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Relational values and management of plant resources in two communities in a highly biodiverse area in western Mexico

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Abstract

In many cultures, interactions between humans and plants are rooted in what is called "relational values"—values that derive from relationships and entail reciprocity. In Mexico, biocultural diversity is mirrored in the knowledge and use of some 6500 plant species and the domestication of over 250 Mesoamerican native crop species. This research explores how different sets of values are attributed to plants and how these influence management strategies to maintain plant resources in wild and anthropogenic environments. We ran workshops in two communities (one Indigenous, the other non-Indigenous) in a highly biodiverse region in western Mexico, to ascertain the values and management activities related to important plant resources. The relationship between values attributed to plants and management activities was examined through redundancy analysis. A total of 180 plant resources were mentioned during the workshops, with a broad spectrum of values attributed to them, including material, non-material, and regulatory dimensions. We divided plant management strategies into three general categories of increasing intensity and complexity. We found that participants in the Indigenous community value and manage more wild plant resources than people in the non-Indigenous community. We also identified relationships between plant resource values and the type of management performed; for example, more intensive forms of management, such as sowing seeds, were used for seasonal plants that had a food value. By valuing and managing different sets of plant resources from forest, agricultural plots, and home gardens, people enabled multi-functional landscapes to form, illustrating a key feature of relational values in agroecosystems, which promotes both conservation and domestication of plants.

Keywords Biodiversity conservation · Ejido · Indigenous community · Plant management · Indigenous and local knowledge · Social values

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Introduction

All societies draw an important part of their sustenance from plants (Altieri 2002; Godoy and Bawa 1993). Values can affect intentions and motivations for promoting the sustainable management of nature and plants (Raymond and Kenter 2016). Several studies have identified that motivation to manage plant resources involves complex socio-ecological factors (Blancas et al. 2013; Moreno-Calles et al. 2011; Rangel-Landa et al. 2016; Reyes-García et al. 2006). These factors include the commercial value, their use, the aesthetics, the moral duty, and biological and ecological factors such as its scarcity or life form. Even within a given community, local people do not use and value plants and nature equally: values attributed to plants may differ by gender (Camou-Guerrero et al. 2008), and differences in access and rights to land can create (dis)incentives for people to value plants (Monroy-Sais et al. 2018). Understanding how values influence decisions about how and why to manage and/or domesticate plant resources provides theoretical elements for analyzing historical processes in agriculture. It also allows for the generation of data about the processes and experiences of innovation needed for designing sustainable management strategies for plant resources, and for steering conservation efforts (Blancas et al. 2013; Gaoue et al. 2017; Rangel-Landa et al. 2016).

The word "value" has different meanings. According to Pascual et al. (2017), values can refer to a principle, a preference, the importance of something, or simply a measure. In the environmental literature, the value of nature has historically been dichotomized between the intrinsic value (the inherent worth of nature as a moral entity; O'Neill 1992) and the instrumental value (the worth of nature in regard to satisfying human needs; Chan et al. 2016). Often, however, people make choices on the basis of how they want to relate to nature. This relational value is the value that emerges from a relationship with nature (Chan et al. 2016), and is considered constitutive of both elements of the relationship i.e., both people and nature (Himes and Muraca 2018). As Allen et al. (2018) argue, relational values are embedded in culture and (re)created through action, and it is the "importance of action" that makes these relational values visible. Allen and collaborators (2018) propose that relational values be used as a concept to bridge conservation science in sustainable agroecosystems and social science on human values. This is a novel concept that requires empirical approaches to understand its applications in different contexts.

Within this relational conception, there is a broad spectrum of types of values that can be attributed to plants, reflecting how plants contribute to people achieving a good quality of life in material, non-material, and regulatory dimensions (Díaz et al. 2018; Godoy and Bawa 1993; Moreno-Calles et al. 2014; Rangel-Landa et al. 2016; Reyes-García et al. 2006; Turner 1988). Plants that have relational values are not replaceable, for instance, by technology (Himes and Muraca 2018). For example, cultural preferences for specific local varieties of maize in different parts of Mexico mean that, in the minds of the farmers, these are not easily replaceable by high-yielding exogenous maize varieties (Bellon and Hellin 2011). Relational values are those that generate a flow of benefits for both parties in a relationship; in other words, they involve reciprocity (Jones and Tobin 2018), in this case, between environment and humans. Yet, how these different values and reciprocity link to actions that might be taken is not entirely clear.

In areas of high biocultural diversity, a more integrated view of the patterns that characterize life on Earth can be observed (Loh and Harmon 2005). According to Loh and Harmon (2005), Mexico is among the countries with the highest biocultural diversity in the world; and the knowledge and use of over 6500 native plant species has been documented (Clement et al. 2021). According to Díaz et al. (2015), biocultural diversity implies: 1) diversity of life, including human culture and languages; 2) links between biodiversity and cultural diversity, and 3) that these links have developed over time through mutual adaptation. There are clear signs of this mutual adaptation in Mexico in the fact that there are over 800 semi-domesticated plant species and nearly 250 domesticated crops species, some of which are important crops that have spread throughout the world (Casas et al. 2007; Clement et al. 2021; Perales and Aguirre 2008). This biocultural diversity evidences a great range of management interactions that shape agroecosystems and reflect actions and decisions that are taken regarding plants.

Natural resources management involves different types of interactions between humans and the functions and components of ecosystems, including plants (Casas and Parra 2017). These interactions encompass the use, control, conservation, protection, recovery, and restoration of populations of species, biotic communities, and ecosystems (Casas and Parra 2017). A wide spectrum of forms of human interactions with plants has been identified, with a gradient that reflects the differing intensities and complexities of management. While the intensity of management is an expression of the amount of effort, energy, or time invested—or the frequency of practices—complexity of management refers to the number of people involved, the number of practices carried out to achieve a goal, the planning and organization of these practices, and the use of sophisticated tools, among other things (Blancas et al. 2013). Several authors (Blancas et al. 2013; Bye 1993; Casas et al. 2007) agree that these interactions include the following main categories of management: (1) gathering or harvesting wild plants or weeds, which may simply involve picking them by hand, but may also involve (community or government imposed) regulations on quantities or seasons of harvesting, as well as special forms of organization for this, which make harvesting a more intense and complex activity; (2) tolerance of wild plants and/or weeds during deliberate disturbance of forests or crop fields and grazing areas management; (3) enhancement of plants through activities such as burning, irrigation, pruning, and dispersing seeds or vegetative propagules; (4) protection of plants from herbivores, competitors, other people, or climatic conditions (e.g. shade, light, wind, or humidity); (5) ex situ transplanting, which involves the removal of vegetative propagules or entire individual plants from their original habitats to other habitats; and (6) sowing seeds to ensure or increase the availability of a desired plant. These forms of management are not mutually exclusive, and they do not follow steps in a management linear trajectory. Altogether, the intensity and complexity of management represent the management strategy.

