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RESEARCH ARTICLE

The evolution of agroecology in Mexico, 1920—2023

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During the last 2 decades, several studies have analyzed the theoretical and practical development of agroecology in different countries. In each country, the transition has followed different paths and paces. Using a detailed review of myriad sources, this article describes the evolution of agroecology in Mexico from 1920 to date. Our analysis was based on a set of indicators such as research teams, courses and degrees, publications, conferences, professional associations and unions, policies and laws, agricultural production, as well as social movements and resistances. We identified 5 main stages: a precursor stage (1920–1960), a foundational stage (1960–1980), an institutionalization stage (1980–2000), a deployment stage (2000–2018), and a scaling-up stage (2018–to date). The article discusses the importance of the role played by the current government in deploying and multiplying agroecological practices throughout the country. Given a history of over 7,000 years of agricultural practices, and a persistent tradition of small-scale farmer resistance movements that reached a peak during the agrarian revolution (1910–1917), in addition to the participation of small-scale producers in agroecologically oriented programs promoted by the current administration, the search for sustainable food systems in Mexico seems promising.

Keywords: Agroecology, Environmental history, Green Revolution, Traditional agriculture, Mexico

Introduction

Agroecology is a new field of knowledge that only emerged a few decades ago. It offers solutions to the serious environmental and food production problems caused by industrialized agriculture and agrobusiness. Similar to ecological economy, political ecology, environmental education, and other recently created fields of knowledge, agroecology is a *hybrid discipline*, since it combines knowledge drawn from both the natural and social sciences. Agroecology thus adopts an inter- and/or multidisciplinary approach that integrates the environmental, social, cultural, and political dimensions of food production throughout the food chain, from production and distribution to transformation and consumption. Agroecology aims to produce healthy food using practices that ensure a healthy ecosystem, *working with nature* rather *than against it*. It also promotes social equality, fair trade, organic markets, responsible consumption, self-reliance, in addition to regional and national food sovereignty.

As an expression of critical thinking, agroecology questions both social inequality as well as environmental damage and disruption. According to Wezel et al. (2009) agroecology is comprised of 3 spheres or dimensions: (a) scientific research, (b) practices applied to agriculture, and (c) inspiration for social movements in rural areas and, more recently, for consumers in urban areas. These 3 spheres are particularly present in Latin America and the Caribbean (Altieri and Toledo, 2011; Toledo, 2011).

In the last 2 decades, the number of agroecological publications and initiatives has increased exponentially, as well as the number of scientific conferences, networks, and societies. Similarly, the number of social and political movements that have adopted agroecology as their main goal has been growing in many countries. While agroecology's scientific and practical dimensions refer to the cognitive and technological fields, respectively, the third dimension is linked to social movements and political actions carried out by rural communities, and the distribution, commercialization, and food consumer networks. Agroecology has also contributed to the defense of territories, natural resources, lifestyles, and biocultural heritage.

After having been rejected or ignored for many years, agroecology has been gaining recognition, even in global multinational institutions. For example, in 2014, the Food and Agriculture Organization (FAO) organized the first international symposium on agroecology and soon after created a platform on this theme (https://www.fao.org/agroecology/home/en/). In 2018, the FAO described the 10 elements of agroecology and considered it an essential component of its commonly shared vision to achieve

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sustainable food and agriculture (FAO, 2018). In 2019, the Committee on World Food Security increased to 13 elements the number of criteria describing agroecology (CSA, FAO, 2019). The recently created Agroecology Coalition has also applied the same criteria (see www.agroecology-coalition.org). Similarly, in recent years the attention given to agroecology by academia, publications, conferences, and societies has increased exponentially (González-Chang et al., 2020; Mason et al., 2021).

The evolution of agroecological thinking has been increasingly explored and has gone beyond reviewing merely productive and technological or political, social, and cultural aspects to include immaterial dimensions such as spirituality (Toledo, 2022) or the mind-set (Cox, 2014; Coe and Coe, 2023). The term mind-set is a convenient shorthand for values, beliefs, motivations, and attitudes underlying the decisions we make and the actions we take. The study of the authors' ideological dimensions or cosmovision enabled us to identify the precursors of agroecology even before the term came into use. This study revealed that, since the appearance of the agro-industrial model at the beginning of the 20th century, there has been resistance and alerts due to the foreseeable environmental, social, and economic effects that it would generate, as well as the search for alternatives that have become the foundations of agroecology. Albert Howard, Masanobu Fukuoka, and Rudolf Steiner are 3 key authors who developed organic agriculture, natural farming, and biodynamics, respectively and published their main work on "sustainable agriculture" before agroecology appeared as a theoretical and social movement (Steiner, 1924; Howard, 1947; Fukuoka, 1978).

In the case of Mexico, although various authors have addressed the development and unfolding of agroecology with an emphasis on recent decades (Astier et al., 2017; Toledo and Barrera-Bassols, 2017; Bartra Vergés et al., 2022), there is a lack of in-depth analyses about its origin, background, and precursors. For this reason, based on a detailed review of myriad sources, this article attempts to contribute toward bridging this historiographic gap through depicting the evolution of agroecology in Mexico from 1920 to date.

Methodological approach

Agroecology is a field of research-action in which a multiplicity of stakeholders, practices, and perspectives converge in the search of alternative forms of agricultural production and social organization that differ from the agro-industrial model and aims to construct sustainable agrofood systems (Francis et al., 2003; Wezel et al., 2020). From this perspective, it is evident that this field is constituted by countless elements that are not necessarily recognized as agroecological, although they do in fact form part of this field. Tracing its evolution throughout history thus requires widening the chronological and conceptual frameworks traditionally applied to the study of agroecology.

As far as the chronological framework is concerned, our study encompasses from 1920 to 2023 in order to provide a medium-term perspective of the evolution of agroecology. This arc of time enabled us to identify both the initial expressions of skepticism and rejection regarding the agro-industrial model and technologies, as well as the search for alternatives that started to emerge at the time. It also made it possible to document the trajectory that this field has followed so far, based on a dialogue established with different disciplines, theories, movements, and institutions, as well as the changing environment itself.

Within this time frame, we researched the evolution of agroecology in 9 areas (research teams, courses, professional training programs, publications, conferences, academic associations, social movements, legislation, and public policies) through official reports, scientific and informative papers, as well as other documents found in historical archives (Archivo General de la Nación, Archivo Miguel Lerdo de Tejada, Archive of the Instituto Nacional de Estudios Históricos de las Revoluciones de México, Archivo de la Biblioteca Pública del Estado de Jalisco, Rockefeller Archive Center, and Teresa Rojas Rabiela's personal archive), as well as the SCOPUS database. Then, using the terminology proposed by authors and working groups that have sought to systematize the "key words" (Wezel and Soldat, 2009; González-Chang et al., 2020) and "dimensions" (Seminar on Agroecology and Society pertaining to the PhD in Ecology and Sustainable Development, ECOSUR, 2023) that refer to and form part of agroecology, together with the terminology that we identified in historical sources, from all the information gathered, we selected those documents containing one or more of the 21 concepts we defined as constitutive of the agroecological field from 1920 to 2023: "agroecology," "agrobiology," "ecological agriculture," "biodynamic agriculture," "biodynamism," "organic agriculture," "political agroecology," "permaculture," "agroecosystem," "small-scale farmer knowledge," "small-scale farmer agriculture," "traditional agriculture," "ethnoagronomy," "agroforestry," "food sovereignty," "family orchards," "urban agriculture," "peri-urban agriculture," "solidarity-based economy," "peasant-to-peasant," "organic fertilizers," and "biological pest control." Finally, the information was systematized in a database and qualitatively analyzed.

This piece of research thus aims to open the space to the diverse voices and initiatives that, in spite of not explicitly considering themselves to be agroecological or using this concept in their proposals, in practice have questioned the agro-industrial model and have sought alternatives for a socially and environmentally sustainable agriculture rooted in science, practice, and social movements.

The precursor stage (1920—1960): Agro-industrial modernization and environmental reflexivity

In the early 20th century, the rural sector underwent deep transformation. The discoveries and innovations produced in the field of plant genetics, industrial chemistry, and agricultural mechanics created the conditions to develop both intensive and extensive agriculture. Improved seeds,

agrochemical inputs, and motorized agricultural machinery transformed cropland's productive scale and pace, and produced the Second Agricultural Revolution in the history of humankind which, in turn, reinforced the industrialization and urbanization processes in course at the time (Mazoyer and Roudart, 1997).

By the end of the Mexican Revolution (1910–1917), both the Mexican government and private stakeholders actively promoted the use of the aforementioned technologies with the goal of modernizing the Mexican countryside and improving agricultural yields. Programs to distribute the corresponding inputs were thus established or financing was granted to purchase inputs; institutions and training programs were created to promote the new agro-productive techniques and technologies, and important campaigns were undertaken exalting the potential of these new components, at the same time as the techniques and inputs of traditional agriculture were discredited.

