Perspectives of the Ethnobotanical Research in Mexico

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Abstract

Ethnobotany is an integrative, multidimensional research field, whose main purpose is understanding interactions and relationships between humans and plants, and their cultural, ecological, and evolutionary consequences throughout history. This purpose is linked with the general interest of science for analyzing interactions between human societies and biodiversity, which is currently relevant not only from theoretical perspectives but also to design strategies to face environmental problems characterizing the global socio-ecological crisis. Ethnobotany, as ethnobiological sciences in general, has advanced in the construction of valuable theoretical and methodological frameworks, which have made visible the enormous value of the local experience of thousands of communities throughout the world. Their knowledge and techniques of managing plants and ecosystems may be the foundation of sustainable forms of biocultural interactions. In this chapter, some relevant theoretical and methodological advances and challenges for ethnobotanists working in Mexico are identified. We emphasize the importance of ethnobotany and ethnobiological sciences in establishing bridges of dialogue among different sectors of the societies that make decisions on biodiversity issues. Such role positions ethnobotany as a key transdisciplinary field for research and action to: (1) understanding

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traditional botanical knowledge, (2) developing criteria to protect biodiversity and intellectual property rights, (3) understanding the origin, diversification, and diffusion of agrobiodiversity, (4) identifying the bases for the sustainable management of plants and ecosystems, and (5) constructing strategies for biocultural diversity conservation. These are central points in the agenda of ethnobotany, and it is intimately linked to anthropology, ecological economy, and ecological and evolutionary sciences. In addition, a main challenge is to link ethnobiological sciences with sustainability science. This is an emerging scientific approach based on new paradigms for conducting research, which are needed to understand and act in the context of the global environmental crisis. The chapters of this book reflect different perspectives and research approaches developed by ethnobotanists in Mexico, but also their views about the ways ahead. We emphasize the need of making explicit the insertion of ethnobotany with other research fields for constructing new theoretical and methodological perspectives, but, especially, to promote studies about cultures, ecosystems, and regions scarcely explored. We identify areas and cultures that are research priorities. Also, we emphasize the necessity to enhance the insertion of ethnobotany and ethnobiological sciences in educational programs and institutions that make decisions and public policies related to biocultural issues. This final chapter summarizes views emerging from the cases included in the book and provide some reflections we consider relevant to study the ethnobotany of the mountain regions of Mexico but that may also be helpful for ethnobotanists in other regions of the world.

Ethnobotany in Mexico

Ethnobotany is an integrative, multidimensional research field, whose main purpose is understanding the different types of interactions and relationships between humans and plants and the ecosystems of which they are part. In particular, ethnobotany looks for answers about what kinds of interactions humans have with plants, when, how, and why these interactions have occurred, and their cultural, socioeconomic, ecological, and evolutionary consequences throughout history (Hernández-Xolocotzi 1971, 1979; Bye 1993; Pieroni and Quave 2014; Casas et al. 2016a; Vibrans and Casas 2022). Ethnobotany is part of more general scientific fields that analyze the interactions between human societies and biodiversity. It involves numerous research questions and hypotheses that integrate methods and concepts of the natural and social sciences to answer and test them.

The construction of ethnobotany theoretical frameworks has been a main concern of scientists working in this field for decades (Schultes 1941; Hernández-Xolocotzi 1971, 1979, 1993; Berlin et al. 1974; Ford 1978; Caballero 1979; Alcorn 1984; Bye 1985, 1993; Martínez-Alfaro 1994; Schultes and von Reis 1995; Toledo 1995; Cotton 1997; Caballero et al. 1998; Alexiades 2003; Albuquerque and Hanazaki 2009; Casas et al. 2016a; Camou et al. 2016; Albuquerque et al. 2019; Vibrans and Casas 2022). Although biology and anthropology are the most related sciences and provide relevant theoretical and methodological approaches, ethnobotany has its own domains, processes, and techniques.

Theoretical constructions of ethnobotany have considered, above all, that interactions and relations between humans and plants have particularities compared with those established among other species. The shared intentionality (O'Madagain and Tomasello 2021) and design of actions by humans, the transmission of their "cumulative culture," their deliberate use of natural elements such as water and minerals, or phenomena like fire and wind to modify materials and systems, as well as their tools and other technologies have all mediated such interactions and their consequences (Vanberg 2006; Tattersall and Schwartz 2009; Stout 2008; Verbeek 2008; Cela-Conde and Ayala 2018). The "reason-based" forms of cultural transmission, and the ability to coordinate actions, according to O'Madagain and Tomasello (2021), are causes of the rapid innovation and cumulative cultural evolution of humans. And the particularities of interactions between humans and biodiversity are part of the also specific ways humans construct their ecological and cultural niches (Zeder 2012; Smith 2012; Boivin et al. 2016; Clement et al. 2021).

Ethnobotany focuses its attention on analyzing the interactions and relations between humans and plants, and the ecosystems they are part of. The cultural and ecological contexts worldwide are highly variable and have changed throughout the history of humans on Earth (Boivin et al. 2016). Therefore, ethnobotany is immersed in diverse and changing constellations of interactions and impacts. In other words, the particularities of interactions between humans and plants (and ecosystems) are far from simple and have a plethora of expressions. These expressions are part of the biocultural diversity (Maffi and Woodley 2010) and understanding them is a main task of ethnobotany.

Nearly half of the terrestrial ecosystems on Earth have been severely damaged by humans (MEA 2005; Barnosky et al. 2011, 2012), and these processes have been especially intensive during the last 300 years: the industrialization era. But they have been dramatic during the last 75 years (Barnosky et al. 2012), closely aligned with modern forms of capital accumulation and the hegemonic policies of economic growth (Pacheco et al. 2018). Sources of global cultural information like Ethnologue (Eberhard et al. 2022) have documented nearly 7000 languages currently existing worldwide but, as biodiversity, a significant proportion disappeared during different historical periods, especially since the European colonialism/imperialism epoch (Gilmartin 2009), and numerous others are in process of extinction in the era of globalization (Maffi and Woodley 2010; Eberhard et al. 2022).