We argue that these different management strategies that people perform to plant resources reflect relational values, expressed as forms of actions involving reciprocity. For example, protecting or enhancing a plant implies forms of "giving back" to the plant, increasing the possibilities of that organism, or group of organisms, thriving. However, studies that have explored how different types of values are linked to forms and the intensity/complexity of management are scarce. For this reason, the purpose of this study was to document the spectrum of values that people assign to plant resources and to analyze the relationship these values have with the different management strategies they perform. We investigated these aspects in two rural socio-ecological contexts: an Indigenous community and a non-Indigenous or *mestizo* community, both located in a highly biodiverse region in western Mexico. Environmental conditions are generally similar in both communities, but the cultural contexts differ widely. We expect to find differences in the values and management strategies, given that relational values are inextricably linked to Indigenous and local knowledge (Sheremata 2018). This study can contribute to a deeper understanding of motivations behind plant management, in addition to providing empirical applications to the concept of relational values. This type of study is particularly important in regions like ours, where relational values can generate alternative ways of reconciling the needs of human populations and the needs of biodiversity conservation.

Methods

Study area and sites

Our study was located near the coast of the state of Jalisco, western Mexico, an area widely recognized for its high biodiversity, and where one wild relative species of maize grows, the *teocintle* or teosinte *Zea diploperennis* (Benz et al. 1994; Noguera et al. 2002). The ecological importance of the area has sparked interest in conservation, and two Biosphere Reserves (BR) have been declared in the region, Chamela-Cuixmala (CCBR) and Sierra de Manatlan (SMBR), both of which harbor several local communities, either within them or nearby (Fig. 1). For over four decades, this region has been bouncing between mainstream biological conservation and incorporation into the mainstream global economy (Benz et al., 1996).

Local livelihoods are mainly based on agricultural, livestock-raising and forestry activities, and this has resulted in significant levels of land degradation (Castillo et al. 2009). Although some land is private, most is held in the form of either agrarian communities (ACs) or *ejidos,* the two main collective land tenure systems in Mexico. ACs have their origin in State recognition and restitution of lands owned by peasants since "time immemorial" (López-Bárcenas 2017), whereas *ejidos* emerged after the Mexican Revolution, when large landholdings were broken up and redistributed to collectives of landless peasants. Both *ejidos* and ACs have a mixed system of property rights, combining collective and private rights over the land and resources (Schroeder and Castillo 2012). Forests are generally considered to be collectively owned while agricultural areas are managed as private property. Land rights (including collective land rights) are held only by formal members of the AC or *ejido* and are vested in the heads of households, who are mostly men. With both types of land tenure, it is common to find people with marked differences in land ownership and rights, ranging from those with full community land rights to the landless—those with no rights at all (Monroy-Sais et al. 2018). We carried out our research in two of these communities, the *ejido* Pabelo located near CCBR and the AC Cuzalapa situated inside SMBR (Fig. 1). Although they have similar biophysical characteristics and highly biodiverse ecosystems, these communities are different in terms of their cultural origin, their history, their land-tenure regime, and their location in the BRs.

The AC Cuzalapa is considered one of the oldest settlements in the coastal region of Jalisco and the community self-recognizes as Indigenous (Estrada-Gutiérrez and Gerritsen 2011). It has a total area of 24,057 ha and more than half of its territory is located inside the buffer zone of the SMBR, which means that there are restrictions regarding land use. The total population is approximately 1560 (INEGI 2020). Despite being of Indigenous Nahua origin, over the last century a process of acculturation has meant that most of the population now speaks only Spanish (Gerritsen 2010). Currently, people rely on maize cultivation (using both seasonal and irrigated systems), along with cattle raising, and conservation activities for their livelihood. The Pabelo *ejido*