Although the new agro-productive technologies were introduced into a diversity of regions, it is important to note that there were those who questioned both the model's convenience and inputs pointing to the environmental, social, economic, and even geopolitical risks and problems they might generate. There were warnings, for example, regarding the risk of depleting the land and deforesting the country if intensive and extensive agriculture became generalized through the use of agricultural machinery (Sindicato de Agricultores de Jalisco, 1921; Martínez de Alva, 1933). It was noted that the use of tractors would generate unemployment in the rural sector, would disarticulate the circular economy existing in the production units, would make small-scale farmers dependent on money and other inputs external to their environment, and would end subordinating Mexico to the interests of the countries producing such technologies (Martínez de Alva, 1933; Liga de Agrónomos Socialistas, 1938). Voices also emerged criticizing the use of agrochemicals not only because of their high cost, which made it difficult to purchase them, but also because the efficacy of synthetic fertilizers depends on specialized management and the availability of water in precise amounts and supply. Besides, pesticide use was not always effective and generated resistance in the organisms the pesticides were meant to eliminate. Once pesticides were applied to croplands, other plant species could thus no longer be consumed and the small animal species that used to supplement people's diets were driven away (M Ramos, personal communication, 28/03/2014). With regard to hybrid seeds, a diversity of voices pointed to the risks implied by their dispersal in terms of the genetic erosion they might cause in the center of origin of corn, as well as to the aberration of losing its hybrid vigor and the consequent impossibility of resowing these seeds as habitually had been done in the past. Their high cost was also noted and the fact that in order to optimize their results and be profitable, it was essential to conduct additional investments in terms of risk reduction, agrochemicals, and machinery, which was beyond the possibilities of small-scale farmers (Sauer, 1941).

The agro-industrial model and inputs received a diversity of critiques from different stakeholders. The proven and probable risks were pointed out, and in various cases their inefficient and inaccessible costs were recognized. In addition, it was argued that both traditional agriculture and science-based alternatives were available. This led to conducting research to validate the existing alternatives, such as developing new methods and inputs in order to dynamize agricultural production (Argueta, 2019; Argueta and Toledo, 2023).

In the face of the issues that hybrid seeds presented, some Mexican and North American agronomists and geneticists under the Rockefeller Foundation's Office of Special Studies developed crop improvement methods that prioritized the conservation of genetic diversity. As Matchett and Fenzi demonstrated, plant improvement was carried out by adopting methods developed in the United States in the 1930s, but that had fallen into disuse following the so-called "success" of hybrid seeds (OEE, 1945; Matchett, 2002; Fenzi, 2017). Other new methods were developed that enabled the development of high-yield varieties for arid and tropical regions with yields that remained stable over time (INIA, 1986; Muñoz Orozco, 2000; Barahona et al., 2003).

Furthermore, to forgo the use of agrochemicals heavily promoted in the agriculture sector after World War I in order to make a profit on the chemical substances and industrial complexes initially developed for war purposes (Russell, 1996, 2001; Anderson, 2005), research was conducted regarding the effectiveness of crop rotation, associated crops, natural and green fertilizers, as well as bacterial inoculation and biological pest control in cropland, among other strategies. Studies were carried out regarding the volume of nitrogen, potassium, and phosphorus that could be contributed by croplands rotated with clover, oats, wheat, potatoes, tobacco, beets, and alfalfa. Analyses were also made of how the application of guano, lime, ashes, hoof and horn meal, bone meal, animal blood, and human waste, among other substances were able to supply these essential elements (Gajona, 1917; Rivas Tagle, 1927; Loria, 1929; Rivas Tagle, 1929, 1931; Opazo, 1940; Dirección de Agricultura, 1948; Pitner, 1948; OEE, 1949; Puertas, 1950; Puente, 1952; Peregrina, 1956; Laird, et al., 1960).

With regard to the use of machinery, some voices were calling for a careful selection of the type of technology and energy that was convenient to use in each region and, in any case, to rationalize their use in order to mitigate the aforementioned risks. The need to revalue the use of animals wherever possible was also noted, inasmuch as it would strengthen the autonomy of small-scale farmers and would play an important role in the agro-productive cycle, since animals generate manure, consume locally generated stubble, and may eventually serve as food (Martínez de Alva, 1933; Belausteguigoitia, 1947).

As can be seen, the agro-industrial model did not arrive on the scene unchallenged by natural alternatives nor was it adopted without criticism. While it is true that in some sectors new technologies were quickly incorporated, there were also those who expressed doubts, concerns, and even

rejection toward the new model and its inputs. Consequently, we can see that within the framework of the agro-industrial modernization process that Mexico launched around 1920, an initial form of agroecological awareness emerged that took action to develop alternative methods and inputs to replace those used by agroindustry (Argueta, 2019; Argueta and Toledo, 2023). Although there was not a clearly defined agroecological movement or agenda between 1920 and 1960, the warnings, resistance, and search for agroecological alternatives expressed a process of environmental reflexivity regarding the probable and proven risks of the agro-industrial model. In addition to the search for alternatives that took place, we consider that it should be understood as constituting the precursor phase in the history of agroecology in Mexico.

The foundational stage (1960—1980): The emergence of the agroecological field

Since the 1960s, the form and content of agroecology in Mexico gradually took shape due to the convergence of the following 2 processes: First, both international and national research emerged revealing the environmental, social, and economic problems the agro-industrial model was generating. Second, in Mexico, research demonstrated the possibility of reformulating this model using an ecological understanding of agriculture and different forms of traditional agro-productive knowledge and practices used by original peoples and small-scale farmers. It was then that these traditional groups began to be studied. Findings could be found in publications, research programs, seminars, and other academic spaces.

As far as the problems generated by the agro-industrial model are concerned, it is worth noting Rachel Carson's pioneering denunciation in 1962 regarding the environmental effects generated by the intensive use of agro-toxic chemicals in the United States. This denunciation paved the way to extensive research in the 1970s documenting other effects generated by the Green Revolution. For example, Falcon (1970), Barreto (1971), and Palmer (1972a, 1972b) observed that the efficacy of technological packages relied on the existence of a set of institutional conditions and access of small-scale farmers to strategic resources. Within the framework of the Green Revolution, the differentiated access small-scale farmers had to these resources increased inequalities in the rural sector. Those different pieces of research were not meant to be a head-on critique of the model, but gradually demonstrated the model's limitations and the need to reformulate some aspects.

Adding another line of thought, Dumont (1971, 1975) and Griffin (1972, 1974) observed the increasing inequalities that the new agro-productive technologies produced or increased in terms of the concentration of land holdings. They also observed that the promised yields were not always achieved and even when they were attained, this did not eradicate hunger resulting from unfair distribution. This evidenced that beyond technological innovations, there were economic policy problems that were imperative to address. Finally, research by Pimentel et al. (1973, 1979) and Green (1978), in the context of the so-called "oil crisis," specifically analyzed the Green Revolution's energy dimension, demonstrating its unfeasibility given its extreme dependence on fossil fuels.

In Mexico, similar research was carried out in tune with the aforementioned papers. Hewitt de Alcántara (1976), Winkelmann (1976), and Clawson and Hoy (1979) documented cases in which the implementation of agro-industrial technological packages had not produced the desired results due to the lack of institutions and resources that would ensure their widespread distribution adequate use, as well as channels to market their crops. These authors stated that the aforementioned unequal access to technology and resources aggravated the already existing agricultural inequalities. They also documented other cases in which the acceptance of these technologies was very limited or rejected outright by communities since they lacked agricultural or cultural relevance regarding local needs. Duloy et al. (1974) studied the economic problems caused by extreme dependence on fossil energies, demonstrating how the oil crisis distorted prices in this sector and how this affected both small-scale producers and end consumers. Lastly, it is important to note the work conducted by Paré (1972, 1976) who demonstrated the social and geopolitical problems that the Green Revolution was producing in the context of the Cold War. She specifically argued that in addition to being inaccessible and ineffective for the small-scale farming sector in Mexico, these technologies were mechanisms that far from resolving the problem of hunger, sought to consolidate a certain productive sector and reinforce the U.S. hegemony in Mexico and other parts of the world.

Independently, but ultimately converging with the emergence of agroecology in Mexico, research was carried out from the perspective of ethnoscience, political ecology, ethnobiology, ethnoecology, and ethnoagronomy, among other disciplines that demonstrated the existence, legitimacy, and efficacy of alternative forms of growing crops. Against the grain of the diffusion theories then in vogue that favored the idea that only a single form of modernization was possible (Rostow, 1960; Basalla, 1967), these other perspectives, forms of knowledge, and techniques encouraged the idea of an *alternative modernization* based on the values of traditional agriculture. By alternative modernization, they mean a modernization that would enable an increase in productivity by using local forms of knowledge and resources to lighten the workload without degenerating ecosystems or affecting human health, as agroecology proposed years later when it became an academic discipline.

