavonia (L.f.) DC.                   | RLF-201           |                    | Yes            | 0          |                |              | Iz              | Ixcatlán        | Gathering                                                              | In situ                                                |
| Krameriaceae | Krameria cytisoides Cav.                     | RLF-97, SRL-251, SRL-1265, SRL-1376 | Chayotillo de burro, berrueguito | Yes            | 0          |                |              | Me, Palm        | Ixcatlán        | Forage, gathering                                                              | In situ                                                |
| Lamiales  | Clinopodium mexicanum (Benth.) Govaerts      | RLF-131, RLF-262, SRL-1190, SRL-1280, SRL-1403 | Chiptro           | Yes            | 0          |                |              | BEA, Me, Pal, Sol, VR | Ixcatlán        | Gathering, protection, transplanting of individuals                              | Ex situ, in situ                                       |
| Lamiales  | Hyptis sp.                                   | SRL-209           |                    |                | 0          |                |              | Sol             | Ixcatlán        | Gathering                                                              | In situ                                                |
| Lamiales  | Leonotis nepetifolia (L.) R.Br.              | SRL-1315          |                    | Yes            | 0          |                |              | Sol             | Naturalized, from other continents, gathering, enhancement, propagation, tolerance | Ex situ                                                |
| Lamiales  | Marrubium vulgare L.                         | ERL-80, RLF-64, SRL-29, SRL-1146 | Manrubio          | Yes            | 0          |                |              | Bal, Pal, Sol   | Naturalized, from other continents, gathering, tolerance | In situ                                                |
| Lamiales  | Salvia candicans M.Martens & Galeotti       | SRL-155, SRL-1456 |                    | Yes            | 0          |                |              | Me              | Ixcatlán        | Gathering                                                              | In situ                                                |
| Lamiales  | Salvia oaxacana Fernald                      | RLF-232, SRL-1161, SRL-1188 | Minto cimarrón     | Yes            | 0          |                |              | BEA             | Ixcatlán        | Forage, gathering                                                              | In situ                                                |
| Lamiales  | Salvia purpurea Cav.                         | RLF-1, RLF-194, SRL-116, SRL-273, SRL-1195, SRL-1202, SRL-1397, SRL-1420 | Terciopelo       | Yes            | 0          |                |              | BEA, BEC, BN, Iz | Ixcatlán        | Gathering                                                              | In situ                                                |
| Lamiales  | Salvia sessei Benth.                         | RLF-33, RLF-195, SRL-1162 | Oaxaqueña          | Yes            | 0          |                |              | BEA, BEM        | Ixcatlán        | Gathering                                                              | In situ                                                |
| Lamiales  | Salvia sp.                                   | RLF-3, Photo record | Minto             | Yes            | 0          |                |              | Sol             | Ixcatlán        | Gathering                                                              | In situ                                                |
| Lamiales  | Salvia thymoides Benth.                      | SRL-140           | Merrubio macho     | Yes            | 0          |                |              | Iz, Me          | Ixcatlán        | Gathering                                                              | In situ                                                |
### Table 4: Native and naturalized plants of Santa María Ixcatlán with ceremonial, edible, and medicinal use (Continued)

| Family      | Species                                | Voucher numbera | Common name          | Ceremonial use | Edible use | Medicinal use | Basic plant | Surop index | Vegetation typeb | Origin | Management practices | Management site with respect to natural distribution |
|-------------|----------------------------------------|-----------------|----------------------|----------------|------------|--------------|-------------|-------------|-------------------|--------|---------------------|-----------------------------------------------|
| Lamiaceae   | *Salvia tiliifolia* Vahl               | ERL-28, ERL-112, RLF-162, SRL-3 | Chía                 | Yes            | 0          |              | Bal, Sol, TS | Ixcatlán    | Gathering, uproot | Ixcatlán | Gathering            | In situ                                      |
| Lamiaceae   | *Salvia cincinnata* Cav.               | RLF-215, SRL-1291 |                     | Yes            | 0          |              | Iz, Palm    | Ixcatlán    | Gathering         | Ixcatlán | Gathering            | In situ                                      |
| Lauraceae   | *Litsea glacesiensis* Kunth           | SRL-1157, SRL-1515 | Laurel               | Yes            | 0          |              | BEA         | Ixcatlán    | Gathering, propagation | In situ | Gathering            | In situ                                      |
| Leguminosae | *Calliandra* sp.                      | SRL-276          | Guaje de gamita     | Yes            | 0          |              | BEA, BCC, BG, BN, Me | Ixcatlán | Gathering         | Ixcatlán | Forage, gathering   | In situ                                      |
| Leguminosae | *Catalpa purpurea* Ortega             | SRL-103, SRL-364 |                     | Yes            | 0          |              | BN, Palm    | Ixcatlán    | Forage, gathering | Ixcatlán | Forage, gathering   | In situ                                      |
| Leguminosae | *Dalea carthaginesis* (Jacq.) J.F.Macbr. | RLF-115, RLF-168, RLF-222, SRL-154, SRL-417, SRL-1185, SRL-1299 | Hierba de Obo   | Yes            | 0          |              | BG, Iz, Me, TS | Ixcatlán | Forage, gathering, tolerance, uproot | Ixcatlán | Forage, gathering   | In situ                                      |
| Leguminosae | *Dalea* sp.                           | SRL-348          |                     | Yes            | 0          |              | Me          | Ixcatlán    | Gathering         | Ixcatlán | Gathering            | In situ                                      |
| Leguminosae | *Dalea somertosa* (Cav.) Willd.       | RLF-214, SRL-214 |                     | Yes            | 0          |              | BN, Iz, Palm | Ixcatlán    | Gathering         | Ixcatlán | Forage, gathering   | In situ                                      |
| Leguminosae | *Desmanthus* sp.                      | RLF-225          | Tepeguaje cimarrón  | Yes            | 0          |              | Iz          | Ixcatlán    | Forage, gathering | Ixcatlán | Forage, gathering   | In situ                                      |
| Leguminosae | *Desmanthus virgatus* (L.) Willd.      | SRL-368          | Guajito de galinto  | Yes            | 0          |              | Palm        | Ixcatlán    | Gathering         | Ixcatlán | Gathering            | In situ                                      |
| Leguminosae | *Lacsona* sp.                         | SRL-1158         | Guaje de gamita     | Yes            | 0          |              | BEA         | Ixcatlán    | Gathering         | Ixcatlán | Gathering            | In situ                                      |
| Leguminosae | *Lupinus kpephyllius* Cham. & Schltdl. | SRL-1410         |                     | Yes            | 0          |              | BEA         | Ixcatlán    | Gathering         | Ixcatlán | Gathering            | In situ                                      |
| Leguminosae | *Phoradendron* sp.                    | SRL-1206         | Ejote de venado     | Yes            | 0          |              | BEA         | Ixcatlán    | Forage, gathering | Ixcatlán | Forage, gathering   | In situ                                      |
| Leguminosae | *Pisidia grandifolia* (Donn.Sm.) M.C.Johnst. | SRL-1210       |                     | Yes            | 0          |              | SB          | Ixcatlán    | Gathering         | Ixcatlán | Gathering            | In situ                                      |
| Leguminosae | *Prosopis laevigata* (Willd.) M.C.Johnst. | SRL-1888         | Mezquite             | Yes            | 0          |              | Pal, SB, Sol | Ixcatlán    | Forage, gathering, tolerance | In situ | Forage, gathering   | In situ                                      |
| Leguminosae | *Senna guatemalensis* (Donn.Sm.) H.S.Irwin & Barneby | RLF-246, RLF-295 |                     | Yes            | 0          |              | Iz          | Ixcatlán    | Forage, gathering | Ixcatlán | Forage, gathering   | In situ                                      |
| Leguminosae | *Tritium* sp.                         | SRL-375          |                     | Yes            | 0          |              | BEA         | Naturalized, unknown origin | Ex situ | Forage, gathering   | In situ                                      |
| Leguminosae | *Zonia reticulata* Sm.                | SRL-300          |                     | Yes            | 0          |              | Paz         | Ixcatlán    | Forage, gathering | In situ | Forage, gathering   | In situ                                      |
| Leguminosae | *Ziconia* sp.                         | SRL-1212         | Tepeguaje           | Yes            | 0          |              | SB          | Ixcatlán    | Forage, gathering | In situ | Forage, gathering   | In situ                                      |
| Leguminosae | *Lonchocarpus* sp.                    | SRL-1217         |                     | Yes            | 0          |              | SB          | Ixcatlán    | Forage, gathering | In situ | Forage, gathering   | In situ                                      |
| Loasaceae   | *Mentzelia hispida* Willd.            | RLF-54, RLF-94, SRL-428 | Pegajosa             | Yes            | 0          |              | Bal, BEA, BG | Ixcatlán    | Gathering, tolerance, uproot | In situ | Forage, gathering   | In situ                                      |
| Lythraceae  | *Cuphea* sp.                          | RLF-100, RLF-143, RLF-172, SRL-20, SRL-352, SRL-1170 |                     | Yes            | 0          |              | Me, Sol, Pal, TS | Ixcatlán | Forage, gathering, tolerance, uproot | In situ | Forage, gathering   | In situ                                      |
| Lythraceae  | *Cuphea* sp.                          | SRL-25           |                     | Yes            | 0          |              | BN, Palm, Sol | Ixcatlán    | Gathering         | Ixcatlán | Gathering            | In situ                                      |
| Lythraceae  | *Cuphea* sp.                          | SRL-105, SRL-296 |                     | Yes            | 0          |              | BEA, BN, Paz | Ixcatlán    | Gathering         | Ixcatlán | Gathering            | In situ                                      |
| Family               | Species                                      | Voucher number(s) | Common name                  | Ceremonial use | Edible use | Medicinal use | Basic plant | Vegetation type | Origin | Management practices               | Management site with respect to natural distribution |
|---------------------|---------------------------------------------|-------------------|------------------------------|----------------|------------|---------------|-------------|----------------|--------|-----------------------------------|---------------------------------------------------|
| Malpighiaceae        | Bunchosia sp.                               | SRL-451           | Huevo de gato                | Yes            | 0          | Sol           | la catlán    |                | catlán                  | Gathering, tolerance                               | In situ                                           |
| Malpighiaceae        | Galphinia multisauris A.Juss.               | RLF-65, RLF-295, SRL-1177 | Flor de chivo                | Yes            | 0          | BEA, BEC, Iz, Me, Palm |                |                | catlán                  | Forage, gathering                                  | In situ                                           |
| Malpighiaceae        | Gaudichaudia galeottiana (Nied.) Chodat     | RLF-241           |                               | Yes            | 0          | Iz            | catlán                  | Gathering                               | In situ                                           |
| Malpighiaceae        | Galphinia galeottiana A.Juss.               | SRL-362, SRL-471, SRL-1272 | Nanche                        | Yes            | 0          | Me, Palm, TS  | catlán                  | Forage, gathering, tolerance                   | In situ                                           |
| Malpighiaceae        | Malpighia galeottiana A.Juss.               | RLF-67, RLF-277, SRL-6, SRL-446, SRL-1125 | Quelte de maíz, violeta       | Yes            | 0          | Bal, BEA, Pal, Sol, TS | catlán                  | Forage, gathering, tolerance, uproot               | In situ                                           |
| Malpighiaceae        | Malva parviflora L.                         | ERL-30, ERL-90, SRL-205, SRL-1124, SRL-1143 | Malva                      | Yes            | 0          | Bal, Sol, TS  | Naturalized, from other continents | Enhancement, forage, gathering, tolerance, uproot | In situ                                           |
| Martyniaceae         | Proboscidea buxifolia (Mill.) Thell.        | SRL-1318          | Cuerno de toro                | Yes            | 0          | Bal, Palm, Sol, TS | catlán                  | Gathering, tolerance                           | In situ                                           |
| Meteoriaceae         | Meteorium deper (Hornsch. ex Müll. Hal.) Mitt. | SRL-1432          | Musgo                         | Yes            | 0          | BEA, BM, Sol  | catlán                  | Gathering, protection, transplanting of individuals | Ex situ, in situ                                 |
| Moraceae             | Ficus ovata (Miq.) Mart. ex Miq.            | SRL-76, SRL-1171  | Amanate                       | Yes            | 0.006     | Sol           | catlán                  | Gathering, tolerance                           | In situ                                           |
| Moraceae             | Morus alba (L.) Kunth                       | ERL-55, ERL-78, ERL-55, ERL-78, ERL-124, ERL-128, ERL-129, ERL-214, ERL-220, ERL-221, ERL-55, SRL-1517 | Moral, morera               | Yes            | 0.051     | AA, Sol       | catlán                  | Gathering, protection, tolerance                | In situ                                           |
| Nyctaginaceae        | Mirabilis jalapa L.                         | ERL-20, ERL-99, SRL-21, SRL-421, SRL-1145 | Hieda cuchi, maravilla        | Yes            | 0.003     | Bal, BG, Sol  | catlán                  | Forage, gathering, tolerance, uproot            | In situ                                           |
| Onagraceae           | Gaura cocinea Nutt. ex Pursh                | SRL-17, SRL-411   | Gradolita                      | Yes            | 0         | Bal, Sol       | catlán                  | Forage, gathering, tolerance, uproot            | In situ                                           |
| Onagraceae           | Oenothera pubescens Willd. ex Hiern.        | RLF-76, RLF-113, SRL-22, SRL-40, SRL-150, SRL-213 | Campanilla grande            | Yes            | 0         | Bal, BEA, ME, Sol | catlán                  | Gathering, tolerance, uproot                      | In situ                                           |
| Onagraceae           | Oenothera rosea L’Her. ex Thunb.            | SRL-1127, SRL-1322 | Sanguinaria                  | Yes            | 0         | Bal, Sol       | catlán                  | Gathering, tolerance, uproot                    | In situ                                           |
| Orchidaceae          | Bauhinia indigena subsp. vranetana (Rchb.f.) Thien | SRL-1509          | Monjita de peña                | Yes            | 0         | CalMy         | catlán                  | Gathering, protection, transplanting of individuals | Ex situ, in situ                                 |
| Orchidaceae          | Dierammanthus cinabarinus (Lex.) Gayr.      | RLF-223, RLF-289, SRL-1155, SRL-1172 | Gola de leon                  | Yes            | 0         | BEA, Iz, Palm  | catlán                  | Gathering                               | In situ                                           |
| Orchidaceae          | Encyclia harveyi (Lindl.) Sch.              | SRL-1519          | Monjita morada de campo       | Yes            | 0         | Me, Sol       | catlán                  | Gathering, protection, transplanting of individuals | Ex situ, in situ                                 |
| Orchidaceae          | Epidendrum radicans (Arms, F.T.Hubb. & C.Schweinf.) Hägse          | RJS-3             | Monjita colorada               | Yes            | 0.002     | BEA, BEM, Pal, Sol | catlán                  | Gathering, protection, transplanting of individuals | Ex situ, in situ                                 |
| Orchidaceae          | Euchile karwinskii (Mart.) Christenson       | RJS-1             | Monjita amarilla               | Yes            | 0.002     | BEA, Pal, Sol  | catlán                  | Gathering, protection, propagation, transplanting of individuals | Ex situ, in situ                                 |