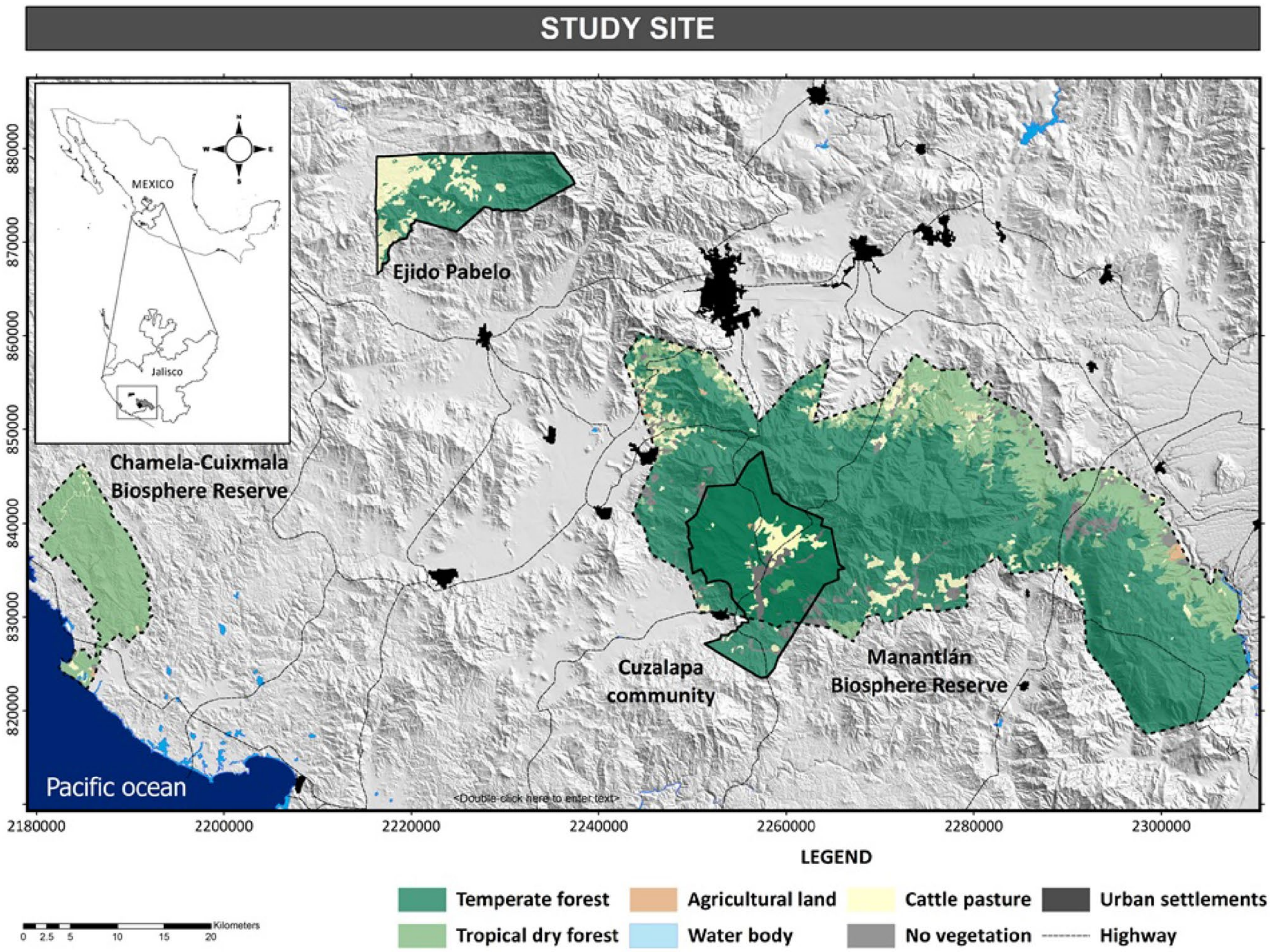

Fig. 1 Location of the study area and the study sites: the *ejido* Pabelo and the AC Cuzalapa. The main types of vegetation and land use, as well as the Chamela-Cuixmala and the Sierra de Manantlán Biosphere Reserves (Program used for artwork: ArcGIS)

was founded in 1938 on what was previously a *hacienda* (a privately owned farming estate) and is 14,347 ha. The population is approximately 939 (INEGI 2020) and is considered *mestizo* or mixed race. Although cattle raising has become the dominant activity, there is also diversified management of the land and the resources, including crop areas, conservation, and forestry (Monroy-Sais et al. 2016). Both communities have the following forest types: pine, oak, pine-oak, cloud, gallery, and subtropical deciduous, as well as large areas of grasslands, crops, and secondary vegetation. Both also have some forests set aside for conservation through Payment for Ecosystem Services programs.

Data collection

We conducted two workshops to generate data about plant values and their management, one in each community, both in 2017. Permission to run the workshops was granted by the community authorities after we explained the objectives of the study and provided an explanation letter from the National Autonomous University of Mexico (UNAM). One co-author had been working in the region for almost 30 years and had built-up social capital and trust, which facilitated communication with regional actors and authorities for developing field work activities. We distributed flyers two weeks before the workshops were scheduled, inviting any adult member of the communities to participate. Those who were interested registered with the community authorities to ensure their place in the workshop. Participants were grouped according to differences in land ownership and gender, to explore differences in values among groups within the communities available in the Online Resource 1. In total, 42 participants attended the workshops, and each group was led by a moderator.

Each workshop was divided into three stages (Fig. 2). The first stage was to explain the aims and main concepts of the workshop, such as "value" and "management of plants". Previous to the workshops we found that people tended to

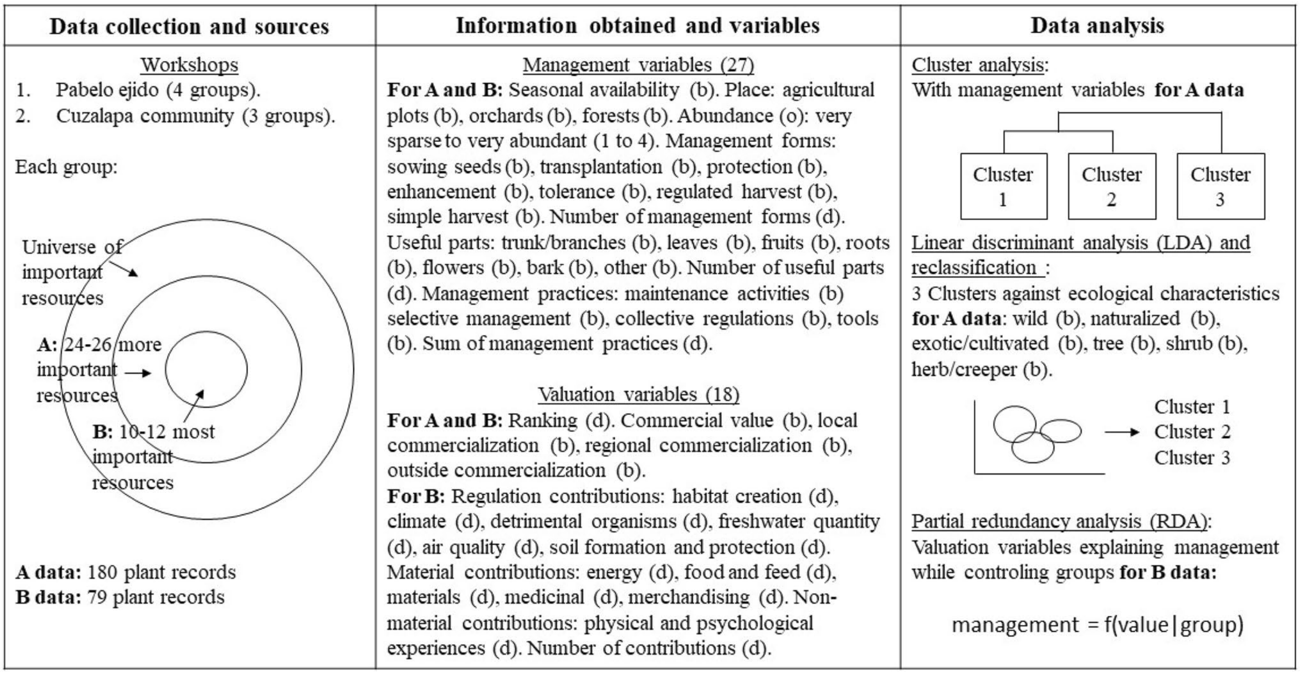

Fig. 2 Framework for the methodological design. The columns represent the different methodological stages: (1) data collection and sources; (2) information obtained and the categorization by variable type [(b) binary variable, (o) ordinal variable, (d) discrete variable]; and (3) data analysis. (Program used for artwork: PowerPoint)

associate the word "value" with monetary value, therefore we used the word "importance" at the workshops. Hereafter we will use "important resource" or "importance" as a synonym for "value" (Pascual et al., 2017). During this stage we asked the participants to name all the plants that they considered important—for any reason. The second stage focused on the management of the plant resources that were considered most important by each group. The third stage centered on the valuation of those resources. All three stages lasted approximately 6 h and are discussed in detail below. The main methodological design and the types of data gathered are summarized in Fig. 2.

