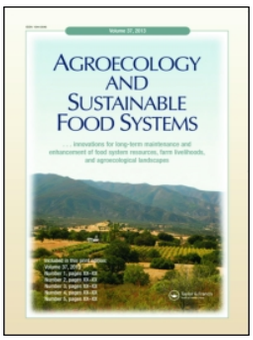

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Back to the roots: understanding current agroecological movement, science, and practice in Mexico

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ABSTRACT

In the middle of the last century, there were two types of agronomic scientists in Mexico. One group perceived traditional agriculture as backward and in need of modernization with advanced technologies. The other group, engaged in intensive fieldwork, studied and found inspiration in peasant and indigenous systems. This latter group of researchers who studied and described the biocultural richness of these systems provided the foundations for the development of agroecology in Mexico. Mexican indigenous systems also inspired many of the pioneers of agroecology at the global level. In this review, we strive to describe the historical landmarks of the development of agroecological education and research in the past and present in Mexico, while elaborating on the challenges that this discipline faces today and in the future.

KEYWORDS

Agriculture; agroecology; education; history; indigenous; Mexico; practice; research

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Introduction

Since the 1970s, agronomists and ecologists have researched, systematized, and documented scientific evidence regarding the agroecological benefits of many traditional practices. This activity marks the beginnings of *agroecology* in Mexico, which would later be nourished by modern scholarship on agronomy and *agroecology* as practiced in other parts of the world.

Several authors have written about the history of *agroecology* in Mexico. Víctor Toledo (2011) emphasizes the communities and social groups created since the Mexican Revolution, and Gliessman (2013) highlights the role of researchers, agronomists, and ecologists who, in the 1970s, went against the current in the agricultural sciences and the Green Revolution promoted by the Rockefeller Foundation in Mexico since the 1940s.

Agroecology appears in different ways. It emerges toward the end of the last century, in the 1980s and 1990s, as a scientific discipline offering alternatives to the Green Revolution, employing elements of both ecology and traditional agricultural systems to study agroecosystems and to affect agricultural development. In the 2000s, several authors took the field to another level, arguing that agroecology involves producers as well as consumers and together are enmeshed in the food system (Gliessman 2007; Wezel and Soldat 2009).

Agroecology is also a political and social movement. In Latin America in the 1980s and 1990s, some political parties took up the banner of agroecology as a path toward sustainable development for rural communities. In other instances, it became a space in which social movements, networks, and civil society organizations converged around concrete experiences of production and consumption guided by the concepts of autonomy, environmental conservation, and agrobiodiversity. In 2007, the Latin American Scientific Society of Agroecology was established to promote agroecology as the scientific basis of a strategy for sustainable development in Latin America. This organization emphasizes food sovereignty, natural resource conservation, and agrobiodiversity, and it seeks to empower rural social movements (Wezel and Soldat 2009).

Along these lines, it should be noted that there is an attempt to reduce and eventually eradicate the dependence on agrochemical inputs, to bring agricultural production systems as closely in line as possible with the principles that guide natural ecosystems, and to recognize small indigenous farmers and their knowledge. *Agroecology* is based on the set of knowledge and techniques that originate within farming communities and their ways of experimenting (Altieri and Toledo 2011), knowledge that is as rich and diverse as the many countries and ethnic and cultural groups that compose Latin America. However, despite the importance of this knowledge and of farming and indigenous communities in terms of the ecological services and conservation of soil, water, and biodiversity that they offer to society, these are frequently

erased or pushed to the margins with the popularization of the homogenizing technological packages promoted by governments, national-level private companies, and transnational corporations in many countries in Latin America.

In early twentieth-century Mexico, there was a great diversity of crops, indigenous knowledge in rural communities, and large *haciendas* that relied on the tools of farming, animals, and seeds brought by the Spaniards such as wheat. External inputs, such as guano from Chile, among others, began to be used. Since the 1940s, ideological pressure from the United States on countries such as Mexico and India has promoted the idea of modernizing agricultural practices to increase the productivity of soils and labor with the objective of modernizing and industrializing societies that were considered primitive and rural (Perkins 1990).

