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Peasants' Motivations to Maintain Vegetation of Tropical Dry Forests in Traditional Agroforestry Systems from Cuicatlán, Oaxaca, Mexico

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The ways traditional rural communities conduct activities to meet their livelihoods commonly contribute to conservation of biodiversity and ecosystem functions. Traditional agroforestry systems (TAFS) are expressions of management that deliberately retain wild vegetation coexisting with crops to obtain multiple socio-ecological contributions. However, processes enhancing productive intensification endanger their permanence. This study aimed to 1) identify the peasants' motivations to maintain the vegetation of tropical dry forest within their agricultural fields, 2) analyze the capacity of TAFS to provide contributions to people's well-being, and 3) identify factors and processes limiting conservation capacities and possible alternatives. The study was conducted in three communities of the Tehuacán-Cuicatlán Valley, Oaxaca, Mexico. We performed a qualitative analysis with information from two workshops with local people, 10 semi-structured interviews with managers of TAFS, participant observation, complementary informal talks, and fieldwork notes. For analyzing the data, we: 1) generated a list of central themes based on the data collected, 2) established preliminary categories of such themes, 3) coded all information through the Atlas. ti software, 4) adjusted the classification of categories and codes to the data, 5) grouped codes and analyzed their relationships. We found that the peasants' motivations to maintain the wild vegetation are the provision of multiple beneficial contributions: material (edible fruit, medicinal plants, fodder, firewood), regulating (shade, soil fertility, humidity keeping, rain attraction), and nonmaterial (regional flavors, ornamental, ritual), among others, which meet some of their fundamental needs (primarily subsistence, identity, and protection). The main reasons for keeping the wild vegetation were material contributions (62%). Also, we observed that TAFS safeguarding a higher forest cover and species diversity provide a broader range of socio-ecological contributions and potential to satisfy human needs than those with lower cover. Peasant agriculture may allow maintaining biodiversity while satisfying fundamental human needs. However, it needs to be revitalized, made more efficient, profitable, and dignified. The agroecological management implemented by peasants in

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TAFS is crucial for ensuring the continuity of essential environmental functions and people's well-being.

Keywords: agroecological management, biocultural diversity, biodiversity conservation, fundamental human needs, nature's contributions to people, peasant agriculture, traditional ecological knowledge

INTRODUCTION

Practically all ecosystems of the planet have had human impact (Noble and Dirzo, 1997; Díaz et al., 2019). Some of them are subject to progressive higher transformation intensity, mainly due to the accelerated industrialization, which is the leading cause of the severe impact on ecosystems at a global scale (MEA, 2005; IPCC, 2013). For this reason, the study of the relationships between human societies and the natural environment urgently requires research approaches and actions towards sustainability, one possible way to guarantee the continuity of the socio-ecological systems (Berkes and Folke, 1998). To ensure the future viability of these systems, it is indispensable stopping the productive intensification that characterizes the current hegemonic trends of the global economy (Casas et al., 2014), which involves the drastic and profound transformation of nature (Rendón-Sandoval, 2020). Besides, it is necessary to design alternative production systems to provide goods while maintaining their capacity to conserve biodiversity and environmental functions.

Important examples to face the global environmental crisis can be found in some of the ways traditional rural communities live. These societies commonly meet their livelihood needs, while contributing to biodiversity conservation and maintaining key ecosystem functions (Perfecto and Vandermeer, 2008; Altieri and Toledo, 2011; Casas et al., 2014). Understanding the rationality of the cultural and ecological features of these traditional communities, their techniques, social organization, and governance, may provide important teachings for redesigning strategies of interrelationships between society and nature. One of the most notable expressions of the biocultural legacy of rural communities are the *traditional agroforestry systems* (TAFS), which are agroecosystems that integrate the deliberate retention of forest cover and wild species managed through different ways (Casas et al., 1997), which coexist with crops and domestic animals to obtain social and ecological benefits (Moreno-Calles et al., 2014; SEMARNAT, 2019).

TAFS are important reservoirs of culture, local knowledge, technical experience, and biological diversity, with a high capacity to conserve the ecosystems surrounding agricultural areas, while providing benefits to societies (Casas et al., 2014; Vallejo et al., 2016). These systems might be reminiscences of early stages of agricultural practices that were integrated into the management of forests and landscapes (Casas et al., 1997; Blancas et al., 2010). Thus, several scholars have suggested that early horticultural practices associated to forest management could be the earliest forms of food production in Mesoamerica (MacNeish, 1967; Smith, 1967; Clement et al., 2021). Current TAFS result from a long history of interactions between societies and ecosystems, that represent millenary biocultural legacies (Boege, 2008; Toledo and Barrera-Bassols, 2008). TAFS are important settings where people experiment with different management forms of their components and processes, including the domestication of plant species, which influences the adjustment of landscapes to human needs (Casas et al., 1997, Casas et al., 2007; Moreno-Calles et al., 2014). Likewise, TAFS are living laboratories of biodiversity and ecosystem management that generate agrobiodiversity.

One of the most relevant ecosystems for the study of TAFS is the tropical dry forest (TDF), a plant community formed by tropical elements dominated by species that lose their leaves during a marked and long dry season (Rzedowski, 1978). The TDF is notable for harboring high species diversity and endemism, and it is the source of origin of wild relatives of outstanding Mesoamerican crops like maize, beans and squashes (Challenger, 1998; Banda et al., 2016). Nevertheless, this ecosystem is highly threatened, and its conservation is one priority worldwide (Janzen, 1988; Olson and Dinerstein, 2002). In Mexico, it is relevant its high level of endemism (Rendón-Sandoval et al., 2020), the highest of the TDF in the Neotropical region, with 60–73% of species restricted to the Mexican territory (Rzedowski, 1991; Banda et al., 2016).

It has been documented that TAFS provide multiple benefits or contributions to societies (Moreno-Calles et al., 2010; Altieri and Toledo, 2011; Vallejo et al., 2016; Rendón-Sandoval et al., 2020). *Nature's contributions to people* are all socio-ecological contributions that humans obtain from nature, including goods and functions from ecosystems (Díaz et al., 2018). However, the concept may also include aspects of nature that may be harmful to people (e.g. pests, pathogens, predation that damage people or their assets) (IPBES, 2019). Recently, Díaz et al. (2018) categorized such contributions in three main groups: 1) *material contributions* (substances, objects, or other tangible elements from nature that directly sustain people's life); 2) *nonmaterial contributions* (nature's effects on subjective or psychological aspects underpinning people's well-being; giving the opportunity of recreation, inspiration, spiritual experiences, and social cohesion); and 3) *regulating contributions* (functional and structural aspects of organisms and ecosystems that influence environmental conditions experienced by people and/or regulate the generation of material and nonmaterial contributions).

TAFS may maintain high proportions of forest cover, and thus provide multiple beneficial contributions, like habitat maintenance, pollination, dispersal of seeds and other propagules, air quality, climate regulation, water purification, soil formation and protection, regulation of hazards and extreme events, regulation of harmful organisms and biological processes, provision of food, fodder, medicinal, learning and inspiration, physical and psychological experiences, supporting identities, and maintenance of options (Díaz et al., 2018).

Such contributions provide the satisfaction of fundamental human needs as those pointed out by Max-Neef et al. (1998), like subsistence, protection, identity, affection, understanding, creation, participation, and leisure. These authors distinguish between *fundamental human needs* (essential human requirements and potentialities, common to all cultures in all historical periods) and *satisfiers* of such needs (different ways or means, selected by each culture to satisfy needs). For instance, food and shelter should not be considered needs, but satisfiers of subsistence need.

The attributes referred to above suggest that TAFS are outstanding alternatives to recover and implement forms of management favorable for the conservation of biodiversity, and compatible with people's well-being. Peasant women and men are crucial actors since they interact closely and continually with these systems; therefore, understanding their motivations for managing them allows documenting their knowledge on biodiversity, their strategies for conservation, and conditions for the permanence of biocultural diversity (Boege, 2008; Toledo and Barrera-Bassols, 2008). The proposals from academic, governmental, civil organizations, and other social sectors, to be viable require to be compatible with the culture, values, and wishes of those that directly manage the local ecosystems.

According to Wolf (1955), peasants have in common the following features: 1) agricultural production as their main occupation, 2) effective control of land and autonomous making decisions on their crops, and 3) their activities are more oriented towards the direct satisfaction of their subsistence rather than to reinvestment. In addition, Ploeg (2010) defines the *peasant condition* considering a base of resources controlled and administered by them, from which emerges *coproduction* (or interaction and mutual transformation between humans and nature), in turn interacting with markets maintaining their autonomy and independence. Around the world, there is a marked correspondence among areas with high biodiversity (*hotspots*) and territories of peasant and indigenous communities. Such information shows that biological and cultural diversity are reciprocally dependent and geographically coexisting (Boege, 2008; Toledo and Boege, 2010).

In this context, we consider the need to implement strategies for strengthening the peasant practices to maintain the diversity of TDF compatible with people's well-being. In such task, TAFS may have substantial contributions. The purposes of this study were to 1) identify the peasants' motivations to maintain the wild vegetation in their agricultural fields, 2) analyze the capacity of TAFS to provide contributions to people's well-being, and 3) identify factors and processes limiting conservation capacities. Previous studies have documented that both maintenance and removal of forest elements from agricultural fields are regulated by needs, values, or potential damage perceived and mediated through different management practices (Moreno-Calles et al., 2010, Moreno-Calles et al., 2012; Blancas et al., 2013; Vallejo et al., 2014, Vallejo et al., 2015, Vallejo et al., 2016; Rangel-Landa et al., 2017). In particular, our team previously documented that TAFS associated with TDF can harbor –on average– 44% of forest cover, 68% of species (30% of them endemic to Mexico), and 53% of the individuals of plants from the neighboring wild vegetation; where 96 species of useful plants (73% of the total) were recorded (Rendón-Sandoval et al., 2020). Therefore, this study seeks to deepen the understanding of the most determinant motivations for maintaining vegetation in the peasants' parcels, and the contribution of their TAFS to human well-being. For such purpose, we conducted qualitative approaches, which do not aspire to represent the state of agriculture and agricultural practices in the study area, but to understand processes and interrelationships influencing the management practices for conservation of forest cover in agricultural plots. In other words, understanding the multiple phenomena operating in a complex system of processes and factors motivating management decisions that influence the ecological expression of the agroforestry systems studied.

MATERIALS AND METHODS

Study Area

The Tehuacán-Cuicatlán Valley is one of the main reservoirs of biocultural diversity of Mexico, with a cultural history of more than 10,000 years. Important archaeological studies in the region revealed early signs of domestication and forest management practiced in the area during the prehistory, which has been recognized among the earliest signs of food production in Mesoamerica (MacNeish, 1967; Smith, 1967). It is a semi-arid zone, the most biodiverse of North America, with 37 types of plant associations (Valiente-Banuet et al., 2000) and more than 3,000 plant species registered up to now (Casas et al., 2001; Lira et al., 2009). In addition, in the Tehuacán-Cuicatlán Valley live eight indigenous groups: the Chocho (called themselves *Ngiba*), the Popoloca (*Ngiwa*), Nahua (*Macehuale*), Cuicatec (*Y'an yivacu*), Mazatec (*Enna*), Chinantec (*Tsa ju jmí*), Mixtec (*Ñuu savi*), and Ixcatec (*Xwja*) people (Casas et al., 2001; Boege, 2008).