Plant resource management

To document management, for practical reasons (such as time and space constraints in the workshops), the most important 24 to 26 plants were selected by each group for further analysis. In total, 180 plant resource records were selected ("A" in the first column of Fig. 2). For the plant resources selected, management was characterized by the participants using the variables of type and intensity of management modified from Blancas et al. (2013), which we presented in the introduction. We recorded plant abundance, as perceived by the workshop participants, as well as where they were located or harvested, and the different parts of the plant that were used. In total, 27 management variables were explored. The term "plant resources" refers to units of the folk taxonomy or ethno-taxonomy, which are condensed forms of knowledge with multiple applications and direct links to the biocultural diversity (Hidayat et al. 2018). A folk taxonomy unit does not necessarily correspond to a single scientific Linnean taxonomic unit (i.e. a species) since people often assign the same name to different species of plants, or one species can have different folk names.

Plant resource valuation

The valuation of resources by people was also divided into two phases. The first was a deliberative ranking of the 24 to 26 plant resources previously listed by each group of participants. In addition to the ranking, we documented whether those plants had commercial value and where they were marketed (locally, regionally, or outside the region). The second phase consisted of taking the 10 to 12 most highly ranked plant resources (the "most important" as indicated by each sub-group) and qualitatively interrogating the values assigned to them ("B" in Fig. 2). We did this by asking "why are these plants important?" and encouraging participants to write the explanation in their own words. We did not use the common categories of use because this language could be instrumentally laden, masking alternative modes of relating to nature and neglecting the complexity and specificity of relations as articulated by the people in their own terms

(Himes and Muraca 2018). These values were later classified and quantified in accordance with Díaz et al. (2018) on the different material, non-material, and regulatory contributions to the people. For example, if people mentioned "this plant is very important because it helps to maintain the water," we later classified it as "Regulation of freshwater quantity, location and timing." We ended the workshops with a reflexive exercise conducted with all the different groups in order discuss their opinions.

Finally, information about each plant's taxonomic identity was sought from botanical collections from the area that had been previously put together by the authors (Monroy-Sais et al. 2016), as well as from other floristic studies (Ruiz Villarreal 2016). Names were then validated via "The Plant List" online databases (www.theplantlist.org).

Data analysis

We performed a cluster analysis to identify broad plant resource management strategies. The data from the 27 management variables relating to the 180 records of plant resources was coded and a management matrix was constructed using Gower's dissimilarity. Clustering was performed on this matrix using the average method (Borcard et al. 2011). The final number of clusters was selected through visual examination of the dendrogram to identify consistent clusters (Borcard et al. 2011). The preliminary results of this classification suggested that clustering could be driven, in part, by some of the biological characteristics of the resources (their life form and whether their origin was wild or cultivated). To determine this, we performed a linear discriminant analysis (LDA); the results were also used to consider reclassifying some plant resources in the final clusters where there were inconsistencies (negative values of silhouette widths and the prediction of the assignment of cluster). Finally, ANOVAS and contingency table analyses were performed to identify differing management variables among clusters.

To assess the influence of valuation on plant resource management, we performed a partial redundancy analysis (RDA). First, a valuation matrix was constructed with 18 variables corresponding to ranking, commercial value, and the number and types of different values people had previously assigned. In this matrix, we included the plant resource records that considered the most important by all groups, which represented a subset of the 180 plant records, with 79 plant resource records (Fig. 2). Then RDA was carried out using the management matrix as response and the valuation matrix as predictor, while controlling for the effect of a third matrix including the groups of participants. RDA calculates canonical axes, resulting from linear combinations of the explanatory variables that best describe the variation of the response matrix (Borcard et al. 2011). These axes were represented in a bi-dimensional graph called a "triplot." A variance partitioning procedure was used to assess how much of the total variance in the response matrix (management) was explained by the predictor and controlling matrices (value and group, respectively). Permutational tests were performed to assess the significance of value variables on the ordination of management variables. All the analyses were performed using basic routines in software R (R Core Team 2019).

Results

Of the 180 plant records mentioned in the workshops, a total of 89 different plant resources or ethno-taxas were represented, because of repetition across groups and across communities. Of these 89 plant resources 25 were shared between the two communities, 33 were exclusive to Cuzalapa, and 31 were exclusive to Pabelo. These 89 plant resources represented 106 species (Online Resource 1). Some of the plants are species of the same genus, as in the case of the oaks (*Quercus* spp.), or the fig trees (*Ficus* spp.), which would significantly increase the number if they were to be counted at species level.

Most of the plants that were mentioned are wild (58%), tree-like species (64%), and had a marked seasonality (59%); moreover, 33% of these plants were perceived as "sparse." They were found equally in cultivation plots (58%), house orchards (56%), and forests (56%).[1] A high proportion were treated with intensive management forms, such as the direct planting of seeds (36%), transplanting (37%), and enhancement (35%). However, the most common form of management was protection (55%). Nearly half of the resources had a recognized commercial value (45%), and most were sold locally within the communities (37%). Interestingly, in the AC Cuzalapa a larger number of native wild resources were listed as important (78%), while in the *ejido* Pabelo, non-native resources were almost equal to wild resources (56%). In the following sections and Table 1 we provide more detail regarding management strategies.

Classification of plant management strategies

From the classification analysis we were able to identify three different management strategies. Cluster 1 corresponds to cultivated plants as well as to some naturalized plants that are mostly subject to more intensive forms of management (i.e., deliberately seeded, selected for propagation). Cluster

[1] These figures add up to over 100% because some resources were located in more than one place. The same is true for the management forms.