Table 4 Native and naturalized plants of Santa María Ixcatlán with ceremonial, edible, and medicinal use (Continued)
Table 4 Native and naturalized plants of Santa María Ixcatlán with ceremonial, edible, and medicinal use (Continued)

| Family          | Species                                                                 | Voucher number | Common name   | Ceremonial use | Edible use | Medicinal use | Basic plant | Vegetation type | Origin | Management practices                                                                 | Management site with respect to natural distribution |
|-----------------|-------------------------------------------------------------------------|----------------|---------------|----------------|------------|---------------|--------------|-----------------|--------|----------------------------------------------------------------------------------------|----------------------------------------------------------|
| Orchidaceae     | Laelia albida Bateman ex Lindl.                                           | ERL-126        | Monjita blanca | Yes            |            |               | Pal, Sol, TS  | 0.002           | Ixcatlán | Gathering, protection, propagation, transplanting of individuals                     | Ex situ, in situ                                         |
| Orchidaceae     | Laelia anceps Lindl.                                                    | SRL-1541       | Monjita morada | Yes            |            |               | AA, Pal, Sol  | 0.002           | Ixcatlán | Gathering, protection, propagation, transplanting of individuals                     | Ex situ, in situ                                         |
| Orchidaceae     | Phycnostele maculata (Lex.) Soto Arenas & Salazar                       | ERL-173, SRL-1476 | Monjita pinta  | Yes            |            |               | BEA, BEM, Pal, Sol | 0.002 | Ixcatlán | Gathering, protection, propagation, transplanting of individuals                     | Ex situ, in situ                                         |
| Orchidaceae     | Spirotheces sp.                                                         | RLF-208        | Monjita de peña | Yes            | 0          | Iz            |               |                 | Ixcatlán | Gathering                                                                                     | In situ                                                 |
| Orobanchaceae   | Castilleja tenuifolia (MMartens & Galeotti)                            | SRL-117, SRL-223, SRL-329, SRL-1438, SRL-1485 | Romero cimarrón | Yes            | Yes        | 0            | BEA, BN, Me, Palm |                 | Ixcatlán | Forage, gathering                                                                             | In situ                                                 |
| Orobanchaceae   | Conopholis alpina Liebm.                                                | SRL-218, SRL-1481 | Flor de elote  | Yes            | 0          | BEA, Pal     |               |                 | Ixcatlán | Fosage, gathering                                                                             | In situ                                                 |
| Orobanchaceae   | Lamourouxia dagamnha (Cham. & Schltdl.) WREimst                       | SRL-1379, SRL-1429 | Lisón          | Yes            | 0          | BEA, BEM, Me |               |                 | Ixcatlán | Gathering                                                                                     | In situ                                                 |
| Orobanchaceae   | Lamourouxia viscosa Kunth                                               | RLF-209, SRL-372, SRL-1292 | Moso de pava, flor de miel | Yes            | 0          | Iz, Pal, Palm |               |                 | Ixcatlán | Gathering, tolerance                                                                            | In situ                                                 |
| Orobanchaceae   | Oxalis aff. latifolia Kunth                                             | ERL-75, RLF-142, SRL-148 | Coyule         | Yes            | 0          | Iz, Me, Sol, TS |               |                 | Ixcatlán | Fosage, gathering, protection, tolerance                                                                 | In situ                                                 |
| Orobanchaceae   | Oxalis aff. nelsoni (Small) R.Knuth                                     | SRL-1273       | Coyule         | Yes            | 0          | Iz, Sol      |               |                 | Ixcatlán | Fosage, gathering, protection, propagation                                                                 | Ex situ, in situ                                         |
| Orobanchaceae   | Oxalis sp.                                                              | RLF-139        | Coyule delgado | Yes            | 0          | BEA, BEM, BN, Me |               |                 | Ixcatlán | Fosage, gathering                                                                             | In situ                                                 |
| Papaveraceae    | Argemone mexicana L.                                                    | ERL-244, RLF-180, SRL-455 | Chicalote      | Yes            | Yes        | 0            | Bal, Pal, Sol, TS |               | Ixcatlán | Gathering, tolerance, uproot                                                                 | In situ                                                 |
| Passifloraceae  | Passiflora bryonoides Kunth                                             | SRL-1148       | Granadilla     | Yes            | 0          | Sol          |               |                 | Ixcatlán | Gathering, protection, tolerance                                                                 | In situ                                                 |
| Passifloraceae  | Passiflora suberosa L.                                                  | SRL-444, SRL-1164, SRL-1165 |               | Yes            | 0          | Sol          |               |                 | Ixcatlán | Gathering, tolerance                                                                         | In situ                                                 |
| Passifloraceae  | Tumera diffusa Willd. ex Schl.                                          | SRL-1220, SRL-1356, SRL-1467 | Tamoreal       | Yes            | Yes        | 0            | CaCe, SB, Sol |               | Ixcatlán | Gathering, protection, transplanting of individuals                                   | Ex situ, in situ                                         |
| Phytolaccaceae  | Phytolacca icosandra L.                                                 | RLF-236        |               | Yes            | 0          | Iz           |               |                 | Ixcatlán | Gathering                                                                                     | In situ                                                 |
| Piperaceae      | Piperomia quadridifolia (L.) Kunth                                      | ERL-140, SRL-1404, 1430 | Verdolaga      | Yes            | 0.014      | BEM          |               |                 | Ixcatlán | Gathering, protection, transplanting of individuals                                   | Ex situ, in situ                                         |
| Plantaginaceae  | Bacopa monnieri (L.) Wettst.                                             | SRL-301, SRL-1132 | Verdolaga de agua | Yes            | Yes        | 0            | Paz, VR      |                 | Ixcatlán | Forage, gathering                                                                             | In situ                                                 |
| Plantaginaceae  | Penstemon barbatus (Cav.) Roth                                          | RLF-23, RLF-49, SRL-133, SRL-466, SRL-1314 | Bandera        | Yes            | Yes        | 0            | BEA, Palm    |               | Ixcatlán | Gathering                                                                                     | In situ                                                 |
| Plantaginaceae  | Ruselia obtusata S.F.Blake                                              | RLF-263, SRL-254, SRL-342, SRL-424, SRL-1494 | Bandera        | Yes            | 0          | BEA, BG, BN, Me |               |                 | Ixcatlán | Gathering                                                                                     | In situ                                                 |
| Plantaginaceae  | Ruselia sp.                                                             | SRL-1198       | Bandera        | Yes            | 0          | BEA          |               |                 | Ixcatlán | Gathering                                                                                     | In situ                                                 |
| Family         | Species                                                                 | Voucher number | Common name               | Ceremonial use | Edible use | Medicinal use | Basic plant | Sunrop index | Vegetation type | Origin | Management practices | Management site with respect to natural distribution |
|----------------|-------------------------------------------------------------------------|----------------|---------------------------|----------------|------------|---------------|--------------|--------------|-----------------|---------|----------------------|-----------------------------------------------|
| Poaceae        | Piptochaetium fimbriatum (Humb., Bonpl. & Kunth) Hitchc.                | RLF-137, SRL-260, SRL-413 | Pasto                    | Yes            |            |               |               | 0.038        | BEA, BG, Me, Paz       | Ixcatlán | Forage, gathering     | In situ                                       |
| Poaceae        | Setaria grisebachii E.Fourn.                                           | RLF-231, RLF-358 | Pasta de semilla        | Yes            |            |               |               | 0.038        | Iz, Palm, Paz               | Ixcatlán | Forage, gathering     | In situ                                       |
| Poaceae        | Setaria grisebachii E.Fourn.                                           | SRL-311         | Pasta de semilla        | Yes            |            |               |               | 0.038        | Ixcatlán                     | Forage, gathering | In situ                                      |
| Polemoniaceae  | Loeselia caerulea (Cav.) G.Don                                         | RLF-265, SRL-96, SRL-353, SRL-1267, SRL-1282, SRL-1354, SRL-1401, SRL-1458 | Yes | 0 | BEA, BN, CaCe, Me, Pal, Palm | Ixcatlán | Forage, gathering | In situ |
| Poaceae        | Piptochaetium fimbriatum (Humb., Bonpl. & Kunth) Hitchc.                | RLF-224, RLF-287 | Verdelaga de suelo      | Yes            |            |               |               | 0 | BEA, Iz                  | Ixcatlán | Forage, gathering     | In situ                                       |
| Portulacaceae  | Portulaca oleracea L.                                                   | Photo record    | Jabonera, hierba de pollo | Yes            |            |               |               | 0 | Pal, Sol                 | Naturalized, from other continents | Gathering, tolerance | Ex situ |
| Primulaceae    | Anagallis arvensis L.                                                   | ERL-108, ERL-228, RLF-200, SRL-87, SRL-100, SRL-1133 | Jabonera, hierba de pollo | Yes | 0 | Bal, BN, Iz, Palm, Sol, TS | Ixcatlán | Gathering | In situ |
| Pteridaceae    | Delphinium bicourtum Hemsl.                                             | SRL-1200        | Conejito                 | Yes            |            |               |               | 0 | BEA                       | Ixcatlán | Gathering | In situ |
| Rhamnaceae     | Condalia mexicana Schltdl.                                              | SRL-1223, SRL-1493 | Hierba de pajerito, campanita grande | Yes | 0 | Me, SB                  | Ixcatlán | Gathering | In situ |
| Rosaceae       | Bouvardia longifolia (Cav.) Kunth                                        | RLF-10, RLF-243, SRL-261, SRL-338, SRL-474, SRL-1257, SRL-1258 | Tlasisle       | Yes | 0 | BEA, BC, BN, Iz, Me, Palm, TS | Ixcatlán | Forage, gathering, tolerance | In situ |
| Rubiaceae      | Bouvardia longifolia (Cav.) Kunth                                        | Photo record    | Huelie de noche          | Yes            |            |               |               | 0 | Me                       | Ixcatlán | Gathering | In situ |
| Rubiaceae      | Bouvardia longifolia (Cav.) Kunth                                        | RLF-41, RLF-166, SRL-262, SRL-334, SRL-1417 | Ventorilla, flor de triste | Yes | 0 | BEA, BC, Me, Palm, Paz, TS | Ixcatlán | Forage, gathering, tolerance, uproot | In situ |
| Rubiaceae      | Chiococca alba (L.) Hitchc.                                              | SRL-336, SRL-470, SRL-1111, SRL-1331, SRL-1441 | Campanita       | Yes | 0.002 | CaCe, Me, Sol | Ixcatlán | Gathering, protection, transplanting of individuals | Ex situ, in situ |
| Rubiaceae      | Cuscuta sp.                                                             | RLF-136, SRL-1180 | Yes                       |               | 0 | Me, Palm      | Ixcatlán | Gathering | In situ |
| Rubiaceae      | Galiurn sp.                                                             | RLF-82, RLF-280, SRL-344 | Yes | 0 | BEA, Me, Pal, Palm | Ixcatlán | Gathering | In situ |
| Rubiaceae      | Randia crispata DC.                                                     | RLF-281, SRL-1208 | Limoncito de coyote      | Yes | 0 | BEA, Pal, VR  | Ixcatlán | Gathering | In situ |
| Rutaceae       | Prelea trifoliate L.                                                     | RER-196, RLF-27, RLF-308, SRL-274, SRL-466, SRL-467 | Hierba de zamillo | Yes | 0.002 | BEA, BC, BG, BN, Me, Pal, Sol, TS | Ixcatlán | Gathering, tolerance | In situ |
| Family         | Species                              | Voucher number | Common name                      | Ceremonial use | Edible use | Medicinal use | Basic plant | Suntrip index | Vegetation type | Origin | Management practices                                                                 | Management site with respect to natural distribution |
|---------------|--------------------------------------|----------------|----------------------------------|----------------|------------|---------------|--------------|---------------|----------------|---------|--------------------------------------------------------------------------------------|--------------------------------------------------------|
| Rutaceae      | Zanthoxylum sp.                      | SRL-1348       |                                  | Yes 0          |            |               |              |               |                | Ixcatlán | Gathering                                                                         | In situ                                                 |
| Santalaceae   | Phoradendron sp.                     | RLF-228, SRL-1268 | Injerto                        | Yes 0          | Iz, Me     |               |              |               |                | Ixcatlán | Gathering, uproot                                                                  | In situ                                                 |
| Selaginellaceae| Selaginella epidiphylla (Hook & Grev.) | SRL-374, SRL-1497 |                               | Yes 0          | BEA, Me    |               |              |               |                | Ixcatlán | Gathering                                                                         | In situ                                                 |
| Solanaceae    | Capsicum annuum L.                   | ERL-165, ERL-204 | Chilar de monte                | Yes 0          |            |               |              |               |                | Ixcatlán | Gathering                                                                         | Ex situ, in situ                                       |
| Solanaceae    | Capsicum sp.                         | RLF-135        |                                 | Yes 0          | Me         |               |              |               |                | Ixcatlán | Gathering                                                                         | In situ                                                 |
| Solanaceae    | Jaltomata procumbens (Cav.)          | SRL-180, SRL-1297 | Hiebre mora                    | Yes 0          | Palm, Sol  |               |              |               |                | Ixcatlán | Gathering, tolerance                                                             | In situ                                                 |
| Solanaceae    | Lycianthes ciliata (M.Martens & Galeotti) | SRL-1149      | Ojo de toro                    | Yes 0          | BEA, BG, Pal, Palm, Sol |                |               |                | Ixcatlán | Gathering, tolerance                                                            | In situ                                                 |
| Solanaceae    | Nicotiana glauca Graham               | ERL-37, RLF-105, SRL-171, SRL-1274 | Gignante                      | Yes 0          | Bal, Pal, Sol, TS |                |               |                | Naturalized, from other parts of American Continent | Gathering, tolerance                                      | Ex situ                                                 |
| Solanaceae    | Physalis philadelphia Lam.           | ERL-36, ERL-63, ERL-64, ERL-113, RLF-312, SRL-26, SRL-1138, SRL-1298 | Miltomate, tomate, tomate de milpa | Yes 0          | Sol         |               |              |               |                | Ixcatlán | Gathering, enhancement, protection, propagation, tolerance, transplanting of individuals | In situ                                                 |
| Solanaceae    | Solanum americanum Mill.             | SRL-1234       | Ticungo                         | Yes 0          | Sol         |               |              |               |                | Ixcatlán | Gathering, tolerance                                                             | In situ                                                 |
| Solanaceae    | Solanum mindsumham D.Don              | ERL-91         | Tepozán                         | Yes 0          | Sol         |               |              |               |                | Ixcatlán | Gathering, tolerance                                                             | In situ                                                 |
| Solanaceae    | Solanum minocotum Cav                 | ERL-195        | Tepozán                         | Yes 0          | BEA, BG, Pal, Palm, Sol |                |               |                | Ixcatlán | Gathering, tolerance                                                             | In situ                                                 |
| Solanaceae    | Solanum insti Hawkins & Hiet.        | RLF-151        | Hiebre del tomate pinto         | Yes 0          | Paz         |               |              |               |                | Ixcatlán | Gathering                                                                         | In situ                                                 |
| Solanaceae    | Solanum estratrum Dural              | SRL-380        | Chialote de burro               | Yes 0          | BEA         |               |              |               |                | Ixcatlán | Gathering                                                                         | In situ                                                 |
| Solanaceae    | Solanum rosapannum Dural             | RLF-22, RLF-95, RLF-120, RLF-275, SRL-128, SRL-302 | Tepozán                      | Yes 0          | Sol, BEA, BEC, Me, Pal, Paz |                |               |                | Ixcatlán | Gathering                                                                         | In situ                                                 |
| Thelypteridaceae| Thelypteris sp.                       | SRL-161, RLF-303 |                                 | Yes 0          | BEA, Iz, Pal |               |              |                |                | Ixcatlán | Gathering                                                                         | In situ                                                 |
| Tropaeolaceae | Tropaeolum majus L.                  | ERL-18, ERL-89, ERL-182, SRL-60, SRL-196 | Mastuerzo                  | Yes 0          | Sol         |               |              |               |                | Ixcatlán | Gathering, enhancement, protection, propagation, tolerance                        | Ex situ                                                 |
| Urticaceae    | Parthenaria pensylvonica MuH. ex Willd. | ERL-73, RLF-88, RLF-266, SRL-18 | Paletaria                      | Yes 0          | BEA, Pal, Sol, VR |                |               |                | Naturalized, from other parts of American Continent | Gathering, tolerance                                      | In situ                                                 |
| Urticaceae    | Urena crassafacina (Jacq.) Gaudich. ex Grizels | SRL-1543 | Chichicasle                  | Yes 0          | Sol         |               |              |               |                | Ixcatlán | Gathering                                                                         | In situ                                                 |
| Verbenaceae   | Glandularia elegans (Kurth) Umbre    | RLF-5, SRL-110, SRL-279, SRL-1326, SRL-1479 |                                 | Yes 0          | Bal, BEA, BN, Sol |                |               |                | Ixcatlán | Gathering                                                                         | In situ                                                 |
| Verbenaceae   | Lantana ochryanthifolia Desf.        | RLF-61, RLF-62, SRL-109, SRL-152, SRL-369, SRL-1296 | Hiebre buena de monte           | Yes 0          | BEA, BN, Me, Pal, Palm |                |               |                | Ixcatlán | Forage, gathering, tolerance, uproot                                              | In situ                                                 |
| Family    | Species                          | Voucher number | Common name                   | Ceremonial use | Edible use | Medicinal use | Basic plant Sutrop index | Vegetation type | Origin | Management practices                          | Management site with respect to natural distribution |
|-----------|----------------------------------|----------------|--------------------------------|----------------|------------|---------------|---------------------------|----------------|--------|-----------------------------------------------|-----------------------------------------------------|
| Verbenaceae | *Lantana camara* L.              | RLF-197, SRL-115, SRL-459, SRL-1112, SRL-1154, SRL-1169, SRL-1365 | Tiundica, siete negritos | Yes           | Yes       | 0             | BEA, BRC, BN, CaCe, Iz, Me, Palm, Sol | Ixcatlán        | Forage, gathering, protection, transplanting of individuals | Ex situ, in situ |
| Verbenaceae | *Lantana velutina* M. Martens & Galeotti | ERL-185, RLF-31, RLF-204, SRL-272, SRL-1115, SRL-1168 | Tiundica blanca, cinco negritos | Yes           | Yes       | 0             | BEA, BRC, BN, Iz, Me, Pal, Palm, Sol | Ixcatlán        | Gathering, tolerance, transplanting of individuals | Ex situ, in situ |
| Verbenaceae | *Lippia graveolens* Kunth       | SRL-71, SRL-1378, SRL-1454, SRL-1549 | Oreganillo, salvarreal de castilla | Yes           | Yes       | 0             | CaCe, Me, Pal              | Ixcatlán        | Forage, gathering                              | In situ                                           |
| Verbenaceae | *Lippia oaxacana* B.L. Rob. & Greenm. | SRL-101, RLF-173, SRL-1373, SRL-1535 | Tripa de diablo               | Yes           | Yes       | 0.014         | CaCe, Sol, TS              | Ixcatlán        | Gathering, tolerance, transplanting of individuals | Ex situ, in situ |
| Vitaceae   | *Cissus* sp.                     | RLF-101, RLF-173, SRL-1373, SRL-1535 | Tripa de diablo               | Yes           | Yes       | 0             | CaCe, Sol, TS              | Ixcatlán        | Gathering, tolerance, uproot                    | In situ                                           |