As demonstrated by McClung de Tapia (1990), Camou-Guerrero et al. (2016), and Dumoulin Kervran (2017), among others, since the 1960s, a great interest emerged in the forms of knowledge held by indigenous peoples and small-scale farmers. Although this interest was the result of a threshold opened by Harold Conklin (1954, 1957) and Claude Lévi-Strauss (1962), it also formed part of a movement to break with the *status quo*, which within the framework of the Third World movement, led the academic community to reformulate its social bonds, as

well as its research projects and goals. From then on, there was an emphasis on the importance of working with and for communities in search of elements to reformulate the foundations of the national project. During this period, 5 authors carried out invaluable research regarding the forms of agricultural knowledge, techniques, and conceptualizations held by indigenous peoples and small-scale farmers. The research into the different forms of agricultural knowledge carried out by Efraím Hernández Xolocotzi (1913–1991), Arturo Gómez Pompa (1934–), Steve Gliessman (1946–), Miguel Ángel Martínez Alfaro (1942–2007), and Víctor Toledo (1945–) became essential. Not only did they carry out field research, as well conceptual and theoretical work, but they also created working teams and even research and professional training institutions through which agroecology was forged in Mexico.

Hernández X. (1958, 1971, 1977) documented the agro-productive forms of knowledge, techniques, and strategies pertaining to indigenous peoples and small-scale farmers and described the existence of traditional agricultural technologies, the fruit of thousands of years of experience. Hernández X. made visible the diverse stakeholders involved, as well as the complex interrelationships forming part of small-scale agriculture's productivity process and proposed using the term *agroecosystem* to understand and study this complexity. Gómez Pompa made fundamental contributions to the field of ecology regarding the understanding of the integrated agricultural management achieved by indigenous peoples and small-scale farmers in tropical zones, particularly coffee crops, floating crop lands, and strip cropping, among other agroecosystems. Gómez Pompa also promoted ethno-scientific studies in different institutions (Gómez-Pompa, 1987, 1988; Gómez-Pompa and Kraus, 1990). Steve Gliessman studied the traditional and conventional agro-productive systems in Tabasco from an ecological perspective, demonstrating the social and biological importance of the former and the unsustainability of the latter. In addition, he promoted the participation of local stakeholders in the construction of knowledge and incorporated the notion of agroecology into the ecology courses he gave at the Higher School of Tropical Agriculture (Gliessman, 1978, 1980, 1984). Studying under both Gliessman and Gómez-Pompa, Miguel Ángel Martínez Alfaro was a pioneer in ethnobotanical studies and made great contributions to the field of ethnomedicine. He was also interested in grassroots agricultural forms of knowledge, particularly the ecology of the slash-and-burn system (Gómez-Pompa, 2016). In addition, the fieldwork carried out in the Sierra Norte de Puebla and Oaxaca convinced him that the local agricultural forms of knowledge were a viable alternative in the face of the limitations of the Green Revolution (Martínez Alfaro, 1978, 1982; Martínez Alfaro et al., 1983; Masferrer Kan and Martínez Alfaro, 1989). Finally, Víctor M. Toledo's studies in human ecology during the 1970s made it possible to document not only the knowledge but also the different forms of using resources of a diversity of indigenous and small-scale farming communities, as well as the cosmovisions providing coherence and sustenance to their knowledge. These studies, carried out in the communally held lands (*ejidos*) of Los Tuxtlas and Uxpanapa in Veracruz, outlined the beginnings of ethnoecology and political ecology that later nourished Mexican agroecology (Toledo et al., 1972; Caballero and Toledo, 1978; Toledo et al., 1978; Toledo et al., 1980; Toledo, 1982).

The interest in local knowledge and an ecological vision of agriculture also led to opening spaces for academic training and research in which the aforementioned authors participated actively. By the mid-1960s, the Antonio Narro University incorporated an ecological perspective and some notions of agroecology into the curriculum pertaining to agriculture, animal husbandry, and forestry. In 1974, Gliessman joined the Higher School of Tropical Agriculture (CSAT by its acronym in Spanish) and also promoted the study of the region's agroecosystems, incorporating an agroecological perspective into the courses he taught. He promoted the creation of a summer course on agroecology between 1978 and 1980. In 1978, he created an MA in Agroecology. In 1975, Gómez Pompa promoted the creation of the National Institute of Biotic Resources (INIREB by its acronym in Spanish), in which spaces were created for research into local ethnobotanical knowledge (Gliessman, 2013; Astier et al., 2017). In 1976, an ecological perspective was incorporated into the courses offered both at the Graduate School of Agro-Biology pertaining to the Michoacan University of San Nicolás de Hidalgo and the High School of the Autonomous University of Chapingo (UACh). In 1979, the UACh's Department of Phyto-Technics made Agroecology a compulsory course. Agroecology was also integrated into the Parasitology curriculum at the same university (Asteinza Bilbao, 1993). Besides, it is important to note that work teams were created in which to research and debate, among other themes, the local knowledge, techniques, and resources mobilized for the production of food. This trend can be illustrated by the seminar "The Analysis of Agroecosystems in Mexico" created by Hernández X. at the Graduate School of Chapingo in 1976, the "Regional Seminar on Agroecosystems" organized by Gliessman at the CSAT in 1978, and the seminar entitled "Regional Development Program Training and Evaluation in Areas of Traditional Agriculture: A Food-Producing Strategy" jointly organized by the Teaching, Research, and Training Center for Regional Agricultural Development (CEICADAR by its acronym in Spanish), the Graduate School (CP), and CILCA in 1980. Lastly, it should be noted that an information bulletin entitled "Agroecosistemas: Boletín Informativo" was launched in 1978. This bulletin, promoted by Hernández Xolocotzi, was a key vector to disseminate the agroecosystemic perspective and traditional agricultural technologies.

According to González Jácome (personal communication, 18/05/2023), the concept of agroecology in Mexico emerged in the early 1980s out of Steve Gliessman's research into the traditional forms of agro-productive knowledge and ecology, as well as her dialogues with him. Although the concept of agroecology had already appeared on the international stage by the end of the 1920s (Bensin, 1930, 1935), apparently it was abandoned until reemerging in the scientific literature of the 1980s in

an academic environment in which, as was noted earlier, concepts such as agroecosystem, agrobiology, sustainable agriculture, and traditional agriculture already played a significant role. Within this context, this concept was used in at least 3 texts published in Mexico during the 1980s (González Jácome and Gliessman, 1979; Gliessman, 1984; González Jácome, 1986a).

The institutionalization stage (1980—2000): The double institutionalization of agroecology

Between 1980 and the year 2000, agroecology went through a dual process in Mexico: it consolidated as a discipline and became institutionalized. The work carried out in Mexico in the fields of ethnosciences and the history of agriculture, and the botanical, entomological and edaphological research produced in Mexico and other countries nourished an ecological perspective regarding agriculture and enabled the consolidation of agroecology as a discipline. Its institutionalization responded to the creation of professional training and specialization programs in different universities and public research centers.

These processes took place within a context marked by the persistence of an agro-productive crisis and the existence of institutional efforts aimed at reformulating Mexico's rural development strategies. In the 1970s, it became evident that the agro-industrial modernization policy promoted by the government had not reached its objectives. An agro-productive deficit prevailed in Mexico, the rural exodus persisted, and the industrial sector continued to be unable to generate minimum levels of well-being for the population as a whole (Bartra, 1979; Paré, 1985; Esteva, 1988). Within this framework, the Mexican government reformulated its agricultural policy and sought to dynamize production in communal lands (*ejidos*) and privately owned small-scale holdings through the creation of credit institutions, technological transfer, and technical assistance programs. Although the development horizon continued to be agro-industrial, the relevance of conventional technologies was under discussion and there was a search for new agro-productive configurations, as well as new forms of agricultural extension more appropriate and better adapted to the target population (Durston, 1983; de la Fuente et al., 1990).

Furthermore, although prior to 1980 ethnoscientific research to a certain degree occupied a marginal position, as of the 1980s it achieved greater legitimacy, which opened up new academic spaces and gained the capacity to exert influence over the government. Research carried out by anthropologists Ángel Palerm (1917–1980), Guillermo Bonfil Batalla (1935–1991), and Arturo Warman (1937–2003) helped to reorient the academic and governmental regard for indigenous peoples and small-scale farmers through visibilizing their ways of living, cosmovisions, and forms of knowledge. They positioned the idea of a form of ethno-development as an alternative to that which was proposed from a techno-industrial perspective (Palerm, 1972; Warman, 1972; Palerm, 1980; Bonfil Batalla, 1987; Warman, 1988). This can be illustrated by the activities promoted by the National Museum of Popular Cultures inaugurated in 1982 with the exhibition *Corn: The Cornerstone of Our Culture* (Museo Nacional de Culturas Populares, 1982), parallel to the founding of the General Office of Popular Cultures pertaining to the Department of Public Education that conducted ethnobiological research between 1980 and 1984 in various regions of Mexico (the Pátzcuaro Lake Watershed, the Totonacapan Region in Veracruz, and the Yucatán Peninsula). The National Indigenous Affairs Institute (INI by its acronym in Spanish) implemented other programs supporting traditional and ecological agriculture. The Department of Fishing and the National Research Institute of Biotic Resources (INIREB by its acronym in Spanish) established Integrated Farms in Hidalgo, Tabasco, and Chiapas states. In addition, the National Institute for Adult Education (INEA by its acronym in Spanish) carried out a dissemination and training campaign in sustainable agriculture, family ecological orchards, and soil conservation in the early 1990s (Arredondo and Juárez, 1985; INI, 1994; Pérez Sánchez, 2007; Ramón Jarquín, personal communication, 18/05/2023).