Table 1 Number of plant resources mentioned according to their characteristics and the management strategy to which they belong

	Total 180	Cluster 1 74	Cluster 2 56	Cluster 3 50
Origin[a]				
Wild***	105 (58.3)	0	55 (98.2)	50 (100)
Exotic/cultivated***	74 (41.1)	74 (100)	0	0
Naturalized***	20 (11.1)	19 (25.6)	1 (1.7)	0
Life form				
Tree***	116 (64.4)	35 (47.2)	31 (55.3)	50 (100)
Shrub**	25 (13.8)	12 (16.2)	13 (23.2)	0
Herb or creeper***	39 (21.6)	27 (36.4)	12 (21.4)	0
Availability				
Seasonal***	106 (58.8)	44 (59.4)	17 (30.3)	45 (90.0)
Abundance***				
Very abundant	47 (26.1)	27 (36.4)	5 (9.0)	15 (30.0)
Abundant	46 (25.5)	24 (32.4)	16 (28.6)	6 (12.0)
Sparse	60 (33.3)	20 (27.0)	22 (39.3)	18 (36.0)
Very sparse	27 (15.0)	3 (1.7)	13 (23.2)	11 (22.0)
Location				
Agricultural plots**	104 (57.7)	50 (67.5)	22 (39.2)	32 (64.0)
House orchards***	101 (56.1)	71 (95.9)	8 (14.2)	22 (44.0)
Forests***	101 (56.1)	13 (17.5)	46 (82.1)	42 (84.0)
Management forms				
Seed sowing***	65 (36.1)	47 (63.5)	2 (3.5)	16 (32.0)
Transplanting***	67 (37.2)	47 (63.5)	6 (10.7)	14 (28.0)
Enhancement***	63 (35.0)	49 (66.2)	6 (10.7)	8 (16.0)
Protection	99 (55.0)	42 (56.7)	24 (42.8)	33 (66.0)
Tolerance***	61 (33.8)	6 (8.1)	15 (26.7)	40 (80.0)
Regulated harvesting***	23 (12.7)	0	13 (23.2)	10 (20.0)
Simple harvesting***	29 (16.1)	4 (5.4)	21 (37.5)	4 (8.0)
Sum of management forms***	2.3 (1.1)	2.6 (1.1)	1.5 (0.8)	2.5 (1.0)
Parts used				
Trunk or stems***	70 (38.8)	17 (22.9)	32 (57.1)	21 (42.0)
Leaves***	107 (59.49	55 (74.3)	20 (35.7)	32 (64.0)
Fruits***	114 (63.3)	58 (78.3)	7 (12.5)	49 (98.0)
Root	17 (9.4)	5 (6.7)	9 (16.0)	3 (6.0)
Bark***	37 (20.5)	2 (2.7)	12 (21.4)	23 (46.0)
Flowers	13 (7.2)	5 (6.7)	7 (12.5)	1 (2.0)
Other	14 (7.7)	4 (5.4)	8 (14.2)	2 (4.0)
Sum of parts***	2.0 (1.0)	1.9 (1.0)	1.6 (0.9)	2.6 (1.1)
Other management practices				
Maintenance practices***	80 (44.4)	62 (83.7)	11 (19.6)	7 (14.4)
Selective management	107 (59.4)	40 (54.0)	40 (71.4)	27 (54.0)
Regulations	47 (26.1)	13 (17.5)	20 (35.7)	14 (28.0)
Use of tools	84 (46.6)	32 (43.2)	30 (53.5)	22 (44.0)
Sum of practices*	1.7 (1.1)	1.9 (0.9)	1.8 (1.2)	1.4 (0.9)

[a]Origin of 19 of the plant resources are both cultivated and naturalized in the area. Figures are total number of resources, with percentages in parentheses, except for sum of management forms, sum of parts, and sum of practices, for which they express average and standard deviation, respectively

*, **, *** Statistically significant at $p<0.05, <0.01, <0.001$, respectively

2 is related exclusively to wild species with less intensive forms of management (mainly protection). Finally, cluster 3 includes trees that are found in the wild and treated with more intensive forms of management than those in Cluster 2, suggesting signs of semi-domestication (i.e., deliberate propagation and practices of human selection in some species; Table 1). Most management variables were significantly different between the clusters as shown by the ANOVA and contingency table analyses (Table 1). We did not find significant differences by gender in the three clusters, but community type (*ejido* versus AC) presented significant differences, as did different groups within each community.

Cluster 1: Cultivated plants with intensive management: This is the cluster with the largest number of plant resources (74) and includes species such as avocado (*Persea americana*), maize (*Zea mays* subsp. *mays*), soursop (*Annona muricata*), and mint or "hierbabuena" (*Mentha spicata*). Around 80% of these were mentioned in the Pabelo *ejido*. All these resources are widely known cultivated plants that are not found in the wild but have been domesticated in other places. Some 25% are naturalized resources. Within this group of resources, the most common life form is trees. Approximately 70% are perceived as abundant or very abundant in the communities, and around 60% have a seasonal availability. More than 95% are found in house orchards, and 70% in agricultural plots. The most common management strategies are enhancement and planting and transplanting, indicating management strategies that are high on the intensity gradient. The fruit of around 80% of these resources are used, as well as their leaves (approximately 70%); on average, two different parts of each plant are used. Maintenance, such as pruning or fertilization, is carried out on just over 80% of the plants. Selective management is performed on around half of the resources and specific tools are employed for their extraction, which also indicates that their management is intensive.

Cluster 2: Wild plants with less intensive management: In this cluster, a total of 56 plant resources are found; they include pines (*Pinus* spp.), oaks (*Quercus* spp.), madroños (*Arbutus occidentalis, A. xalapensis*), and lechuguilla (*Agave maximiliana*). Nearly 65% were mentioned in the AC Cuzalapa. Except for the naturalized weed species *Portulaca oleracea*, all these plants are wild species. The most common life form is trees. Seventy percent were available all year, as with the oaks (*Quercus* spp.). A large number were perceived as sparse (39%), although 29% were considered abundant. Nearly 80% of these plants are found in forests, with around 40% in agricultural plots. The most common management form is protection, followed by simple harvesting and tolerance, which indicates less intensive management compared to the other clusters. The trunks and stems of around 70% of these resources are used, followed by their leaves (35%). Selective management occurs with a little more than 70% of the resources, involving the use of both tools and collective regulations.

Cluster 3: Wild trees with intensive management: A total of 50 plant resources were classified in this cluster, including fig trees (*Ficus* spp.), mojote (*Brosimum alicastrum*), nance (*Byrsonima crassifolia*), and nogales (*Juglans olanchana, J. major*). These were mentioned in a similar way in both communities. All are wild trees native to the region. It is interesting that 90% have seasonal availability, around 60% are perceived as sparse or very sparse, but also 30% are perceived as very abundant. They are mostly found in forests (84%), although they also grow in cultivated plots (64%), and in orchards (44%). The most common management form is tolerance, but protection, sowing, and transplanting are also common. On average these resources are treated with two or three management forms, which shows that they are subject to more intensive management than resources in the other clusters. With almost all these resources (with one exception), the fruit is consumed; in nearly half, the use of leaves, bark, and the trunk and branches stand out; in other words, a greater number of parts per plant are used compared to those in Clusters 1 and 2. Selective management is performed on almost half of the resources, and specific tools are also used for their extraction.