To conserve such biological and cultural richness, the region was decreed as a Biosphere Reserve in 1998, and then inscribed in the List of World Heritage (cultural and natural) of the UNESCO in 2018, due to the extraordinary values of the natural environments and cultural Mesoamerican traditions. In addition, the Tehuacán-Cuicatlán Valley has been cataloged as one of the 23 Priority Biocultural Regions for Conservation of Mexico (Boege, 2008).

Our research was conducted in three mestizo communities with Cuicatec and Mazatec origin in the "Cañada" region, belonging to the municipality of San Juan Bautista Cuicatlán, Oaxaca (**Figure 1**). This territory, located at elevations averaging 700 m, has a semi-arid dry climate with annual rainfall averaging 485 mm, with eight dry months, and 25°C of annual mean temperature (García, 2004). It is the confluence zone of several rivers that allow the presence of riparian vegetation, coexisting with different types of columnar cacti forests and TDF. Our study was conducted in the peasant communities of Santiago Quiotepec, Cuicatlán, and Santiago Dominguillo, where the land tenure is communal and ejidal (two forms of collective tenure regimes). These communities have primary activities like

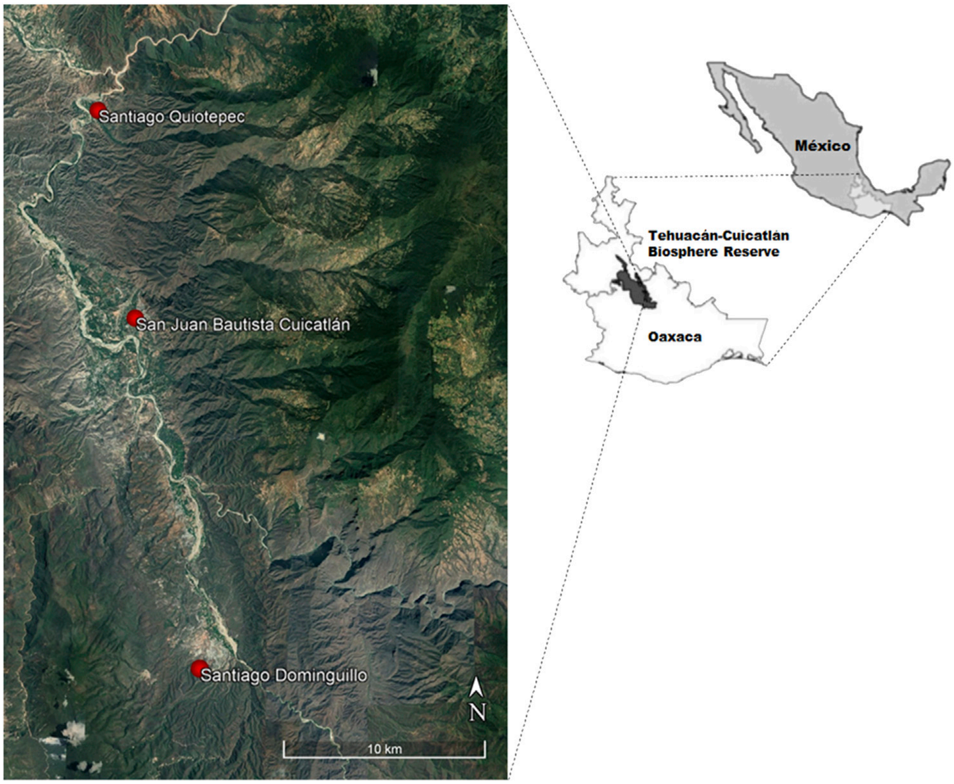

FIGURE 1 | Location of the communities where the study was conducted in the Tehuacán-Cuicatlán Biosphere Reserve, Mexico. Based on Google Earth Pro and Vallejo et al. (2015).

traditional "milpa" agriculture (a multi-crop system with maize, beans and squash), cultivation of fruit trees (lemon, mango, sapodilla, spondias plum, annona, black sapote) in irrigated areas, raising of goats, and gathering of timber and non-timber forest products (Brunel, 2008; Rendón-Sandoval et al., 2020).

Methodological Design

We carried out a qualitative analysis including as methodological referent the Grounded Theory proposed by Glaser and Strauss (1967). The Grounded Theory is a qualitative research method whose purpose is to generate theoretical explanations based on the data obtained from the specific context studied; therefore, it does not start from *a priori* selected theories. The Grounded Theory uses an inductive approach to generate theoretical concepts and identify their relationships from the analysis of the information obtained, in such a way that the explanations emerge from the data itself and is closer to reality, as it does not impose the verification of a pre-established theory (Taylor and Bogdan, 1987; Strauss and Corbin, 2002).

Qualitative analysis is supported by continual feedback from data to interpretations, a process in which: 1) the information is analyzed systematically to generate *codes* (or identifiers of particular themes), 2) these codes and their interpretations are debugged and/or nuanced through a continual contrasting with the data obtained, 3) their properties are identified, 4) codes are classified and grouped into categories, 5) their interrelationships are explored, and finally 6) these are integrated into a coherent explanation (Taylor and Bogdan, 1987).

The fieldwork started with exploratory visits to study communities, observing TAFS in their territories, and asking permission from local communitarian authorities to carry out the research. We also visited the authorities of the Tehuacán-Cuicatlán Biosphere Reserve to inform us about our research project, ask for their permit and advice.

Data Collection

For obtaining the information we carried out: 1) 10 semi-structured interviews with peasants whose agricultural fields were sampled for previous ecological studies (see Rendón-Sandoval et al., 2020). These interviews yielded results that reached the principle of information saturation, which refers to the stage in qualitative data collection when collecting more data produces little important new information or understanding relevant to the research questions (Newing et al., 2011). Semi-structured interviews allow integrating closed-ended questions (questionnaire type) as well as open-ended questions in the same tool, which makes it possible to capture specific data while delving deeper into certain topics that require more exhaustive exploration, thus providing in-

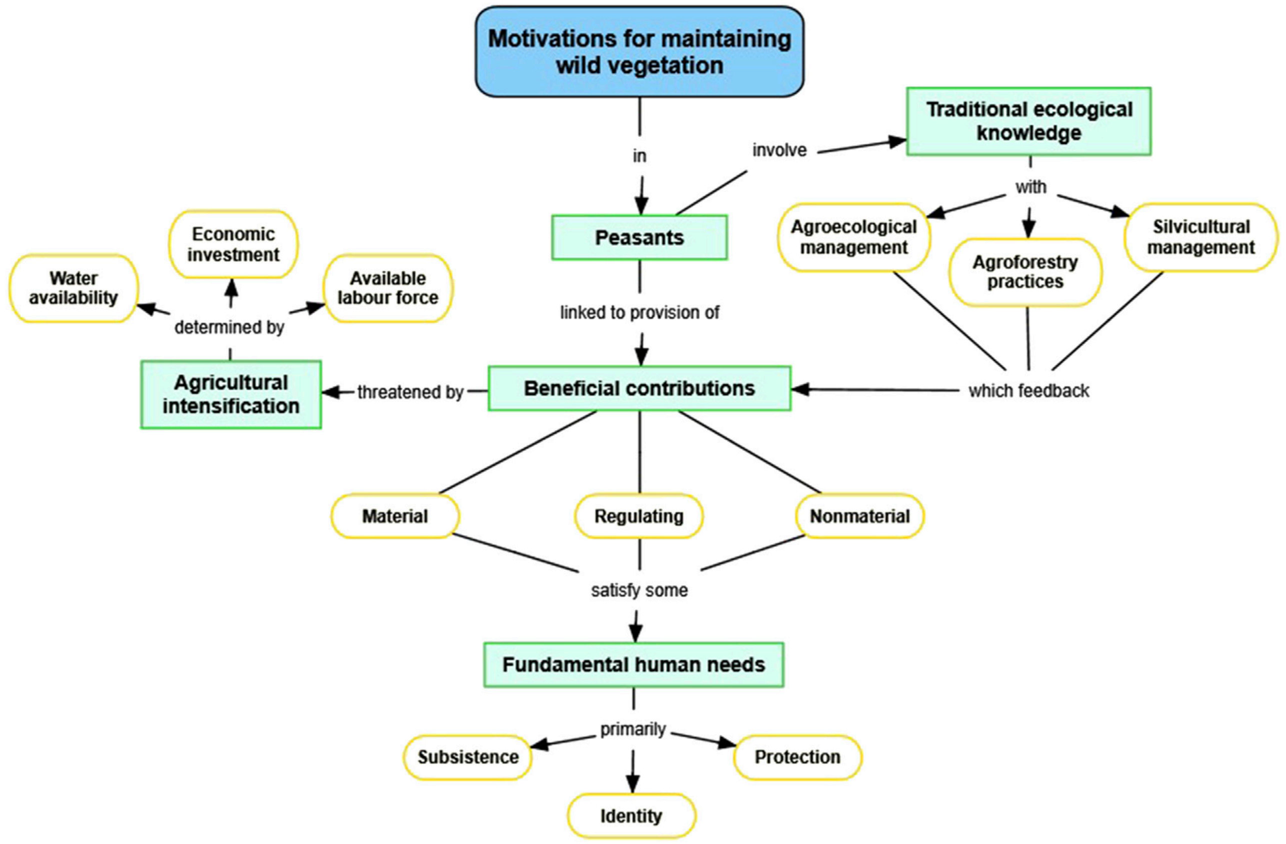

FIGURE 2 | General diagram explaining the peasants' motivations for maintaining wild vegetation within traditional agroforestry systems in the Cañada region, Oaxaca, Mexico. The blue box indicates the central research question: What motivates peasants to maintain wild vegetation within their agricultural fields? The green rectangles contain the main categories that emerged in the qualitative analysis conducted through Atlas. ti. The yellow boxes contain the main subcategories involved in, and helping to explain, the observed situation. Lines and arrows indicate relations and causative directions.

depth information. Our interview script (see **Supplementary Material**) was constructed with these characteristics (Drury et al., 2011). For the design of the interview guide we based the proposal on previous studies conducted in the region (e.g. Moreno-Calles et al., 2010, Moreno-Calles et al., 2012), incorporating relevant themes from other related studies (e. g. Pelcastre et al., 2020) to answer the research questions posed. People interviewed included two women and eight men 29–81 years old (average 60 years), from February 2018 to August 2019; 2) two workshops with local people from the community of Quiotepec (with the participation of 13 young and adult people) about "benefits of wild plants", the elaboration of free lists about nature's contributions, and the agricultural calendar followed by the community. The workshops were conducted as an additional technique to the interviews that served to complement and triangulate the information obtained through interviews. The workshops were based on guiding questions about the contributions that vegetation makes –and that motivate its conservation within the TAFS–, as well as about the seasonality of agricultural activities carried out throughout the year (e.g. planting, harvesting, seed selection and storage, fallow). People's responses were recorded on flip charts for subsequent systematization and analysis. Interviews and workshops provided more than 25 h of audio recording which were transcribed to be analyzed; 3) participant observation in communitarian activities (e.g. maize harvesting, preparation of pasture bags, goats grazing, religious ceremonies, and funerary rites); 4) informal talks with peasants during forest walks, sharing of food or resting in their homes; and 5) registering notes in a fieldwork diary.