This article documents a trajectory of resistance to technological homogenization and the imposition of private and corporate interests, as noted by Gliessman (2013), in addition to stories of conservation and the recovery of the practice of agroecology as a whole. It begins by explaining the origin of this discipline, its historical and sociocultural background, and the agricultural sciences in the mid-twentieth century in Mexico. It then briefly reviews contemporary efforts in this field in the arenas of science, practice, and social struggle.

From resistance to alternatives: the dawn of agroecology in Mexico

The agroindustrial model was introduced and adopted in Mexico through a complex process with the participation of diverse institutions. According to Cotter (2003), the modernization process began after the Mexican Revolution, when different strategies were utilized to transform the agricultural landscape through new techniques and instruments. With this objective, educational institutions were founded for teaching and experimentation, extension programs, financing, etc. An important outcome of this new modernizing effort was the founding in 1943 of the Office of Special Studies (*Oficina de Estudios Especiales*—OEE) based on an agreement between the Rockefeller Foundation and the Mexican Government. This organization provided the technical tools, knowledge, and agents offered by the Rockefeller Foundation to the Mexican State's modernization program to create high-yield varieties, promote the use of agrochemicals, and mechanize agricultural tasks.

However, the modernization process did not occur mechanically, nor was it without controversies and resistance. The introduction of new techniques and inputs implied the displacement of those that were traditionally utilized, such as the covering up of new agents and the eclipsing of others. This phenomenon led to interesting debates regarding the suitability of the

agroindustrial model in countries such as Mexico and the search for alternatives that would today be considered agroecological. In this context, by the 1940s, we can identify actors, institutions, and research programs that, through their opposition to the agroindustrial model or the search for alternative strategies, mark a fundamental watershed for understanding the history of agroecology in Mexico.

It should be noted that in 1941, the geographer Carl Sauer voiced early opposition to the Rockefeller Foundation's project to invest in Mexican agriculture. In response to the idea of promoting hybrid seeds, agrochemicals, and the mechanization of agriculture, Sauer highlighted the risks entailed by this type of modernization regarding the economy, culture, and local genetic resources (Harwood 2009).[1] Similarly, agronomists Edmundo Taboada, Edmundo Limón, and Pandurang Khankhoje warned of the problems of adopting hybrid varieties in Mexico, which forced farmers to buy seeds annually, because these varieties rapidly lost their hybrid vigor and ceased to be profitable. They also criticized the use of the so-called technological packages and instead sought to develop "stabilized varieties" that would be capable of offering high yields and being planted indefinitely (Barahona 2003; Muñoz 2000). These types of concerns were also discussed within the Rockefeller Foundation, and in an attempt to generate seeds that would be better suited to the type of agriculture and small-scale farming economy, its Office of Special Studies developed "synthetic varieties" that could be replanted indefinitely without having to incorporate the entire technological package associated with hybrid varieties (Matchett 2006).

The use of chemical pesticides and fertilizers also generated debates and a search for alternatives as of the late 1930s. In this sense, various researchers discussed the suitability of biological pest control, the use of green manures, crop rotation, and other strategies. Authors including Silverio Flores Cáceres, Rodolfo P. Peregrina, Juan del Toro, Reggie J. Laird, Mariano Jiménez, Fidencio Puente, Horacio Aburto V., and Eleazar Jiménez J., published articles demonstrating the effectiveness of agroecological methods in journals such as *Chapingo* (published by the National School of Agriculture), *Agricultura y Ganadería* (edited by Rafael A. Osorio), and *El Campo* (edited by Armando Palafox). The search for alternatives was also nourished by emerging research on entomology and population ecology as well as local knowledge and actors that, while still marginal in this period, gradually became positioned as important sources of thought and action for alternative agricultural development.

It is important to note the role in this process played by seminal works published by several authors that testify to the concerns at the time over the foreseeable consequences of the agroindustrial model and to demonstrate an explicit recognition of local knowledge regarding various aspects of botany, entomology, and agriculture. It is also interesting to note that these authors attempted to understand and record local knowledge on its own terms.