Valuation and management of the plant resources

The first part of the valuation, which considered the 180 plant resources records based on ranking, commercial value, and whether commercialization was local, regional, or outside the region, did not distinguish statistically between the clusters. For example, maize (from Cluster 1) was ranked the highest, as well as *Quercus* species (Cluster 2) and *Brosimum alicastrum* (Cluster 3) by different groups. This indicates that within all three management clusters there are highly valued plant resources, which is an interesting and unexpected result. Regarding the commercial value, we found that nearly half of the resources were similarly commercialized in the three clusters, most of them at the local scale (Online resource 1).

When examining the values of the most highly ranked plants, we found a total of 12 values representing different contributions. These values included material, non-material, and regulatory dimensions. Regarding the type of contribution, material contributions were most mentioned, with 254 recorded values, followed by regulation (54), and finally non-material contributions (9). Regarding material dimension, the food and fodder value of the resources was the most important, with 126 records, followed by the medicinal value, with 63, while monetary value had just 26 records. In addition, within the food and fodder value, 10 different contributions were documented, for example: nutritive, for specific dishes, drinks, or fodder. For the regulation dimension,

Table 2 Variance partitioning associated with the RDA analysis. P values refer to permutational ANOVA tests

	Degrees of freedom	R squared	Adjusted R squared	p value
Valuation	17	0.35672	0.17744	p < .001
Group	5	0.12028	0.06002	p < .001
Val and group	22	0.45532	0.24133	p < .001
Residuals	–-	–-	0.75867	–-

climate was the most mentioned value, with 23 records. With respect to the non-material dimension, only aesthetic value was mentioned. Associated values by resource ranged from 1 to 10, with an average of 4. Pine (*Pinus* spp.) was the plant resource with most values attributed to it, encompassing all three dimensions.

The results of the partial RDA performed with the 79 most valued plant resources show a significant relationship between the perceived value of the resources and the management performed. The group of participants had also a significant effect on explaining differences in management (Table 2). The first two ordination axes of the RDA are represented in the triplot in Fig. 3.

Resources valued for their importance in the supply of energy and materials, for example, timber, are located towards the right end. They have less intensive management forms, but are subjected to other practices, such as collective regulations, selective management, and use of specific tools —as with the oaks or pines. These plants are also considered more abundant. Most of the resources in Cluster 2 are located towards this end. Toward the left end of Fig. 3, we can see those resources valued for their food contributions. In general, these resources are managed more intensively, as is evident from the number of different forms of management, such as sowing and transplanting. Several parts of these resource are used, especially their fruit and leaves. Resources in Cluster 3 are more oriented towards this end. The second ordination axis is related to resources with commercial value, as well as with regulatory contributions such as soil maintenance. This axis reflects variations in the number of other management practices, such as collective regulations, selective management, and specific tools.

Expressing relational values

The aim of this section is to explain, in a more qualitative way, the valuation exercise and the collective reflection on the value and management of plants. In general, we observed that, within both communities, plants that were considered important were complementary. Some (usually women) valued edible plants most, while others valued plants for timber extraction more (more commonly men), for example. This

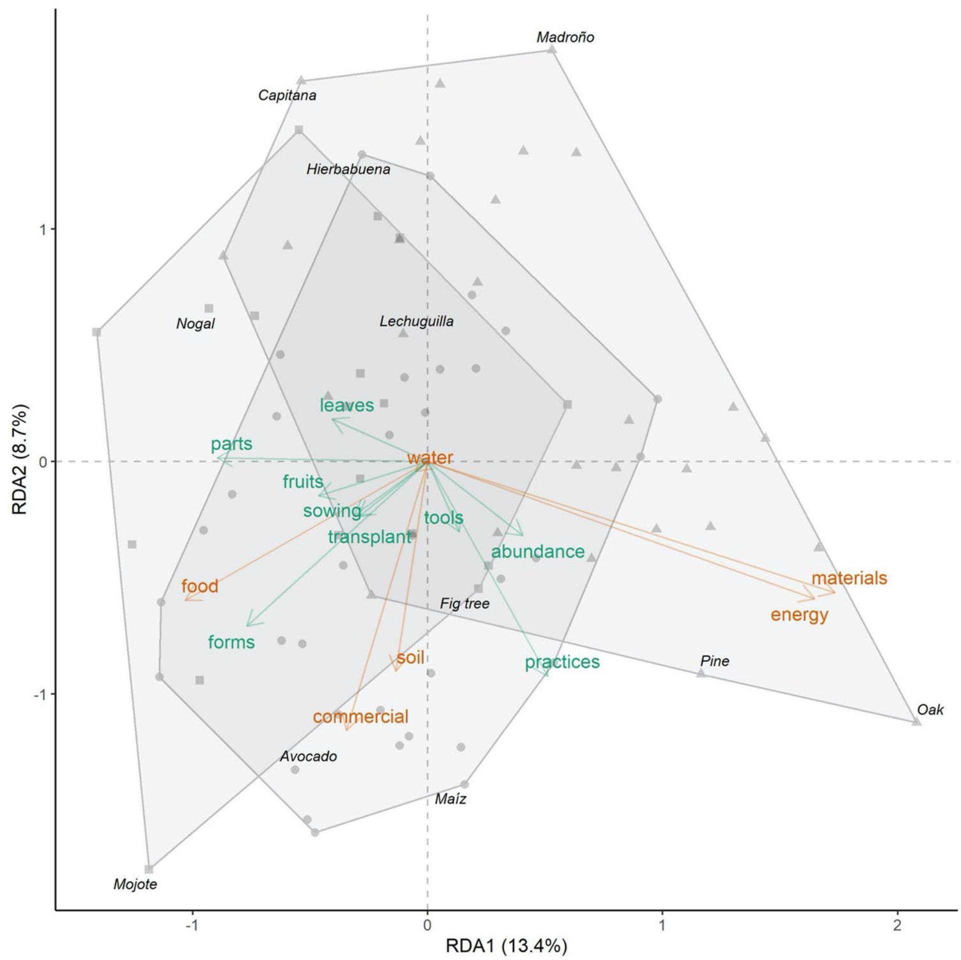

Fig. 3 RDA triplot with the two main canonical axes showing the valuation variables (orange) and their relation to the management variables (green), differentiating the three management clusters delimited by the grey polygons: Cluster 1 (circles), Cluster 2 (triangles), and Cluster 3 (squares), as summarized in Table 1, including some common names of plant resources in italics (Program used for artwork: R statistics)

is shown in the following quotes from different participants in the IC:

> "The mojote [*Brosimun alicastrum*] is very important because it is for human consumption, fodder and medicinal [uses], [it] is one of the trees that carries most benefits for the community." "Maize, logically, is one of the most important [plants] because it is consumed by everybody in the community, and coffee because it helps the family and community economy." "Without the higueras [*Ficus* spp.] we wouldn't have water, what would we do without water?!". "We should care for these plants in the forest because they give so many benefits to everybody."