### Key to collector
- ERL = Erandi Rivera Lozoya
- JS = José Rosario Jiménez Salazar
- SRL = Selene Rangel Landa
- RLF = Ricardo Lemus Fernández

### Key to vegetation type
- AA = ancient settlements
- Bal = urban secondary vegetation
- BEA = *Quercus liebmannii* and *Q. laeta* forest
- BRC = *Quercus urbanni* forest
- BEM = *Quercus* spp. forest
- BG = gallery forest (*Taxodium huegelii*)
- BN = *Juniperus flaccida* forest
- CaCe = *Cephalocereus columna-trajanni* shrubland
- CaMy = *Pseudomytrocereus fulviceps* shrubland
- Iz = Izotal (shrubland dominated by rosettes)
- Iz = *Mexical*
- Pal = mescal factories
- Palm = palm shrubland of *Brahea dulcis*
- Paz = grassland
- SB = tropical dry forest
- Sol = homegardens
- TS = agricultural fields
- VR = riparian vegetation
Ornamenting of altars is mostly attended with plants cultivated in homegardens. Due to the scarcity of copal and other plants used in ceremonies, people practice gathering them in different sites throughout their territory (Tables 5 and 6). In addition, we recorded storing of copal resin for use throughout the year (Table 5).

Several species considered scarce in the wild are, however, enough for satisfying the needs of the community; this is particularly the case of Tillandsia grandis (Table 5). The availability of useful plants depends on seasonality, annual rainfall, and incidence of pests (Tables 5 and 6).