Within this context, the work conducted in the field of agricultural history also played an important role. Research carried out by Teresa Rojas Rabiela (1993, 1994) and Alba González Jácome (1985, 1986a, 1986b), among others, documented not only the knowledge held by the original peoples and small-scale farmers about how to manage a diversity of species but also recorded forms of knowledge and technologies mobilized since pre-Hispanic times for managing water and other resources and even complex agro-productive landscapes.

As has been documented by a diversity of authors, in Mexico and other Latin American countries, agroecology emerged in the 1980s as both a science and a movement (Altieri, 2015). This resulted from social and academic internal processes, as well as the influence exercised at the time by Altieri, Gliessman, and Rosset et al., among other authors, who delved more deeply into an ecological understanding of agriculture and contributed with industrial input substitution strategies. The publication and extensive dissemination of the following books—*Agroecology: The Scientific Basis of Alternative Agriculture* (Altieri, 1983), *Agroecology: Researching the Ecological Basis for Sustainable Agriculture* (Gliessman, 1990), and *Agroecology* (Rosset et al., 1990) catalyzed the social and academic processes that were already searching for alternatives to industrial agriculture, and described the general guidelines that provided form and content to agroecology as a new field of study. This marked a turning point in the history of agroecology.

From the perspective held by these authors, agroecology was a new scientific discipline studying agricultural systems from an ecological and socioeconomic perspective, aiming to construct sustainable agriculture. In the face of industrial agriculture that based its intensive and extensive production dynamics on inputs and technologies that are external to the production units (fossil energy, agrochemicals, engine-powered agricultural machinery, modified varieties for monocropping, and irrigation), agroecology proposed an integrated management of agroecosystems based on the inputs and technologies

available to small-scale farmers (polycropping, agroforestry systems, green fertilizers, crop and biological control, among others). Whereas industrial agriculture's main goal is to maximize yields and profits as swiftly as possible, agroecology sets forth the need to ensure a timely sustainable production based on an ecological management of the production unit and an optimized use of resources (Gliessman, 1990). To summarize, agroecology sets forth the possibility of alternative agro-productive modernization based on the experience of traditional agriculture, as well as research carried out by biological sciences using an ecological perspective (Cox and Atkins, 1979; Gliessman and Amador, 1980; Altieri, 1990).

In addition to the aforementioned academic production, during the process of consolidating agroecology in Mexico, the creation of professional training and research institutions specializing in agroecology and fields that are akin was of crucial importance in the 1990s. Although since 1970, great efforts have been made to create spaces for training, there were not yet any university degrees in agroecology. It was merely an academic subject addressed in summer courses, seminars, and working groups. In fact, Romero Lima (2000) notes that the creation of an Agroecological Engineering degree at Chapingo Autonomous University had been proposed in 1978, but the project did not flourish due to the lack of support from the authorities, who considered that the viability of industrial agriculture had been proven and that agroecology had not yet gained sufficient disciplinary robustness to become a university degree. However, this context changed in the 1990s. The development of agroecology in prior decades had formed a body of theories, methods, and knowledge with an identity of its own. The critique made by the environmentalist movement to the agro-industrial model further reinforced the pertinence of agroecology. It is also interesting to note that, as stated by Jarquín (personal communication, 18/05/2023), at that time, the number of students studying degrees in conventional agronomy were declining in relation to other degrees that had a greater demand in the labor market. A restructuring of the agro-productive curriculum was required in order to accommodate the new needs and expectations.

It is within this context that the first two BA degrees in Agroecology were created in Mexico, as well as agroecology-related research centers and graduate programs. In 1991, both Chapingo Autonomous University (UACh) and the San Luis Potosí Autonomous University (UASLP) created a degree in Agroecological Engineering (Romero Lima, 2000; Ramón Jarquín, personal communication, 18/05/2023). In 1994, the College of the Southern Border (ECOSUR) was created. In 1995, the Department of Ecology and Natural Resources from the University Center of the Southern Coast pertaining to the University of Guadalajara opened. In 1995, the College of the Southern Border launched a PhD in Ecology and Sustainable Development Sciences. In 1996, the Antonio Narro Autonomous University inaugurated its Engineering degree in Agroecology.

It should be noted that although in Mexico agroecology has its roots in the work carried out by both social sciences (ethnosciences, history, and anthropology) and biological sciences with an ecological perspective (botany, entomology, and edaphology, among others), it is the latter perspective that to a large extent defined the research content and programs during this stage. Therefore, most of the degrees were preferably geared to educating professionals with technical abilities to sustainably manage an agroecosystem's biotic components, neglecting the teaching of skills and knowledge to delve more deeply into agroecology's social, cultural, political, and economic aspects.

The deployment stage (2000—2018): A stage of expansion and multiplication

In the period between 2000 and 2018, agroecology experienced an intense phase of expansion and multiplication of experiences in the academic realm, as well as in the educational, productive, and political spheres. This was the result of a succession of phenomena taking place in Mexico and internationally, such as the theoretical diversification of the international literature, the consolidation of agroecology in Latin America, or the celebration of important forums organized by the FAO (see special issue of *Agroecología*: https://revistas.um.es/agroecologia/issue/view/15921). During that period, 9 conferences were held in Mexico with both a national and international scope, and the number of publications increased significantly (**Figure 1**). Lastly, in this stage an important social mobilization and agroecological territorialization process took place due to the confluence of small-scale farmer, citizen, and academic organizations in defense of native corn varieties facing the possible entry of genetically modified seeds, the shade-grown coffee systems (coffee gardens), and the resistance of the Mayan producers of organic honey against the cultivation of genetically modified soybeans (Toledo and Barrera-Bassols, 2017).

Theoretical diversification

As of the year 2000, agroecology underwent a reconfiguration process. Multi-, inter-, and trans-disciplinary work enabled an expansion of the content and boundaries of the discipline. A diversification took place not only regarding the themes studied so far but also the applied theories and methods (Rosado-May, 2015). Previously, in the 1980s and 1990s, the research carried out tended toward specialization, predominantly concentrating on the study of the natural components of agroecological systems using methods and models pertaining to the biological sciences and minimal attention was devoted to social aspects. According to Rosado-May (personal communication, 23/05/2023) that orientation was the result of the efforts made by the community of agroecologists aimed at validating the scientific character of the nascent discipline, defending the legitimacy and efficacy of this approach while facing criticisms made by orthodox sectors.

As demonstrated by Wezel and Soldat (2009), González-Chang et al. (2020), and Mason et al. (2021), the international literature has evidenced the diversification of agroecological research since the onset of the 21st century. Theoretical and methodological frontiers have

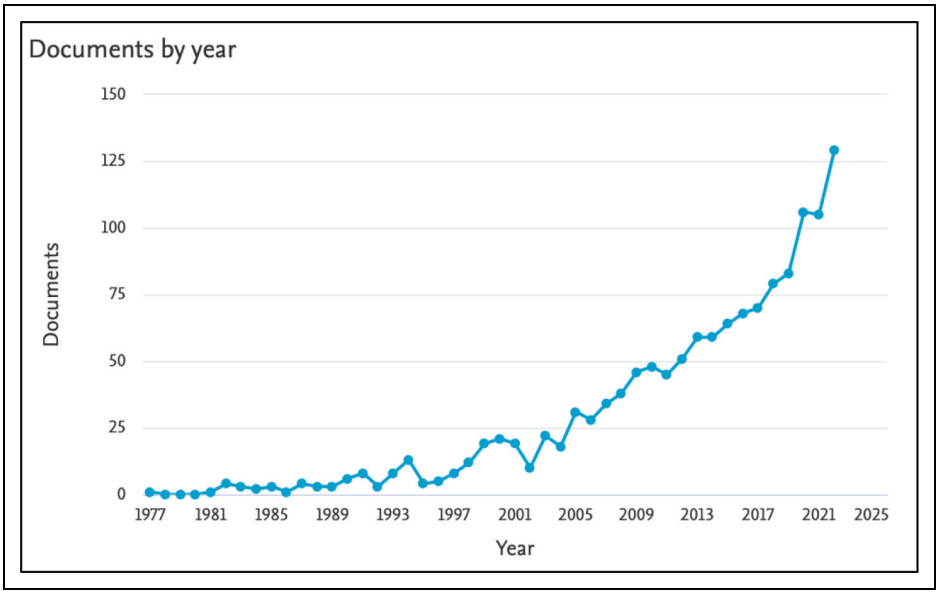

Figure 1. Number of publications on agroecology in Mexico recorded in SCOPUS from 1977 to 2022 based on 22 key words.

expanded and themes of study diversified. Agroecology ceased using the agroecosystem as the exclusive unit of analysis and integrated the entire agrofood system as a new scale of analysis (Francis et al., 2003; Gliessman, 2007). This was a paradigm shift. Agroecology went from searching for techniques that would make ecological agriculture possible to seeking strategies that would also ensure food sovereignty, include the democratic participation of all stakeholders constituting the agrofood system, maintaining agro-diversity, as well as valuing and preserving different forms of knowledge and technologies. With the above, agroecology ceased to be a body of standards and became a research-action program with highly diverse trajectories (Buttel, 2003; Clements and Shrestha, 2004; Méndez et al., 2013; Norder et al., 2016).