It is interesting that these quotes also emphasize the collective benefits over the individual benefits that these plants provide. In addition, people in Cuzalapa recognized that it was a difficult task to rank the plants because, for them, all plants are important, while in some working groups in Pabelo, this task was easier. For example, the group formed by authorities in charge of the timber extraction could easily determine the most important resources and reach consensus on this. The following quote from a woman from Cuzalapa supports this statement:

> "Sometimes we live so fast that we don't stop to think about the importance that not only one plant has, but all the plants, the water, the soil. This workshop made us think, and this is good… It was very difficult to say which one was the most important, because all plants are important."

Lastly, older participants in both communities recognized that, over time, these important plants have changed because priorities have changed. In Cuzalapa, female participants mentioned that it is their duty to transmit this knowledge to new generations and to be more conscious about how they use these plants.

Discussion

Our results suggest that the kind of value assigned to plant resources has an influence—partial, but significant—on their management, as we expected. For example, if a plant had a food value, people were motivated to manage them in intensive and complex ways—such as sowing seeds, transplanting, and carrying out maintenance activities—to ensure availability. Considering the biological and ecological barriers of each plant, these management practices could result in the domestication of some species, as documented in other regions of Mexico and the Americas (Casas et al. 2007; Clement et al. 2021). Although less intensive management strategies are used for wild resources, they are equally important. Many wild plants are valued for providing wood or for regulation processes—such as soil and water maintenance—and ultimately have favored conservation of ecosystems. These intense and less intense management strategies can be understood as two extremes of a continuum of management, defined partly by the values of the plants. The value-management association is dependent on the socio-ecological context, in our case, the different communities and groups. The fact that different management strategies and values complement one another highlights the prominence of relational values that create multifunctional landscapes. In the sections that follow we discuss these key findings and delineate future research questions.

On the complementarity of management strategies

Our results show that management approaches for plant resources have similar strategies for sets of resources that share certain characteristics, such as life form, origin, location, and seasonality. These management strategies were significantly different between the two communities. Within these management strategies, there was a marked gradient from the most intensively managed resources (Cluster 1), then those with an intermediate level of management (Cluster 3), to those less intensively managed (Cluster 2). Many plant resources in Clusters 1 and 3—above all those perceived to have food value, seasonal availability, or commercial value—depend on specific management practices to assure their continued abundance. This is the case for plants such as maize (*Zea mays*), avocado (*Persea americana*), or guava (*Psidium guajava*). Management practices for these resources tend to be more intense and complex than simple harvesting, and include sowing, transplanting, or enhancement. As Blancas et al. (2013) and Rangel-Landa et al. (2016) noted, this can be explained as a strategy to decrease the risk of declining supplies. In this sense, the management strategies of Cluster 3 are notable because they represent important domestication processes and the conservation of the local biodiversity.

For a considerable number of plants in Cluster 2, collective regulations for extraction were in place, indicating passive but certainly important forms of management (Casas and Parra 2017). For example, oak trees (*Quercus* spp.) are free for personal use in these communities—such as for fences or firewood—but their commercialization (sale as timber) is forbidden. However, the value participants assign to the plants explained only a fraction of the variation in management. It is possible that biological and ecological characteristics are important forces influencing management strategies as well (Blancas et al. 2013). For further research, it would be worthwhile to determine the influence of valuation and biological characteristics such as life cycle, life form, mechanisms of reproduction and dispersion, among others, along the management intensity gradient.

Another noteworthy result from the ranking is that the most highly valued resources are evenly distributed among all three management clusters. In other words, along the whole gradient of management (from less to more intensive) participants identified plants of great value. This is a novel result that gives credence to the idea that relational values create multifunctional landscapes, as Allen et al. (2018) argue. This was also evident from the responses in the reflexive exercise at the workshops, where some people championed the complementarity of different resources and argued that all were important as they provided a range of different benefits. From a more instrumental perspective, this diversification in the incorporation-appropriation of plant resources indicates that they help people to deal with uncertainty and to cover a wide gamut of needs. As other scholars have indicated (Barrera-Bassols and Toledo 2005; García-Frapolli et al. 2008; Rangel-Landa et al. 2016; Toledo et al. 2003), these strategies connect ecological and economic processes and represent an array of possibilities in different situations, buffering ecological, social, and economic uncertainties, and helping to maintain local biodiversity (González-Cruz et al. 2015; Moreno-Calles et al. 2011).

From a more relational perspective, the variety of plant resources, their values, and the management strategies applied to them, create a web of interactions such as: i) multi-directional relationships with biodiversity; ii) connections between community members and their land; iii) a source of knowledge and education for younger generations; iv) balance in the use of the landscape (e.g., forests, cultivation plots, and orchards); and v) reciprocity with plants under the different forms of management, such as protection or enhancement. While some of these interactions have already been recognized as key elements of the relational values in different places around the world (Allen et al. 2018; Arias-Arévalo et al. 2017; Gould et al. 2019; Jones and Tobin 2018; Sheremata 2018), we propose that management forms are also an expression of relational values in agroecosystems. With this study we demonstrated empirically that the relational values local people have contribute to maintaining multifunctional landscapes, and, in turn, policy should adequately align with these local values (Allen et al. 2018).