Examples include works by Maximino Martínez (1888–1964) such as *Catálogo alfabético de nombres vulgares y científicos de plantas que existen en México [Catalogue of Common and Scientific Names of Plants Found in Mexico]* (1923), *Las plantas más útiles que existen en la República Mexicana [The Most Useful Plants Found in the Mexican Republic]* (1928), and *Las Plantas Medicinales de México [The Medicinal Plants of Mexico]* (1933); works by Augusto Pérez Toro (1902–1974) such as *La Milpa [The* Milpa*]* (1942, republished in 1946 with some additions under the title *La agricultura milpera de los Mayas de Yucatán [Milpera Agriculture among the Yucatan Maya]* and *El indio en la agricultura [Indians and Agriculture]* (1949); and works by Manuel Maldonado Koerdell (1908–1972) such as *Estudios etnobiológicos. Definición, relaciones y métodos de la etnobiología [Ethnobiological Studies: Definition, Connections, and Methods of Ethnobiology]* (1940). The research and teaching of French scholars Gabriel Itie and Leon Fourton are also noteworthy; coming from the National School of Agriculture, they argued that attention should be paid to local knowledge before "modernizing" Mexican agriculture because local knowledge is the fruit of wisdom accumulated over generations and the best method of ensuring annual production year after year (Cotter and Osborne 1996).

The 1960s saw a second wave of opposition to the agroindustrial model and searching for alternatives. According to McClung de Tapia (1990), in this period, the knowledge possessed by traditional, indigenous, and small-farming peoples became central to academic programs deployed by a new generation of researchers such as Efraím Hernández Xolocotzi (1913–1991), Arturo Gómez Pompa (1934–), José Sarukhan Kermez (1940–), Miguel Ángel Martínez Alfaro (1942–2007), and Rafael Ortega Packza (1944–), among others. Efforts to study this type of knowledge have since sought to document not only the existing local production alternatives but also the importance of their agents and the economic and cultural implications that give them meaning (Argueta, Corona, and Moreno 2012). Anthropological works by researchers such as Ángel Palerm (1917–1980) and Arturo Warman (1937–2003), among others, have also been essential to this process.

Efraím Hernández Xolocotzi was undoubtedly a central figure during this phase. His work both in the field and in the classroom had an indelible impact on the disciplines of agronomy, ethnobotany, and agroecology in Mexico and Latin America. Born in 1913 in San Bernabé Amaxac, Tlaxcal, he began his education in the United States, where his mother had emigrated. He studied applied agriculture at Farmingdale State College and Cornell University and later went to Harvard University. In the late 1940s, he began collaborating with the Mexican Agricultural Project undertaken by the Rockefeller Foundation in Mexico, and in 1953, he became a professor at the National School of Agriculture (which, in 1978, became the *Universidad Autónoma de Chapingo*). Some of his most important texts addressing issues of local knowledge and agricultural ecology include *Maize Granaries in Mexico* (Hernández 1949), *La agricultura en la*

península de Yucatán [Agriculture on the Yucatan Peninsula] (Hernández 1959), *Exploración etnobotánica y su metodología [Ethnobotanical Exploration and its Methods]* (Hernández 1971), *Metodología para el estudio de agroecosistemas con persistencia de tecnología agrícola tradicional [Methodology for the Study of Agroecosystems Using Traditional Agricultural Technology]* (Hernández and Ramos 1977), and *Reflexiones sobre el concepto de agroecosistemas [Reflections on the Concept of Agroecosystems]* (Hernández 1977), to name a few. Although Efraím Hernández did not propose the term agroecosystem until 1977, his publications since the 1940s demonstrate an effort to understand ecological interactions and human strategies for adaptation and resource management.

To understand this historical process, it is important to note the *Comisión de Estudios sobre la Ecología de las Dioscoreas* [Commission for the Study of Dioscorea Ecology] created in 1959 to study and exploit the yam species known as *barbasco* (*Dioscorea composita*), used for making synthetic hormone products. The commission was directed by Arturo Gómez Pompa, with Efraím Hernández X. and Faustino Miranda participating as advisors for thesis writers including José Sarukhan and Miguel Ángel Martínez Alfaro (Figure 1). The works produced were essential for the formation of the Mexican school of tropical ecology, in which farmers from different regions of the country played a central role. In this sense, the important results obtained by the Commission demonstrated that ecology, far from being a

Figure 1. IV Congresso Latinoamericano de Agroecología, Universidad Agraria La Molina, Lima, Perú, September 9–10, 2013.

science developed in the isolated spaces of university laboratories, was a discipline that relied on local knowledge (Soto 2009).