Current research tools allow the reconstruction of the diversity of ecosystems and biodiversity that have existed on the planet (Pereira et al. 2012; Navarro et al. 2017), and how landscapes have been transformed by humans at different times (Boivin et al. 2016; Balée 2018; Franco-Moraes et al. 2021). Linguistic approaches trace the history of language diversification, but also estimate their loss rates and monitor trends of both languages and culture loss (Cavalli-Sforza 1997; McMahon and McMahon 2005; Eberhard et al. 2022). The notion that biodiversity and culture are parts of complex biocultural systems has gained strength in this millennium (Maffi 2005; Maffi and Woodley 2010) and today, biodiversity and culture should be analyzed holistically. Luisa Maffi, one of the main pioneers and promoters of this trend, identified ethnobiology as a principal source of research and thinking on biocultural diversity, and the base for theoretical frameworks (Maffi 2005).

The dramatic loss of biocultural diversity contrasts with its increase during millions and thousands of years of natural and cultural history, respectively. This information makes possible to dimension the magnitude of the catastrophic impact of the global socio-ecological crisis on diversity (Hamilton et al. 2015; O'Connor et al. 2020). Recognizing the characteristics of the interactions between humans and biodiversity, the diversity of interactions and interrelationships developed between humans and plants, and the processes causing their loss are all main challenges of ethnobotanical research. Such understanding is not only valuable from theoretical perspectives, but it is also crucial for designing strategies for biocultural conservation and restoration from the local to global scales. These general challenges inevitably lead the way ethnobotanical research should take in the near future, in Mexico and worldwide.

The chapters of this book display a wide array of research approaches and knowledge on the diversity of interactions between cultures, plants, and ecosystems in Mexico. It complements the previous work Ethnobotany of Mexico (Lira et al. 2016), and surely further works will contribute to broadening its reach. The book includes case studies in communities and regions, general topics of ethnobiology related to conservation of biocultural diversity, as well as views on some plant genera representative of the biocultural diversity in Mexico. But it is only a sample of the research groups working in this country, the topics and methodological approaches we use, and a small portion of plant groups that form part of Mexican cultures. The chapters also identify some of the conceptual, methodological, and information gaps still needing to be filled to advance several research issues, and to cover more regions, ecosystems, and cultural groups.

As part of the series Ethnobotany of the Mountain Regions, this book emphasizes studies of peoples living in the mountains, the predominant landscapes of the Mexican territory. However, some studies also include adjacent and connected lowlands and highland plateaus.

Ethnobotanists working in Mexico are part of the growing international scientific community of this field, and its advances and limitations partly reflect worldwide trends. Therefore, these results may be relevant for colleagues working in other regions of the world. The theoretical and applied challenges of ethnobotany and ethnobiological sciences in the face of an overwhelming socio-ecological global crisis are great, but its approaches could play a role to mitigate its effects. Some reflections and concerns are shared in this final chapter of the book.

Contemporary Theoretical Challenges for Ethnobiological Sciences

A number of ethnobotanists have discussed key questions and hypotheses for developing ethnobiological sciences. Here, we emphasize some lines of thought that we consider particularly relevant.

Tracing theoretical frameworks provides insights on the origins and trajectories of disciplines, and their context. Victor Manuel Toledo in his work “New paradigms for a new ethnobotany: reflections on the case of Mexico” (Toledo 1995) examined the turn of ethnobotany (in Mexico, but with more general implications) based on the framework of the structure of scientific revolutions developed by Thomas S. Kuhn (1962). Toledo analyzed the stages of ethnobotany in Mexico and the need to connect its approaches with new paradigms emerging from sciences studying the nature of the environmental crisis, a proposal that continues to gain importance. According to Toledo, at the end of the twentieth century, ethnobotany in Mexico was transitioning from a “normal” stage of exploring new plant products for industry and other purposes, and analyzing the role of plants in the material and cognitive culture of humans. The transition to a new ethnobotany, according to Toledo, was fostered by ethnobotanists with critical views, for whom ethnobotany was not a neutral science but a research field with social implications that should lead to strong commitments with the indigenous and rural communities they worked with. Toledo envisioned ethnobotany as a research field with political implications, integrating social, economic, ecological, and political problems of rural communities. He examined the ways that the documented botanical and ecological knowledge might contribute to support local peoples’ goals and concerns. Stronger and explicit engagement with communities rather than documenting and extracting local knowledge should be a main feature of a “post-normal” ethnobotany, according to Toledo. The subsequent development of the field partially followed these premises, resulting in the emergence and development of agroecology and participatory research, among other approaches.

Several authors have investigated the history of ethnobotany and ethnobiological sciences. Clément (1998) reconstructed the emergence of these fields from botany and anthropology, reminding us that ethnobotany developed in the context of the discoveries during the colonial expansion, a period marked by both disparagement of indigenous knowledge and the myth of the noble savage. However, this disparagement did not blind people to the advantages of prospecting plants, animals and other organisms, for benefiting the “more civilized world” and industry, as did other scientific disciplines. Clément (1998) described the first stages of ethnobiological sciences as part of the drama of colonialism and its mindset, discrediting all views, knowledge and ways of life different from the European ones, but seizing the opportunity to assimilate what was considered useful. This raiding of natural resources, including plants and animals, became a central issue in the Earth Summit of Río de Janeiro in 1992 and in subsequent meetings (Sánchez et al. 2019). The issue currently continues to be an important concern for ethnobiologists. This new perspective induced more ethical and integral views on the meaning of ecosystems for understanding local cultures and vice versa, as societies and biodiversity in interaction. Ethnobiologists became interested in working in favor of local communities and people, cooperating to resolve their problems, ensuring their rights, and supporting their views and projects for improving their lives. Also, ethnobotanists contributed to make visible the huge relevance of traditional cultures for building a sustainable future of the planet.

Soon after Clément's work, Miguel Alexiades (2003) highlighted the inherent conflict between Western views and systems of protection of intellectual property on the one hand, and traditional knowledge and useful plant products on the other. What was originally considered public goods became privately appropriated, and sometimes patented, clearly taking advantage of the diverse local knowledges (Alexiades 2003). Alexiades as other authors (see Brush 1993; Brush and Stabinsky 1996) suggested that the commoditization and politicization of genetic resources and local knowledge required fair systems of sharing knowledge and benefits. This subject continues to be a main concern in ethnobiological research. It is a complex issue for which there are no simple answers.