On differences in the socio-ecological context

Our results show that there are important differences in resource values and management strategies between the two communities and, in some cases, within communities. We believe that these differences represent particular needs and perceptions related to social and cultural differences in history, knowledge, land tenure, and the development of productive activities. For example, in the AC Cuzalapa we found that there was a greater appreciation of local wild resources, while in the Pabelo *ejido* many valued resources have been domesticated from other places and are widely used. From our perspective, this result is related to the ample ILK in communities such as Cuzalapa, as documented by others (e.g., by Farfán-Heredia et al. 2018; Moreno-Calles et al. 2011; Toledo et al. 2003). On the other hand, in the Pabelo *ejido*, which was founded more recently and comprises people from different regions, it is noticeable that fewer valued resources have a local or wild origin in the surrounding ecosystems. This does not mean that local knowledge is not present in the non-Indigenous community, but it does imply that the long coexistence of Indigenous people in specific places creates meaning-saturated relationships with nature, and relational values (Chan et al. 2018). This study shows that despite the erosion of knowledge about plant use due to the acculturation process, and despite the loss of their original language, people in Cuzalapa have retained important knowledge about local plant resources. We are not advocating for generalizations about Indigenous or non-Indigenous communities; rather, we want to highlight the context-dependency and place-based nature of relational values, as others have suggested (Arias-Arévalo et al. 2017).

Other features can be playing a role in shaping peoples' values, such as, the institutional context, gender, and land tenure. The institutional context has been acknowledged as highly relevant in the articulation of nature values (Brondizio et al. 2009; Pascual et al. 2017). In the Indigenous community the presence of the Biosphere Reserve plays a role by fostering conservation projects, for example. Our two main differences between groups inside communities were gender and land tenure rights. Although when comparing gender alone we did not find significant differences. Indeed, we found that both men and women considered similar plant resources important. Yet, gendered division of labor for plant management (Camou-Guerrero et al. 2008) is a feature still to be explored in our study area. Land rights and access to certain resources (i.e., forests, agricultural plots, and orchards) had marked differences between groups. We believe these differences influence values and management strategies regarding plant resources, since these differences in land rights are known to be a key factor in determining how resources are valued at the landscape level (Monroy-Sais et al. 2018; Moreno-Calles et al. 2016). Lastly, it is worth mentioning that a considerable number of highly valued plant resources are shared both among sub-groups of a community and between communities, which gives them a high sociocultural value in the region.

On the dimensions of values and contributions

Another interesting result is how some types of values stand out above others. In our case, the value of plants used for food and fodder were the most frequently mentioned in the two communities, which shows that resource diversity related to local culinary traditions is of great importance. The resources with nutritive value help to ensure food security in the communities and represent an important part of diversified local livelihoods (Barrera-Bassols and Toledo 2005). These resources were also associated with commercial value and more intensive forms of management. In our study case, many of the resources with a food value were also found to have a medicinal value. As noted in other case studies, by Heywood (2013), there is usually a strong connection between agrobiodiversity, nutrition, and human health. Despite Mexico's shift towards more commercialized food systems, a large number of local plants are still consumed in rural communities (Mapes and Basurto 2016) or are undergoing domestication processes (Casas et al. 2007; Clement et al. 2021; Perales and Aguirre 2008).

Contributions of plant resources to the maintenance or regulation of ecological processes—such as the quality and quantity of freshwater—are evidently perceived to be of great importance. For example, people in both communities assigned the highest value to fig trees (*Ficus* spp.), ranking them in first place. These resources are, in turn, protected and conserved through collective agreements and regulations in the ecosystems in which they occur (Blancas et al. 2013; Monroy-Sais et al. 2016; Rangel-Landa et al. 2016). On the other hand, resources such as the mojote (*Brosimum alicastrum*) and pines (*Pinus* spp.), which attracted a wide spectrum of values that encompassed various dimensions, are also abundant in the area. It has been suggested that the "ecological salience" of a resource (the abundance in an area) may explain the greater value and significance attributed to these resources (Turner 1988; Turner and Bhattacharyya 2016). In this sense, we would expect more shared knowledge and common management strategies for species that are abundant and have higher value scores. Although, this shared knowledge might be restricted to specific communities and/or languages (Cámara-Leret and Bascompte 2021), highlighting the relevance of preserving language in order to maintain biocultural diversity and relational values.

The framework for nature's contributions to people recently proposed by Díaz et al. (2018)—and on which the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) relies—was useful for determining why plants are important in these contexts. Although in our study non-material contributions such as “learning or inspiration” or “psychological or physical experiences” were not mentioned to a great extent, it is important to start looking at the value of plants (and nature in general) in different dimensions (material, regulatory, and non-material) in order to open up the scope of utilitarian-instrumental approaches. We attribute the limited mention of such contributions in our study to the difficulty of documenting this non-material dimension (Gould and Schultz 2021). This dimension might require other approximations and methods, since valuation methodologies tend to elicit particular values and have blind spots for others (Jacobs et al. 2018). Yet, in the final reflexive exercise this non-material dimension was elucidated to the extent that values such as care, responsibility, and collective well-being were evident.

This study supports the idea that relational and instrumental values can coexist in a single system without diminishing agricultural sustainability (Jones and Tobin 2018), and that there is fluidity between instrumental, intrinsic, and relational values from different contributions (Arias-Arévalo et al. 2017; Pascual et al. 2017). As our results show, values are interconnected and, through ILK, the value of resources is strengthened and diversified, making the relationship with resources and ecosystems closer. This is part of the engine that maintains biocultural diversity.

Conclusions

The participants in our study revealed a diversity of values and forms of management for plant resources that went beyond the material dimensions, and beyond the notion of harvesting versus agriculture. A considerable number of highly valued plant resources do not have a monetary value and a large proportion of valued plants come from surrounding ecosystems and have complex management strategies which support ongoing domestication processes. We suggest that these different management strategies mirror the concept of relational values between managers and plants, because they entail reciprocity. In addition, this association between value and management in the communities we studied favors a balance in the use and knowledge of different landscape units (forests, orchards, and agricultural plots) and multifunctional landscapes, another key aspect of relational values.

Values derived from different contributions (material, non-material, and regulatory) are usually interlinked. Often, the diversity of values embedded in agroecosystems is obscured or neglected, by both research and policy, which tend to focus on profit or yield maximization (Tobin et al. 2020), creating conflicts within the local value system. In order to have sustainable agroecosystems, these relational values should be part of policy, but in order to elicit such a diversity of values, more sensitive methodologies and a variety of different approaches are needed. This type of study can help to understand the complexities in how nature is valued—beyond the instrumental dimension—and can help in the design of conservation and management strategies. This study also shows the important role that Indigenous and local knowledge plays in how plant resources are valued, even by those who have experienced cultural change and lost their original language. This result has implications for the maintenance of biocultural diversity.

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