The development of this new phase was associated with the emergence of new institutions, professorships, research programs, and dissemination bodies. Gliessman (2013) has highlighted the importance of three academic initiatives. The first of these is the creation of the seminar known as *"Análisis de los agroecosistemas de México"* ["Analysis of Agroecosystems in Mexico"] in 1976, which served as a gathering space for the emerging community of agronomists, biologists, and anthropologists who wanted "the study of traditional agricultural technology, practiced in broad regions of the country, to be incorporated into agricultural instruction at all levels so that future professionals can be incorporated into the millenarian current of Mexico and be poised to contribute efficiently to the development of global agriculture" (Hernández 1977). The second is the creation of the *Instituto Nacional sobre Recursos Bióticos* [National Institute for Biotic Resources] (INIREB) in 1975 in Xalapa in the state of Veracruz; this center was directed by Arturo Gómez-Pompa and made strides in addressing tropical deforestation through local strategies and knowledge. It was a pioneer in applied research for studying indigenous agricultural systems such as *cafetales* and *chinampas*, in addition to the development of alternatives and technologies such as integrated farms (Figure 2). Morales (1984) describes the productive systems of *chinampas* and puts them into practice while integrating plant, animal, and fish production through the management and recycling of organic material in Veracruz. (See Figures 2 and 3.)

The third initiative was the creation of the *Colegio Superior de Agricultura Tropical* [College of Tropical Agriculture] (CSAT), founded in 1974 in Cárdenas in the state of Tabasco. Although, according to Rosado-May (2016), the CSAT was designed to disseminate and implement Green Revolution technology in the Mexican humid tropics, some of the professors hired taught the application of ecology to tropical agricultural systems. Hence, although short-lived, it was a key institution that trained many important agroecologists. The journal *Agroecosistemas, boletín informativo* [*Agroecosystems Newsletter*] helped articulate and disseminate Mexican agroecology. Published from 1978 to 1985, its 52 volumes include many of the research results generated in these spaces. The CSAT created a master's degree in tropical agroecology with the objective of addressing problems related to tropical agricultural development, incorporating the knowledge of farmers and indigenous people (Gliessman 2002). In 1976, Gliessman began his work with the CSAT; in 1981, with García and Amador, he published a key work for agroecology in Mexico entitled *The Ecological Basis for the Application of Traditional Agricultural Technology in the Management of Tropical Agroecosystems*. It includes the principles of management used in traditional systems such as *chinampas* and indigenous

Figure 2. Efraím Hernández Xolocotzi and his team. Hotel Reforma Mérida. Yucatán, 1989.

Figure 3. INIREB (Chinampas Morro de la Mancha) Veracruz, April 1980. Efraín Hernández X.

family gardens and also uses these to design modules to be put in practice in the future. The following paragraph illustrates the new vision of the authors:

> The rural inhabitants of the lowland tropical region of southeastern Mexico have managed their traditional agro-ecosystems for centuries with a focus on sustaining yields on a long-term basis rather than maximizing them in the short term. Recently introduced agricultural technology in the region has been rapidly displacing and even eliminating local practices in favor of large-scale commercial farming and cattle-raising but without achieving the production levels originally proposed. This is accompanied by a loss of diversity in local cropping systems, leading to an ever-increasing dependence on imported food products, poorer nutrition, and degradation of natural resources. …The ecological processes observed to be functioning in local agro-ecosystems include high species diversity in both time and space, high rates of biomass accumulation, closed nutrient cycling, and biological control mechanisms for weeds, pests, and disease. (Gliessman, García, and Amador 1981)

Since 1977, several authors have documented systems of management and domestication for the species present in small farming and indigenous agroecosystems throughout the country. Works were presented in the seminars on agroecosystem analysis organized by the engineer Efraím Hernández X. and collaborators from the *Colegio de Postgraduados* [Postgraduate College] of Chapingo. Some of the ethnobotany symposia were convened by the Ethnology and Social Anthropology Department at INAH, others by the Biology Department at UNAM's Faculty of Sciences, and later by the Botanical Society of Mexico. A volume edited by the ethnobotanist Teresa Rojas (1994) entitled *"Agricultura indígena pasado y presente" [Indigenous Agriculture, Past and Present]* includes papers presented at the country's First Colloquium on Indigenous Agriculture, including studies on archaeological and contemporary agricultural systems in the regions of the Maya, Purepecha, Nahuatl, and Mixteca (Casas et al. 1997). It also includes research papers from biology and ecology regarding the physiological, genetic, and cytogenic aspects of cultivated and wild species, such as their management and cultivation by the ethnic groups that know and consume them. Sarukhan (1985) describes this as the work of interdisciplinary teams studying biological–social phenomena.