The interviews comprised 85 questions on: 1) characteristics and history of parcels, 2) level of agricultural intensification, 3) management of vegetation, 4) contributions to human well-being, and 5) motivations for maintaining or removal of wild plant species in agricultural fields. Previously, we conducted samplings to analyze the cover and composition of forest patches in parcels of TAFS managed by people interviewed. Vegetation sampled in TAFS parcels was compared with that of native forests (see Rendón-Sandoval et al., 2020).

Data Analysis

To analyze the information, we: 1) examined the interviews to identify the most relevant elements and generate a list of central

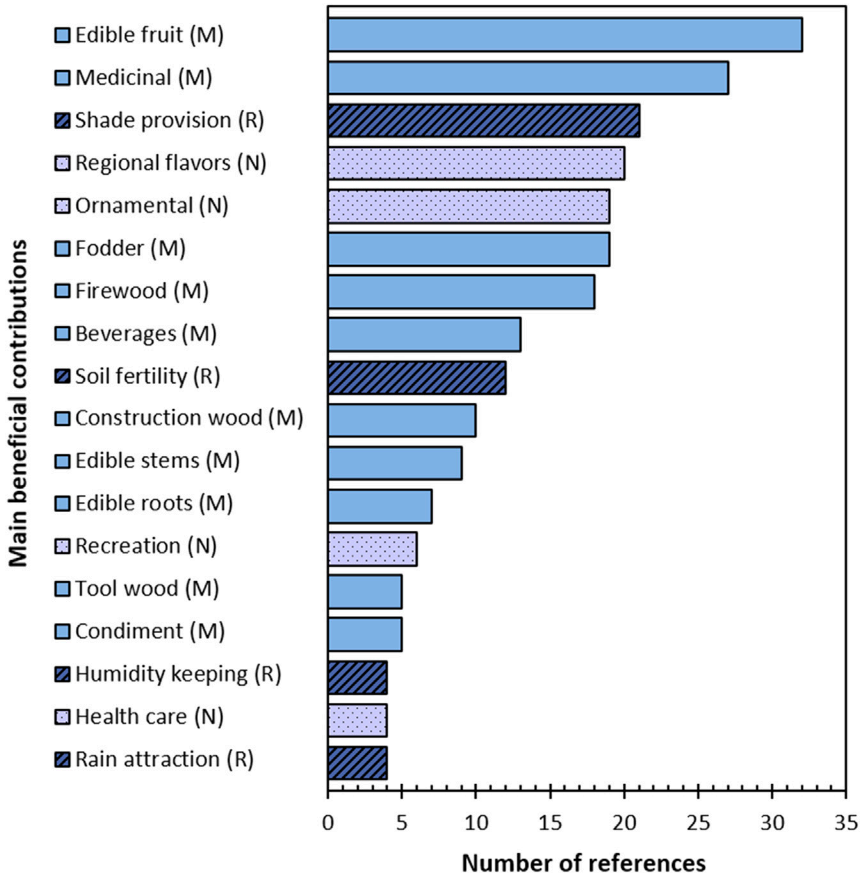

FIGURE 3 | Main beneficial contributions –motivating the maintenance of native vegetation from the tropical dry forest– referred by peasants in the Cañada region, Oaxaca, Mexico. Material contributions (M), Regulating contributions (R), Nonmaterial contributions (N).

themes, which was then complemented with information from workshops, participant observation, informal talks, and fieldwork notes; 2) classified into preliminary categories those similar themes, and identified *a priori* codes that served as the basis for an in-depth analysis of the information in a qualitative analysis software; 3) analyzed profoundly the interviews through the Atlas.ti software (version 7), which facilitated the creation of more robust codes that were grouped into more precise categories and subcategories of analysis –related to the peasant condition, traditional ecological knowledge, socio-ecological contributions, agricultural intensification, and fundamental human needs– (**Figure 2**); and 4) we analyzed the relations between codes, and between the codes and the local context, carrying out a continue observation of the coherency between data and the interpretations given, to assure the veracity of the results and explanations. The number of contributions for each TAFS was obtained from a list that condensed all the contributions registered in the three communities studied. Each contribution was contrasted with the data from the specific interviews for each TAFS, assigning values of presence-absence (0–1, respectively) for each one of them. In addition, this information was related to some ecological attributes (forest cover, and species diversity) obtained specifically for each TAFS analyzed in a previous study (see Rendón-Sandoval et al., 2020).

RESULTS

Peasants' Motivations to Maintain Vegetation

> *"What for sowing a «cucharito»* (the legume tree *Acacia cochliacantha*) *if it does not provide benefit? You have to sow a lemon tree to obtain a product . . . a mango, a chicozapote which give something"; "Herb that does not serve, why do I leave them?"; "I prefer trees that provide something –and although they do provide nothing, either way– I left them standing so that they continue living".*

The peasants' foremost motivations to maintain wild vegetation within their agricultural fields are the provision of several beneficial contributions that meet some of their fundamental needs (**Figure 2**; **Supplementary Material**). These beneficial contributions represent the most recorded contributions (83%, **Figure 3**), while 17% were detrimental

FIGURE 4 | Some outstanding material contributions that motivate the maintenance of native plants from tropical dry forests in the Cañada region, Oaxaca, Mexico. Provision of edible fruit and stems: "tunillo" *Stenocereus stellatus** **(A)**, "biznaga" *Ferocactus recurvus** **(B)**, "tempesquistle" *Sideroxylon palmeri** **(C)**, "nopal de cruz" *Acanthocereus subinermis** **(D)**. Medicinal plants: "cuachalalá" *Amphipterygium adstringens* **(E)**, "mala mujer" *Cnidoscolus tubulosus* **(F)**. *Species endemic from Mexico.

contributions. We identified that obtaining material contributions represents the peasants' main reasons to maintain plant components of TDF (62%). These were followed by regulating contributions (20%), and nonmaterial contributions (18%).

The most outstanding material contributions –which represent also the focal reasons to maintain biodiversity– include species providing edible fruit, greatly appreciated in the region (especially those of the Cactaceae family), medicinal plants, species used for live fences (with the capacity to regrowth of cuttings), fodder species, firewood for cooking, plants used for preparing beverages, those providing construction wood, edible stems and roots, condiments, materials for fabricating tools, domestic utensils and handcrafts, and edible flowers (**Figure 4**; **Table 1**).

The most relevant regulating contributions include plant species that provide shade, soil fertility, humidity keeping, rain attraction, pest control, pollinators habitat and other beneficial species, and protect soil against erosion. The nonmaterial contributions include species appreciated for special flavors conferred to regional stoves and beverages (which have high identity value), ornamental plants that are ceremonial, source of recreation, health, inspiration, as well as aromatic, ritual, and ludic plants (**Table 1**).

All these contributions of vegetation to the well-being of local people help to meet fundamental needs of subsistence, protection, and identity, but also others like affection, understanding, creation, participation, and leisure. We can visualize a direct relation between the number of contributions and the capacity to meet fundamental human needs (**Table 1**).

A few detrimental contributions of vegetation (17%), with a noteworthy importance, were referred to by peasants: 1) competence with crops for space, luminosity, humidity, and/or nutrients (primarily species with high reproductive success like "guaje" *Leucaena leucocephala*, "mantecoso" *Parkinsonia praecox*, "mezquite" *Prosopis laevigata*, "guamúchil" *Pithecellobium dulce*, and other legume trees); 2) the forest cover represents habitat of undesirable animal species since their damage to crops (e.g. birds like "chiquitón" *Melanerpes hypopolius* recognized as a seed consumer, ants *Atta mexicana* which cut flowers of some crops, or the coati *Nasua narica* which consume maize); 3) potential risk of injured due to breaking of branches and stems of giant plants (like the columnar cacti

TABLE 1 | Contributions of vegetation to local people's well-being through the satisfaction of some fundamental human needs in the Cañada region, Oaxaca, Mexico.

Contributions	Fundamental needs	Preferred plants
Material		
Edible fruit	Subsistence, identity	Cactaceae spp. ("jiotilla" or "xonostle" *Escontria chiotilla**, "garambullo" *Myrtillocactus geometrizans**, "nanabuela" or "barba de viejo" *Pilosocereus chrysacanthus**, "pitaya" *Stenocereus pruinosus**, "tunillo" *Stenocereus stellatus**), "guaje" *Leucaena leucocephala*, "tempesquistle" *Sideroxylon palmeri**
Medicinal	Protection	"Cuachalalá" *Amphipterygium adstringens* (healing), "oreganillo" *Lippia graveolens* (digestive), "mala mujer" *Cnidoscolus tubulosus* (antirheumatic)
Live fences	Protection	Cactaceae, Burseraceae, and Fabaceae spp.
Fodder	Subsistence, protection	Fabaceae spp. (immature fruits), "mantecoso" *Parkinsonia praecox* and "cardón" *Pachycereus weberi** (flowers), "caulote" *Guazuma ulmifolia*
Firewood for cooking	Subsistence	"Cucharito" *Acacia cochliacantha**, "mezquite" *Prosopis laevigata*, "oaxaqueño" *Senna atomaria*
Preparation of beverages	Identity	"chupandía" *Cyrtocarpa procera*, Cactaceae spp.
Construction wood	Protection	"Mezquite" *Prosopis laevigata*, "quebracho" *Acacia pringlei**, "cedro" *Cedrela odorata*, "caoba" *Swietenia humilis*, "cucharito" *Acacia cochliacantha**, "guajillo" *Lysiloma divaricatum*
Edible stems and leaves	Subsistence, identity	"Quelites" ("chepíl" *Crotalaria pumila*, "chepiche" *Porophyllum ruderale*, "quintonil" *Amaranthus hybridus*), "nopal de cruz" *Acanthocereus subinermis**
Edible roots	Subsistence	"Jícama de pochote" *Ceiba parvifolia**
Condiments	Identity, subsistence	"Oreganillo" *Lippia graveolens* and "aguacate" *Persea americana* (leaves)
Wood for fabricating tools and domestic utensils	Creation	"Agalán" *Karwinskia humboldtiana*, "palo prieto" *Colubrina elliptica*, "matagallina" *Quadrella incana*, "rompezallo" *Celtis pallida*
Edible flowers	Subsistence, identity	"Cacayas" of "rabo de león" *Agave quiotepecensis** and "mano de león" *Agave seemanniana**, "flor de pitayavieja" *Pilosocereus chrysacanthus**
Aphrodisiac	Affection	"Mezquite" *Prosopis laevigata*
Quench thirst	Subsistence	"Biznaga" *Ferocactus recurvus** (fruit)
Appetite stimulant	Protection, subsistence	"Chepiche" *Porophyllum ruderale* (leaves and stems)
Ferments	Identity	"Pulque rojo" of "cardón" *Pachycereus weberi**
Toys	Leisure	"Canoítas" *Amphilophium crucigerum* (fruit)
Materials for handcrafts	Creation	"Copalillo" *Bursera submoniliformis* (for fabricating sculptures of fantastic animals or "alebrijes")
Resins	Identity	"Linaloe" *Bursera linanoe**, *Bursera* spp.
Saponifiers (soap)	Protection	"Cholulo" *Ziziphus amole** (fruit)
Poisons	Protection	"Brea" *Bursera aptera** (resin)
Regulating		
Shade provision	Protection	"Mezquite" *Prosopis laevigata*, "guamúchil" *Pithecellobium dulce*, "guapinole" *Acacia coulteri**, "guaje" *Leucaena leucocephala*
Soil fertility	Protection	"Chimalacate" *Viguiera dentata*, Fabaceae spp.
Rain attraction	Protection, subsistence	*"All wild trees call rain"*
Humidity keeping	Protection, subsistence	"Mezquite" *Prosopis laevigata*, "higo" *Ficus cotinifolia,* "palo de agua" *Astianthus viminalis*
Pest control	Protection	"Venenillo" *Cascabela thevetia* (latex against the ant "chicatana" *Atta mexicana*)
Habitat for other species	Protection	"Mantecoso" *Parkinsonia praecox* (host of the edible mushroom "nanacate" *Schizophyllum commune*)
Prevention against soil erosion	Protection	*Agave* spp., *Hechtia* spp., *Opuntia* spp.
Nonmaterial		
Regional flavors	Identity, affection	Native (or "creole") maize *Zea mays*, "pulque rojo" of "cardón" *Pachycereus weberi**, "tesmole cuaresmeño" with "nopal de cruz" *Acanthocereus subinermis** and "tempesquistle" *Sideroxylon palmeri**, "chilhuacle" *Capsicum annuum*
Ornamental	Affection, understanding	"Roseta" *Echeveria laui**, "biznaguita" *Mammillaria huitzilopochtli**, "chilitos" or "piñitas" *Coryphantha calipensis**, "huesito" *Plocosperma buxifolium*, "solterito" *Petrea volubilis*, "cacaloxóchitl" *Plumeria rubra*, "cazahuate" *Ipomoea pauciflora*, "garañona" *Hintonia latiflora*
Source of inspiration, recreation, and health	Affection, leisure	*"Plants make feel good"*
Ceremonial or ritual	Participation, identity	"Copales" and "cuajiotes" of the genus *Bursera*, "huesito" *Plocosperma buxifolium*, "solterito" *Petrea volubilis*
Aromatic	Affection	Resins of *Bursera* spp.
Ludic	Leisure	"Canoítas" *Amphilophium crucigerum* (fruit)
"They have right to live"	Understanding	*"All wild plants"*