Local forms of knowledge and agroecology

In addition to the work that had already been carried out in the field of ecological agriculture, the contributions of specific social sciences opened up some new lines of research in the realm of agroecology. Ethnobotanical and ethnoecological studies regarding not only local forms of knowledge held by small-scale farmers and original peoples in rural areas but also collective forms of knowledge established in urban and periurban areas became of key importance. The following 3 books: *Sistemas biocognitivos tradicionales* [which could translate as *Traditional Biocognitive Systems*] (Moreno Fuentes et al., 2010), *Saberes ambientales campesinos* [which could translate as *Small-Scale Farmers' Environmental Forms of Knowledge*] (Reyes Escutia and Barrasa García, 2011), and *Saberes coletivos y diálogo de saberes en México* [which could translate as *Collective Forms of Knowledge and Their Dialogue in Mexico*] (Argueta Villamar et al., 2011) are of key importance and compiled dozens of studies on local forms of knowledge. Similarly, Barrera-Bassols contributed with nodal research on traditional knowledge of soils at different scales, a topic of great agroecological importance (Barrera-Bassols and Zinck, 2000, 2003; Barrera-Bassols et al., 2006). In addition to the above, there is the biocultural perspective, synthesized in 2 pieces of work: *La Memoria Biocultural* [which could translate as *Biocultural Memory*] (Toledo and Barrera-Bassols, 2008) and *El patrimonio biocultural de los pueblos indígenas de México* [which could translate as *The Biocultural Heritage of Indigenous Peoples in Mexico*] (Boege, 2008). This perspective relates the forms of knowledge to the territories and their defense, productive practices and cosmovisions, the preservation of native languages, and other aspects such as ethnoagroforestry (Moreno Calles et al., 2016) and natural protected areas (Betancourt Posada, 2014). These efforts remarkably enriched agroecology with new concepts, theories, and even methodologies that enabled a better understanding of not only the socioenvironmental systems but also the repertory of values and cosmovisions shaping the relationships between society and nature.

Feminist agroecology

During this period, feminist theory renewed agroecology. From a feminist perspective, forms of formerly unknown or underestimated patriarchal oppression were made visible. It has been demonstrated that the functioning of the capitalist system in general and the agro-industrial model in particular rely on care work that historically women have carried out without receiving payment or recognition. Besides, decolonial feminisms have demonstrated how colonialism interwoven with patriarchy and capitalism has functioned as a historical project that generates epistemic violence and social inequality based on gender, sex, social class, ethnicity, and race (Mies and Shiva, 1993; Federici, 2013). For all of the above, feminist agroecology has set forth the need to denounce and fight such forms of domination and visibilize women's work, as well as the need to think about the sustainability of agrofood systems

not only from an environmental perspective but also through the lens of the care and reproduction of life in all of its forms and expressions (Trevilla-Espinal et al., 2021). From this perspective, a fruitful process of action-research has unfolded, visibilizing the forms of knowledge, practices, values, and organizations through which women, as part of their everyday activities, defend agrodiversity, territories, the right to a healthy diet, and biological memory, among many other aspects that are constitutional and essential for the reproduction of life (González-Santiago, 2008; Merçon et al., 2012; Merçon et al., 2018; Ambrosio Montoya et al., 2020; González-Santiago and Fernández-González, 2020; Trevilla-Espinal and Peña-Azcona, 2021). Today, in Mexican and Latin American agroecology, the participation of women is already a powerful force for transformation.

Agroecological education

Between 2006 and 2018, 4 undergraduate and 5 graduate degrees in agroecology were created in Mexico. Undergraduate degrees were created in Yucatán (2006), Quintana Roo (2007), and Guerrero (2013). Graduate degrees were launched in institutions as diverse as the National Polytechnic Institute (an MA in 2007 and a PhD in 2016), the University of the Environment (an MA in 2013), and the Colegio de Postgraduados (an MA in 2016). A BA and an MA in Agroecology were created at the Small-Scale Farmer and Indigenous University pertaining to the Center for Rural Development Studies (CESDER by its acronym in Spanish), particularly devoted to training youth from indigenous communities in the northern mountains of the state of Puebla known as Sierra Norte de Puebla. It is also interesting to note that in this period a diversity of laboratories, research centers, departments, working groups, and many other academic institutions were created in which agroecology was of central importance. In addition, most training programs in agro-productive or environmental issues already included agroecology with different expressions and degrees of intensity as courses, seminars, workshops or specializations in agroecology, or denoted as rural development, productive innovation, permaculture, sustainable, organic, or regenerative agriculture, etcetera (Zepeda del Valle et al., 2022).

Non-academic educational programs

Parallel to the above, a diversity of agroecological training projects external to educational institutions emerged following the perspective of emancipatory pedagogy aimed at encouraging stakeholders to retrieve their historical agency and from that position develop a critical awareness enabling them to understand and transform the world (Freire, 1970, 1971; Fals Borda, 1979, 1986). These organizational and training spaces use methodologies such as grassroots and decolonializing education, dialogues between different forms of knowledge, learning by doing, and processes of Participatory Action Research (Gómez Martínez et al., 2017). These methodologies are extremely important for the agroecological territorialization and strengthening of social agency. Such is the case of the "Escuelas Campesinas" (Small-Scale Farmer Schools) founded in 2003, pertaining to the Agroecological Department of the Autonomous University of Chapingo that today forms part of a National Network constituted by 32 initiatives and projects. The "Escuelas Campesinas" have held 15 national forums (González Santiago et al., 2018) with the noteworthy participation of the U Yits Ka'an School of Ecological Agriculture (Escuela de Agricultura Ecológica U Yits Ka'an) established in Maní, Yucatán in 1996, the Tosepan Titataniske Cooperative in Puebla, or the Vicente Guerrero Group in Tlaxcala.

Conferences

This consolidation stage is also confirmed by the 10 national and international conferences held during this period (**Table 1**). In 2011, the Third Latin American Agroecological Conference took place following 6 international conferences convened between 2015 and 2021 by the National Association of Small-Scale Farmer Enterprises (ANEC by its acronym in Spanish) together with many other organizations and universities. This series of events brought together the main civil associations, academic institutions, and groups of Mexican producers committed to agroecological production that induced the inception of the Mexican Agroecological Movement and later created the Mexican Association of Agroecology (SOMEXA by its acronym in Spanish). SOMEXA organized the First and Second National Conferences in 2019 and 2022. In all of these conferences, there has been a noteworthy presence of not only producers but also traders and consumers, confirming that agroecology encompasses the entire food chain.

Productive processes

Three hundred organic agriculture and coffee projects have been included in the inventory of successful sustainability initiatives in Mexico developed by Toledo and Ortiz-Espejel (Toledo and Ortiz Espejel, 2014). Rita Schwentesius–Rindermann, a specialist in organic agriculture in Mexico, identified the existence of approximately 165,000 producers until 2012 (Bustamante Lara and Schwentesius Rindermann, 2018). Using the inventory of political agroecology in Mexico carried out by Toledo and Barrera-Bassols (Toledo and Barrera-Bassols, 2017), we will briefly review 3 of the most important agroecological production sectors during this period: corn production in a biodiverse form of cultivation known as *milpas*, shade-grown coffee, and honey farming.