As shown in several chapters of this book, people in traditional communities as well as in modern contexts, exchange products, knowledge and techniques within and between families, communities, and regions. This pattern allows visualizing that traditional knowledge is in reality highly dynamic and continually adapts to changing circumstances (Berkes et al. 2000). It includes processes of generation, conservation, and decrease of knowledge as documented by Hart and Salick (2017), or retention, erosion, adaptation, and hybridization, as proposed by Sharifan et al. (2022). The Western societies have frequently taken advantage of the ways of sharing and reciprocity norms in traditional societies. The Western property rules are commonly meaningless in the traditional communities' context. What is the solution to this problem? There is no simple answer. If we leave traditional knowledge outside of the intellectual property regime, it will be taken advantage of and perhaps appropriated by various actors. On the other hand, implementing intellectual property for traditional knowledge requires identifying persons and/or collectivities to benefit from this asset or knowledge, which is a difficult task. It may cause conflicts and hinder the continuous improvement and adaptation which is a feature of much traditional knowledge or managed organisms.

Bioprospection based on traditional knowledge and biopiracy by patenting products based on that bioprospection are both real. Compensation or retribution systems may be the fair way to legitimize the appropriation of both plant products and knowledge. But, compensate whom? Identifying individual innovators of current processes might be possible, although innovations in communities are rapidly diffused, tested, and subject to new innovations. The process of innovation is per se a topic of research (Blancas et al. 2010; Rangel-Landa et al. 2016). But identifying discoverers of plant properties or inventors of management techniques and the preparation of a plant used for long time periods is practically impossible. Traditional knowledge and experience are eminently collective, but collectivities are not restricted to a community or a region, their geography is rather complex. Contributing to developing fair systems of retribution continues to be a challenging topic for ethnobiologists, as well as for various social groups and organizations, governments, anthropologists, biologists, and ecologists.

Alexiades points out that validating traditional knowledge has been one of the main concerns of ethnobotanists and continues to be so. Validation of local ecological knowledge was galvanized from the mid-twentieth century onwards, with intensifying pharmacological studies of traditional medicines, searching for new active principles in medicinal plants, with some success. However, success was uneven, as numerous ailments recognized by traditional practitioners cannot be understood with the principles of Western medicine (Plotkin 1993; Prance et al. 1994).

In contrast, the search for new and improved edible plants in traditional contexts did have a good reputation as the crops sustaining the economy of the world originated there. Prospection was directed at interesting landraces of the main crops, crop wild relatives (Heywood et al. 2007), orphan crops, and important neglected and underutilized wild and weedy plants with promising value (Ulian et al. 2021).

The called Green Revolution began to show its failures in the 1960s and 1970s in numerous local contexts. The standardized formulas of the technology spread from institutions through extensionists to rural people and local environments; however, they encountered a complex world. The outstanding work by Paulo Freire "Extension or Communication?" (Freire 1973) summarized the central reasons of the failure: (i) local agriculturalists were not passive receptors of technologies designed in laboratories and experimental fields; (ii) the local environmental and cultural contexts could not be incorporated into the standardized technologies; (iii) the local farmers knew better than technicians, promoters, and extensionists what could and should be done in the local contexts; and, among other issues, (iv) the "improved" hybrid varieties produced, patented, and commercialized as part of the programs not only generated dependence of their users but were not always productive or profitable; (v) the "improved" varieties favored displacement of local varieties, thus contributing to a loss of genetic variation historically shaped by local cultures, a process that in the 1970s was recognized as genetic erosion (Frankel and Benett 1970; Brush 2004). In Mexico, during the heyday of the Green Revolution, some agronomists, outstandingly Efraim Hernández-Xolocotzi (1959; Hernández-Xolocotzi and Ramos-Rodríguez 1977; Hernández-Xolocotzi et al. 1980), recognized that local knowledge and techniques were more effective than the modern technologies in traditional contexts, and these should be studied and understood. All these conclusions strongly reinforced the Paulo Freire vision. Hernández-Xolocotzi based his criticism on profound research of traditional agriculture. His vision propelled Mexican ethnobotany and established the bases of Mexican agroecology.

Ethnobotanists exhibited evidence of the deficiencies of mainstream agricultural science, and also the extraordinary value of traditional knowledge for finding solutions. The same trajectory can be observed in environmental sciences. The contribution of local traditional knowledge to the solution of numerous and complex issues was increasingly recognized. The collaboration of different sectors, most importantly local managers, are crucial for attending long term problems (Grumbine 1994). The boost of the concept of traditional ecological knowledge (Berkes 1993, 1999), the governing of the commons (Ostrom 1990), agroecology (Altieri and Toledo 2011), and the emergence of sustainability science (Kates et al. 2001, 2011) became conceptual frameworks integrating local people' knowledge in the design of sustainability (Berkes et al. 1994; Nelson and Shilling 2018). The transdisciplinary and participatory approaches of science as discussed below are based on this framework.

Alexiades (2003) analyzed the challenges imposed by the global environmental crisis and the potential role of ethnobotany and ethnobiological sciences in interdisciplinary and intercultural programs, as well as participatory approaches of science. Local knowledge is much more than certain names and uses of organisms that industry can potentially use. It involves whole systems of knowledge, worldviews, and an ample diversity of forms of interaction (Berkes 1993, 1999; Berkes et al. 2000; Toledo and Barrera-Bassols 2008). In his reflection about main challenges to ethnobotany, Alexiades (2003) raised two important questions: (1) "How to construct, articulate and operationalize the relationship between different knowledge systems, actors, needs and views in the context of the inter-cultural and interdisciplinary (and we would add transdisciplinary) dialogue?", and (2) "What opportunities and challenges lie beyond the rhetoric of participation and interdisciplinarity that permeates much of development, conservation and environmental scholarship?" These questions continue to be influential. In the last three decades, scholars, NGOs, and other sectors together with local people have developed numerous initiatives (Illsley-Granich et al. 2004, 2007; Bebbington 2007; Casas et al. 2017).

One important result of that process is the recognition of the value of local knowledge and technical experience for developing better ways of interacting with biodiversity and building sustainable management systems (Nelson and Shilling 2018). The other result contributed avenues for participatory, interdisciplinary, and transdisciplinary processes beyond the rhetoric. There is no one single way, but initiatives in different regions of the world have created several areas of interactions: agroecology (Altieri 2002), non-timber forest products management (Illsley-Granich et al. 2004), agroforestry, ethnoagroforestry (Moreno-Calles et al. 2013, 2016), biocultural landscape conservation (Hong et al. 2014; Barrera-Bassols and Floriani 2018), food sovereignty, eco-technologies, governance of the commons (Ostrom 2007), sustainable food systems, resilient systems (Gunderson and Holling 2002; Walker and Salt 2012), among others.