**Species endemics of Mexico.*

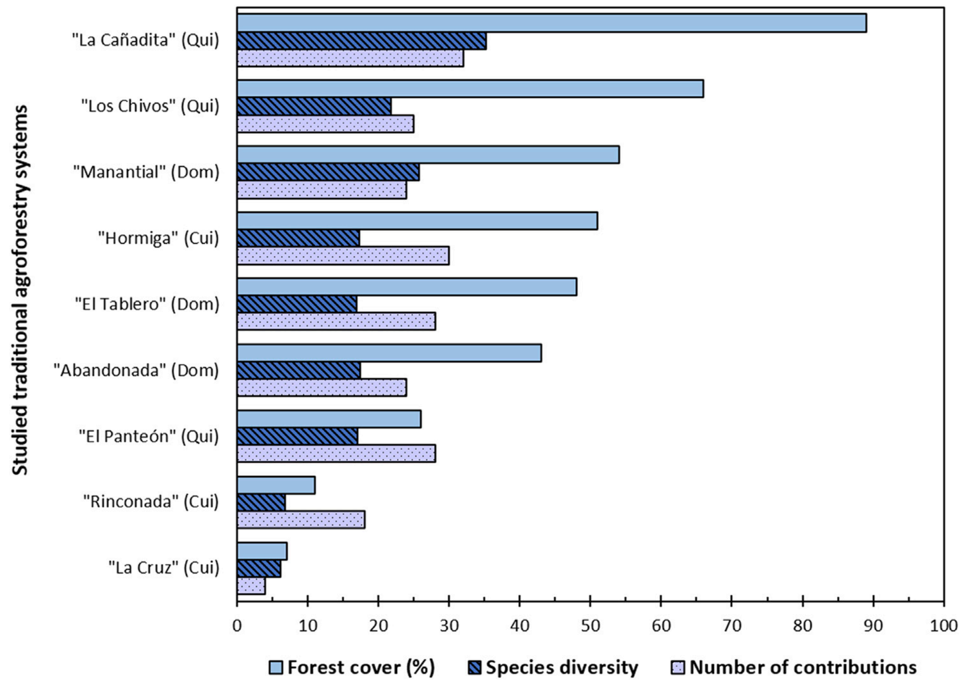

FIGURE 5 | Relation between the percentage of forest cover, species diversity, and number of contributions of vegetation to peasants managing traditional agroforestry systems –in three communities from the Cañada region, Oaxaca, Mexico–. The words in quotation marks correspond to the local names of the studied traditional agroforestry systems. Communities of Santiago Quiotepec (Qui), Santiago Dominguillo (Dom), Cuicatlán (Cui).

"cardón" *Pachycereus weberi* and "tetecho" *Neobuxbaumia tetetzo*); and 4) the presence of thorny plants hurting and making arduous agricultural labors (especially the "chile de perro" *Opuntia pubescens*, "cocoche loco" *Opuntia decumbens*, "uñas de gato" *Mimosa lactiflua*, *M. luisana* and *M. polyantha*, and the "mala mujer" *Cnidoscolus tubulosus*).

When considering some ecological parameters estimated previously by Rendón-Sandoval et al. (2020), like species diversity (average 19.38 ± 7.9 effective species per 500 m^2 sampling unit; min. 6.12, max. 35.23), and the proportion of forest cover maintained in TAFS (average 43.89% ± 26.12 min. 7%, max. 89%), we can observe that as long as these ecological attributes decline, number of contributions also decreases (average 23.67 ± 8.43 min. 4, max. 32; **Figure 5**).

Distinctive Features of the Peasant Condition

> *"The doctor does not eat his medicines, a teacher does not eat his letters, all food comes from the field, from the peasants' work who sow maize and beans..."; "Having maize and beans we are saved"; "I never added chemical, but only organic fertilizer"; "The «creole»* (native) *maize does not have chemicals, it is clean, pretty, tender, soft... and has good flavor".*

The continuity of the peasant condition documented in the Cañada region represents a form of small-scale agriculture –associated with TDF– practiced in parcels smaller than 3 ha (average 1.66 ± 0.55 ha; min. 0.69, max. 2.38) of communal or ejidal land tenure. There, peasants: 1) inherit land to successive generations, and may buy other parcels; 2) use traditional and modern tools and practices simultaneously; 3) use their own and family workforce, which represents a demanding and exhausting activity; 4) leave parcels in fallow, usually when they have more than one parcel; 5) have a communitarian organization that confers to them belonging; it is characterized by agreements in assemblies and collaboration among people of the community in non-profitable activities like "tequio" (a form of community work that is unpaid and morally obligatory only if there are no rules and sanctions for compliance) to maintain infrastructure of common use (e.g. repairing roads or irrigation systems); 6) practice a strategy of multiple use of natural components –to obtain a variety of products– (Boege, 2008; Toledo and Barrera-Bassols, 2008) which also includes the diversification of options to guarantee subsistence (e.g. a multiplicity of crops, which are spatially and temporally complementary, as well as livestock and free raising of goats in forest areas, backyard poultry, gathering of forest products, commerce, local services, and seasonal employment).

A fundamental aspect in the continuity of the peasant condition is the permanence and regeneration of the traditional ecological knowledge, which involves the set of beliefs and knowledge on relations of living beings and their environment, transmitted and recreated from generation to generation (Berkes et al., 1994). The peasant knowledge that we documented is characterized by long term planning –based on

FIGURE 6 | Traditional agroforestry systems ("milpa" and fruit plantations irrigated with "apancles") associated with tropical dry forests in the Cañada region, Oaxaca, Mexico. Communities of Santiago Quiotepec **(A,B)**, Santiago Dominguillo **(C,D)**, and Cuicatlán **(E,F)**.

careful observation and continuous interaction with the natural environment– comprising aspects mainly related to climate forecasting, ecological interactions, phenology, edaphology, taxonomy, animal behavior, germination, environmental requirements of plants, hydraulics, luminosity, morphology, territoriality, forest recovering stages, life forms, seasonality, sexual and asexual reproduction, pest control, physiology, pollination and seed dispersal syndromes. In addition, based on a complex interaction of factors and indicators they have a local precise agricultural calendar.

In the region, agriculture is characterized by the presence of TAFS which are fields irrigated through "apancles" (or irrigation channels) with water from rivers, streams, and springs that allow two cultivation cycles per year (**Figure 6**). They practice the traditional system of multi-crop "milpa" with native (or "creole") varieties of maize (white, yellow or golden, black or "negrito" or "prieto", and "pinto"), beans ("delgadito", and "mosquito"), and squashes ("támala") mainly destined to direct consumption and, sometimes, for barter, presents, or commercialization at local scale. They also cultivate fruit trees (especially lemon, sapodilla, mango, and spondias plum) destined partly for regional commercialization, and direct consumption.

People interviewed said to allow their crops coexisting with plants belonging to TDF through different forms of silvicultural management, or *in situ* management according to Casas et al. (1997): 1) *tolerance* (leave standing, selectively, some species of useful plants); 2) *promotion or enhancing* (increasing the abundance of plants valued for different purposes); 3) *protection* (eliminating competitors or herbivores, pruning, fertilizing, providing shade or light by clearing canopy of neighboring plants); and 4) *propagation* of wild plants locally appreciated through seed sowing, planting vegetative structures or transplanting entire individual plants.