Gathering was the only practice for 28 ornamental species (Table 3); species used for ornamenting the altars are gathered by women in areas close to the village, but plants used in communitarian celebrations, as well as the resin of Bursera spp., are carried out by men (Table 5). Journeys for gathering these products may take several hours or days and are considered dangerous activities, particularly those to obtain Beaucarnea stricta, T. grandis, and Burmannia biflora (Table 6). For the extraction of these plants, several techniques are common to prevent damage, such as leaving stems and main branches of the most valuable species (orchids, B. biflora, B. stricta, C. alba, and L. glaucescens). These techniques favor survival and resprouting of plants (Table 6). In total, 22 species that germinate and
| ID  | Species                                      | Us | SIB | SIU | Con | UF | Var | EI  | R1  | SCS  | UP | HEP | HT0 |
|-----|----------------------------------------------|----|-----|-----|-----|----|-----|-----|-----|------|----|-----|-----|
| Bbif | Bursera biflora (Rose) Standl.              | 7  | 0   | 0.028 | 1  | 5  | 1 | 1, 3 | 1, 2, 3, 6 | 4  | 3  | 9  |
| Blon | Bouvardia longiflora (Cav.) Kunth           | 1  | 0   | 0.006 | 0.01 | 3  | 0 | 1 | 1  | 2  | 1  | 1  |
| Bstr | Beaucarnea stricta Lem.                    | 2  | 0.005 | 0 | 1 | 4  | 0 | 1 | 1, 2, 3 | 1  | 2  | 4  |
| Calb | Chiococca alba (L.) Hitchc.               | 3  | 0.002 | 0.066 | 0.99 | 4  | 0 | 1 | 1  | 2  | 2  | 1  |
| Dser | Dasylirion serratifolium (Karw. ex Schult. & Schult.f.) Zucc. | 5  | 0.010 | 0 | 1 | 4  | 2 | 1 | 1, 2, 3 | 1  | 2  | 7  |
| Dspp | Dahlia apiculata (Sherff) P.D.Sorensen; Dahlia coccinea Cav. | 2  | 0 | 0.12 | 4  | 1 | 1 | 0 | 2  | 1  | 1  |
| Ekar | Euchile karwinskii (Mart.) Christenson      | 3  | 0.002 | 0.033 | 0.99 | 3.5 | 0 | 1 | 1, 2, 3 | 0  | 2  | 1  |
| Erad | Epidendrum radioferens (Ex Com.) | 2  | 0.002 | 0.85  | 3  | 0 | 1 | 1, 2, 3 | 0  | 3  | 1  |
| Lalb | Lactea albida Bateman ex Lindl.            | 2  | 0.002 | 0.052 | 0.77 | 4  | 0 | 1 | 1, 2, 3 | 0  | 2  | 1  |
| Ldas | Lamourouxia dasyantha (Cham. & Schltdl.) W.R. Ernst | 2  | 0 | 0.039 | 0.17 | 3  | 2 | 1 | 1  | 2  | 1  |
| Lgla | Litsea glaucescens Kunth                   | 3  | 0.010 | 0 | 1 | 6  | 0 | 1 | 1, 2, 3, 4 | 1  | 3  | 3  |
| Lmes | Lindleya mespiloides Kunth                 | 2  | 0  | 0.015 | 0.05 | 4  | 0 | 1 | 1, 2, 3 | 0  | 1  | 1  |
| Mdep | Meteorium deppei (Hornsch. ex Müll. Hal.) Mitt. | 2  | 0 | 0 | 1 | 4  | 1 | 1 | 0 | 2  | 1  |
| Octa | Octavillo                                   | 2  | 0  | 0.025 | 0.01 | 2 | 0 | 1 | 1, 2, 3 | 0  | 1  | 2  |
| Prub | Plumeria rubra L.                          | 2  | 0 | 0.007 | 0.05 | 2  | 2 | 1, 3 | 1  | 0  | 2  | 3  |
| Rmac | Rhynchostele maculate (Lex.) Soto Arenas & Salazar | 2  | 0.002 | 0.095 | 0.92 | 2 | 0 | 1 | 1, 2, 3 | 0  | 2  | 3  |
| Spur | Salsola purpurea Cav.                      | 3  | 0  | 0.016 | 0.05 | 3.3 | 2 | 1 | 1  | 0  | 2  | 1  |
| Tgra | Tillandsia grandis Schltdl.                | 2  | 0 | 0.009 | 1 | 5 | 0 | 1 | 1  | 1  | 2  | 9  |
| Tluc | Tagetes lucida Cav.                        | 4  | 0.003 | 0.007 | 0.5 | 1 | 0 | 1 | 1, 2, 3 | 0  | 2  | 1  |
| Tusn | Tillandsia usneoides (L.) L.               | 5  | 0 | 0 | 1 | 3 | 0 | 1 | 1  | 0  | 2  | 1  |
| Acris | Anoda cristata (L.) Schltdl.              | 4  | 0 | 0.012 | 0.05 | 2 | 0 | 1 | 1  | 0  | 3  | 2  |
| Ahyb | Amaranthus hybridus L.                    | 3  | 0.024 | 0.252 | 0.95 | 4.5 | 3 | 1, 3 | 1, 2, 4 | 1  | 3  | 1  |
| Aker | Agave kerchovei Lem.                      | 4  | 0 | 0.015 | 0.2 | 2 | 0 | 1 | 1, 2, 3 | 0  | 1  | 3  |
| Apot | Agave potatorum Zucc.                     | 8  | 0.057 | 0.072 | 0.25 | 3.5 | 2 | 1 | 1, 2, 3, 4 | 1  | 2  | 3  |
| Bdul | Breda dolcis (Kunth) Mart.                | 11 | 0.106 | 0.002 | 1 | 2 | 0 | 1, 2, 3, 4 | 1 | 3, 5 | 6 | 5 | 3 | 7 |
| Cber | Chenopodium berlandieri Moq.              | 2  | 0.006 | 0.022 | 0.15 | 3 | 3 | 1 | 1, 2, 3 | 0  | 1  | 3  |
| Crme | Crataegus mexicana Moc. & Sess, ex DC       | 1  | 0.002 | 0.011 | 0.35 | 4 | 3 | 1, 2, 3 | 1, 2 | 0, 1, 2, 3, 6 | 1 | 2 | 1  |
| Damb | Dipsidia ambrosioides (L.) Mosyakin & Clemants | 3  | 0.065 | 0.024 | 1 | 6 | 3 | 1, 3 | 1, 2, 3, 4 | 2 | 2 | 1  |
| Dser | Dasylirion serratifolium (Karw. ex Schult. & Schult.f.) Zucc. | 5  | 0.010 | 0.110 | 0.95 | 4 | 2 | 1 | 1, 2, 3, 4 | 0 | 2 | 3 | 7 |
| Lgla | Litsea glaucescens Kunth                  | 3  | 0.010 | 0.026 | 0.14 | 3.5 | 0 | 1 | 1, 2, 3, 4 | 1 | 3 | 3  |
| Lspp | Lantana camara L.; L. velutina M.Martens & Galeotti | 5  | 0 | 0 | 0.05 | 4.5 | 1 | 1 | 1  | 0  | 2  | 1  |
| Msspp | Mammillaria haageana Pfeiff.; Mammillaria spachelata Mart. | 3  | 0 | 0 | 0.05 | 3.3 | 1 | 1 | 1, 2 | 0  | 2 | 1  |
| Noff | Nasturtium officinale R.Br.                | 1  | 0.002 | 0.013 | 0.15 | 2.5 | 0 | 1 | 1  | 0  | 1  | 1  |
| Oas | Opuntia lasiacantha Pfeiff.               | 6  | 0.042 | 0.043 | 1 | 6 | 3 | 1, 3 | 1, 2, 1, 2, 4, 6 | 5 | 3 | 5  |
| Ospp | Opuntia aff. latifolia Kunth; Opalis aff. nelsonii (Small) R.Knuth | 2  | 0 | 0.007 | 0.45 | 3 | 1 | 1, 3 | 1, 2, 4, 6 | 1 | 3 | 1  |
| Pliu | Parthenium linaria (Cav.) DC.             | 2  | 0 | 0.078 | 0.95 | 6 | 0 | 1, 3 | 1, 2, 4 | 6 | 3 | 1  |
| Pole | Portulaca oleracea L.                    | 3  | 0 | 0.010 | 0.05 | 4 | 0 | 1 | 1  | 0  | 1  | 3  |
| Pphi | Physalis philadelphica Lam.              | 2  | 0 | 0.035 | 0.15 | 6 | 0 | 1 | 1, 2, 3, 4 | 1 | 3 | 3  |
| Pquia | Peperomia quadrifolia (L.) Kunth        | 2  | 0.014 | 0.070 | 0.95 | 4 | 3 | 1 | 1, 2, 3 | 0 | 1 | 3  |
| Prud | Porophyllum ruderale subsp. macrocephalum (DC.) R.R.Johnson | 1  | 0.004 | 0.161 | 0.9 | 5 | 0 | 1, 3 | 1 | 2 | 1  |

**Table 5** Sociocultural parameters estimated for species considered in in-depth studies.
Selective harvesting of plants based on use quality of their parts and absence of signs of herbivory are criteria for gathering most species documented. Although local people recognize at least five species with intraspecific varieties (identified according to flower color and forms), their use and management are indistinct (Tables 5 and 7). Except for *Tagetes erecta*, in which people select seeds for cultivation, and *Cosmos bipinnatus*, a species commonly producing violaceus ligula, people select the scarcer variety with white ligula.

Local regulations forbid extraction of plants for commercialization out of the village and establish restrictions in using some plants in communitarian celebrations (Table 7).

### Edible plants

We recorded 138 plant species used as food, 80 of them being wild and naturalized species and 20 considered as “basic” (Tables 3 and 4). The most valuable species are *Amaranthus hybridus*, *Porophyllum* spp., *Opuntia lasiancanta*, *Dysphania ambrosioides*, *Dasylirion serratifolium*, *Peperomia quadrifolia*, and *Physalis philadelphica*, which are consumed by more than 90% of households from 1 to...
| Use     | ID  | Species                          | Management motives and observations about use and availability                                                                                                                                                                                                                                                                                                                                 |
|---------|-----|----------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ceremonial | Bbif | *Bursera biflora* (Rose) Standl. | Trees are abundant, but copal could become scarce. Care should be taken not to damage the tree, to tree continue producing the copal. Only the one produced naturally, by the worm (butterfly larvae) in hot terrain is good for burning. Not (transplant or cultivation) because the tree would not survive or produce copal here in the village. I have a little tree that I take out of the forest for the luxury of my house and I hope that someday it will produce copal, although maybe it would not be enough or good. I plant a stick, there in the mountain where I go to collect the “copal”, I did to see if it roots. |
| Ceremonial | Blon | *Bouvardia longiflora* (Cav.) Kunth | Now it is almost no longer used, there are other flowers (flowers of introduced species).                                                                                                                                                                                                                                                                                                                                                                     |
| Ceremonial | Bstr | *Beaucarnea stricta* Lem.        | The gathering is dangerous, the plant is in very difficult places to walk. Care must be taken to not injure the tree, the [apical meristem], so that the plant continues to produce, sometimes the tree is damaged, but that should not be done.                                                                                                                                                                                                                                  |
| Ceremonial | Calb | *Chiococca alba* (L.) Hitchc.    | Before it was used [to offer it] in the church, but now no longer because they criticize, only is placed on the altars of the houses. I really like its flowers, its scent, I put it on my altar. Once I brought a little tree to the house but it do not survive. Out of curiosity I try to [cultivate], but it does not [germinate].                                                                                                                                                  |
| Ceremonial | Dser | *Dasylirion serratifolium* (Karw. ex Schult. & Schult.f.) Zucc. | It should leave part of the trunk, if there is good rain it can sprout. It has not occurred to us to bring the plant to the village, “it is natural” [it occurs naturally in the field], we always have found it to make the adornments.                                                                                                                                                                             |
| Ceremonial | Dspp | *Dahlia apiculata* (Sherff) P.D.Sorensen; *Dahlia coccinea* Cav. | I like to have them in the house, for luxury [ornamental use] and put the flowers on the altar.                                                                                                                                                                                                                                                                                                                                                               |
| Ceremonial | Ekar | *Euchile karwinskii* (Mart.) Christenson | It must remain [pseudobulbs] to have it for another time, they are the ornament of the trees [in the forest]. After the flower dries, the (pseudobulb) is placed in some tree in the house, and so it is going to have for luxury [ornamental use] and have flowers to adornment the altar. When I am gathering firewood and I cut a branch that have “monjitas” [orchids], sometimes I transplant it in other branch and sometimes I bring it to the house. |
| Ceremonial | Erad | *Epidendrum radioferens* (Ames, F.T.Hubb. & C.Schweinf.) Hägsater | It must remain [pseudobulbs] to have it for another time. They are the ornament of the trees [in the forest]. After the flower dries, is placed in some tree in the house, and so it is going to have for luxury [ornamental use] and have flowers to adornment the altar, however it is difficult, it is a delicate plant. |
| Ceremonial | Lalb | *Laelia albida* Bateman ex Lindl. | I take care it [cultivation] to have flowers for the altar in Todos Santos [celebration] and for the luxury of my home.                                                                                                                                                                                                                                                                                                                                     |
| Ceremonial | Ldas | *Lamourouxia dasyantha* (Cham. & Schltdl.) W.R. Ernst | There is much when rain is good, but when it is not given, I use whatever available flower.                                                                                                                                                                                                                                                                                                                                                               |
| Ceremonial | Lgla | *Litsea glaucescens* Kunth        | There is a lot in the forest, there is always when it is needed and the tree will regrow if you do not hurt it. I have not had the curiosity [transplanting] and the need because there is [enough], and there is also little terrain to have it maybe it will dry. Out of curiosity, I put some seeds but they did not germinate. |
| Ceremonial | Lmes | *Lindleya mespiloides* Kunth      | There is a lot in the forest, but sometimes there are no flowers due to the drought.                                                                                                                                                                                                                                                                                                                                                                           |
| Ceremonial | Mdep | *Meteorium deppei* (Hornsch. ex Müll. Hal.) Mitt. | After the celebration, I put it in my yard for luxury, but it dried.                                                                                                                                                                                                                                                                                                                                                                                                  |
| Ceremonial | Octa | “Octavillo”                       | I have always found when I am going to collect, but sometimes, in order to not go up to the mountain, I better buy others [other plants in regional markets]. I think it would not survive [transplanting, cultivation], is a delicate plant and its environment is very different, more template.                                                                                                                                                    |
Table 6 Meaningful consultant’s commentaries about the use, abundance, and their motives to manage plants (Continued)