It is not our intention to review here all these approaches, issues and processes, which deserve their particular own analysis. But members of the academic community collaborating in social movements are studying and systematizing information at a global scale. For example, the International Forestry Resources and Institutions (IFRI 2013), founded by Elinor Ostrom, examines the ways people from different regions of the world reach agreements around forest management and their products with formal and informal institutions. Their aim is to provide policy makers criteria based on rigorous evidence-based experiences. Another important global initiative is the Resilience Alliance, which since 1999 conducts international research on the dynamics of socio-ecological systems, from multidisciplinary perspectives. The members of this organization document and systematize information, and conduct comparative research and synthesis of experiences (Resilience Alliance 2010). They have significantly contributed to the IPCC, the Millennium Ecosystem Assessment and the Future Earth projects, and have made extraordinary contributions to constructing frameworks on the sustainability of socio-ecological systems

(Gunderson and Holling 2002; Walker and Salt 2012; Carpenter et al. 2012; Walker 2020).

Other organizations are alliances of different sectors of the society. Probably the most common and successful are those of communities and social organizations, NGOs, and scholars, most commonly ethnobiologists, agroecologists, ecologists, and anthropologists (see for instance Illsley-Granich et al. 2007; Casas et al. 2017; Gavito et al. 2017). They often emerge as initiatives to address concrete environmental problems associated to mining, deforestation, over-exploitation of specific resources, dispossession of land and/or water, soil erosion and desertification, drug trafficking, and organized crime, among others. The local organizations commonly look for the collaboration of scholars and universities to obtain information to solve these problems. After initial contacts, the links and collaborations increase and search for appropriate ways of communication, ethical frameworks, and compromises. These developments have pushed the interdisciplinary, transdisciplinary, and participatory approaches beyond the rhetoric. However, the interactions are still often improvised, and a better understanding of the process is urgently needed. Some chapters of this book recount direct experiences on these issues; we will return to this topic further on.

Another valuable reflection on challenges of ethnobotany was recently published by Albuquerque et al. (2019), based on a previous thinking by Albuquerque and Hanazaki (2009). The authors lay out some questions/issues they consider to be the most relevant challenging ethnobotanical research. One of them refers to how to adequately represent the views and knowledge of traditional people. Other subjects are about the appropriate methodological approaches to assess the continuous biocultural changes; the role of plants in socio-ecological systems and the mechanisms of intergenerational transmission of knowledge; the role of ethnobotany in supporting processes of biodiversity governance; the dialogue of ethnobotany with other sciences; the effect of human migration on distribution of plants and the effect on local flora; the properties of knowledge and plant composition in urban contexts and their influence on the surrounding areas; the effects of extraction of medicinal plants and other used plants, and how ethnobotany should interact with ecology to recommend sustainable ways of using these plants. All these are relevant issues and require significant effort to find solutions.

Sustainability science is a general challenge for science and has been treated by several authors, outstandingly Kates et al. (2001, 2011), Swart et al. (2002), among others. The theoretical constructions associated with the concept of sustainability, such as resilience of socio-ecological systems (Holling 2001; Gunderson and Holling 2002), governance and institutions (Ostrom 1990, 2007, 2009), among others, have seen a renewed momentum during the first decade of this millennium. All these reflections emphasize that reducing the impact of the global crisis is still possible but requires multiple perspectives, based on the consideration that social and ecological systems are mutually inter-dependent and complex, with emerging properties, nonlinear responses, and high uncertainty (Young et al. 2006; Weible et al. 2010; Costanza 2014). Environmental problems require the interaction of natural and social sciences (Kates et al. 2001, 2011; García 2006, 2011; Casas et al. 2016b). Additionally, sustainability science has among its premises the need of science to interact with knowledge and technological experiences developed by local people and other sectors of society through transdisciplinary approaches (Kaufman et al. 2003; Brandt et al. 2013).

Adaptive management is another relevant concept. It recognizes that the complexity of socio-ecological systems and their nonlinear behavior make it difficult if not impossible to predict the exact response of the system after interventions (Allen et al. 2011; Keith et al. 2011; Rist et al. 2013; Allen and Garmestani 2015). Therefore, the proposal emerging from this concept is to implement management practices based on the best and deepest knowledge and techniques available but considering them as provisional interventions. Then, the response of the system is evaluated, the effectiveness or failures of the practices analyzed, and a new stage of management initiated by adjusting the actions based on learning from the previous stage (Allen and Garmestani 2015). This concept recognizes that the contemporary scientific and technological systems are not infallible, and that local knowledge may have valuable solutions tested in practice.

Ethnobotany is also concerned with the loss of languages, cultures and institutions (Gibson et al. 2000; Eberhard et al. 2022). Language, knowledge, worldviews, management practices, technologies, and institutions are all integrated in culture and their loss means the loss of human experience to solve environmental problems. Ecology, ethnobiology, and anthropology can build bridges to promote dialogues between different social sectors, and thus contributing to a better understanding of sustainability.

Another main challenge of ethnobotany and ethnobiological sciences is how to consolidate their theoretical and methodological frameworks and integrate them with more general frameworks and emerging paradigms such as sustainable social-ecological systems, biocultural diversity conservation, and restoration.

Methodological Approaches

Studying interactions between humans, plants, and ecosystems may involve different types of questions, some of them answerable through quantitative methods, some others requiring qualitative approaches. One is not better than the other nor using one or the other makes ethnobotany a more authentic science. Methods are ways, systematically used by science, to answer questions and understanding phenomena. Quantitative approaches evaluate relations between variables, representativeness, and generalizability of phenomena, whereas qualitative methods help to analyze problems that are difficult to measure but necessary to understand the internal functioning of socioecological systems. Ethnobotany needs both approaches as discussed below.