All these forms of management are carried out in the following agroforestry practices: 1) *live fences*, commonly constructed with plants relocated from inside the parcels to the borders, or transplanting plants –or their parts– from forests; these fences delimit and protect the parcels; 2) *remnants of native vegetation,* which are portions of TDF with different degrees of conservation, generally associated to zones of the parcel inaccessible or difficult to use for agriculture; 3) *isolated trees*, frequently large-sized trees which are valued for providing multiple beneficial contributions; 4) *forest cover patches,* which are areas with plant species whose abundance is promoted because of their usefulness and high

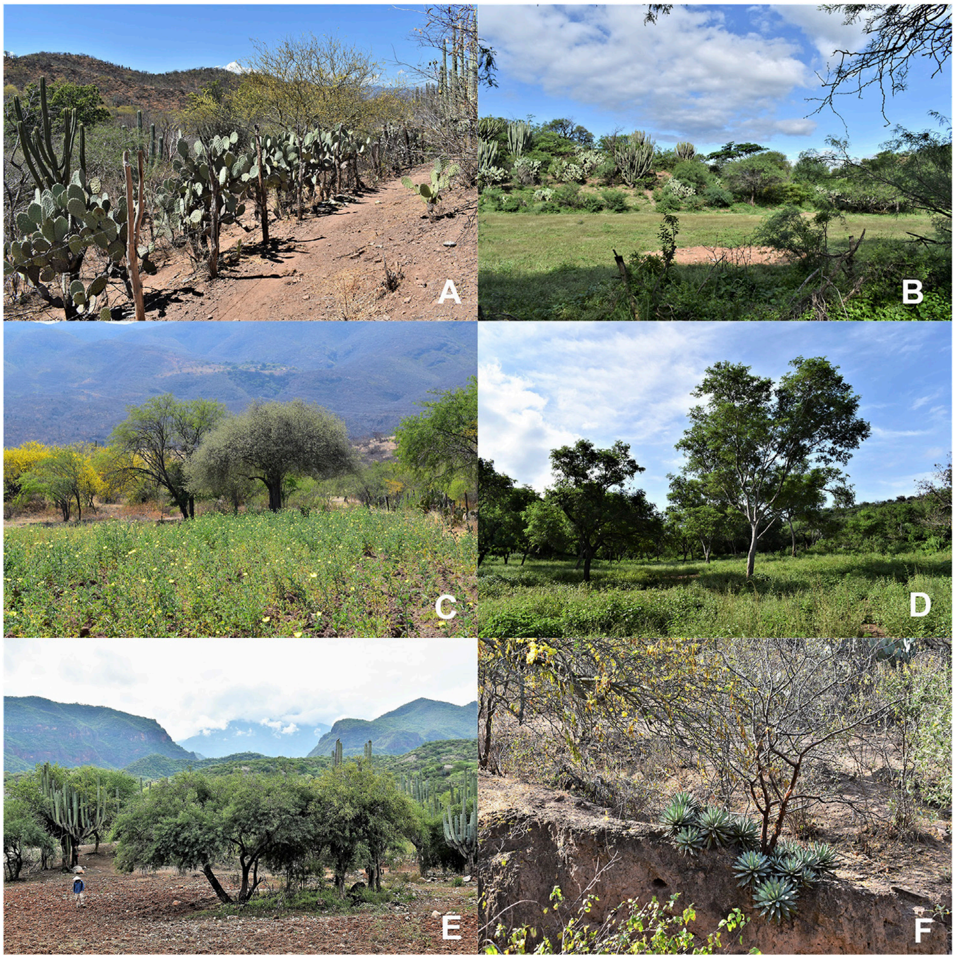

FIGURE 7 | Agroforestry practices implemented by peasants from the Cañada region, Oaxaca, Mexico. Live fences **(A)**, remnants of native vegetation **(B)**, isolated trees **(C)**, forest cover patches **(D)**, vegetation isles **(E)**, fringes against soil erosion **(F)**.

commercial value in the region; 5) *vegetation isles*, which are small patches of useful plants inside parcels; and 6) *fringes against soil erosion*, which are lines of plants arranged and maintained with the purpose of stabilizing the terrain, protecting soil against erosion, and/or maintaining humidity (**Figure 7**).

One of the attributes of the peasant condition favoring the maintenance of biocultural diversity is the agroecological management implemented, which comprise: 1) the intergenerational maintenance of agrobiodiversity through selecting and storing native seeds (a practice mainly carried out by women); 2) use of organic manures (goats and bats dung, and ash); 3) care of soil fertility by using leaf litter; 4) use of organic conservatives and repellents against pests (e.g. garlic against weevil, latex against ants); 5) the systematic experimentation of interventions on vegetation (e.g. to test less toxic pesticides on a few individuals, and to record how they respond); and 6) practice of agriculture without external inputs.

Peasants indicated some advantages of native (also called "creole") seeds over commercial varieties. According to them, native seeds have higher resistance and adaptability to the local environments, lower incidence of pests, lower cost (since after harvest these are stored for the following agricultural cycle), and lower dependence on agrochemical inputs. People consider native seeds better than the commercial ones in appearance, texture, nutritional value, performance, and, primarily, flavor (an outstanding aspect of identity and pride). It is also relevant that, according to peasants, until the mid-20th century, annual crops, and trees like avocado and papaya had good performance without using agrochemicals.

Finally, the peasant condition involves values expressed in: 1) local myths, referring to "enchanted" hills, offerings to obtain good harvests permit for using plants; 2) hope (especially to have constant rainy season); 3) gratitude (recognizing the benefits provided by nature, and the privilege to have several rivers in a semi-arid region); and 4) admiration (towards ornamental plants, natural landscapes, archaeological sites ancient, and rock paintings). It is also interesting that, in general, women frequently expressed affection and tenderness to the natural environment, while men expressed admiration and enthusiasm. Unfortunately, we also recorded cases of alcoholism, violence, abuse of authority, corruption associated with illegal traffic of species, and disputes for territories generating severe conflicts within and between communities.

Agricultural Intensification

> *"Time ago, people sowed and it was well, (I did not live that) my parents and grandparents talked to me . . . that they sowed, and they did not need neither chemical nor even plow. Plants grew big without fertilizers since the Earth was virgin, new, it had natural nutrients"; "We are finishing our lands".*

We recorded in the Cañada region some indicators of a process of agricultural intensification, which is directed to increase the total volume of agricultural production based on greater input productivity (such as labor, land, time investment, fertilizers, seeds, or cash) (FAO, 2004). In particular, we recorded the progressive replacement of native seeds –of maize and beans– by commercial varieties which causes loss of local agrobiodiversity and food autonomy. Likewise, plantations of lemon (*Citrus aurantifolia*) have increased, this represents a profitable crop that allows obtaining continuous (or at least with low uncertainty) monetary incomes throughout the year, compared with traditional "milpa". Also, local people started to practice plantations of the mezcal agave "espadín" (*Agave angustifolia*), since this profitable crop is resistant against drought. Despite these trends, we documented an active pattern of peasant diversification, with commercial crops (lemon, mango, sapodilla, spondias plum, and guaje) integrated to TAFS, coexisting with native species of TDF and traditional "milpa".

A notorious trend recorded is that in TAFS people are decreasing the forest cover inside their parcels, moving plants to the edges, in some cases even expressing disparagement for wild vegetation because they strongly competed with crops for light, water, or nutrients, which can severely limit agricultural activity. Removal of TDF occurs in the absence of communitarian agreements to protect it, since this responsibility is delegated to the Biosphere Reserve authorities.

Most people interviewed (80%) have one or two parcels relatively small (average 1.66 ha), which makes it difficult to leave resting the land. In such context, we recorded a gradient of agricultural intensification characterized by: 1) minimizing manual work and prioritizing monetary income; 2) a devaluation of the crops destined for self-consumption, where commercialization is privileged; 3) using fire to land "clearing"; 4) using tractor for soil tilling; 5) use of chemical fertilizers (nitrogenates like urea and ammonium sulfate), insecticides (malathion), herbicides (glyphosate), and fungicides (sulfured); which are expensive and unhealthy, cause a progressive resistance of pests (mainly "gusano cogollero" *Spodoptera frugiperda*, "araña roja" *Tetranychus urticae*, and "cenicilla" caused by fungi of the family Erysiphaceae), and which cause a gradual loss of peasant knowledge and agroecological management.

In contrast, there are expressions of peasant agriculture through which people: 1) give priority to native crops for direct consumption; 2) invest a high amount of familiar labor force; 3) use plow to prepare the land (since it allows precise management, where it is possible to sow "milpa" intercropped with lemons or other fruit trees); 4) employ traditional tools (mainly the "stake" for sowing, the hoe or "talacho" for weeding, and the "chicol" for collecting fruit); 5) minimizing the use of agrochemical; 6) reduce pest incidence; and 7) valuing and maintaining in TAFS some components of wild vegetation.

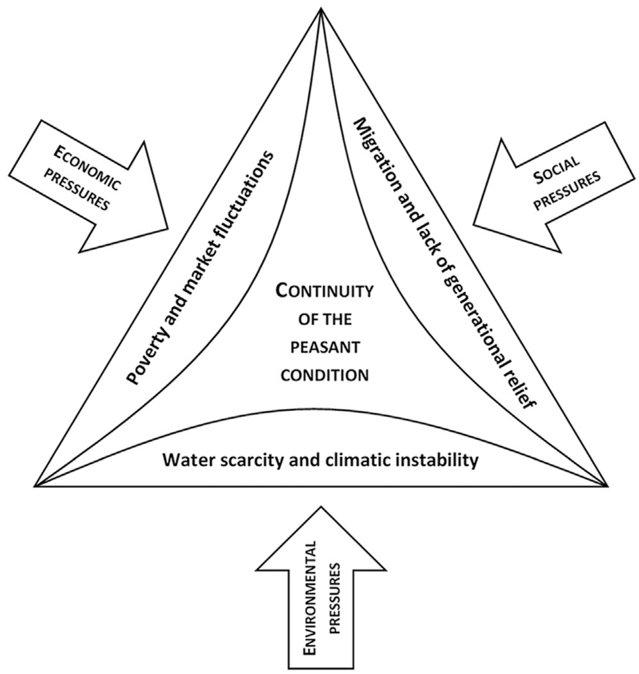

FIGURE 8 | Main environmental, economic, and social factors that weaken the continuity of the peasant condition in the Cañada region, Oaxaca, Mexico. Those attributes emerged in the qualitative analysis, and represent the most prominent factors and processes determining conservation capacities. The main economic pressure is poverty of local people and fluctuations in prices of profitable agricultural products, factors that are related to the main social pressure which is migration to cities of Mexico or the United States. These factors and the main environmental pressure which is the scarcity of water cause the eventual abandonment of agriculture and interrupt the peasant condition. Based on diagrams by Ploeg (2010).

Agricultural intensification is enhanced also by external factors like the promotion of agrochemical inputs and commercial seeds by the government and technical assistants oriented to productive intensification. Likewise, we identified other factors determining environmental, economic, and social pressures undermining the continuity of the peasant condition (**Figure 8**).

In the Cañada region, one of the most significant environmental pressures for the continuity of the peasant condition –involving the maintenance of vegetation and its provision contributions– is water scarcity, since TAFS depend directly on water from streams and springs. This condition is intimately linked to the climatic instability associated with variations in the rainy season, which is recognized by local people to have worsened since approximately 1 decade ago. Water availability represents a determinant factor favoring agricultural intensification. It was recorded that in sites irrigated throughout the year, people use to cultivate commercial varieties of "elotero" maize to be consumed as corn on the cob, which has high water requirements and agrochemical inputs. This crop is destined for commercialization in the region.

The most remarkable economic pressures are represented by the marked economic limitations of the peasants and the scarce opportunities to find salaried jobs in the communities, fluctuations in market prices, their dependence on intermediaries (or "coyotes") who hoard a considerable proportion of profits, as well as the investment in inputs and/or services like commercial seeds, agrochemicals, renting of the machinery and labor hand complementary to activities like sowing and land preparation.

The most critical social pressures are the abandonment of agriculture linked with migration to find jobs in other regions, and the weak generational relief since young people consider agriculture a demanding and tiring activity involving high uncertainty.