| Use       | ID    | Species                                | Management motives and observations about use and availability                                                                 |
|-----------|-------|----------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Ceremonial| Prub  | *Plumeria rubra* L.                    | I have not tried [propagation], I have not had the curiosity, I like it a lot but I do not try to have it, but there are people that have it. I plant a stick to have the tree here in the house, but it rotted, maybe I try again later. |
| Ceremonial| Rmac  | *Rhynchostele maculate* (Lex.) Soto Arenas & Salazar | It must remain [pseudobulbs] to have it for another time. They are the ornament of the trees [in the forest]. After the flower dries, the [pseudobulb] is placed in some tree in the house, and so it is going to have for luxury [ornamental use] and have flowers to adornment the altar. It is difficult take care of it because it is delicate, but it is a pride to have it. |
| Ceremonial| Spur  | *Salvia purpurea* Cav.                  | Used more before. There is much when rain is good, but when it is not given, I use whatever available flower, now there are other flowers [introduced that are grown or bought in local stores]. Once I take one from the mountain, to have the flowers for my altar and luxury of the house, but it dried and I have not tried again. |
| Ceremonial| Tgra  | *Tillandsia grandis* Schltdl.           | There has always been when it is needed. Once I brought some small plants [transplanting] but dried, is very delicate, needs its natural environment. |
| Ceremonial| Tluc  | *Tagetes lucida* Cav.                   | There is much when rain is good, but when it is not given, I use whatever available flower. |
| Ceremonial| Tusn  | *Tillandsia usneoides* (L.) L.          | I have this plant, I bring it from the mountain and from the adornment of holidays, it is for decoration of my trees and also to feed the cattle when there is nothing, to clean the frets, for what is could needed here I got it near, in my house. |
| Edible    | Acris | *Anoda cristata* (L.) Schltdl.          | Before the people collected it, they gathered. Now it is scarce and people say that who eats it does not have money to buy food. |
| Edible    | Ahyb  | *Amaranthus hybridus* L.                | It is very tasty, it is important to eat it, but it is left to the time and the rain, there has been no need to cultivate it, it is only left on the edge of the cropland to produce seed. There are different colors but if it is “tierno” [shoots] taste does not change, but others prefer the green. When there are a lot and is “sazón” [mature] it could damage the other plants so it is plucked. |
| Edible    | Aker  | *Agave kerchovei* Lem.                  | People say that when someone eats “cacayas” [floral buttons] it’s because they do not have money for food, but we like it. Only is gathered, it is close, it is not necessary to propagate it. |
| Edible    | Apot  | *Agave potatorum* Zucc.                 | This “cacaya” was eaten a lot, was eaten boiled with sauce when there was nothing else or when corn was scarce it was mixed with the nixtamal [boiled corn] to raise it to make the tortillas. When we cooked maguey with coyule [Oxalis spp.] we gave to friends and relatives and other part is for sell it. Now people have it in their fields for mescal, but it was getting scarce, now they are sowing it [mescal producers and external institutions]. Its leaf and thorns vary in shape and color, its size is different, ones gives more mescal, although we like it to be large we cut everything. When we collect seed for [cultivate] it, we go to sites where we know the maguey is big and produce more mescal, others only get the first [capsules with seeds] available. |
| Edible    | Bdul  | *Brahea dulcis* (Kunth) Mart.          | When a field is opened [for agriculture], the palm is left, it is our sustenance, the hat. I do not wave the hat but my neighbors do it, it is the sustenance of the town, it is the motive because I left it in my terrain [tolerance]. |
| Edible    | Cber  | *Chenopodium berlandieri* Moq.          | Abundance: Before there was more because they no longer work the land as the older. On the edge of the land some are left (tolerated) to produce seeds and there are for the next year. |
| Use | ID | Species | Management motives and observations about use and availability |
|-----|----|---------|-------------------------------------------------------------|
| Edible | Crme | *Crataegus mexicana* Moc. & Sess, ex DC | Before there were more, now no one cares for them, the animals eat [cattle]. There are with large and small fruit, with sweet and sour taste. I tried to [propagates] but it does not [germinate]. |
| Edible | Damb | *Dysphania ambrosioides* (L.) Mosyakin & Clemants | Sometimes my neighbor and my aunt ask me for some of it and as I have, I give them a little. I saw a little plant that I liked for its large and green leaves and brought it to my house, I take care of it and now I have all the time. There are green, purple and “criollo” (from the store), the last does not have smell, nor taste. |
| Edible | Dser | *Dasylirion serratifolium* (Karw. ex Schult. & Schult.f.) Zucc. | Although the plant is abundant, the “manita” [Floral buttons] becomes scarce because of the drought, when that happens we were left with the desire to eat it that year. It has not occurred to me to take the “manita” plant to the village, “it is natural”. There are green “manitas” that are sweet and purples that are bitter, but at the whim we eat the same two. |
| Edible | Lgla | *Litsea glaucescens* Kunth | For food it requires little, a few twigs. I have not had the curiosity, the need [propagation], I only go to the field and collect it. Out of curiosity, I put some seeds but they did not germinate. |
| Edible | Lspp | *Lantana camara* L.; *L. velutina* M.Martens & Galeotti | They eat it when they go to the field, but they are not sweet, they are simple. |
| Edible | Mspp | *Mammillaria haageana* Pfeiff.; *Mammillaria sphacelata* Mart. | I brought one to my house for luxury, not to eat the “chilitos” [fruits], I like the way it looks. |
| Edible | Noff | *Nasturtium officinale* R.Br. | It is no longer consumed because there is no one who collects it. When harvested, the root must be left to it could sprout. |
| Edible | Olas | *Opuntia lasiacantha* Pfeiff. | As I have many plants I always have, I give it to my family when they ask me and sometimes other people come to ask me, sometimes I give them and others I sell it depending on how much it is. I brought a “penquita” [cladode] and now all those who fall and take root I care of them because it is the “nopal” that I like, those that come from outside are not good. There are some more spiny than others and they give “tunas” [fruits] of different color. |
| Edible | Ospp | *Oxalis aff. latifolia* Kunth; *Oxalis aff. nelsonii* (Small) R.Knuth | I brought this [Oxalis plant] out of curiosity, for luxury of the house [ornamental], when we want make the “conserva” [Traditional dish prepared with *Agave potatorum* stems and *Oxalis* leaves] we go to the mountain where it grow big. |
| Edible | Plin | *Porophyllum linaria* (Cav.) DC. | Its left on the edge of the cropland to produce seed. Some people have had the curiosity to cultivate it, they have it all the time, sometimes they give me a little. I only like the plants that I have inside of the “corralito” [space inside the yard delimited by a fence] or that are in crop lands, it is abundant in roads and the yard but is nasty by the animals. |
| Edible | Pole | *Portulaca oleracea* L. | I leave some plants to flower and give seed to have in abundance next year, although when it is a lot it is plucked. |
| Edible | Pphi | *Physalis philadelphica* Lam. | Last year was good [good production], it reach to give 6 kilos to my brothers who live outside It is abundant, but it is because we take care of it. I leave some [fruits] so that the next year can continue, in homegardens is watered, fertilized, so that they can produce [fruits]. There is “milomate” of the maize crop land, “dulce” (sweet) from the wheat cropland and one big that we get in the store, the last one is not so good and to have [manage and cultivate] we choose the milomate and the sweet, of which it is pretty [big]. |
Table 6 Meaningful consultant’s commentaries about the use, abundance, and their motives to manage plants (Continued)

| Use    | ID  | Species                                      | Management motives and observations about use and availability                                                                                                                                                                                                                                                                                                                                                     |
|--------|-----|-----------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Edible | Pqua| *Peperomia quadrifolia* (L.) Kunth            | Now that we are old and we can not go to the mountain, we just eat it when my son-in-law shares us. There is, but it is retired, in rains it is more [juicy]. The one from Gandudo is more tastier. Somebody brought to have here, but it dries, here is not their environment.                                                                                           |
| Edible | Prud| *Porophyllum ruderale* subsp. *macrocephalum* (DC.) R.R.Johnson | I have not had the curiosity to sow it, but there are some people who have it in their homes, they take care of it and have to eat all the year. When it is collected only the tender twigs should be cut so that it continues to sprout.                                                                                                    |
| Medicinal | Amai | *Ageratina mairetiana* (DC.) R.M.King & H.Rob. | Only the twigs are cut, the rest is left and thus sprouts. Only the twigs are cut, if everything is harvested, it runs out. When there is one in the house or the agricultural field, is tolerated.                                                                                             |
| Medicinal | Apsi | *Ambrosia psilostachya* DC.                  | In the harvest, the twigs are cut and the stem is left so it can sprout. We do not bring it to the house because we do not know if it will survive, we do not know what it need to produce. We store it because there is no in dry season.                                                                                                       |
| Medicinal | Bsai | *Barkleyanthus salicifolius* (Kunth) H.Rob. & Brettell | Before, many people had it in their homes, now they do not like it so much. It is easy to have it, does not need care as fertilizer or irrigation. I have it, because when it is needed, I only go to the yard, besides it’s luxury [ornamental] for my house.                                                                                   |
| Medicinal | Cline | *Clinopodium mexicanum* (Benth.) Govaerts | It is not necessary to cut all the plant, only the twigs, leaving the stem can sprout and continues [be available]. I always have dry, it is more to drink, because it is almost not used as medicine. For medicine, it is collected when it’s needed, is not necessary to bring it [to the houses]. Here [mescal factory] it is natural [natural distribution], we only take care of it when is harvested and that the animals (cattle) do not foraged it. |
| Medicinal | Cmex | *Chrysactinia mexicana* A.Gray              | I have not tried to bring it to the house, but if I would do it, it could be, to do not have to go by it, although I do not know if it could survive. I always have some of this plant, I let it dry and I keep it for when it is needed, when I go to the field and there are, I gather it, so I always have. When I need it and I do not have it stored, I ask someone to give me a little. |
| Medicinal | Dcar | *Dalea carthagenensis* (Jacq.) J.F.Macbr. | This is no longer used so much, but when I need it I’m going to gather it to the edge of town or somebody brings it to me.                                                                                                                                                                                                                                                                   |
| Medicinal | Gglu | *Gymnosperma glutinosum* (Spreng.) Less.     | There is much everywhere, you only have to gather it when do you need it.                                                                                                                                                                                                                                                                                                                                                   |
| Medicinal | Ginu | *Grindelia inuloides* Willd.                | There are those who have it (managed in the houses or dry), when it is needed, we ask them for it or we are going to look for it to field. I think it is not difficult, but maybe the soil did not help to survival of the one that I tries to propagate.                                                                                   |
| Medicinal | Loax | *Lippia oaxacana* B.L.Rob. & Greenm.        | Only the twigs are cut so that it can sprout. When drying this plant does not lose its quality, it is very strong. We store it so we can have it when we need it. I worry that there is not [available when its needed], but I do not bring seedlings to the house because if I bring them and they dry, I will only run out them. I brought a little plant but it dried. |
| Medicinal | Mpar | *Malva parviflora* L.                       | I leave some plants on the edge to have it, but when there is a lot, it must be rooted out.                                                                                                                                                                                                                                                                                                          |
| Medicinal | Mpur | *Matelea purpusii* Woodson                  | I brought it to my house because I’m [need it], so I always have it here.                                                                                                                                                                                                                                                                                                                                                   |
10 times per season (Fig. 2, Table 5). About 40 species are occasionally consumed where they are gathered and rarely carried to homes. These are the cases of *Chrysactinia mexicana* and *Cyrtocarpa procera*. Other 30 species are consumed occasionally, but it is considered that most of them were highly consumed in the past; these are the cases of *Chenopodium* spp., *Anoda cristata*, *Nasturtium officinale*, *Agave kerchovei*, and *A. potatorum*. Consumption of these plants has decreased due to higher presence of cultivated and processed food (Table 6). Other species are consumed occasionally by few households, as is the case of *L. glaucescens* which is used as a condiment or *Tagetes lucida*, *Lippia* sp., and *Turnera diffusa*, which is used as a condiment or *Tagetes lucida* Cav. (Continued)

| Use       | ID  | Species                        | Management motives and observations about use and availability |
|-----------|-----|--------------------------------|---------------------------------------------------------------|
| Medicinal | Mvul| Marrubium vulgare L.           | Is very resistant, while more you cut, more there are. I leave some plants on the edge to have it, but when there is a lot, it must be rooted out. |
| Medicinal | Ppen| Parietaria pensylvanica Muhl. ex Wild. | There are at the edge of the village, in my house I leave them in case that someday I would need it. |
| Medicinal | Pros| Pinarappus roseus (Less.) Less. | Before it was used when it was at hand, there are others that are used for [the same]. |
| Medicinal | Rcom| Ricinus communis L.            | I have of the two [green and red] each one has its use, they are also luxury [ornamental]. I brought the first from the road, I transplant the [seedlings] and take care of them, there are those who have taken the seed of those that they need to sow it. When they are abundant, they have to be rooted out. |
| Medicinal | Spra| Senecio praecox (Cav.) DC.     | Now little is used, before it was stored, now only a few use it. I brought a little plant, out of curiosity, now it is luxury of my house [ornamental] and by the time I need it I have it at hand. |
| Medicinal | Tdif| Turnera diffusa Willd. ex Schult. | When drying this plant does not lose its quality, it is very strong. When I need it and I do not have it stored, I ask someone to give me a little. |
| Medicinal | Tluc| Tagetes lucida Cav.            | I always have dry for when it is needed, this plant does not lose its quality when is drying, it is very strong. If part of the stem is left it can sprout, it must be left to continue [be abundant]. |
| Medicinal | Apot| Agave potatorum Zucc.          | Now few cooked the “conserva” [maguey stem cooked with *Oxalis* spp. leaves], but when they do it, they share it with their friends or they also sell it. The cacayas are eaten [flowers] when we meet one while walking in the field, to make mescal we have to go especially to cut the maguey and sometimes we have to buy it to other communities. Now there is scarce before there was here on the shore, now we have to walk to find, about three hours or more to [prepare] the mescal. Now [governmental] programs bring the maguey, we plant them in the fields and some [mescal producers] are already producing the plant, but it still lacks [time] to have it again. |
| Medicinal | Qacu| Quercus acutifolia Née         | When needed [for medicinal use] we look for it, just a few branches with tender leaves. It is also widely used by firewood. For wood, trees should not cut only the branches. I have two little trees, I brought acorns to feed my animals, but I leave some because I like these plants, but it is difficult they are delicate they hardly [germinate or survive], it takes a lot of patience and a lot of cares. |

*Excluded variables and species in the performance of principal component analyses (PCA) and canonical correspondence analyses

Commercialization of managed weedy plants is allowed, and the most common is the green tomato *P. philadelphica*. Others occasionally commercialized are *O. lasiacantha* and cooked *A. potatorum* (Table 5). *P. philadelphica*, *C. mexicana*, *Porophyllum* spp., and *D. ambrosioides* are interchanged in local stores (Table 5). Local people share with relatives and friends part of the plants gathered or harvested (Tables 5 and 6). These are the cases of *D. serratifolium*, *P. quadrifolia*, *C. mexicana*, *P. philadelphica*, *D. ambrosioides*, *Opuntia* spp., *Porophyllum* spp., *A. potatorum*, and *A. hybridus*.