Documenting traditional knowledge. Ethnobotany requires methods for understanding traditional botanical and ecological knowledge, its connections with technologies and social organization and its ecological, economic, and evolutionary consequences. Berkes (1993) defined some general characteristics of traditional ecological knowledge: (i) it is mainly qualitative; (ii) it has an intuitive component; (iii) it is holistic; (iv) mind and matter are considered together; (v) it is moral (as opposed to supposedly value-free); (vi) it is spiritual (as opposed to mechanistic); (vii) it is based on empirical observations obtained by trial-and-error (as opposed to experimentation and systematic, deliberate accumulation of information); (viii) it is based on data generated by resource users themselves (not by specialized researchers); (ix) it is based on diachronic data, i.e., long time-series on information at one locality (as opposed to synchronic data, i.e., short time-series over a large area). These characteristics and others confer ethnobotany and other ethnobiological sciences the need for broad, flexible, adaptive, and contextual methodological approaches.

Local systems of knowledge, worldviews, practices, and technologies are contextualized by the local social relations and particularities of ecosystems, all of which are dynamic. There is no single way to understand these systems. Albuquerque et al. (2019) suggested a multiple-evidence base (MEB) research, referring to a reflection by Tengö et al. (2014). Both qualitative and quantitative approaches are needed to understand these complex systems. Qualitative approaches are good windows for exploring the multiple relations and interconnected views within the systems whereas quantitative approaches help to test more specific hypotheses. Qualitative methods allow access to the meanings peoples give to processes, the quantitative approaches inform on the representativeness of ideas or practices in communities at different scales. Ethnobotanists have been criticized for their descriptive work which is common at the early stages of a research field, and in the last decades they have widely adopted and developed quantitative tools, partly to legitimize ethnobotany as a scientific field. However, it has now been recognized that the interactions between humans and plants are expressions of complex systems. Specific interactions may be better understood through quantitative approaches, but the study of complexity requires multiple approaches, including qualitative examination (Castillo et al. 2020).

In social-ecological systems, documenting and analyzing the views (understood as the perceptions, feelings, and meanings to phenomena) of local people and the different sectors of the society are valuable sources of information for understanding problems and, therefore, are crucial bases for developing suitable actions. Thus, qualitative research are not only scientific but necessary to assess complex systems. In ethnobotanical research, quantitative research is mainly based on surveys, and qualitative studies are mainly based on in-depth interviews, participant observation, and other instruments. Surveys and in-depth interviews provide different kinds, but complementary information. One method is not better than the other; every method should be chosen according to the questions the researcher wants to answer.

According to Drury et al. (2011), external validity evaluates if survey results can be generalized; it requires that the data be representative of the phenomena studied. Sample sizes can be large. Internal validity refers to representing “the diversity of individuals and groups being analysed and examining complex concepts in ambiguous and complex contexts.” In these cases, surveys are not commonly able to include locally important categories and other aspects defining the complexity, and, as the authors state, “Research investigating what people feel, think, plan and do commonly depends on asking respondents about their views or actions,” which are difficult to be caught through surveys. As Drury et al. (2011) state:

> Natural scientists accustomed to concentrating on external validity may perceive samples of respondents in qualitative studies as too small or inadequately selected to represent wider populations. But the fact that one cannot make statistical statements based on qualitative data does not render the findings invalid. Conversely, a large sample, with all informants receiving the same standardized research tool, does not automatically yield good data if that tool or sample is poorly designed or applied.

In other words, qualitative approaches may help to understand relationships, thinking, views, and other complex aspects in much more depth, and may facilitate the design of appropriate questionnaires for surveys. Therefore, qualitative and quantitative research techniques are commonly complementary, providing different types of information.

Inventorying and systematizing the Mexican biocultural heritage. The documentation of the heritage of nomenclature, classification, use, and management of biodiversity has been the foundation of ethnobotanical research. This research avenue is helpful for many different types of studies. In the past this activity was undervalued as merely descriptive. However, having a complete inventory of the local biodiversity, the ecosystems where it occurs and the human experience of using and managing it constitutes valuable information for different types of analyses, in the same way that floristics is essential for botanical disciplines such as systematics and biogeography. Although this has been the dominant approach, the inventory is still incomplete for Mexico, as pointed out in chapter 2 by Caballero et al. (2022). Some estimations suggest Mexican people may use more than 11,500 vascular plant species, whereas databases contain information of less than 8000 species (Caballero et al. 2022). But much more is needed. First, not all ethnobotanical information recorded in the literature has been systematized. Also, uses and management forms of a species may differ from region to region, and the information for species is incomplete. It should be increased substantially by ethnobotanical studies in poorly explored regions. Nearly half of the main cultural groups of Mexico have been poorly or not studied, and some regions and vegetation types have been more studied than others. Based on the diagnosis of chapter 2 and the study by Camou et al. (2016) we identify in Table 1, those states, regions, cultural groups, and ecosystems of Mexico that require more research efforts.

Most ethnobotanical information stored in databases is about plant uses, but inventorying uses is insufficient. We need to understand the nature of some uses and medicinal and nutritional aspects better. The effectiveness of traditional medicine, the nutraceutical properties of edible plants and the nutritional aspects of plants used as food and fodder, are examples of recurrent societal demand of information. Such information would substantially strengthen the role of traditional knowledge in both health and food systems. Management techniques, spatial information on distribution and abundance of the species, and biocultural aspects require more

Table 1 Priority regions and cultural groups for ethnobotanical research in Mexico. The table enumerates regions and cultural groups with limited ethnobotanical studies of twenty states. The levels of relative priority (in italics in the last column) are the average of the information scarcity ranking proposed by Camou et al. (2016) and a ranking based on the number of records in the database BADEPLAM (Caballero et al. 2022). Numbers closer to 1 indivate higher level of priority for conducting studies. Regions and ethnic groups in bold are those considered exceptionally important in each state