Altieri and Trujillo (1987) demonstrate mechanisms for pest control and nutrient transfer in traditional agroforestry and corn polyculture systems in Tlaxcala. Gliessman makes reference to Altieri's treatises on agroecology (published in 1983 and 1987) in his 1990 book *Agroecology: Researching the Ecological Basis for Sustainable Agriculture*. Gliessman writes: "Rather than dwelling so heavily on the problems of modern conventional agriculture, his book went much further in describing a theoretical foundation for the study of agricultural ecology by presenting examples of agroecosystems that incorporate the concepts of ecology into their design and management. His

examples ranged from traditional Third World agroecosystems to small-scale alternative and organic systems in developed countries" (Gliessman 1990).

The trajectory of professional training

The first university degree programs in agroecology were proposed in the late 1980s and began operating in the early 1990s. Although we do not offer a complete list of agroecology programs, in what follows, we describe some of the oldest and most established among them.

At the *Colegio de Postgraduados*, Professors Efraím Hernández Xolocotzi (1913–1991) and Ángel Palerm Vich (1917–1980) had a great influence on research and teaching. Professor Xolocotzi's thinking was based on understanding and reasserting traditional agriculture through the study of its ecological, technological, and social processes. He made the agroecosystem the central concept of agricultural research and teaching in Mexico. For his part, Ángel Palerm Vich was a Spanish anthropologist, professor, and researcher who proposed models for the study of small farmers and argued that it was necessary to view farmers as part of a holistic system composed of their use of the environment, the work of their families, and their ties to and integration with a rural community.

In the 1990s, Tomas Martínez Saldaña broadened the dialogue between the social sciences and agronomy and initiated the debate on issues related to smallholder agriculture. Meanwhile, he and Javier Trujillo Arriaga promoted multidisciplinary working groups on smallholder agriculture in the face of free trade. A group led by Ronald Ferrera Cerrato organized two international symposia on agroecology, sustainability, and education in 1992 and 1994 and published the proceedings of the events, in which Ferrera presents the proposal of creating a doctorate in agroecology at the *Colegio de Postgraduados*. He also highlights the participation of phytopathologist Roberto García Espinoza (1944–2012), who established the holistic focus (from the general perspective of systems theory) in his works on vertical resistance, disease, and agroecology. Agroecology was formally included in the *Colegio de Postgraduados* in 1995, with a course coordinated by Julio Sánchez Escudero. More courses were subsequently offered, and approval was recently granted to a master's in agroecology and sustainability. Scholarships are expected to be available for domestic students as of January 2017.

The *Colegio de la Frontera Sur* [College of the Southern Border] was founded in 1994 and began offering a doctorate in agroecology and pest management in 1995. The legacy of Hernández X., who had a significant influence on this group, was complemented by the perspectives on complex systems, conservation, and the function of biodiversity in agricultural settings

offered by John Vandermeer and Ivette Perfecto, in addition to the focus on agroforestry systems of the *Centro Agronómico Tropical de Investigación y Enseñanza* [Center for Research and Teaching on Tropical Agronomy]. Today, the agroecology group is composed of 24 researchers primarily concentrated at a campus in San Cristóbal de las Casas. These researchers address issues related to agricultural germplasm, soil ecology, landscape ecology, farming territories, traditional knowledge, sustainable food systems, and social movements.

The main activity of the group is to provide training in agroecology, and with this objective in mind, the doctoral program was redesigned in January 2015 and renamed "Agroecology and Society." Between 1995 and 2014, 38 doctoral students graduated from this program with training in agroecology and pest management. Seven students are currently enrolled in the new "Agroecology and Society" program, and 10 entering students are expected in 2016.