Other Factors Influencing Forest Conservation

> *"I hardly take them off: the «mantecoso», «mezquite», «cuachalalá», «copalillo», «tuna», «pitayas», «xoconostles», «cardón», «tetechos»...* (several species of wild plants) *all of them are in my land. I do not take them off since they have the right to live"; "Now, people of «La Biosfera»* (authorities of the Biosphere Reserve) *are who forbid to cut down trees"; "We have projects of the Biosphere Reserve to reforestation".*

During our analysis, other important elements emerged to consider the TDF conservation. These factors include: 1) the critical thinking of local people on the use of agrochemicals and health care, 2) the admiration for biodiversity and natural landscapes, the regional food, and multiple components of wild vegetation that are valued, 3) the practices directed to the restoration of biodiversity (e.g. the scattering of seeds of native trees in wild areas), 4) the respect and care of nature with ethic values and feelings of compassion towards others forms of life, 5) the restrictions from authorities of the Biosphere Reserve to use some species at risk, 6) the implementation of projects of the Biosphere Reserve like the rescue of wild plant species illegally extracted, reforestation, and environmental education, 7) the pride in biodiversity and agrobiodiversity, and 8) the inaccessibility of some areas of the territory (Trejo and Dirzo, 2000).

DISCUSSION

Peasants' Motivations to Maintain Vegetation

The peasants interviewed obtain a wide variety of socio-ecological contributions from the vegetation sheltered in the TAFS they manage. This fact shows that peasant agriculture can maintain biodiversity and provide multiple beneficial contributions that satisfy some fundamental human needs. Most of these socio-ecological contributions correspond to beneficial contributions (83%), while only 17% of the contributions we record are detrimental, which suggests that wild vegetation represents a primary source of well-being for people. This idea is supported by evidence showing that exposure to nature has a positive effect on physical and mental human health (Pretty, 2004).

The most determining motivations of peasants –to maintain components of wild vegetation within their agricultural fields– are obtaining material contributions, which help to meet subsistence, protection, and identity needs primarily. These are followed by regulating contributions which mostly provide protection, and some nonmaterial contributions that offer opportunities to meet needs for affection (through satisfiers such as admiration, care, and respect), understanding (through experimentation, rationality, and interpretation), and leisure (through tranquility, imagination, and nonchalance).

In this classification of nature's contributions to people the categories may partially overlap (Díaz et al., 2018). For instance, consuming fruits of wild cactus species helps to fulfill the need for subsistence, and simultaneously contributes to the identity of being "country people" and being able to enjoy regional flavors (that are highly valued for their ability to confer pleasure and pride). In this way, some material contributions can also have nonmaterial effects. Moreover, many contributions may be perceived as benefits or detriments depending on the cultural, socioeconomic, temporal, or spatial context (Díaz et al., 2018).

If we consider a gradient starting from material contributions (which are clearly useful, tangible, and conspicuous), through regulating contributions (which are involved in generating other contributions), these contributions could represent the *means* to realize some fundamental needs. Meanwhile, on the other side of the gradient, nonmaterial contributions (which might mistakenly be considered useless, and which are intangible, and inconspicuous) could constitute some of the ultimate *ends* of human existence, such as pleasure, inspiration, and recreation.

Remarkably, these socio-ecological contributions take shape only when there are previous valuations of natural goods in people's perceptions. Therefore, only when some values present in the natural components are known, experienced, and understood, do the contributions they make become manifest. The latter is related to the term of *resource diversity* proposed by Gerritsen (2002) to refer to the components of nature that peasants consciously identify and value, which is also recognized as a social promoter of agrobiodiversity. Thus, whereas monetary values have been broadly examined in the literature, description or measurement of symbolic, cultural, identity, and other non-economic values remain largely unexplored (Chan et al., 2012, Chan et al., 2016; Gómez-Baggethun and Barton, 2013).

The Satisfaction of Fundamental Human Needs

We distinguish the subsistence need, as a particular type of fundamental human need that is really *vital*, so it is often prioritized over other needs. However, without the satisfaction of the rest of fundamental needs, even if the human person can survive, it will be incomplete and will generate both individual and collective pathologies (Max-Neef et al., 1998).

We observed that TAFS that safeguard a greater proportion of forest cover and species diversity might provide a broader range of contributions (**Figure 5**), and thus have a greater potential to meet fundamental human needs. Is important to recognize the benefits of peasant agriculture in terms of its high capacity to provide beneficial contributions to all of humanity, compared to industrial agriculture that devastates ecosystems and eliminates ecological processes, and then seeks to replace them with commercial inputs. This acknowledgement should help overcome existing power asymmetries between western science and traditional ecological knowledge (Díaz et al., 2018).

Peasant agriculture stands out because it represents: 1) reservoirs of agrobiodiversity with thousands of edible plants strengthening food autonomy; 2) small-scale diversified systems representing a more varied diet with beneficial health implications; 3) reservoirs of local crop varieties; 4) regenerative systems that protect the soil by incorporating organic matter; 5) scenarios where local innovations, horizontal exchanges, cooperative relationships, knowledge and holistic experimentation of nature occur; and 6) a complex matrix of biological corridors at the landscape level that provide habitat for a wide variety of associated species (Perfecto and Vandermeer, 2008; Rosset and Altieri, 2019).

In addition, peasant agriculture involves some aspects that make possible the maintenance of native vegetation, with principles of respect and reciprocity towards the natural components that emanate from the traditional ecological knowledge of the peasants. However, these peasant interventions in favor of biodiversity conservation and human well-being are threatened by a prevailing model of agricultural intensification.

Finally, it would be desirable to recover, promote, and put into practice those expressions of peasant agriculture, especially the agroecological management, as well as the implementation of agroforestry practices and forms of silvicultural management, which can contribute to satisfy fundamental human needs without drastically, profoundly, and irreversibly deteriorating the natural environment.

Some Circumstances Behind the Agricultural Intensification

We identified that the principal threat affecting biodiversity conservation in TAFS is agricultural intensification. Such intensification is linked to clear environmental pressures such as water scarcity and climate instability, where increased availability of water for irrigation increases agricultural intensification.

In addition, there are economic pressures such as the poverty conditions in which many peasants live (in the face of dependence on expensive agroindustrial inputs), and fluctuations in market prices when selling their crops, which are exacerbated by the intervention of intermediaries who capture a significant share of the profits that should go to the peasants. Interestingly, some peasants expressed their willingness to increase agricultural intensification if they had the financial resources to do so, which would undoubtedly reduce the presence of native vegetation on their parcels. Serious social pressures also operate on the continuity of the peasant condition, such as migration, which causes the abandonment of agriculture and makes it difficult for the generational relief.

Furthermore, there are other structural conditions such as the historical marginalization and systematic disarticulation of the peasantry. As well as their struggle for autonomy, which takes place in a context characterized by relationships of dependence and deprivation, as Ploeg (2010) points out in his definition of the peasant condition.

The decrease in forest cover and species diversity –that commonly occur in the TAFS– also declines the number of contributions (**Figure 5**) and their potential to meet human needs. Therefore, the removal of wild vegetation from agricultural fields may represent a disadvantageous practice, but in fact, this is a trade-off since wild vegetation limits yield in agricultural production by competing with crops. This means losses for peasants, which leads most of them to use practices with varying degrees of intensification to obtain a higher yield in the shortest possible time. This is a necessity more than an option of agricultural management –if we take into account the precarious conditions peasants live–. Thus, a single detrimental contribution of wild vegetation (such as competition with crops) may outweigh the multiple beneficial contributions, and thus become a motivation to remove it.

Motivations for maintaining or removing vegetation are explained more by local contextual circumstances in multiple aspects (political, economic, environmental, cultural, historical, among others) influencing the well-being, and not only by the valuation of beneficial contributions (material, regulating, and nonmaterial). This consideration is fundamental for designing and implementing optimal strategies for both biodiversity conservation and human well-being. The underlying reasons and conditions of peasants –whose livelihoods are intrinsically linked to nature–, but whose opportunities for planned long-term agroforestry management are extremely limited for the majority must be made visible, which has to do, we reiterate, with the structural conditions of inequity and historical inequality in social sectors of the country such as the peasantry.

The Importance of Nature's Contributions for Peasants

It is essential to contemplate the importance of nature's contributions for peasants, beyond putting our valuations oriented towards biodiversity conservation (e.g. the paradox of prioritizing biodiversity conservation when the fundamental need for subsistence is not meet) because it is a fact that the exhausting peasants' work does not allow conservation to be considered as a priority.

Any hope for conserving biological diversity is predicated on a concomitant effort to appreciate and protect cultural diversity (Pretty et al., 2009). In this context, we delegate a great responsibility to peasants. When, at best, their essential labor is valued and recognized, we run the risk of idealizing their way of life, pretending that peasants renounce the comforts they could access through the capitalist commodification of their production.

We expect peasants to carry out a diversified agroecological production, nature-friendly, agrochemical-free, with community organizations linked to markets to supply the cities, etc. although they are the ones who generate and safeguard agrobiodiversity, currently produce the majority of food for human consumption (70%) –compared to industrial agriculture– (Graeub et al., 2016; Shiva, 2016; ETC Group, 2017), and have conserved biocultural diversity for thousands of years, and continue to do so today. All this in contexts of disadvantage, as mentioned above.

Finally, some relevant factors that could explain the continuity of the peasant condition, which has historically prevailed in resistance against the tide, are: 1) the cooperation (with a relative balance between individual and collective interests); 2) the relations of reciprocity and mutual aid; and 3) the dynamics where exchange-values are reinserted into peasant agriculture and converted into use-values, to produce and reproduce their base of resources (Ploeg, 2010).

Concluding Remarks

With this study we recognize the need to continue research to address the importance of the beneficial contributions of vegetation to the economy and direct subsistence of local communities. We have carried out several studies on use, extraction rates and spatial availability of plant components in forests, agricultural, and agroforestry systems of the region (e.g. Pérez-Negrón and Casas, 2007; Moreno-Calles et al., 2012). In those studies, we compared the value of forest products with that of products from agricultural systems of maize, the main crop in the area. We found that maize production in the area is, in general, insufficient to satisfy the annual local demand of households (on average, local production covers nearly 60% of the local needs). Local people, therefore, have to import most of their food and complement their economy by commercialization of fruit produced in homegardens and plantations. But importantly, they complement their diet by gathering forest products from the wild vegetation. We have estimated that, on average, the annual diet in rural communities of the Tehuacán-Cuicatlán Valley is nearly 12% formed by wild and weedy food products (Casas et al., 2008; Casas et al., 2014; Casas et al., 2016; Casas et al., 2017). In addition, Moreno-Calles et al. (2012) found that TAFS with intermediate forest cover have higher economic value than monocultures and forests.

Nevertheless, in several studies, but in this one in particular, we document that several beneficial contributions of vegetation are not marketable (e.g. shade provision, humidity keeping, or habitat for pollinators), and these are often undervalued even though they are really essential.

Small-scale peasant agriculture has some undeniable advantages over industrial agriculture. Especially when considering the social, environmental, and economic costs (or *externalities*) involved in agroindustrial production that conventional economic accounting fails to capture (Sathirathai and Barbier, 2001; Goméz-Baggethun and Martín-López, 2010; Holt-Giménez, 2017). For instance, severe environmental and social damages such as massive removal of wild vegetation and habitat destruction, biodiversity loss, demand for huge amounts of water and polluting chemical inputs, transgressing the peasant way of life, and causing disabling dependency to the detriment of local autonomies can be mentioned (Ploeg, 2010; Giraldo, 2018).