State	Region	Ethnic group	Relative research priority
Querétaro	• **Amealco** • **Tolimán**	• Otomí	(6, 1) = 3.5
Colima	• **Comala**	• Nahua	(10, 2) = 6
Baja California	• **Ensenada** • **Mexicali** • **Tecate**	• **Ku'ahl** • **Pa ipai** • **Cochimí** • **Kiliwas** • **Cucapá** • **Kumiai**	(9, 4) = 6.5
Sinaloa	• Northern region • Fuerte River	• **Yorome-Mayo** • **Tepehuan** • Tarahumara	(2, 12) = 7
Aguascalientes	• Western mountain region	• Nahua	(3, 11) = 7
Guanajuato	• **Chichimeca, sierra de Guanajuato** • Sierra Gorda	• **Chichimeco Jonaz** • Otomí	(1, 14) = 7.5
Durango	• Mezquita • Buenaventura, • Jícoras • **Mezquital** • **Guanaceví** • **Ocampo** • **San Bernardo**	• Tepehuanos del Sur • Nahua (Mexicaneros) • **Huichol** • Tarahumara	(8, 7) = 7.5
Coahuila	• **Melchor Músquiz**	• **Kikapú**	(5, 13) = 9
Zacatecas	• Valparaiso • Fresnillo	• Tepehuanos del Sur • **Huichol**	(14, 5) = 9.5
Campeche	• Throughout the state • **Champotón** • **Edzná** • **Campeche** • Eastern part of the state	• Maya • **K'ich** • **Awakatec** • **Akatec** • **Chuj** • **Jakaltec** • **Kaqchikel** • **Mame** • **Ixil** • **Q'echi** • Ch'ol	(12, 9) = 10.5
Tlaxcala	• Throughout the state	• Nahua	(15, 6) = 10.5
Jalisco	• Mezquitic • Bolaños	• Huichol	(17, 8) = 12.5

(continued)

Table 1 (continued)

State	Region	Ethnic group	Relative research priority
Sonora	• Low Mayo River • **Upper Mayo** River • Lower Yaqui River • Sonoran Desert • **Yécora** • **Colorado River** • **Bacerac**	• Seri • **Pima** • Tohonó-Oódham • **Cucapá** • **Ópata** • Mayo • **Guarijío** • **Kikapú** • **Yaqui**	(4, 23) = 13.5
Chihuahua	• Guachochi • Guadalupe y Calvo • **Madera** • **Uruachi**	• Tarahumara • Tepehuanos del Norte • **Pima** • **Guarijó**	(7, 25) = 16
San Luis Potosí	• Eastern part of the state • South-eastern part of the state • **Río Verde** • **Ciudad del Maíz** • **Arroyo Seco**	• Huastec • Nahua • **Pame**	(13, 21) = 17
Tamaulipas	• Southern part of the state	• Nahua • Huastec • Totonac	(19, 15) = 17
Quintana Roo	• **Maya Balam** • **Miguel Hidalgo** • **Kuchumatán** • Throughout the state	• **Akatec** • **Chuj** • **Ixil** • **Q'anjobal** • **Jakaltec** • **K'ich** • **Kaqchikel** • **Mame** • **Q'anjobal** • **Q'echi** • Maya	(11, 27) = 19
Chiapas	• **Amatenango** • Las Margaritas • **Mazapa** • **Motozintla** • Ocosingo • San Cristóbal • Rayón • La Trinitaria	• **Jakaltec** • **Kaqchikel** • **Mame** • K'anjob'al • Tojolabal • **Teko** • **Mochó** • Tzeltal • Lacandon • Tzotzil • Zoque • **Chuje**	(18, 29) = 23.5
Nuevo León	• Southern part of the state	• Huastec	(20, 28) = 24

emphasis. Ecological information on life history traits and interactions with other species should be incorporated into the ethnobotanical fact sheets as it is relevant for designing management plans. Ethnobotanists with a background in the biological sciences have the necessary skills to obtain them. Detailed information on the cultural, economic, and relational values of the species people interact with is extraordinarily important. Anthropologists, economists, biologists, and professionals trained in interdisciplinary programs have the capacities to document these aspects. Inventories of biocultural heritage also support the construction of theoretical and methodological frameworks as we discussed before.

Therefore, inventories of biocultural information continue to be necessary. However, we stress that some aspects have been covered poorly. There are numerous efforts throughout the country constructing local or regional databases. The construction of a national database of ethnobotanical (and, in general, ethnobiological information) requires efforts to design and support ad hoc formats and the disposition to share the information. Establishing clear and fair rules of construction, operation and use, assigning the responsibilities of the curatorial work, the most appropriate institutional seat, and the coordination of work are priorities. After decades of these efforts, ethnobotanists and ethnobiologists must take steps toward more robust collaborative activities to systemize information at a national scale.

Historical reconstruction approaches. Historical perspectives of culture and interactions with plants require collaborations with archaeological and ethnohistorical studies, as well as documental research in historical archives. Archaeological studies have advanced in documenting plant remains associated to ancient humans and thus reconstruct their historical interactions. Some classical studies referred to throughout this book are those conducted by MacNeish (1967, 1992), Flannery (1986) Smith (1997), Zeder (2017); Piperno and Pearsall (1993); Piperno et al. (2009); McClung-de Tapia et al. (2001); and Acosta-Ochoa (2008). Methods for identifying micro and macrofossils have improved and the combination of dating methods have increased precision. The recent and outstanding field of paleogenomics has increased accuracy in the identification of remains, as well as domestication imprints (see Lindqvist and Rajora 2019). By contributing evidence of the prehistoric interactions between humans and plants, the origin and diffusion of cultures, a number of views have changed recently. Maize, beans, peppers, squashes, and cacao have had much more complex interactions between North, Central, and South America than expected (see for instance Pease et al. 2016; Zarrillo et al. 2018; Kistler et al. 2020). Also, the earliest date of human occupation of the Americas has been pushed back repeatedly. Recently, Ardelean et al. (2020) dated human presence in the Chiquihuite Cave in Zacatecas as 24,000 years ago and probably earlier.

Ethnohistorical and historical sources have been reviewed by several authors (see for instance Bye and Linares 2016; Camou et al. 2016). These extraordinary written and pictographic documents enrich the understanding of past and current patterns of interactions between humans and plants. This approach has a long tradition in Mexico and continues to provide interesting information and novel insights.

History reconstruction of the last century is commonly possible through interviews with the oldest people in a community. Timelines are highly useful tools for analyzing aspects of ecosystem management and resilience. Life stories help to understand patterns of wider historical, social, environmental, and political contexts (Adriansen 2012). Interviews can be complemented with other sources of information, thus combining qualitative and quantitative sources. For instance, chronological analysis of a life history can be complemented with bibliographic information or statistical data. Several helpful software tools for qualitative analysis and specifically for timeline analysis are available.