At the *Universidad Autónoma Chapingo*, a group of professors including Fidel Márquez Sánchez, Laura Trujillo Ortega, Carlos Guadarrama Zugasti, Rafael Ortega Paczka, Maria del Rocío Romero Lima, Javier Trujillo, and Georgina López Ríos created a degree program in agroecological engineering in 1991. Located in the center of the country, this university program is influential at the national level, with the majority of its graduates and projects located in the central, southern, and southeastern regions of the country. It aims to train agroecologists who are capable of proposing solutions to environmental problems stemming from conventional agriculture and its impacts on rural life, with a focus on interdisciplinary training. Teaching practices have been developed over the last 20 years through processes of participatory management with farming communities and with a multidisciplinary focus to overcome the fragmentation of knowledge. There are now 535 graduates of the program, the first having earned their degrees in 1995, and 78 students are currently enrolled.

Established in 1991, the agroecological engineering degree at the *Universidad Autónoma de San Luis Potosí* is awarded by the Faculty of Agronomy and Veterinary Science. Its mission is to train professionals to contribute to the sustainable use of agroecosystems based on the notion of the interconnectedness of society and nature and to generate and apply knowledge and technology in connection with society, grounded in the need to preserve local cultural values while promoting a global and enterprising vision. Located in the geographic center of Mexico, it has a particular influence in the arid regions of the Mexican highlands, in El Bajío and La Huasteca. As of late 2015, 191 students had graduated from the program and 135 were enrolled.

Individual efforts at different educational and research institutions have kept research and experimentation on agroecology alive in the state of Jalisco. These efforts began to emerge in the 1990s to respond to and accompany rural

organizations geared toward sustainable agriculture. It is important to note that the University of Guadalajara and the *Instituto Tecnológico y de Estudios Superiores de Occidente* [Western Institute of Technology and Higher Education] have had a constant presence in this area. In the Department of Ecology and Natural Resources at the University of Guadalajara's *Centro Universitario de la Costa Sur* [Southern Coast Campus], work related to community development and agroecology has a 25-year-long history and is focused on three major areas: first, extracurricular training in agroecology and peasant organizing; second, applied research to reinforce regional agroecological processes; and third, training large numbers of professionals at the bachelor's and master's degree levels on issues related to agroecology and rural development. Research on agroecology at the *Instituto Tecnológico y de Estudios Superiores de Occidente* began in 1993 as a central component of advisory and accompaniment processes, and therefore, since the outset, participatory and applied research has been used to resolve the problems of small farmers. Research activities have focused on the central and southern regions of Jalisco and in the metropolitan area of Guadalajara, where topics include (a) the impacts of industrial agriculture; (b) strategies by farmers to promote sustainable agriculture; (c) technological processes in ecological agriculture; (d) peri-urban agriculture and its contributions to sustainability; and (e) the care and conservation of the native seeds of the *milpa* or cornfield.

More recently, in 2007, the *Instituto Politécnico Nacional* [National Polytechnic Institute] created a master's program in the agricultural management of pests and disease. The purpose of the program is to provide training to equip professionals with the knowledge, ability, and attitudes necessary to conduct research on phytosanitary problems and to offer alternatives for environmentally sound and sustainable management. In this manner, the program is in line with the mission of the institution, which aims to provide university-level training to professional development in the agricultural sector. This master's degree is awarded by the *Centro de Desarrollo de Productos Bióticos* [Center for the Development of Biotic Products] located in Yautepec in the state of Morelos. Currently, 22 students are enrolled in the program, and 34 have graduated during its 8 years of operation. The most well-developed areas of research in this program are related to the agroecological management of pests and the agroecological management of disease, contributing to the creation and application of knowledge regarding alternative methods for pest and disease management from the perspective of sustainability.

Agroecological research in the twenty-first century

As demonstrated above, although many studies have not explicitly used the term "agroecology," Mexico has a long tradition of research in the areas of small farming, ethnobotany, and ethnoecology. However, a series of key

studies identify and characterize ancient and indigenous systems that utilize complex agro-silvo-pastoral systems. For example, the transdisciplinary work on the historical, social, cultural, and technical–productive aspects of agriculture in the farming communities of Tlaxcala by González-Jácome (2003) remains relevant: "… these socio-historical elements, although apparently external to strictly ecological factors, are the motors that transform agricultural systems in directions that have little or nothing to do with ecological theory and can do much to explain aspects such as the oft-cited sustainability and its ecological and sociopolitical feasibility."