Most edible plant species are considered abundant (Table 7), but such abundance is associated with care during extraction or the management in crop fields and
### Table 7 Ecological and management parameters estimated for species considered in in-depth studies

| ID | APe | VEA | LCI | Rep | HPa  | Nea | TAv | Cre | MPr | Sel | MAFS | MLA | MST |
|----|-----|-----|-----|-----|------|-----|-----|-----|-----|-----|------|-----|-----|
| **Ceremonial** | | | | | | | | | | | | | |
| Bbif | 4 | 2 | 2 | 1, 2, 9 | 1 | 2 | 1 | 2, 6 | 0 | 0.05 | 1 | 1, 3 |
| Blon | 2 | 2 | 2 | 5 | 3 | 2 | 0 | 1 | 1 | 0 | 0 | 1 |
| Bstr | 3.3 | 3 | 2 | 2 | 3 | 3.3 | 1 | 1, 2 | 1 | 0 | 0 | 1 |
| Calb | 1.5 | 3.5 | 2 | 2 | 1, 5 | 3.5 | 2 | 1 | 2 | 1 | 0 | 0 | 1 |
| Dser | 2 | 2 | 2 | 8, 9 | 4 | 1 | 1, 2 | 1, 2 | 1 | 0 | 0 | 1 |
| Dsp | 2.5 | 2 | 2 | 1 | 5, 9 | 3.5 | 2 | 1 | 2, 7 | 1 | 0.17 | 4 | 1, 3 |
| Ekar | 3.5 | 2 | 2 | 1, 8, 9 | 1 | 3 | 1 | 1, 2, 5, 6 | 1 | 0.63 | 1 | 1, 3 |
| Erad | 3.5 | 1 | 2 | 1, 8, 9 | 1.5 | 3 | 1 | 1, 2, 5, 6 | 1 | 0.32 | 1 | 1, 3 |
| Laib | 5 | 2 | 2 | 1, 8, 9 | 1 | 3 | 1 | 1, 2, 5, 7 | 1 | 1.29 | 1 | 1, 3 |
| Ldas | 1.5 | 3 | 2 | 2 | 5 | 3 | 3 | 0 | 1 | 1 | 0 | 1 |
| Lgla | 2 | 2 | 2 | 5 | 3.5 | 1 | 1, 2, 3 | 1 | 0.63 | 1 | 1, 3 |
| Lmes | 2 | 3 | 2 | 2 | 5 | 4 | 3 | 0 | 1 | 1 | 0 | 0 | 1 |
| Mdep | 1 | 1 | 2 | 1 | 10 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| Octa | 3 | 4 | 2 | 2 | 5 | 3 | 1 | 1 | 2 | 1 | 0 | 0 | 1 |
| Prub | 4 | 0 | 2 | 2 | 5 | 1 | 2 | 0 | 1, 7 | 1 | 0.10 | 3 | 1, 3 |
| Rmac | 3.5 | 2 | 2 | 1, 8, 9 | 1 | 3 | 1 | 1, 2, 5, 6 | 1 | 0.30 | 1 | 1, 3 |
| Spur | 3.5 | 2 | 1 | 2 | 5 | 3 | 3 | 1 | 1, 2 | 1 | 0 | 0 | 1 |
| Tgta | 4 | 4 | 2 | 2 | 10 | 2 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| Tluc | 2.7 | 2 | 2 | 2 | 9 | 4 | 2 | 0 | 1 | 0 | 0 | 0 | 1 |
| Tusn | 1 | 0 | 2 | 1 | 5, 10 | 4 | 1 | 0 | 1, 6 | 0 | 1.33 | 1 | 1, 3 |
| **Edible** | | | | | | | | | | | | | |
| Acris | 2 | 1.5 | 1 | 2 | 4, 10 | 4 | 2.5 | 0 | 1, 3 | 1 | 0.39 | 2 |
| Ahyb | 2 | 3 | 1 | 2 | 4, 10 | 4 | 2.5 | 1 | 1, 2, 3, 4, 5 | 1 | 1.33 | 2 |
| Aker | 1 | 1.5 | 2 | 1 | 1, 8 | 4 | 2 | 0 | 1, 3, 6 | 1 | 0.07 | 1, 2 |
| Apot | 2 | 2 | 2 | 1, 1, 3, 8, 10 | 2.8 | 1 | 1, 2 | 1, 3, 4, 5, 6, 7 | 1 | 1.16 | 1, 2, 3, 4 |
| Bdul | 1 | 2 | 2 | 1, 3, 8, 9, 9 | 4 | 2 | 1, 2 | 1, 2, 3, 5, 4, 6 | 1 | 2.01 | 1, 2, 3 |
| Cber | 3 | 3 | 1 | 2 | 4, 10 | 4.5 | 2.5 | 0 | 1, 3, 4 | 1 | 0.53 | 2 |
| Crme | 4 | 4 | 2 | 2 | 6 | 2 | 2 | 1 | 2 | 2 | 0.07 | 1 | 2 |
| Damb | 2 | 4 | 1 | 2 | 3, 4 | 5 | 1.5 | 1 | 2, 3, 4, 5, 6, 7 | 1, 2, 3 | 0.62 | 2 |
| Dser | 4 | 2 | 2 | 2 | 8, 9 | 3 | 2 | 1, 2 | 1, 2 | 1 | 0 | 1 |
| Lgla | 2 | 2 | 2 | 2 | 5 | 3.5 | 1 | 1, 2, 3 | 1 | 0 | 0 | 1 |
| Lspp | 1 | 2 | 2 | 2 | 4, 6 | 3.5 | 2 | 0 | 1, 3, 6 | 0 | 0.84 | 1, 2, 3 |
| Mspp | 1.5 | 2 | 2 | 1 | 1, 6 | 4 | 3 | 0 | 1, 3, 6 | 0 | 0.68 | 1, 2, 3 |
| Noff | 3.5 | 1 | 2 | 2 | 4, 10 | 4 | 2 | 0 | 1 | 1 | 0 | 1 |
| Olas | 3 | 3 | 2 | 1 | 4, 6 | 5 | 2 | 0 | 1, 3, 4, 5, 6, 7 | 1, 2, 3 | 0.70 | 1, 2, 3 |
| Ospp | 2 | 2 | 2 | 1 | 3 | 4 | 2 | 0 | 1, 3, 6 | 1 | 1.59 | 1, 2, 3 |
| Plin | 1 | 2 | 1 | 2 | 10 | 4.3 | 2 | 0 | 1, 3, 4, 5, 6, 7 | 1 | 0.53 | 1, 2, 3 |
| Pole | 2.3 | 0.7 | 1 | 2 | 4, 10 | 3.6 | 2 | 0 | 1, 3, 4, 6 | 1 | 0.30 | 2 |
| Pphi | 2.5 | 4 | 1 | 2 | 6 | 4.5 | 2 | 0 | 1, 3, 4, 5, 6, 7 | 1, 2, 3 | 1.97 | 2 |
| Pqua | 3.5 | 1.5 | 2 | 1 | 9 | 1.5 | 1.5 | 0 | 1 | 1 | 0 | 1 |
| Prud | 2 | 2 | 2 | 2 | 4 | 4 | 2 | 1 | 2, 3, 4, 5, 7 | 1 | 0.24 | 1, 3 |
homegardens as it was documented for *P. philadelphica* (Table 6). Most species are considered vulnerable to environmental factors and pests (Table 7), and some of the most appreciated resources are perceived to be scarce. This is the case of *D. serratifolium*, which due to the scarcity of its inflorescences people stopped consuming them (Table 6).

Gathering of edible plants is generally carried out while practicing other activities—by men when plants are gathered from the forest and by women and children when plants are harvested from agricultural fields and homegardens. Gathering is the only practice for 30 species, which are immediately consumed (Table 3). Practices of care during gathering of useful parts aim to procure plant survival, and these are carried out only in gathered plants and those under management (Tables 6 and 7). In order to ensure further availability, the abundance of seven species is enhanced by letting individual plants produce seeds and deliberately dispersing their seeds in appropriate places (Tables 3 and 7). At least 40 species are let standing in AFS, with the purpose of ensuring their availability (Tables 3, 6, and 7). For ensuring productivity and quality of products for consumption, 28 species receive irrigation, addition of organic matter, and exclusion from domestic animals (Tables 3 and 7). Nearly 20 species of weedy plants (among them *P. philadelphica* and *D. ambrosioides*) are transplanted into homegardens where people consider the plants to have better conditions for growing (Table 3). Other species occurring in the wild are transplanted to homegardens with the purpose of having them closer and to consume them for longer time (*Porophyllum* spp.) or for ornamental purposes (*Mammillaria* spp. and *Lantana* spp.) (Fig. 2, Tables 3 and 7). We recorded the deliberate propagation of 11 species through seeds and vegetative parts (Tables 3 and 6), as food (*Porophyllum* spp., *D. ambrosioides*, *P. philadelphica*, *Opuntia* spp.), for ornamental purposes, and for satisfying curiosity (*Oxalis* aff. *nelsoni*). Other species have started to be propagated, as is the case of *A. potatorum*, and others have had failed attempts (*L. glaucescens*, *C. mexicana*).

From seven species whose varieties are distinguished by morphology, flavor, and odor, we identified human selection in five of them; the preferred variants are tolerated, protected, or enhanced. For *D. ambrosioides*,

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**Table 7 Ecological and management parameters estimated for species considered in in-depth studies (Continued)**

| ID  | APe | VEA | LCI | Rep | HPa | Nea | TAv | CRe | MPr | Sel | MAFS | MLa | MSTa |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|-----|------|
| **Medicinal** | | | | | | | | | | | | |
| Amai | 3.5 | 1.5 | 2 | 2 | 5 | 3.5 | 2 | 1 | 1, 2, 3, 5, 6 | 1 | 0.37 | 1, 2, 3 |
| Apsi | 3 | 2 | 2 | 1 | 5 | 3 | 2 | 1 | 1, 2, 3 | 1 | 0.07 | 1, 2 |
| Bsal | 1 | 1 | 2 | 2, 1, 3, 5 | 5 | 1 | 0 | 1, 3, 5, 6 | 0 | 1.04 | 2 |
| Clme | 2.5 | 1.5 | 2 | 1 | 5 | 4 | 2 | 1 | 2, 5 | 1 | 0.60 | 1, 2 |
| Cmex | 4 | 2 | 2 | 2, 5, 10 | 3 | 2 | 1 | 1, 2 | 1 | 0 | 1 |
| Dcar | 3 | 2 | 2 | 2 | 4 | 4 | 2 | 0 | 1, 3 | 1 | 0.07 | 1, 2 |
| Gglu | 2 | 1 | 2 | 2 | 5 | 4 | 2 | 0 | 1, 3 | 0 | 1.94 | 1, 2 |
| Ginu | 2 | 2 | 2 | 2, 5, 10 | 4 | 2 | 1 | 2, 4, 5, 6 | 0 | 0.30 | 1, 2, 3 |
| Loax | 2.5 | 2.5 | 2 | 2 | 4.5 | 3 | 2 | 1 | 1, 2 | 1 | 0 | 1 |
| Mpar | 1 | 2 | 1 | 2 | 10 | 5 | 2 | 0 | 1, 3, 4 | 1 | 0.72 | 2 |
| Mpur | 2 | 2 | 2 | 2 | 6.9 | 4 | 2 | 0 | 1, 7 | 1 | 0.19 | 1, 2, 3 |
| Mvul | 1 | 2 | 2 | 2 | 4 | 5 | 1 | 0 | 1, 3 | 1 | 0.77 | 2 |
| Ppen | 1 | 1 | 2 | 2 | 10 | 5 | 2 | 0 | 3, 5 | 0 | 0.25 | 2 |
| Pros | 1 | 1 | 2 | 2 | 3 | 4 | 2 | 0 | 1 | 1 | 0.67 | 1, 2 |
| Rcom | 1 | 1 | 2 | 2 | 0, 3 | 5 | 1 | 1 | 1, 2, 3, 4, 5, 6 | 1, 2 | 0.43 | 2 |
| Spia | 4 | 0 | 2 | 2 | 2 | 3 | 1 | 0 | 1, 3, 5, 6 | 0 | 0.10 | 1, 3 |
| Tdif | 2 | 0 | 2 | 2 | 5 | 2 | 2 | 0 | 1, 2 | 0 | 0 | 1 |
| Tlac | 2.7 | 2 | 2 | 2 | 9 | 4 | 2 | 0 | 1, 2 | 0 | 0 | 1 |
| Apot | 2 | 2 | 2 | 2 | 1, 1, 3, 8, 10 | 2.8 | 1 | 1, 2 | 1, 3, 4, 5, 6, 7 | 1 | 1.16 | 1, 2, 3, 4 |
| Qauc | 2 | 0 | 2 | 2 | 1, 1, 5, 6, 7, 9 | 4 | 2 | 1, 2, 3 | 2, 5, 6, 7 | 1 | 0.03 | 1, 3 |

*ID* identification tag assigned to the species analyzed (check Table 3 to identify the species), *APe* abundance perception, *VEA* vulnerability to environmental factors, *LCI* life cycle, *Rep* reproduction, *HPa* harvested part, *Nea* nearness to harvest site, *TAv* temporal availability, *CRe* collective regulations, *MPr* management practices type, *Sel* artificial selection, *MAFS* management in AFS, *PrN* practice number, *MLa* maintaining labors, *MST* management system type

*Excluded variables and species in the performance of principal component analyses (PCA) and canonical correspondence analyses*
O. lasiacaantha, and P. philadelphica, we documented human selection favoring plants providing seeds or cladodes for cultivation (Tables 6 and 7). Local customs and regulations forbid gathering wild edible plants for commercializing them out of the village, with the only exception of Brahea dulcis and A. potatorum, which are edible, but parts commercialized are destined for other uses. In the Communitarian Assemblies, we recorded discussions among local people and the Biosphere Reserve authorities for regulating and planning the use of A. potatorum, B. dulcis, and D. serratifolium. In the case of L. glaucescens, the Assembly decided to allow external people to extract it, but the permit stopped.