Considering the trend of productive intensification documented in this study, it would be interesting to try to predict possible scenarios of change of the TAFS in the future. Moreno-Calles et al. (2010); Moreno-Calles et al. (2012), for instance, pointed out that TAFS in the Tehuacán-Cuicatlán Valley are losing their capability to maintain forest cover, mainly because of 1) decreasing amount of land managed by households, determined by a progressive fragmentation of the land area given to new families, 2) adoption of technologies to intensify agriculture, and 3) governmental programs penalizing the presence of vegetation patches within agricultural parcels since they are considered "useless" areas.

However, a more recent study by our team (Vallejo et al., 2019) found that, despite local people and researchers perceive a progressive decline in both natural ecosystems and TAFS, agricultural areas are being abandoned, thus favoring the regeneration of wild vegetation, as well as a 9% increase of TAFS over conventional agricultural systems. Nevertheless, it should be carefully analyzed whether this "recovery" –of wild vegetation and TAFS– is being driven primarily by the abandonment of agriculture in a context of migration and/or restrictions imposed by authorities of the Biosphere Reserve and other factors determining environmental, economic, and social pressures undermining the continuity of the peasant condition (**Figure 8**).

For future research, we recommend using approaches that help to understand the complexity of TAFS. A good example could be the *Ethnoagroforestry* approach, as this perspective provides a theoretical framework that integrates socio-ecological aspects from different disciplines with traditional ecological knowledge. Ethnoagroforestry seeks to establish the basis for integrating cultural, agricultural and forest diversity –as well as the abiotic components of the system– recognizing that peasants and indigenous communities are the main drivers and planners of the use of landscape diversity. This approach also notes out that expressions of traditional agroforestry management may be able to provide the basis for food sovereignty and sustainable management of socio-ecological systems (Moreno-Calles et al., 2016).

There is an unquestionable need for complementary researches between different disciplines and worldviews, since biodiversity conservation issues cannot be addressed only by biological sciences, but must consider all the dimensions that link human societies with natural components (Alves and Albuquerque, 2012). Qualitative studies like the one we report here allow identifying processes and relationships among factors influencing management decisions and their consequence on vegetation cover, composition and potential to recover ecosystems. Pertinent questions for extensive surveys and sampling methods for rapid diagnoses of agroforestry systems at regional level may be designed based on the researches conducted until now, and that is our purpose for further studies.

The conservation and the sustainable use of nature's components is determinant for guarantee the well-being of societies. All the social-ecological systems depend on ecosystems and their components to sustain long-term conditions for life (Odum, 1989). Peasant agriculture can maintain biodiversity at the same time satisfying some fundamental human needs. However, it needs to be revitalized, made more efficient, profitable, and dignified. The agroecological management implemented by peasants –in traditional agroforestry systems– is very important for ensuring the maintenance of essential environmental functions for humanity's quality of life on the planet.

Moreover, beyond commitment and responsibility (with moral-ethical foundations), we need *affective relationships* of respect and reverence for all expressions of life and nature (including some life-sustaining components, such as water, wind, rocks), since humans and nonhuman entities are interwoven in deep relationships of kinship and reciprocal obligations (Berkes, 2017). We need an active understanding back to the relationships of reciprocity between society and nature.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

FR-S designed the study, performed fieldwork, analyzed the information, and wrote the manuscript. AC designed and advised the study, and wrote the manuscript. PS-R contributed to the methodological design, performed fieldwork, and wrote the manuscript. EG-F and AM-C designed and advised the study, and proofread the manuscript. All authors read and approved the final manuscript.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fenvs.2021.682207/full#supplementary-material

REFERENCES

Altieri, M. A., and Toledo, V. M. (2011). The Agroecological Revolution in Latin America: Rescuing Nature, Ensuring Food Sovereignty and Empowering Peasants. *J. Peasant Stud.* 38, 587–612. doi:10.1080/03066150.2011.582947

Alves, R., and Albuquerque, U. (2012). Ethnobiology and Conservation: Why Do We Need a New Journal? *Ethnobio Conserv* 1, 2–4. doi:10.15451/ec2012-8-1.1-1-03

Banda, R. K., Delgado-Salinas, A., Dexter, K. G., Linares-Palomino, R., Oliveira-Filho, A., Prado, D., et al. (2016). Plant Diversity Patterns in Neotropical Dry Forests and Their Conservation Implications. *Science* 353, 1383–1387. doi:10.1126/science.aaf5080

Berkes, F., Folke, C., and Gadgil, M. (1994). Traditional Ecological Knowledge, Biodiversity, Resilience and Sustainability. *Biodivers. Conserv.* 4, 269–287. doi:10.1007/978-94-011-0277-3_1510.1007/978-94-011-1006-8_15

Berkes, F., and Folke, C. (1998). *Linking Social and Ecological Systems. Management Practices and Social Mechanisms for Building Resilience.* Cambridge: Cambridge University Press.

Berkes, F. (2017). *Sacred Ecology*. 4th ed. New York: Routledge. doi:10.4324/9781315114644

Blancas, J., Casas, A., Pérez-Salicrup, D., Caballero, J., and Vega, E. (2013). Ecological and Socio-Cultural Factors Influencing Plant Management in Náhuatl Communities of the Tehuacán Valley, Mexico. *J. Ethnobiol. Ethnomed.* 9, 39–22. doi:10.1186/1746-4269-9-39

Blancas, J., Casas, A., Rangel-Landa, S., Moreno-Calles, A., Torres, I., Pérez-Negrón, E., et al. (2010). Plant Management in the Tehuacán-Cuicatlán Valley, Mexico1. *Econ. Bot.* 64, 287–302. doi:10.1007/s12231-010-9133-0

Boege, E. (2008). *El patrimonio biocultural de los pueblos indígenas de México. Hacia la conservación* in situ *de la biodiversidad y agrodiversidad en los territorios indígenas*. 1st ed. Ciudad de México: INAH, CDI.

Brunel, M. C. (2008). Poner la conservación al servicio de la producción campesina, reto para la construcción de un nuevo paradigma de desarrollo. *Argumentos* 57, 115–137.

Casas, A., Caballero, J., Mapes, C., and Zárate, S. (1997). Manejo de la vegetación, domesticación de plantas y origen de la agricultura en Mesoamérica. *Bot. Sci.* 61, 31–47. doi:10.17129/botsci.1537

Casas, A., Camou, A., Otero Arnaiz, A., Rangel Landa, S., Cruse-Sanders, J., Solís, L., et al. (2014). Manejo tradicional de biodiversidad y ecosistemas en Mesoamérica: el Valle de Tehuacán. *Investig. Ambient.* 6, 23–44.

Casas, A., Lira, R., Torres-García, I., Delgado-Lemus, A., Moreno-Calles, A. I., Rangel-Landa, S., et al. (2016). "Ethnobotany for Sustainable Ecosystem Management: A Regional Perspective in the Tehuacán Valley," in *Ethnobotany of Mexico. Interactions of People and Plants in Mesoamerica*. Editors R. Lira, A. Casas, and J. Blancas (Utrecht: Springer), 179–206. doi:10.1007/978-1-4614-6669-7_1

Casas, A., Otero-Arnaiz, A., Pérez-Negrón, E., and Valiente-Banuet, A. (2007). *In Situ* Management and Domestication of Plants in Mesoamerica. *Ann. Bot.* 100, 1101–1115. doi:10.1093/aob/mcm126

Casas, A., Parra-Rondinel, F. A., Aguirre-Dugua, X., Rangel-Landa, S., Blancas, J., Vallejo, M., et al. (2017). "Manejo y domesticación de plantas en Mesoamérica. Una estrategia de investigación y estado del conocimiento sobre los recursoés genéticos," in *Domesticación en el continente americano. Volumen 2. Investigación para el manejo sustentable de recursos genéticos en el Nuevo Mundo*. Editors A. Casas, J. Torres-Guevara, and F. A. Parra-Rondinel (Morelia: Editorial Morevalladolid), 69–102.

Casas, A., Rangel-Landa, S., Torres-García, I., Pérez-Negrón, E., Solís, L., Parra-Rondinel, F. A., et al. (2008). "In Situ Management and Conservation of Plant Resources in the Tehuacán-Cuicatlán Valley, Mexico: An Ethnobotanical and Ecological Approach," in *Current Topics in Ethnobotany*. Editors U. P. Albuquerque and M. Alves (Kerala: Research Signpost), 1–25.

Casas, A., Valiente-Banuet, A., Viveros, J. L., Caballero, J., Cortés, L., Dávila, P., et al. (2001). Plant Resources of the Tehuacán-Cuicatlán valley, Mexico. *Econ. Bot.* 55, 129–166. doi:10.1007/BF02864551

Challenger, A. (1998). *Utilización y conservación de los ecosistemas terrestres de México: pasado, presente y futuro*. Ciudad de México: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, Universidad Nacional Autónoma de México y Agrupación Sierra Madre, S.C.

Chan, K. M. A., Balvanera, P., Benessaiah, K., Chapman, M., Díaz, S., Gómez-Baggethun, E., et al. (2016). Why Protect Nature? Rethinking Values and the Environment. *Proc. Natl. Acad. Sci. USA* 113, 1462–1465. doi:10.1073/pnas.1525002113

Chan, K. M. A., Satterfield, T., and Goldstein, J. (2012). Rethinking Ecosystem Services to Better Address and Navigate Cultural Values. *Ecol. Econ.* 74, 8–18. doi:10.1016/j.ecolecon.2011.11.011

Clement, C. R., Casas, A., Parra-Rondinel, F. A., Levis, C., Peroni, N., Hanazaki, N., et al. (2021). Disentangling Domestication from Food Production Systems in the Neotropics. *Quaternary* 4, 4. doi:10.3390/quat4010004

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., et al. (2018). Assessing Nature's Contributions to People. *Science* 359, 270–272. doi:10.1126/science.aap8826

Díaz, S., Settele, J., Brondízio, E. S., Ngo, H. T., Agard, J., Arneth, A., et al. (2019). Pervasive Human-Driven Decline of Life on Earth Points to the Need for Transformative Change. *Science* 366, eaax3100. doi:10.1126/science.aax3100

Drury, R., Homewood, K., and Randall, S. (2011). Less Is More: the Potential of Qualitative Approaches in Conservation Research. *Anim. Conserv.* 14, 18–24. doi:10.1111/j.1469-1795.2010.00375.x

ETC Group (2017). *Quién nos alimentará? La red campesina alimentaria o la cadena agroindustrial?* 3rd ed. Montreal: ETC Group.

FAO (2004). *La ética de la intensificación sostenible de la agricultura*. Roma: Food and Agriculture Organization of the United Nations (FAO).

García, E. (2004). *Modificaciones al sistema de clasificación climática de Köppen (para adaptarlo a las condiciones de la República Mexicana)*. 5th ed.. Ciudad de México: Instituto de Geografía, Universidad Nacional Autónoma de México.

Gerritsen, P. (2002). *Diversity at Stake. A Farmer's Perspective on Biodiversity and Conservation in Western Mexico*. Wageningen: Wageningen Universiteit.

Giraldo, O. F. (2018). *Ecología política de la agricultura. Agroecología y posdesarrollo*. 1st ed.. San Cristóbal de Las Casas: El Colegio de la Frontera Sur.