From this same perspective, researchers have published works that contain detailed descriptions of management practices in systems transformed and managed by different ethnic groups, including *milpa* and agroforestry systems. Morales, Perfecto, and Ferguson (2001) of ECOSUR have studied mechanisms for regulating pests that use beneficial insects and by fertilization type in *milpas*. Soto-Pinto et al. (2000), working in Chiapas, have determined the appropriate level of shade to prevent reductions in coffee yields. Manson et al. (2008), in Veracruz, create a typology of coffee plantations, from the most traditional to the most technical, analyzing and documenting the plant and animal organisms present and studying the soil and water conditions. They make an important recommendation that applies to other productive and agroecological systems, which is that producers should focus on the environmental services that directly affect the production and functioning of their crops, such as pollination, the biological control of pests and disease, soil conservation, and fertility, instead of simply seeking to take advantage of markets such as carbon sequestration. Toledo and Moguel (2012) undertake an interdisciplinary exploration of the multiple values and benefits of these agroforestry systems.

The publications by Moreno-Calles, Toledo, and Casas (2013) and Aguilar-Støen (2008), Aguilar-Støen et al. (2011) are also notable. From a biocultural perspective, the former describes several of the traditional agroforestry systems practiced in Mexico today, whereas the latter demonstrates how plots and agroforestry systems near the home maintain agrobiodiversity and increase the resilience of agricultural units.

Research regarding varieties of tomatoes and other crops such as amaranth in the context of traditional agricultural systems has been conducted (Ríos-Osorio et al. 2014; Sánchez-Olarte et al. 2015). Meanwhile, countless studies regarding the origin and distribution of corn have been conducted to analyze and explain the distribution of its diversity and its maintenance in different communities, ethnic groups, and biogeographic regions in Mexico (Brush and Perales 2007; Orozco-Ramírez et al. 2016).

Many studies describe ancient and traditional forms of management, such as agroforestry systems for coffee growing, native corn-growing systems, the Mesoamerican *milpa*, the Mayan *milpa*, the floating gardens (*chinampas*) of

Xochimilco, and the *cajete* system in the Alta Mixteca region, among others. They describe the ecological principles of these systems; their potential for achieving food sovereignty and conserving and restoring soils, forests, and water; and their potential to supply germplasm and functional biodiversity and their role as carbon sinks (Benítez et al. 2014; Chappell et al. 2013; Moya et al. 2003; Nigh and Diemont 2013; Rogé and Astier 2015). Analyses of the economic viability and the actual supply represented by the products in the market originating from these production systems have also been performed (Revollo-Fernández 2015, 2016; Torres-Lima, Canabal, and Burela 1992).

A research group for evaluating natural resource management systems while incorporating sustainability indicators (known by its Spanish initials as MESMIS) was created in 2000 with the publication of the book *Sustainability and Natural Resource Management* (Masera, Astier, and López Ridaura 1999). This text and another publications series have had a significant impact on training programs in Latin America as well as on research on the evaluation and practice of the concept of sustainability in the context of small-farming systems.

Several of these studies analyze the challenges that these systems entail, highlighting technical problems such as pests and disease as well as the lack of markets and opportunities for commercialization. Beyond these common problems, there is also evidence of failures by the government in terms of the lack of public policy and programs geared toward promoting and incentivizing the use of these agroecological systems.

Agroecology in practice

Agroecology is put into practice in family and organized farming that utilizes diversified productive strategies and services that foster food sovereignty (Bartra 2014). This discipline is fully expressed through networks of production, distribution, and consumption, most of which are created by organizations and social movements composed of consumers and producers. They strengthen the economy of local markets, which simultaneously bolsters local work and local products, promoting a virtuous cycle of income regeneration and work in the local environment (Escalona Aguilar 2010).

Nigh and González-Cabañas (2015) analyze the potential and functionality of alternative food networks and their impact on small-farming families. They recover the economic aspects of these systems in terms of, for example, the lower prices that are found in these networks compared to through intermediaries or stores. Meanwhile, they note the ethical dimension that emerges in alternative food networks, which recognize farmers for their work and the quality that distinguishes their products. Some examples of alternative food networks can be found in the markets of Jalisco and the production–consumption network known as RASA (*Red de Alternativas Sustentables Agropecuarias* [Sustainable Agricultural Alternatives Network])

(Gerritsen and Morales 2009). There are also the alternative networks and markets in Chiapas and Jalisco described by González (2011), in addition to experiences that have been functioning for more than 10 years, such as the *tsiri* network in the Purepecha region (Masera-Astier and Astier 2014).