Medicinal plants
We recorded 219 medicinal plant species, 178 of them being native and naturalized, and 22 considered “basic plants” (Tables 3 and 4). Currently, 85% of households use medicinal plants, generally complementing their healing treatment with massages, cupping therapy, and treatments by the national system of health through the local health center and private physicians. Women heads of families mainly make the decision on the appropriate treatment, while for traditional treatments, it is common to consult the relatives with more experience or one of the four traditional physicians in the village. The native plant species are mainly used for attending accidents (hurts, cuttings, twists, fractures, bites of poisonous animals), respiratory and stomach infections, pains, child tantrums, angers, “susto” (frights), illnesses caused by “aires,” monitoring of pregnancy, and recovering of childbirth. Medicinal plants may be ingested and placed in affected body zones, steam baths, and “limpias” (ceremonies for cleaning the body and spirit).

Almost all medicinal plants are collected when they are needed, but for some of them (Lippia oaxacana, T. lucida, T. diffusa, Chrysactinia mexicana, Ambrosia psilostachya), people used to store dry materials or ask somebody else to get the needed plant (Fig. 2, Table 5).

No commercialization of medicinal plants was recorded; most medicinal plants are shared. Some plants are interchanged for plants with other uses, for instance, Quercus acutifolia, used and commercialized as fuelwood, and A. potatorum used in mescal production (Table 5). Except C. mexicana and Pittocaulon praecox, all medicinal plants are considered abundant, but dryness and frosts are factors affecting their availability (Table 7).

Gathering of wild medicinal plants is conducted by men and women; men gather plants occurring far away and women those occurring in homegardens. Gathering is the most common practice for all medicinal plants, and the only practice for 81 species (Tables 3 and 4). Practices for preventing damage of gathered plants are common on the most valuable plants (Ambrosia psilostachya, Clinopodium mexicanum, C. mexicana, L. oaxacana, T. diffusa, T. lucida, Ageratina mairetiana, Grindelia inuloides) (Table 7, Fig. 2). In AFS, 79 medicinal plants are let standing during vegetation clearing, as well as the 65 species distributed in homegardens (Table 3). Among them, Ricinus communis, Marrubium vulgare, and Malva parviflora are submitted to practices for controlling their abundance through weeding, similarly to 37 other species (Table 1). We recorded 31 species receiving care such as removal of competitors, addition of organic matter, and irrigation (Table 3). Abundance of nine species is enhanced by leaving plants to produce seeds or by spreading the seeds in appropriate sites for their germination and growth (Tables 6 and 7). We also documented the transplanting of 25 species, 8 of them from forests to homegardens (G. inuloides, P. praecox, and A. mairetiana) for their medicinal and ornamental uses (Tables 3 and 7). In addition, we recorded the propagation by seeds of 12 species, 2 of them mainly motivated to have them available when needed (G. inuloides and Matelea purpusii) (Fig. 2, Tables 3, 6, and 7). We documented failed attempts of transplanting and propagating six species, among them A. mairetiana, A. psilostachya, G. inuloides, and L. oaxacana (Table 6). Reasons for not transplanting individual plants from forests to homegardens were the following: lack of information about plant requirements and the supposition or experience that in changing habitat, plants do not survive and that using appropriate techniques of extraction or storing strategies are enough for ensuring their availability (Table 6). We recorded the recognition of varieties of three species, but people make differential use and management only of R. communis (Fig. 2, Table 7).

Management intensity and risk
Management intensity of edible, ceremonial, and medicinal plants studied is explained mainly by practices and communitarian regulations in the first component and by their presence in AFS in the second component (Fig. 3). Management intensity among use types was significantly different (KW $X^2 = 9.9$, df = 2, $p = 0.007$). Edible plants had the highest management intensity, most of them managed in AFS involving human selection, while most species used for ceremonial and medicinal purposes are gathered from forests and protected through communitarian regulations (Fig. 3).

In plants with ceremonial use, the regression analysis indicates no relation among management intensity and risk indexes ($R^2 = 0.003$, $p = 0.819$) (Fig. 4, Table 8). Partial CCA explains 95% of the variation of management, significantly explained by the intersection of sociocultural and ecological factors (14%) (Fig. 5a, Table 9).
with intermediate management intensity (Table 8), management regulated by collective rules occurs in plants basic for life and exclusively with sexual reproduction. These are the cases of *L. glaucescens*, *D. serratifolium*, *B. stricta*, and *T. grandis* (Fig. 5b, Table 9). Plants intensively managed (Table 8) in AFS are those providing several parts or the whole plant as resources, having asexual reproduction, and being abundant, like *Tillandsia usneoides*, or that are scarce, like *Laelia albida*, *Euchile karwinskii*, *Epidendrum radioferens*, and *Rhynchostele maculata* (Fig. 5b, Table 9).

In edible plants, the regression analysis indicates that there is a highly significant relation among management intensity and risk indexes ($R^2 = 0.48$, $p = 0.0007$) (Fig. 4, Table 8). Partial CCA explained 92% of the variation of management, significantly explained by sociocultural factors (60%) and the intersection of sociocultural and ecological factors (14%) (Fig. 5c, Table 9). Plants with the
lowest management intensity (Table 8) are those protected through collective regulations, like *D. serratifolium* and *L. glaucescens*, which are shared among relatives and used in communitarian ceremonies, as well as in those gathered and perceived to be scarce, like *N. officinale*, *P. quadrifolia*, and *C. mexicana* (Fig. 5d, Table 9). Plants with the highest management intensity like *P. philadelphica*, *O. lasiacantha*, *A. hybridus*, and *D. ambrosioides* (Table 8) are those with different varieties, under human selection through several types of practices, considered to be abundant, shared among members of the community, and obtained through different strategies, among them interchange and commercialization (Fig. 5d, Table 9).

In medicinal plants, the regression analysis indicates no significant relation among management intensity and risk ($R^2 = 0.19$, $p = 0.074$) (Fig. 4, Table 8). Partial CCA explains 79% of the variation of management, mainly by sociocultural factors (46%) (Fig. 5e, Table 9). Plants with low risk like *Pinaropappus roseus* and *Gymnosperma glutinosum* are directly consumed by people who gather them and, along with *Marrubium vulgare*, occur in most of the homegardens and crop fields sampled. These plants are only gathered and left standing (Fig. 5e, Table 9). Management through collective regulations determining care during gathering was documented on *C. mexicana*, *L. oaxacana*, and *A. psilostachya*, with relatively high management intensity and risk (Table 8) associated to their value in reciprocity, use frequency, strategies for obtaining them, and the perception of vulnerability to environmental factors (Fig. 5e, Table 9).

**Discussion**

**Management intensity**

As we hypothesized, the gradient of management intensity is higher in edible plants, which are managed through different types of practices in AFS, more frequently, and involving human selection. Contrarily, plants used for ceremonies and as medicine are mostly tolerated or simply gathered. These general trends are similar to other reports for edible plants studied in the region which are managed with more complex practices than other useful plant species [6, 22, 43–45].

Collective regulations importantly influence the management intensity, but differently to that proposed for a general model of management intensity [46], the highest complexity of such regulations was observed in plants that are only gathered in areas of common access, such as the most valuable medicinal and ceremonial plants.
For the contrary, edible species are mainly managed in AFS, where managers have higher control of access to plant resources. These differences reflect the trade-offs in managing natural resources of common use, as it has been discussed previously for edible plants of the region and for several resources of common use [13, 47]. In the case studied, this pattern is illustrated by the fact that collective regulations appear to be effective for plants culturally valuable but not for plant resources with high economic value. The inefficacy of collective regulations for plants like *A. potatorum* appears to be due to the lack of rules coherent with the weakening of local institutions for ordering the use of a resource of increasing demand [28]. The failure of regulations for achieving a balance between cost and benefit of its management has enhanced private management in sites for exclusive use. But also, external actors have promoted the reforestation in areas of common use [16, 26], actions that should be accompanied by strengthening the effectiveness of local institutions.

The selective management characterizes the high management intensity in plants under the three types of use, according to flavors, colors, and sizes of plants or plant parts, which indicates ongoing processes of domestication, which may have advanced expressions like in *P. philadelphica* or, rather incipient, like in *O. lasiacantha* and *R. communis* [5, 15, 48]. The indistinct use of species with varieties recognized such as *Chenopodium*...
berlandieri suggests that there exists a process of decreasing of consumption and interest in human selection, differently to what is happening with A. potatorum, whose propagation starts with gathering seeds from several sites where agaves are recognized to have differential productivity. Such contrasting situations indicate the dynamic aspect of the processes of domestication, in which changes in values, the introduction of new food or products, and changes in markets, among other factors, have direct effects on management of plant resources.

Sociocultural and ecological factors and management intensity
As expected, management intensity in edible plants is associated with their high risk to disappear, compared to the pattern found in medicinal and ceremonial plants.