Ecological ethnobotany and sustainable management. The integration of ecological principles in ethnobotanical studies have resulted in new approaches and insights into the use patterns of forests or agricultural systems. Several authors have called this integration ecological ethnobotany (Caballero et al. 1998, 2022; Delgado-Lemus et al. 2014; Camou et al. 2016). A number of studies from the last decades analyzed use patterns and population management, and their impact on genetic variation (Cruse-Sanders et al. 2013; Félix-Valdéz et al. 2016; Paz-Guerrero et al. 2019; Cabrera-Toledo et al. 2019; Alvarez-Ríos et al. 2020) and demographic rates (Martínez-Ballesté et al. 2005, 2006, 2008; Torres-García et al. 2015, 2020). Many of these studies tried to identify management forms that conserve genetic diversity and sustainable harvest rates based on local practices, through matrix analyses and integral projection models (see Torres-García et al. 2015, 2020). These approaches have been implemented with and by traditional communities for non-timber forest products (Illsley et al. 2004).

Ecological methods for evaluating sustainability also include the biotic communities. They are particularly relevant for measuring species diversity (see Pérez-Negrón and Casas 2007) and interactions (pollination, facilitation, seed dispersal, herbivory; see for instance Torres-García et al. 2013; Rangel-Landa et al. 2015). These are affected by human practices and show pathways to ensure the permanence of the communities.

Guides for the management of whole ecosystems are developed with multicriteria methods. These methods are based on the identification of critical points and attributes of the systems. Synchronic approaches explore the effect of interventions and design diachronic strategies of adaptive management. MESMIS is one of the most commonly used and highly versatile methods to analyze sustainability of forest, agroforestry, and agricultural systems (Masera et al. 2000).

Evolutionary ethnobotany, domestication, and agrobiodiversity. Evolutionary ecology and relational anthropology are highly valuable for understanding interactions between humans and plants, management and domestication. These approaches are fundamental to understand the development of agrobiodiversity, including crops and non-crops. Evolutionary ecology documents the evolutionary consequences of human-plant interactions whereas relational anthropology and ethnographic studies describe and analyze how the interactions are. In Mexico, studies of plant management and domestication have increased during the last three decades. They show how the broad spectrum of management types of plant populations and communities influence the frequency of phenotypes and species in an area. This information is relevant to understand the human influence in molding landscapes and populations and their mutual influences (see Casas et al. 2016a).

Ethnobotanical approaches identify useful species for different purposes, and their different qualities and values for people. These values (relational, cultural, and economic) drive human interactions with the species and communities. People create and identify phenotypic variation in attributes like size, color, texture, flavor, toxicity, and other features that enhance or limit use of plants as food, medicine, textiles, handcrafts, and others (Casas et al. 2007; Aguirre Dugua et al. 2012). They encourage favorable phenotypes through different forms of management and discourage others. These selective processes may act in several directions and with different intensity, thus influencing different degrees of domestication. But people also influence these processes through intervening on how the gene flow occurs. They move reproductive individuals from place to place, thus removing spatial barriers to pollination; also, they commonly move seeds or vegetative propagules from distant regions to others, creating reproductive bridges that influence plant evolution under domestication (Cruse-Sander et al. 2013). They also frequently create small, isolated populations which favor genetic drift. All these processes are also influenced by natural evolutionary forces (selection, genetic drift, breeding systems, and gene flow), which operate together with those guided by humans.

By comparing wild and managed populations, we can characterize and evaluate the results of these processes that involve morphological, physiological, phytochemical, reproductive biology, and genetic variation in populations (Casas et al. 2016b). These approaches allowed identifying that some plants represent advanced stages of domestication, but plant populations exist on a continuum between wild and domesticated, depending on the type and intensity of management, but also on life cycle and other biological attributes of plants (Blancas et al. 2010, 2013; Rangel-Landa et al. 2016). New methods allow to measure morphological details of plants, or to monitor movements of pollinators and seed dispersers by telemetry. Techniques for the isolation, characterization, and identification of phytochemical compounds have increased their capacities; genomics and metabolomics are methods more rapid and efficient for screening chemical constituents of plant tissue. Chromatographic and spectroscopy methods (ultraviolet, infra-red, mass spectroscopy, and nuclear magnetic resonance) have modernized and recent methods like matrix-assisted laser desorption, electron impact, chemical ionization, atmospheric pressure ionization, among others, broaden the menu of options to characterize the compounds occurring in plants (Olufunke 2012).

Advances in genomics are particularly relevant for strenghtening previously developed approaches like population genetics, phylogenetics, and phylogeography (Gepts 2014; Kantar et al. 2017; Chomicki et al. 2020). The level of resolution reached with single nucleotide polymorphism (SNPs) is extraordinary. Metagenomics helps to identify assemblages of organisms and their trends through time and strengthen the understanding of patterns related with human management. The capacity of genomics to identify coding regions and their relation to domestication traits is equally impressive (Zarrillo et al. 2018; Chomicki et al. 2020). Until a couple of decades ago, identifying coding regions required different approaches from quantitative genetics to field experiments to determine the heritability of characters. This approach helps to study evolutionary aspects of the most important crops of the world (about 150 species), but the number of species under domestication is much higher (more than 7000) and much work is still needed. These methods will contribute to their understanding faster than until now. Also, these methods are corroborating or correcting the hypotheses on the evolutionary influences of humans through the broad spectrum of interactions documented by ethnobotanical studies.

Food systems and sovereignty. Ethnobotany contributes substantially to food sciences and food anthropology. Its holistic studies on traditional food and food security can support programs for food sovereignty. Ethnobotanical studies in Mexico have documented more than 2000 edible plant species (Mapes and Basurto 2016) and they are part of food systems. Most crops or managed plants are edible (Clement et al. 2021). Clearly, the main efforts of domestication have been directed to food plants in Mexico and elsewhere (Casas et al. 2022). Agrobiodiversity studies concentrate on edible plants and these studies are intimately connected with the study of diet patterns. Several chapters of this book treat problems related to food patterns and risks to food sovereignty. There are particular contexts in all cases but the trend to abandon traditional food and adopt industrialized food is clear and worrying. Multiple factors influence this complex situation. The urbanization of people migrating to cities of Mexico and the USA, which is commonly related to abandonment of agricultural practices and traditional ways of life. In addition, the food producing companies promote their products as a gateway to higher status. Also, the rural economy is becoming monetized, and people have much less time for agriculture and cooking. Another factor is racism and cultural discrimination, which rural people try to escape by adopting urban habits (Casas et al. 1994).