The milpa polyculture

The most frequent and extensive food producing system in rural Mexico is the *milpa* (a term derived from the Nahuatl words, *milli*—crop field, and *pan*—on top of), a polyculture system that can be traced back at least 7,000 years, in which corn constitutes its main crop. Mexico is the storehouse for over 65 races of corn cultivated throughout the country that have resulted from the millenary coevolution between corn and Mesoamerican indigenous peoples who traditionally managed, domesticated, diversified, and enhanced corn in a process that continues to this day. In Mesoamerica, the Mexican

Table 1. Conferences on agroecology held in Mexico from 2011 to 2023

#	Agroecology Events in Mexico	Place and Date	Number of Participants	Organizers
1	Third Latin American Conference on Agroecology	Oaxtepec, Morelos, August 17–19, 2011	750	Latin American Scientific Agroecology Society (SOCLA)
2	First International Encounter of Small-Scale Agriculture and Agroecology in the Americas	Mexico City, August 31–September 2, 2015	310	National Association of Small-Scale Farmer Enterprises (ANEC) and others
3	Second International Encounter of Small-Scale Agriculture and Agroecology in the Americas	UACh, Texcoco, State of Mexico, August 11–13, 2016	More than 800	ANEC and UACh's Department of Agroecology and others
4	Third International Encounter of Small-Scale Agriculture and Agroecology in the Americas	Saltillo, Coahuila, August 24–26, 2017	More than 300	ANEC and "Antonio Narro" Autonomous Agrarian University (UAAAN) and the Mexican Agroecological Movement (MAM)
5	Fourth International Encounter of Small-Scale Economy and Agroecology in the Americas	Tonalá University Center, UDG, Guadalajara, Jalisco, Mexico, October 16–18, 2018	Not available	ANEC, MAELA, MAM
6	Fifth Encounter of Small-Scale Economy and Agroecology in the Americas.	UACh, Texcoco, State of Mexico, October 16–18, 2019	Not available	ANEC, MAELA, MAM, as well as, UACh, UAAAN, and others
7	First Mexican Conference on Agroecology	San Cristóbal de las Casas, Chiapas, May 12–17, 2019	980	College of the Southern Border, San Cristóbal Campus (ECOSUR), Intercultural University of Chiapas (UNICH), and Mexican Agroecological Society (SOMEXA)
8	Sixth Encounter of Agroecology and Small-Scale Economy	Mexico, November 11–12, 2021	Online	ANEC, MAELA, MAM, as well as, UACh, UAAAN, and others
9	Second Mexican Conference on Agroecology	UACh, Texcoco, State of Mexico, September 6–9, 2022	More than 350	SOMEXA in addition to the UACh and other institutions
10	International Conference on Food Self-sufficiency and Agroecology	Oaxaca, November 28–December 2, 2023	1,600	SADER, BIENESTAR, SEMARNAT, CONAHCYT, INIFAP, and many others

Neolithic Revolution not only implied the domestication of corn and nearly 200 other plants (Casas et al., 2007) but also the creation of the *milpa* in which numerous and varied annual, biannual, semi-domesticated, and tolerated plant species coexist in crop associations contingent on the biocultural regions (Toledo and Barrera-Bassols, 2021). Currently, two and a half million small-scale farmer households cultivate kernels of native corn by over one half of the total agricultural surface of Mexico in production units of less than 5 hectares (Turrent et al., 2012).

The first great battle against the entry of genetically modified corn took place during the enactment of the Federal Law of Genetically Modified Organism Biosecurity in 2005. This battle was linked to the discovery of the genetic contamination of native corn in indigenous territories and small-scale farmer communities (Quist and Chapela, 2001; Ezcurra et al., 2002; Cleveland et al., 2005; Serratos-Hernández et al., 2007; Dyer et al., 2009; Piñeyro Nelson et al., 2009), triggering a countrywide uprising of unprecedented social resistance (Barrera-Bassols et al., 2016), a movement strongly influenced by agroecological principles. This resistance movement has been nourished across a wide range of levels, spanning urban, scientific, cultural, intellectual, and artistic realms on a national, regional, and local scale, to rural areas, small-scale farmers, and indigenous peoples.

In relation to the cultivation of corn, the spread and multiplication of the agroecological paradigm is inseparable from the uprising resistance to the threat of genetically modified varieties. The "corn fairs" and "organic markets (*tianguis*)" have been 2 important grassroots responses to this threat. Corn fairs represent the revival of ritual activities that strengthen eroded community bonds, providing dignity and meaning to communal life. The number of these events has substantially increased in recent years. At least 20 fairs were celebrated during 2009, increasing to 80 by 2016. Activities in fairs include seed exchange between local small-scale farmers and those in

other states and regions, the recovery of local culinary traditions, exhibits of farming implements and old photographs, lectures about the consequences of the use of genetically modified seeds and the corporations promoting them, seed blessing, as well as the staging of plays and projection of films, among other activities. From 2002 to 2015, native seed fairs were held in 44 locations on the Yucatán Peninsula (Dzib-Aguilar et al., 2016). In the states of Tlaxcala, Chiapas, and Puebla, corn and *milpa* fairs have noticeably increased in number and diversity.

The *tianguis* is a traditional marketplace that has existed in Mesoamerica since pre-Hispanic times and has been evolving in form and number throughout centuries. The contemporary alternative markets, also called *tianguis* after the Nahuatl word for market (*tianquiztli*), have expanded exponentially since they first emerged in 1996. By the end of 2014, more than 60 alternative ecological or agroecological exchange markets had been held throughout Mexico (Escalona-Aguilar, 2009; García-Bustamante, 2015) and by 2020 one hundred alternative markets had been held in 22 Mexican states (Rocío García-Bustamante, personal communication, 28/11/2023).

Shade-grown coffee crops

Organic coffee production is a second sector that has expanded dramatically. Coffee has been cultivated in Mexico since the 19th century, initially almost exclusively in medium- to large-sized specialized farms owned by foreigners (and later by Mexicans) in the states of Chiapas, Oaxaca, and Veracruz. The scenario of coffee production in Mexico began to be transformed by different events taking place during the 20th century, such as the agrarian revolution that broke up large privately owned agricultural estates, dividing and distributing land into thousands of communally held lands (*ejidos*) and communities, acknowledging the property rights of indigenous peoples, and the expropriation by the government during World War II of estates owned by German, Japanese, and Italian citizens. A period of Statism ensued, beginning in 1959 with the creation of INMECAFE, a governmental organization devoted to regulating coffee prices, providing incentives to national coffee producers in the form of credits and technical support, suppressing middlemen, and establishing thousands of coffee production and commercialization units in coffee-producing regions (Nolasco, 1985). INMECAFE was dismantled in the early 1990s after the withdrawal of the State and the advent of neoliberalism and its free trade policies. This led to a process of autonomous organization of hundreds of coffee-producing cooperatives run by small-scale farmers and indigenous communities. During these 2 decades, these cooperatives gradually adopted the principles of agroecology (Moguel and Toledo, 1996). As a result, coffee production in Mexico is currently in the hands of small-scale property owners, 90% of whom own less than 5 hectares—organized in hundreds of cooperatives, an important proportion of which pertain to indigenous people (Moguel and Toledo, 1999; Toledo and Moguel, 2012).

Mexican coffee is produced without using agrochemicals and under the shade of a forest canopy, which helps to preserve the natural habitat and, consequently, biodiversity and soil quality, and prevent water runoff; 94% of the total production of Mexican coffee is grown in the states of Chiapas, Veracruz, Puebla, and Oaxaca. Nearly 80% of the Mexican coffee production is exported. Coffee-producing regions are among the richest in flora and fauna in Mexico and are considered strategic for the conservation of biodiversity (Moguel and Toledo, 1999). According to recent statistics, Mexican organic coffee was produced by approximately 128,000 small-scale producers, most of whom pertain to indigenous cooperatives and small-scale farming organizations encompassing an area of approximately 350,000 hectares. Mexican organic coffee is exported to and consumed by the United States, Canada, France, the Netherlands, Germany, and Japan, among other countries.

Agroecology and the honey bee farming

The Yucatán Peninsula—in which 63% of the total inhabitants are of Mayan descent—is the most important honey-producing region in Mexico. Before the Spanish invasion, Mayan beekeepers collected honey and wax from the native stingless bees (*Melipona beecheii*), which in Mayan were called *Koolelkab* and *Xuna'ankab*, meaning goddess of honey. European beehives (*Apis mellifera*) were introduced into the Yucatán Peninsula in the early 20th century mostly by private entrepreneurs. It was then that Mayan communities adopted beekeeping and a few decades later became the largest community of beekeepers in Mexico. According to CONABIO (CONABIO, 2009), at present the region comprises approximately 40,000 beekeepers organized in 162 cooperatives. The honey harvested by small-scale farmers using highly diverse systems revolving around the *milpa* is mostly exported to the European Union (85%).

In 2012, the Mexican Department of Agriculture granted Monsanto a permit to cultivate genetically modified soybeans, including the use of the herbicide glyphosate in 253,000 hectares in the Yucatán Peninsula, San Luis Potosí, and Chiapas. The authorization by the Mexican Government was met with resistance from local small-scale farmers similar to the resistance to genetically modified corn throughout the country. Because genetically modified soybean pollen was found in honey exported to the European Union, thus affecting exports of the product from the region, thousands of honey producers launched a campaign to withdraw the official authorization for cultivation of genetically modified soybeans in the region—signed by over 63,000 people—and filed 2 lawsuits that were favorably resolved. The authorization for genetically modified soybean production in the region was thus reverted. In the year 2020, Leydy Pech, one of the main women leaders of the resistance movement, won the Goldman Environmental Prize, considered the "Green Nobel Prize," for her struggle against chemical spraying. In general, this battle reinforced or induced the adoption of agroecological principles among beekeepers in the Yucatán Peninsula.