| Risk variable                        | Ceremonial |           | Edible |           | Medicinal |           |
|--------------------------------------|------------|-----------|--------|-----------|-----------|-----------|
|                                      | Df | X²   | F   | p     | Df | X²   | F   | p     | Df | X²   | F   | p     |
| Sociocultural and ecological variables |   |       |     |       |   |       |     |       |   |       |     |       |
| Uses number (Us)                     | 1  | 0.017 | 3.24 | 0.103 | 1  | 0.014 | 1.98 | 0.105 | 1  | 0.016 | 1.46 | 0.175 |
| SI basic plants (SIB)                | 1  | 0.190 | 35.41 | 0.002 | 1  | 0.008 | 1.09 | 0.219 | 1  | 0.021 | 1.84 | 0.11  |
| SI by use type (SIU)                 | 1  | 0.003 | 0.47  | 0.695 | 1  | 0.003 | 0.45  | 0.497 | 1  | 0.026 | 2.33 | 0.09  |
| Consumption (Con)                    | 1  | 0.029 | 5.35  | 0.024 | 1  | 0.013 | 1.80  | 0.125 |     |       |     |       |
| Use frequency (UF)                   | 1  | 0.040 | 7.48  | 0.012 | 1  | 0.013 | 1.83  | 0.180 | 1  | 0.024 | 2.15 | 0.078 |
| Economic interchange (EI)            | 1  | 0.010 | 1.85  | 0.22  | 1  | 0.006 | 0.79  | 0.389 |     |       |     |       |
| Reciprocity interchange (RI)         | 1  | 0.006 | 1.08  | 0.454 | 1  | 0.173 | 24.47 | 0.002 | 1  | 0.052 | 4.68 | 0.007 |
| Recognized variants (Var)            | 1  | 0.008 | 1.41  | 0.345 | 1  | 0.048 | 6.79  | 0.003 | 1  | 0.014 | 1.24 | 0.269 |
| Sociocultural strategies (SCS)       | 1  | 0.014 | 2.62  | 0.13  | 1  | 0.028 | 4.00  | 0.034 | 1  | 0.025 | 2.22 | 0.084 |
| Abundance perception (Ape)           | 1  | 0.026 | 4.88  | 0.045 | 1  | 0.027 | 3.76  | 0.035 | 1  | 0.011 | 1.01 | 0.398 |
| Harvested parts (HPa)                | 1  | 0.048 | 8.89  | 0.008 | 1  | 0.008 | 1.20  | 0.326 | 1  | 0.004 | 0.40 | 0.735 |
| Life cycle (LCi)                     | 1  | 0.002 | 0.37  | 0.734 | 1  | 0.005 | 0.74  | 0.465 | 1  | 0.001 | 0.06 | 0.981 |
| Reproduction (Rep)                   | 1  | 0.052 | 9.65  | 0.002 | 1  | 0.026 | 3.73  | 0.066 | 1  | 0.019 | 1.70 | 0.183 |
| Vulnerability (VEA)                  | 1  | 0.015 | 2.72  | 0.111 | 1  | 0.007 | 0.97  | 0.416 | 1  | 0.001 | 0.06 | 0.967 |
| Residual                             | 5   | 0.027 |       |       | 5   | 0.035 |       |       | 5   | 0.056 |       |       |
| Sociocultural variables              |   |       |       |       |   |       |       |       |   |       |       |       |
| Uses number (Us)                     | 1  | 0.017 | 1.028 | 0.352 | 1  | 0.014 | 1.29  | 0.114 | 1  | 0.016 | 1.77 | 0.106 |
| SI basic plants (SIB)                | 1  | 0.190 | 11.232 | 0.005 | 1  | 0.008 | 0.71  | 0.321 | 1  | 0.021 | 2.24 | 0.084 |
| SI by use type (SIU)                 | 1  | 0.003 | 0.148 | 0.925 | 1  | 0.003 | 0.29  | 0.680 | 1  | 0.026 | 2.83 | 0.051 |
| Consumption (Con)                    | 1  | 0.029 | 1.698 | 0.212 | 1  | 0.013 | 1.17  | 0.215 |     |       |     |       |
| Use frequency (UF)                   | 1  | 0.040 | 2.374 | 0.131 | 1  | 0.013 | 1.19  | 0.217 | 1  | 0.024 | 2.61 | 0.037 |
| Economic interchange (EI)            | 1  | 0.010 | 0.587 | 0.587 | 1  | 0.006 | 0.51  | 0.529 |     |       |     |       |
| Reciprocity interchange (RI)         | 1  | 0.006 | 0.343 | 0.808 | 1  | 0.173 | 15.89 | 0.001 | 1  | 0.052 | 5.68 | 0.001 |
| Recognized variants (Var)            | 1  | 0.008 | 0.447 | 0.687 | 1  | 0.048 | 4.41  | 0.029 | 1  | 0.014 | 1.51 | 0.189 |
| Sociocultural strategies (SCS)       | 1  | 0.014 | 0.832 | 0.487 | 1  | 0.028 | 2.60  | 0.099 | 1  | 0.025 | 2.70 | 0.048 |
| Abundance perception (Ape)           | 10 | 0.170 |       |       | 10 | 0.109 |       |       | 10 | 0.092 |       |       |
| Ecological variables                 |   |       |       |       |   |       |       |       |   |       |       |       |
| Abundance perception (Ape)           | 1  | 0.034 | 1.73  | 0.169 | 1  | 0.047 | 2.29  | 0.047 | 1  | 0.018 | 1.21 | 0.214 |
| Harvested parts (HPa)                | 1  | 0.089 | 4.51  | 0.023 | 1  | 0.011 | 0.55  | 0.443 | 1  | 0.010 | 0.64 | 0.509 |
| Life cycle (LCi)                     | 1  | 0.001 | 0.05  | 0.983 | 1  | 0.024 | 1.18  | 0.196 | 1  | 0.002 | 0.14 | 0.953 |
| Reproduction (Rep)                   | 1  | 0.033 | 1.68  | 0.221 | 1  | 0.045 | 2.19  | 0.075 | 1  | 0.017 | 1.12 | 0.274 |
| Vulnerability (VEA)                  | 1  | 0.052 | 2.63  | 0.107 | 1  | 0.004 | 0.20  | 0.815 | 1  | 0.042 | 2.77 | 0.03  |
| Residual                             | 14  | 0.277 | 14    | 0.284 | 12  | 0.181 |       |       |     |       |     |       |

Number of permutations = 999; p values in italics are significant at 0.05
However, in the analysis about how sociocultural and ecological factors influence on variation of management, we found a high variety of interactions. The economic value, which has been considered one of the most important factors motivating plant management [12, 13], was not significant in any of the systems studied. This result can be due to the low proportion of plant species that are interchanged through barter and commercialization, as well as the isolation of the community, a factor recognized to be significant for introducing non-timber forest products in markets [49]. Nevertheless, among the more intensely managed species, we recorded some whose management represents expenses (P. philadelphica) or their commercialization represents main incomes for households (B. dulcis and A. potatorum), which indicates a relation between management intensity and the economic role of plants in subsistence [46].

Consumption was only significant in ceremonial plants, explaining the gradient of management intensity according to the feasibility of propagation, which may be difficult in plants highly used (Tillandsia grandis and Chiococca alba), compared with species lowly used but having vegetative propagation that makes easy their management (Plumeria rubra, Dahlia sp.).

The perception of abundance and its interaction with cultural value and management feasibility was a meaningful factor for explaining gradients of management intensity of ceremonial and edible plants. For instance, Peperomia quadrifolia, a highly valued species as food, is only gathered following the principle of leaving part of the plant in order that it continues propagating, since it is scarce, but it has very specific habitat requirements. Tillandsia usneoides is intensely managed in homegardens, although it is abundant in forests, since it is easily propagated; P. philadelphica, a basic species, is considered abundant because of the effect of intense management. The examples suggest that the balance between the invested effort in management and benefits obtained according to needs is an important factor for making decisions [50].

The interchange of plant species related to reciprocity was significant for explaining variation of management of edible and medicinal plants. In both use types, the interchanged plants are the most valuable species. In the case of edible plants, our analysis explained the variation in the extremes of the gradient of management intensity; plants of difficult access are managed by collective regulations, and those intensely managed are in AFS. Among the medicinal plants, our analysis identified those species managed following collective regulations and stored, but in the case of emergency, people practice interchange. Importance of this factor coincides with other reports analyzing management of AFS, where it has been found that the social relations of local people are a main factor influencing biodiversity in these systems since plant species are introduced to the systems and because numerous species are maintained to be shared [44, 51, 52]. The study of these relations is covering importance for understanding management of AFS. We suggest that these may be considered for understanding management of species, since these are expressions of affect, respect, and solidarity, through which people construct social nets of mutual support that are part of the cultural identity and strategies for facing risks in their subsistence [28, 53–55].

In edible and medicinal plants, the interest for obtaining resources through sociocultural strategies influences the management intensity. Strategies like mobility for increasing the harvesting area and gathering for storing, among other practices, may determine some degree of risk on plants, which are placed through collective regulations and management practices.

The cognitive prominence by use type may be an indicator of resource quality, but this was no significant factor in our analysis. The perception about the quality of resources arose as a factor related to the place where plants grow. This aspect enhances plant management in AFS [51, 53, 56], which was documented with P. philadelphica and O. lasiacantha. In wild plants, this perception influences the communitarian regulations, as was recorded for Bursera biflora, whose resin is naturally produced and is preferred over that produced after cutting the stem [57].

**Management motives**

Interactions between cultural importance, perception of scarcity, and feasibility of management suggest that several factors contribute to motivate management techniques, which was confirmed through the in-depth interviews qualitatively analyzed (Table 6). The worries expressed by people about the future availability of plants with ceremonial, edible, and medicinal uses suggest that uncertainty is a main motive determining management. Such worries can be explained because of the fact that in the analysis of cognitive prominence of plants considered as basic, people mentioned plants with the three uses, which means that they are considered indispensable elements of subsistence. This fact coincides with the general hypothesis of control of uncertainty as a main motive of management for ensuring resource availability [12]. However, the differences documented in types of management strategies and their intensity among use types may be due to the differential operation of other motives, as we hypothesized in this study.

Making easier the access to plants was an important motivation for transplanting or cultivating wild and weedy plants for the three use types analyzed. For edible and medicinal plants managed in homegardens, the main management motive is to have them close
to home [22, 45, 58, 59]. And this is why people transplant and propagate plants that are naturally abundant into other ecosystems (e.g., *Porophyllum* spp.), protect with different labors the maintenance of *D. ambrosioides*, or tolerate weedy and ruderal plants like *Malva parviflora* and *Barkleyanthus salicifolius*. In ceremonial plants, the need to have flowers easily accessible is also an important motive for transplanting and propagating plants (for instance orchids and *Dahlia* spp.), but this motive is associated with the purpose of embellishing an area (60% of the ceremonial plant species are considered ornamental), a quality highly valued by the Ixcatec [6, 23, 24, 26, 52, 53, 60].

The symbolic value associated with plants and animals has been proposed relevant for making management decisions [8, 61, 62]. It is particularly important in plants used for ceremonies, like *B. biflora* [21], *L. glaucescens*, *Euchile karwinski*, and other orchids, and may influence the perception of importance of being careful during their gathering and as a motive for propagation.

Our study suggests that ethical principles are important for regulating use and management in order to prevent damage to plants (Table 6), recognizing them as living beings with “the right to exist.” This is expressed in numerous tolerated plants with low cultural and economic value or even those without use [26]. Such criteria interact with others particularly in weedy and ruderal plants, with edible and/or medicinal uses such as *A. hybridus*, *M. parvifolia*, *R. communis*, and *M. vulgaris* in which the perception of their potential as invasive plants determines a balance of efforts for maintaining and removing them [23, 26]. Other motives identified in the maintenance of homegardens [59, 63, 64], such as experimental curiosity, were mentioned by people in order to develop continual innovation in management techniques.

This study aspires to contribute to understand the multifactorial influence of social and ecological aspects on decisions for managing plant resources [26, 65] with different purposes. It is clear from this and other studies that management of edible resources are mainly influenced by factors associated with availability of food or means for obtaining it, whereas medicinal plants, which are consumed less frequently, involve quality rather than quantity, and ritual plants involve symbolic aspects. The three groups of plants involve management, but the intensity required in each case varies. However, some plant resources are particularly valuable because of their multi-functionality [65]; these are species that in this study are called “basic” by local people and are outstandingly important resources receiving the greatest management intensity.

Ixcatlán is the only site in the world where the Ixcatec language is spoken, and only 15 persons speak this language. Our ethnobiological studies look for contributing to efforts of a linguistic group working in favor of conserving and recovering this language. Information recovered in this study includes audio and image systems that have helped to produce educative materials useful for teachers in schools for teaching the Ixcatec language. In addition, the information about resource use, and particularly about management techniques, are helpful for planning actions for ordination, conservation, and recovering forest areas and resources, as well as agroforestry systems, which are part of the biocultural heritage of the Ixcatec for the Ixcatec people, people of the Biosphere Reserve Tehuacán-Cuicatlán, and the Mexican people.

### Conclusions

For managing edible, medicinal, and ceremonial plants, the Ixcatec have developed a broad variety of practices and regulations. Management strategies are motivated as responses to uncertainty in their availability and other motivations like embellishing an area, satisfying customs, emotions, and curiosity operating simultaneously in the decisions. Such a variety of factors is associated to a well-being premise combining both material and spiritual needs, as well as maintaining social relations and traditions that are part of the Ixcatec cultural identity [27, 50].

The highest management intensity in economic valuable species, mainly edible plants, indicates that uncertainty is significant in indispensable plants for satisfying subsistence needs. However, species of medicinal and ceremonial uses and some edible plants are managed through diverse management practices without response to abundance perception. These facts make necessary to analyze more deeply how needs, worries, external pressures, and management responses are articulated with subsistence strategies of households and communities in these processes, as well as the role of systems of ethical values and traditional regulation institutions.

Our study confirms the importance of sociocultural factors associated with use and interchange of resources, and ecological processes influencing the vulnerability and feasibility of managing them [12, 16, 17]. The multiple criteria may be useful to analyze conditions guiding early management motives that modeled the biocultural heritage of peoples of the Tehuacán Valley.

### Abbreviations

AFS: Agroforestry systems; CCA: Canonical correspondence analyses; PCA: Principal component analyses; TEK: Traditional ecological knowledge; UNAM: Universidad Nacional Autónoma de México

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Availability of data and materials
Data that support the analysis and additional data are provided in Tables 1, 5, and 7.

Authors’ contributions
SRL is the main author, involved in the study design, field work, and analysis of the data; wrote the first draft; and concluded the final version of this paper. AC is main coordinator-supervisor of the research project, participated in data analyses, and reviewed several drafts of the manuscript. EGF and RL contributed to designing and following the progress of the research and reviewed the final drafts of the manuscript. All authors read and approved the final manuscript.

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Permits for conducting our investigation were obtained from local authorities and Ethics approval and consent to participate from Sustentabilidad (IIES), UNAM. AC and EGF are full-time researchers at IIES, SRL is a postgraduate student at the Instituto de Investigaciones en Ecosistemas y Sustentabilidad (IIES), UNAM. AC and EGF are full-time researchers at IIES, UNAM. RL is a full-time researcher at UBIPRO-FES Iztacala, UNAM.

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