Traditional food is tied to cultural identity and is a target of discrimination. Ethnobotanical studies commonly report that people omit to mention traditional food such as quelites or insects during interviews, considering them worthless or embarrassing, or refer to these elements as part of the diet of poor, indigenous, mountain people. Several social organizations, NGOs collaborating with ethnobotanists, anthropologists, and agroecologists, have been promoting traditional food with a certain amount of success. Some governmental research initiatives (like the Agrobiodiversity project, and others related to the use of biodiversity by CONABIO) have helped also, but there is still much to do. Local, regional and national collaborations linking research with promotion of traditional food are possible and necessary. Mexican ethnobotanists should include this priority line of research and action in their agendas.

Transdisciplinary research and participation. As mentioned above, ethnobotanists and other scholars have been influenced by social movements defending their biodiversity and ecosystems, territory and ways of life, as well to those requiring innovations in management systems, internal organization and community institutions, public policies, development of educational programs, among other issues. All these experiences have represented different forms of establishing dialogues and interactions and participatory processes (Castillo et al. 2005, 2018). The modalities of all these ways of cooperation are numerous and require a careful systematization to be able to learn and use them to develop or reinforce current and future processes. These collaborations are based on: (1) the recognition of the importance of

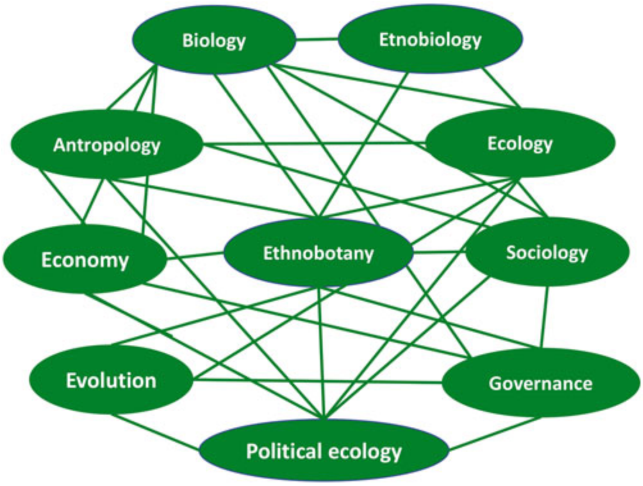

Fig. 1 General outline of inter and multidisciplinary collaboration of ethnobotany with other sciences when studying a shared problem

knowledge and experience of other participants; (2) respect and empathy with persons representing different sectors; (3) the disposition of each sector to acknowledge their own limitations; (4) the proclivity to imagine the actual and potential value of knowledge and experience of others; (5) the capacity to listen to the others and to transmit the own knowledge and skills; (6) the courage to put into practice tentative experiments to explore adaptive management processes; (7) the disposition to learn from the experience; (8) the capacity to communicate the failures and successes of the process to other members of the cooperating communities. Interaction networks based on these principles can deliver novel and helpful advances in rural systems. To consolidate ethnobotany as a research field, ethnobotanists should strengthen their ties with other academic disciplines (Fig. 1). Ethnobotany is connected with all sciences illustrated in the figure and others. It has its own domains but is supported and advanced by methodological and theoretical frameworks developed in those other disciplines. Interaction with other sectors is also needed (Fig. 2), and transdisciplinary approaches base on the recognition of the value of knowledge and experience of all these sectors. Each sector may in turn be composed by subsectors (S1, S2, S3, etc.) dialoguing within and between sectors. For instance, the rural communities may be composed by ejidatarios, comuneros, agriculturalists, ranchers, foresters, men, women, young, and elder people, among others. Scholars may be ethnobotanists, anthropologists, agronomists, ecologists, and others. NGOs may be regional, national, and international. Entrepreneurs may be merchants specialized in non-timber forests and/or agricultural products, those trading handcrafts or businesses purchasing rural products. Governmental agencies may involve those making decisions on conservation, forest management, land tenure, hunting and fishing, and biosphere reserve regulations.

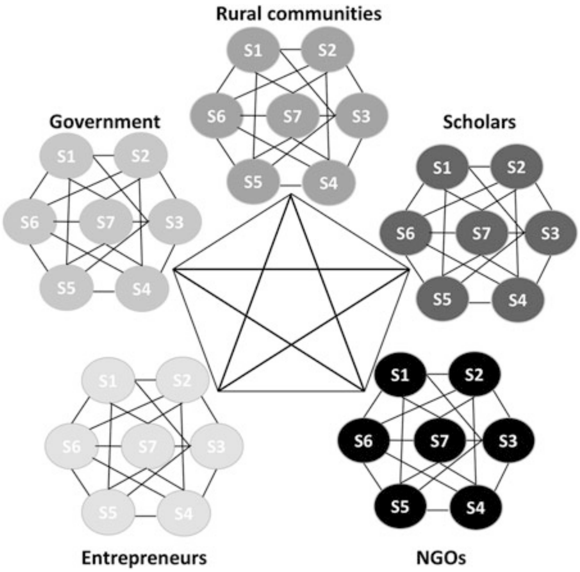

Fig. 2 Exchange of knowledge, experiences, needs, demands, visions, and techniques pertinent among different sectors related to biodiversity management

An example of these interaction networks is that built by the NGO Grupo de Estudios Ambientales (GEA for its acronym in Spanish) the Sanzekan tinemi (an organization of rural communities of the central region of the state of Guerrero) and scholars of different specialities (engineers, biologists, anthropologists, geologists, sociologists, environmental scientists, economists, among others). They have worked for several decades in programs of soil and water conservation, environmental restoration, sustainable management of mescal agaves and palms, and others. GEA has based its actions on the respect of communitarian institutions and has been propellant of initiatives to invite the scholars to collaborate (Illsley et al. 2004, 2007; Casas et al. 2017).

Final Comment

Theoretical and methodological frameworks are research tools under continual revision in all sciences and ethnobotany is not the exception. The trends discussed in this chapter suggest reinforcing the efforts to strengthen the theory and generalizations on the broad spectrum of topics covered by ethnobotanical research. This is not only of scholarly importance but, as discussed above, highly relevant for guiding human activities toward a sustainable world.

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