The scaling-up stage (2018—2023)

Agroecology has developed remarkably in France, Spain, India, and particularly in many Latin America and Caribbean countries, both academically and in terms of the projects and initiatives it has spawned. As part of the aforementioned agroecological development, there has been a significant increase in the number of publications on the subject. Using the Web of Science database, Mason et al. (2021) demonstrate how the number of publications in agroecology increased from a few publications recorded in the 1980s to between 500 and 700 annual publications in 2016 and 2018, respectively. According to these authors, between 1982 and 2018, the total number of publications in agroecology reached 3,277 papers, books, and conference proceedings. It is important to note that a substantial part of these publications led to the need to scale up agroecology, particularly among small-scale land holders (with between 1 and 20 hectares each), globally representing 93% of the total land holders. However, only 26% of these lands are dedicated to agriculture and animal husbandry (Lowder et al., 2021). When discussing the need to scale up agroecology, some authors have become obsessed with urging the discipline to go beyond "islands of success" to "seas of change." The pioneering publications by Altieri and Nicholls in 2008 and 2012 were followed by FAO's initiative calling to scale-up agroecology. Gliessman (2018) critically commented on this initiative and both prior to and following the announcement of this initiative a diversity of publications came out expressing different points of view (Henderson and Casey, 2015; Giraldo and Rosset, 2018; Anderson et al., 2019; Anderson et al., 2020; Gascuel-Odoux et al., 2022). They all call for "institutionalizing" agroecology but demand a bottom-to-top process in which the social movements of organized small-scale producers are the core stakeholders.

Within this context, the fifth stage can be considered as an actual scaling-up, a qualitative leap forward generated by the transition in Mexico to a new progressive and anti-neoliberal government (2018 to 2024). All the power demonstrated by the development of agroecology during the consolidation period (2000–2018) was crucial for the environmental issue and the integration since 2011–2012 of its key concepts—sustainability, agroecology, and bioculturality—into the political platform of the National Regeneration Movement (MORENA) (Ramírez, 2011). MORENA's electoral victory in 2018 therefore enabled a total shift to take place in the field of agrofood public policies. From policies almost exclusively geared to agribusiness, exports, and support for large-scale farmers and livestock farmers during the neoliberal regimes, the policies shifted to favoring food sovereignty, agroecology, and providing core support to small-scale farmers. The arrival of dozens of environmental scholars and militants to the highest decision-making positions within the Mexican Department of the Environment (SEMARNAT), the Department of Agriculture and Rural Development (SADER), and the Department of Health (SS), as well as the National Council of Humanities, Sciences and Technologies (CONAHCyT) played a decisive role.

Today, 5 years later, the number of small-scale farmers and hectares of integrated agroecological transition lands—approximately one million small-scale farmers working around 1.2 million hectares—confirms that agroecology in Mexico has become an outstanding process of agricultural, productive, food, and environmental transition, leading to a radical paradigm shift. However, the implementation of these programs has also generated problems. In only 5 years, the number of programs has increased very quickly without allowing for the conditions to make adjustments, adaptations, and corrections, that is, there has not been enough time to develop the capacity for self-assessment. The bottlenecks include the low quality of manufactured inputs in bio-factories, the excessive rigor to reach quantitative objectives, limited support for technicians in terms of ensuring safe transportation, a minimum level of collaboration with Mexican scientific institutions and researchers, and especially the lack of marketing channels for the produce generated by the *Sembrando Vida* cooperatives and the Rural Schools run by the Department of Agriculture and Rural Development (SADER by its acronym in Spanish). Nevertheless, so far there have been very few academic publications regarding these issues that would enable us to become aware of the magnitude of the problem, largely because it is highly complex to evaluate current policies in a pertinent and rigorous manner for 4 reasons: (a) the programs' enormous scope (they cover over 1,000 municipalities with more than a million producers); (b) it brings together and combines a whole range of dimensions that should be addressed in a comprehensive, interdisciplinary, and cross-cutting way; (c) the colossal economic resources they have been allocated; and (d) the fact that the programs are relatively recent and there has not been enough time to observe the effects in different fields.

The agrofood policies that have been implemented can be said to constitute a shift of policy direction from previous administrations. The agroecological scaling-up is based on 6 important changes: (1) a radical change in economic and technical support favoring small-scale land owners over medium- and large-scale land owners in northern and central Mexico who had been receiving greater support during the neoliberal period; (2) technical support shifted toward a model based on a "dialogue between different forms of knowledge," considering not only the biological, ecological, agricultural, and food dimensions but also the social, economic, cultural, and political spheres; (3) self-reliance and/or food sovereignty became a priority goal in government policy; (4) the integration and recognition of the role played by women throughout the food chain became an objective with the same priority; (5) agroecology as a theme has been adopted parallel to a social and solidarity-based economy expressed in the creation of cooperatives, credit unions, and actions of reciprocity and mutual support; and (6) humanistic, scientific, and technological research were in sync with the earlier precepts contained in CONAHCyT's policies.

The following overview is based on different sources: 2 books *Revoluciones Agroecológicas en México* [which could

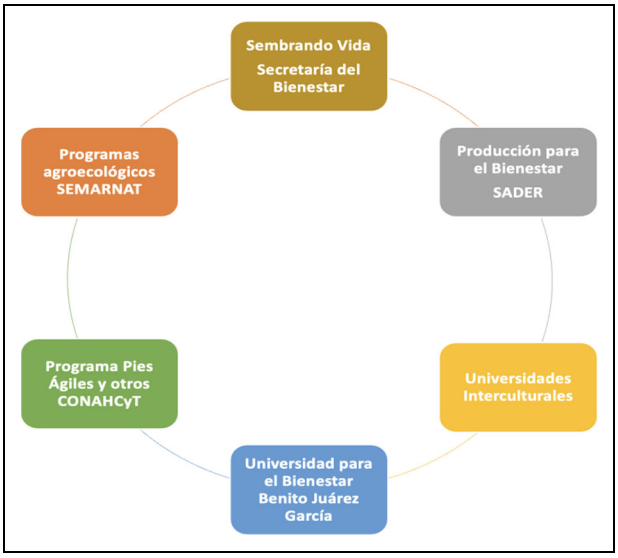

Figure 2. The 6 areas of the federal government in which the scaling-up of agroecology is conducted in Mexico. Graph based on Toledo (2023).

translate as Agroecological Revolutions in Mexico] (Bartra Vergés et al., 2022) and *La Agroecología como Eje Transformador en el Campo Mexicano* [which could translate as Agroecology as a Transforming Linchpin in the Mexican Countryside] (Anonymous, 2023), plus 2 special issues of *La Jornada del Campo* (September 16 and October 21, 2023) complemented with recent data from both official and academic sources, as well as interviews with different officials (see Toledo, 2023). This scaling-up of agroecology has been conducted in 6 areas of the current federal government (**Figure 2**), including productive projects and educational programs, as well as scientific and technological research.

As well as federal programs, state-level projects, such as those carried out in the states of Michoacán, Puebla, Veracruz y Oaxaca, must also be referenced (Anonymous, 2023).

The first and most important action was implemented within the "Sembrando Vida" (Sowing Life) Program, pertaining to the Department of Welfare. Until May 2023, this program was comprised of 455,000 small-scale producers (30% women and 70% men), each holding 2.5 hectares, representing a total surface of 1,125,000 hectares. Each rural land owner is committed to creating and maintaining an agroforestry system by planting 2,500 trees of timber-yielding, agro-industrial, and food-related species in combination with *milpas* (biodiverse cropping including corn, beans, squash, and other species). Each producer forms part of a "Small-Scale Farmer Learning Community" (CAC by its acronym in Spanish), each of which is constituted by an average of 25 small-scale farmers supported by a "productive technician" and a "social technician," as well as 2 or 3 scholarship holders pertaining to the "Youth Building the Future Program" (50,000 participants). CACs today comprise 18,000 distributors in more than 1,000 municipalities in 21 states. Some of the most outstanding CACs are located in southeastern Mexico: in Chiapas (3,336 CACs), Veracruz (2,724), Tabasco (2,252), and Oaxaca (1,563). Each CAC comprises a cooperative inspired in 2 innovative paradigms: *agroecology* and *social and solidarity-based economy*. Both paradigms are implemented under the leadership of 4,500 professionals with at least a BA degree who are selected through a test and an interview. The "production-related technicians" include agronomists, biologists, ecologists, and veterinarians, among other specialists, whereas the "social technicians" are comprised of sociologists, economists, anthropologists, lawyers, and professionals in similar fields. Each CAC has a plant nursery, a biofactory, and an irrigation system. It is self-governed using participatory democracy. The supreme authority is the members' assembly that appoints a Board of Directors (President, Secretary, and Treasurer), as well as the coordinators of 7 commissions who are rotated every year.

The impressive plant nurseries are guided by agroecological principles. Depending on the region in which they are located, the nurseries grow between 30,000 and 45,000 plants per year, supported by biofactories that supply organic fertilizers, biological pest control, worm composting, mineral broths, natural disinfectants, fungi, and bacteria, and so on. Planting trees reinforces or retrieves the relationship that small-scale farmers have with nature, inducing an agroforestry culture, whereas the social dimension reinforces the communal social fabric with the creation of credit unions and actions supporting communal lands (*ejidos*) and communities. The "Sembrando Vida" Program has an impressive annual investment that increased from 15 billion pesos in 2019, to 28.5 billion pesos in 2020, and 37.1 billion pesos in 2023.