Glaser, B., and Strauss, A. (1967). *The Discovery of Grounded Theory*. Chicago: Aldine Press.

Gómez-Baggethun, E., and Barton, D. N. (2013). Classifying and Valuing Ecosystem Services for Urban Planning. *Ecol. Econ.* 86, 235–245. doi:10.1016/j.ecolecon.2012.08.019

Goméz-Baggethun, E., and Martín-López, B. (2010). "Los costes socioeconómicos asociados a la pérdida de biodiversidad," in *Lychnos. Consideraciones socieconómicas asociadas a la conservación* (Madrid: Fundación General CSIC), 68–74.

Graeub, B. E., Chappell, M. J., Wittman, H., Ledermann, S., Kerr, R. B., and Gemmill-Herren, B. (2016). The State of Family Farms in the World. *World Develop.* 87, 1–15. doi:10.1016/j.worlddev.2015.05.012

Holt-Giménez, E. (2017). *El capitalismo también entra por la boca: comprendamos la economía política de nuestra comida*. New York: Monthly Review Press, Food First Books.

Intergovernmental Panel for Climate Change (IPCC) (2013). *Climate Change. The Physical Science Basis*. New York: Intergovernmental Panel for Climate Change (IPCC).

IPBES (2019). *Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. Bonn: IPBES secretariat.

Janzen, D. H. (1988). "Tropical Dry Forests: The Most Endangered Major Tropical Ecosystem," in *Biodiversity*. Editors E. O. Wilson and F. M. Peters (Washington, D.C.: National Academy Press), 130–137.

Lira, R., Casas, A., Rosas-López, R., Paredes-Flores, M., Pérez-Negrón, E., Rangel-Landa, S., et al. (2009). Traditional Knowledge and Useful Plant Richness in the Tehuacán-Cuicatlán Valley, Mexico. *Econ. Bot.* 63, 271–287. doi:10.1007/s12231-009-9075-6

MacNeish, R. S. (1967). "A Summary of the Subsistence,," in *The Prehistory of the Tehuacán Valley. Volume 1. Environment and Subsistence*. Editor D. S. Byers (Austin: University of Texas Press), 290–309.

Max-Neef, M., Elizalde, A., and Hopenhayn, M. (1998). *Desarrollo a Escala Humana. Conceptos, Aplicaciones Y Algunas Reflexiones*. 2nd ed.. Barcelona: Icaria Editorial.

Millennium Ecosystem Assessment (MEA) (2005). *Ecosystems and Human Well-being Biodiversity Synthesis*. Washington, D.C: Island Press.

Moreno-Calles, A., Casas, A., Blancas, J., Torres, I., Masera, O., Caballero, J., et al. (2010). Agroforestry Systems and Biodiversity Conservation in Arid Zones: the Case of the Tehuacán Valley, Central México. *Agroforest Syst.* 80, 315–331. doi:10.1007/s10457-010-9349-0

Moreno-Calles, A. I., Casas, A., García-Frapolli, E., and Torres-García, I. (2012). Traditional Agroforestry Systems of Multi-Crop "milpa" and "chichipera" Cactus forest in the Arid Tehuacán Valley, Mexico: Their Management and Role in People's Subsistence. *Agroforest Syst.* 84, 207–226. doi:10.1007/s10457-011-9460-x

Moreno-Calles, A. I., Casas, A., Rivero-Romero, A. D., Romero-Bautista, Y. A., Rangel-Landa, S., Fisher-Ortíz, R. A., et al. (2016). Ethnoagroforestry: Integration of Biocultural Diversity for Food Sovereignty in Mexico. *J. Ethnobiol. Ethnomed.* 12. doi:10.1186/s13002-016-0127-6

Moreno-Calles, A. I., Toledo, V. M., and Casas, A. (2014). "La importancia biocultural de los sistemas agroforestales tradicionales de México," in *Hacia un modelo intercultural de sociedad del conocimiento en México*. Editors L. Olive and L. Lazos-Ramírez (Ciudad de México: Universidad Nacional Autónoma de México), 35–56.

Newing, H., Eagle, C. M., Puri, R. K., and Watson, C. W. (2011). *Conducting Research in Conservation. A Social Science Perspective*. New York: Routledge.

Noble, I. R., and Dirzo, R. (1997). Forests as Human-Dominated Ecosystems. *Science* 277, 522–525. doi:10.1126/science.277.5325.522

Odum, E. P. (1989). *Ecology and Our Endangered Life-Support Systems*. Sunderland: Sinauer Associates.

Olson, D. M., and Dinerstein, E. (2002). The Global 200: Priority Ecoregions for Global Conservation. *Ann. Mo. Bot. Garden* 89, 199–224. doi:10.2307/3298564

Pelcastre, V., García-Frapolli, E., Ayala-Orozco, B., and Lazos-Chavero, E. (2020). Perspectives on Native maize Conservation in Mexico: a Public Programme Analysis. *Envir. Conserv.* 48, 33–40. doi:10.1017/S0376892920000417

Pérez-Negrón, E., and Casas, A. (2007). Use, Extraction Rates and Spatial Availability of Plant Resources in the Tehuacán-Cuicatlán Valley, Mexico: The Case of Santiago Quiotepec, Oaxaca. *J. Arid Environ.* 70, 356–379. doi:10.1016/j.jaridenv.2006.12.016

Perfecto, I., and Vandermeer, J. (2008). Biodiversity Conservation in Tropical Agroecosystems. *Ann. Acad. Sci.* 1134, 173–200. doi:10.1196/annals.1439.011

Ploeg, J. D. (2010). *Nuevos campesinos. Campesinos e imperios alimentarios*. Barcelona: Icaria.

Pretty, J., Adams, B., Berkes, F., Ferreira, S., Athayde, D., and Dudley, N. (2009). The Intersections of Biological Diversity and Cultural Diversity: Towards Integration. *Conserv. Soc.* 7, 100–112. doi:10.4103/0972-4923.58642

Pretty, J. (2004). How Nature Contributes to Mental and Physical Health. *Spirituality Health* 5, 68–78. doi:10.1002/shi.220

Rangel-Landa, S., Casas, A., García-Frapolli, E., and Lira, R. (2017). Sociocultural and Ecological Factors Influencing Management of Edible and Non-edible Plants: the Case of Ixcatlán, Mexico. *J. Ethnobiol. Ethnomed.* 13, 1–43. doi:10.1186/s13002-017-0185-4

Rendón-Sandoval, F. J., Casas, A., Moreno-Calles, A. I., Torres-García, I., and García-Frapolli, E. (2020). Traditional Agroforestry Systems and Conservation of Native Plant Diversity of Seasonally Dry Tropical Forests. *Sustainability* 12, 4600–4627. doi:10.3390/su12114600

Rendón-Sandoval, F. J. (2020). "El potencial de los sistemas agroforestales en la conservación y restauración de la vegetación nativa de la Caatinga,," in *Ecologia da Caatinga: curso de campo 2018*. Editors P. Sena, B. Pinho, D. Gomes Sousa, F. Pimentel Lopes de Melo, M. Tabarelli, and I. R. Leal (Recife: UFPE), 108–119.

Rosset, P., and Altieri, M. (2019). "Evidencias de la efectividad de la Agroecología," in *Agroecología: Ciencia Y Política*. Editors P. Rosset and M. Altieri (Zacatecas: Universidad Autónoma de Zacatecas), 87–119.

Rzedowski, J. (1991). El endemismo en la flora fanerogámica mexicana: una apreciación analítica preliminar. *Acta Bot. Mex.* 15, 47–64. doi:10.21829/abm15.1991.620

Rzedowski, J. (1978). *Vegetación de México*. Ciudad de México: Limusa.

Sathirathai, S., and Barbier, E. (2001). Valuing Mangrove Conservation in Southern Thailand. *Contemp. Econ. Pol.* 19, 109–122. doi:10.1111/j.1465-7287.2001.tb00054.x

SEMARNAT (2019). *Experiencias de Agroforestería en México*. Editor A. I. Moreno-Calles. 1st ed. (Ciudad de México: Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT).

Shiva, V. (2016). *Who Really Reeds the World? the Failures of Agribusiness and the Promise of Agroecology*. Berkeley: North Atlantic Books.

Smith, C. E. (1967). "Plant Remains," in *The Prehistory of the Tehuacán Valley. Volume 1. Environment and Subsistence*. Editor D. S. Byers (Austin: University of Texas Press), 220–255.

Strauss, A., and Corbin, J. (2002). *Basics of Qualitative Research. Techniques and Procedures for Developing Grounded Theory*. London: Sage Publications, Inc.

Taylor, S. J., and Bogdan, R. (1987). "Análisis de los datos en la investigación cualitativa," in *Introducción a los métodos cualitativos de investigación. La búsqueda de significados* (Barcelona: Paidós), 152–176.

Toledo, V. M., and Barrera-Bassols, N. (2008). *La memoria biocultural. La importancia ecológica de las sabidurías tradicionales*. Barcelona: Icaria Editorial.

Toledo, V. M., and Boege, E. (2010). "La biodiversidad, las culturas y los pueblos indígenas," in *La biodiversidad de México*. Editor V. M. Toledo (Ciudad de México: FCE-CONACULTA), 160–192.

Trejo, I., and Dirzo, R. (2000). Deforestation of Seasonally Dry Tropical forest. *Biol. Conser.* 94, 133–142. doi:10.1016/S0006-3207(99)00188-3

Valiente-Banuet, A., Casas, A., Alcántara, A., Dávila, P., Flores-Hernández, N., Arizmendi, M. d. C., et al. (2000). La vegetación del Valle de Tehuacán-Cuicatlán. *Bot. Sci.* 67, 25–74. doi:10.17129/botsci.1625

Vallejo, M., Casas, A., Blancas, J., Moreno-Calles, A. I., Solís, L., Rangel-Landa, S., et al. (2014). Agroforestry Systems in the highlands of the Tehuacán Valley, Mexico: Indigenous Cultures and Biodiversity Conservation. *Agroforest Syst.* 88, 125–140. doi:10.1007/s10457-013-9660-7

Vallejo, M., Casas, A., Pérez-Negrón, E., Moreno-Calles, A. I., Hernández-Ordoñez, O., Tellez, O., et al. (2015). Agroforestry Systems of the lowland Alluvial Valleys of the Tehuacán-Cuicatlán Biosphere Reserve: an Evaluation of Their Biocultural Capacity. *J. Ethnobiol. Ethnomed.* 11, 8. doi:10.1186/1746-4269-11-8

Vallejo, M., Moreno-Calles, A. I., and Casas, A. (2016). TEK and Biodiversity Management in Agroforestry Systems of Different Sociocological Contexts of the Tehuacán Valley. *J. Ethnobiol. Ethnomed.* 12, 31. doi:10.1186/s13002-016-0102-2

Vallejo, M., Ramírez, M. I., Reyes-González, A., López-Sánchez, J., and Casas, A. (2019). Agroforestry Systems of the Tehuacán-Cuicatlán Valley: Land Use for Biocultural Diversity Conservation. *Land* 8, 24. doi:10.3390/LAND8020024

Wolf, E. R. (1955). Types of Latin American Peasantry: A Preliminary Discussion. *Am. Anthropol.* 57, 452–471. doi:10.1525/aa.1955.57.3.02a00050

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