In 2004, the *Red Mexicana de* Tianguis *y Mercados Orgánicos* [Mexican Network of *Tianguis* and Organic Markets] (RED) was born out of the need to articulate and make visible the local processes performed by the *tianguis* and as an initiative to promote fund-raising and political action to demonstrate that consuming healthy and high-quality foods does not have to be expensive (Escalona Aguilar 2010). RED is based on the principles of collaborative work and aims to promote food sovereignty; processes of training, production, and technological development; the exchange of genetic materials; and alternative certification initiatives. It has promoted the National Law on Organic Production, whose regulations and guidelines are based on participatory organic certification. Mexico is one of the few countries in which this type of certification is legally recognized (Escalona Aguilar 2010).

Countless initiatives such as these can be found throughout the country: alternative markets; organic markets; farmer's markets; groups and cooperatives of producers, processors, and marketers; seed exchange networks; and production–processing–consumption networks. These entities favor the return of farmers and revitalize local markets as well as creating increased social awareness. Movements such as Via Campesina have come to this same conclusion (Martinez-Torres and Rosset 2010).

Challenges for agroecology and agroecologists in twenty-first-century Mexico

The agricultural management systems used by small-farming and indigenous communities are becoming even more important because of the ecological services that they offer to society. We may note shade-grown coffee plantations that are equally or more biodiverse than forests, *milpas* and arid corn-growing systems that are a dynamic reserve of native breeds, agroforestry systems, etc. Although interest in these systems appears to be on the rise, scientific studies of the application and concepts of agroecology are not growing at the same rate (Manson et al. 2008).

The conservation of native varieties is essential to the global agriculture industry. These varieties are the source of the variability that is necessary for crops to be able to adapt and resist emerging epidemics, in addition to the changing soil conditions and climatic conditions that will have to be confronted in the near future. This situation is complex, as low prices for traditional crops, migration, the introduction of contract farming, and/or farming export drive land use changes that ultimately lead to the abandonment of traditional systems and crops.

All of this is associated with an alarming loss of biodiversity in many rural communities. In areas that are dominated by the adoption of modern technology and improved seeds (e.g., irrigation zones), traditional varieties are progressively abandoned, in addition to the indigenous knowledge that is associated with their cultivation and consumption. The introduction of genetically modified seeds could exacerbate this situation due to the genetic uniformity entailed by this technology.

In connection with this, smallholder agricultural systems continue to face challenges such as pests, disease, climate variability, and a lack of markets in which these types of agroecological products are effectively differentiated.

In recent years, agroecology in Mexico has produced countless studies regarding management practices to be recovered in agroecosystems throughout the country. Mexico is one of the main producers and exporters of agricultural products at the international level, and it is the Latin American country with the largest quantity of small farmers engaged in organic agriculture.

The challenge today is to project the principles of agroecology, with its technological elements on different scales, so that small farmers and their food systems can continue to exist despite local and global attacks. Agroecological production systems must continue to be connected to civil society and the communities and networks of farmers, markets, and consumers that promote them. However, much more can be achieved if incentives are generated (in public policy and the economy) to strengthen processes of transition to sustainable agriculture.

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Notes

1. In his letter, Carl Sauer writes: "A good aggressive group of American agronomists and plant breeders could ruin the native resources for good and all by pushing their American commercial stocks. The little agricultural work that has been performed by the experiment station people here has been making that very mistake, by introducing U.S. forms instead of working on the selection of ecologically adjusted native items. The possibilities of the disastrous destruction of local genes are great unless the right people take hold of such work. Additionally, Mexican agriculture cannot be pointed toward standardization on a few commercial types without hopelessly upsetting the native economy and culture. The example of Iowa is about the most dangerous of all for Mexico. Unless the Americans understand that, they'd better keep out of this country entirely." Sauer, Carl Ortwin, "Memo regarding Wallace's ideas for a program in Mexico," Rockefeller Archive Center, Rockefeller Foundation records, projects, RG 1.2, series 323, box 10, folder 63, p. 2.

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