"Producción para el Bienestar" (Production for Well-Being) is the productive program with the most extensive coverage in the agricultural sector. In 2022, it supported 1,809,000 basic grain producers—growing mainly corn and beans—as well as coffee, sugar cane, cocoa, honey, chia seed, and amaranth producers, with an investment of 14 billion pesos out of which 13.1 billion pesos were allocated to benefiting producers with direct cash support. Currently, 83% of the producers registered in the program have plots of agricultural land of up to 5 hectares and the plots of land of the remaining 17% are between 5 and 20 hectares each. The total agricultural territory is comprised of over 6 million hectares (Anonymous, 2023).

Within the aforementioned support, there is the Technical Accompaniment Strategy (EAT by its acronym in Spanish) that deals with the *agroecological transition*. EAT works with more than one thousand technicians in 34 regions, from the Tarahumara Mountain Range in Chihuahua to the Yucatán Peninsula. They are "technicians," not "agricultural extensionists," so rather than disseminating instructions about how to use agrochemicals and patented seeds, thus leaving producers without decision-making freedom or agency they work in order to favor a symbiosis between scientific and technical knowledge and ancestral forms of knowledge held by small-scale farmers rooted in the Mesoamerican cultures. In this case, the technicians are experts in agronomy, biology, ecology or professionals pertaining to other agriculture-related disciplines. EAT

relies on 4,200 Agricultural Schools (ECAs by their acronym in Spanish) in which 300 thousand producers participate in training and 129 thousand producers carry out agroecological practices.

The third program is entitled "Pies ágiles" (standing for Interinstitutional Program Specializing in Food Sovereignty and the Management of Strategic Local Advocacy). In this instance, CONAHCyT promotes horizontal science and advocacy, an educational program launched in 2021 in 18 states aimed at promoting different forms of agroecology and food sovereignty. The 280 registered scholarship holders carried out trials of different possibilities to redesign agroecosystems and strengthen learning communities with innovative practices using no glyphosate or other agrotoxics. The program's curricular content is a combination of online classes and fieldwork that revolves around a Participatory Action Research methodology. The scholarship holders specialize in promoting training and territorial advocacy processes through studying and implementing different agroecological practices such as experimenting with bio-inputs, exchanging seeds, protecting pollinators, promoting agroforestry, retrieving local gastronomy, managing collective water systems, and conducting collective organizing from a social justice and gender equity approach (see: https://alimentacion.conacyt.mx/piesagiles/). In addition, CONAHCyT has published a series of newsletter reports regarding the use of cultural practices, integrated weed management and other strategies to promote alternatives to glyphosate. So far, 25 issues have been released.

The fourth sphere of action is the Department of the Environment (SEMARNAT) that set up the General Office of Agroecology and Biocultural Heritage in 2020 and carried out a diagnosis regarding agroecology in Mexico with support from the FAO. The experiences include the Urban Agroecological Orchard in the Coyoacán plant nurseries and the Floating Gardens School (Escuela Chinampera) in Xochimilco, both of which are located in Mexico City.

All these actions are educationally complemented and reinforced through the creation of new degrees at the "Universidades para el Bienestar Benito Juárez García/UBBJ" (Universities of Well-Being), a project of the current administration that to date includes 45,581 students and 1,168 faculty members in 150 different campuses. The Universities of Well-Being are concentrated in some of the most remote regions in the country and/or engage socially marginalized youth. This system includes degrees devoted to agrofood-related themes, guided by the agroecological paradigm regarding sustainability and sustainable development, as well as agroforestry taught on 55 campuses attended by 9,640 students with 317 faculty members. Another effort is represented by the "Intercultural Universities," pertaining to the Mexican Department of Public Education, an initiative launched more than a decade ago, but that the current government has continued and expanded. New campuses in Baja California, Guanajuato, Oaxaca, Tlaxcala, and the "University of the Yaqui People" in Sonora have been added to the 11 existing universities. Most of the universities offer a degree in sustainable development and some of them have degrees in agroecology. Lastly, crowning all of these actions and programs is the leadership of Mexico's current president, Andrés Manuel López-Obrador, who issued 2 decrees on December 31, 2020, and February 13, 2023, banning the use of genetically modified corn for human consumption, foreseeing its gradual substitution, as well as phasing out the importation, use, and distribution of glyphosate, its accompanying herbicide. These decrees confirm the interest of the current administration in favoring public policies geared to achieving food production that is healthy for the environment and humankind.

Discussion

How did agroecology originate, persist, and develop in Mexico over a century? In other words, what enabled Mexico to strengthen and expand agroecology as a serious academic field, agricultural practice, and government policy? We think that this can be explained by the synergic combination of at least 5 factors: (i) the lengthy biocultural history of Mesoamerican civilization that led to the domestication of at least 200 food species, the most prominent of which was corn, and the creation of a considerable variety of agricultural and agro-forestry systems (Casas et al., 2016); (ii) the agrarian history that culminated in the Mexican Revolution in the early 20th century that returned land to the indigenous peoples and small-scale farmers (Boege, 2008); (iii) the publication of works by key authors and founding members of agro-ecology in Mexico; (iv) the considerable development of research into traditional and local forms of knowledge carried out by ethnoecologists and ethnobiologists; and (v) the emergence of social movements promoting programs that were adopted by the new progressive and anti-neoliberal government elected in 2018, which decided to support small-scale producers, adopting agro-ecology in large-scale projects. The strengthening and expansion of agroecology in Mexico has been illustrated in the previous sections concerning these 5 factors.

The Mexican biocultural heritage is among the best illustrated worldwide (Toledo et al., 2010). A history of over 9,000 years of agriculture, and a persistent tradition of small-scale farmer social resistance movements that culminated during the agrarian revolution in the early 20th century, continuing in the indigenous resistance in Chiapas that led to the Zapatista uprising in 1994, and continues to be expressed in current local and regional confrontations defending territory (Toledo and Barrera-Bassols, 2017). This lengthy history is still palpable today in each of the relationships rural communities hold with local natural resources. Ethnobiological research, for instance, reveals that out of 30,000 species of flora, at least 6,500 have a specific use, 1,555 undergo some type of management, and 251 species have become domesticated (Clement et al., 2021).

Most of the world's agricultural production continues to be practiced by traditional small-scale farmers, whose knowledge and practices are the result of over 10,000 years of tradition. They represent 97% of the planet's total agricultural and livestock producers (approximately 608 million producers), although they make use of only 26%

of the land (Lowder et al., 2021). Within Latin America, agriculturally speaking, Mexico holds a special position since over half of its territory (more than 104 million hectares) is held by small-scale producers that form part of social farming units (*ejidos* and small-scale farming communities) that use the largest surface of land for the cultivation of basic grains and other foodstuffs. This situation was one of the outcomes of the early 20th century agrarian revolution in Mexico that was incorporated into the 1917 Constitution, which led to the dismantling of large estates (*haciendas*) and the splitting of the territory into thousands of productive units. Until 1910, the agrarian structure in Mexico included 5,932 *haciendas* occupying 94% of the total land surface, 32,557 ranchers owning 5% of the land, and the remaining 1% of the land was in the hands of small-scale farming communities and native peoples (Córdoba, 1972). This social transformation also re-indigenized Mexico by returning a substantial portion of the territories to the ancestral peoples—descendants of the Mesoamerican civilization—currently holding 28 million hectares of the national territory (Boege, 2008). This repossession of land is reflected in the demographic upturn experienced during the past 15 years by indigenous peoples, increasing from a population between 10 and 12 million in the year 2000 to over 25 million in 2015, turning Mexico into the country with the largest indigenous population on the American continent. At present, 31,500 *ejidos* and small-scale farming communities hold 54% of the total agricultural land of Mexico, which added to 35.7% of the total owned by 1.6 million small-scale landholders (most owning 5 hectares or less), accounts for 90% the country's territory being in the hands of small-scale farmers (Robles-Berlanga, 2015). This panorama turns Mexico into a very special country in which the lengthy tradition of agrarian resistance favors the development of agroecology.

Even though in the foundational phase various authors were cited as pioneers of this perspective, 2 of them were of key importance. In 1976 E. Hernández-Xolocotzi, created a seminar entitled "Analysis of Agrosystems in Mexico" at the Universidad Autónoma de Chapingo (the Autonomous University of Chapingo). A year later, his book "*Agroecosistemas de México*" [which could translate as "Mexican Agroecosystems"] was published. This was followed by the launching of an information newsletter entitled "*Agroecosistemas: Boletín Informativo*" [which could translate as "Agrosystems: An Information Newsletter"] in 1978. Another key author was S. Gliessman who in 1978 organized the "Regional Seminar on Agroecosystems" at the Advanced School of Tropical Agriculture (CSAT by its acronym in Spanish) and published various papers in that period, including the noteworthy paper presented by A. González-Jácome at the Forty-Third International Congress of Americanists (González-Jácome and Gliessman, 1979). These 2 agronomists could be considered pioneers in ecological agriculture in Mexico. These first academic contributions were accompanied and influenced by studies about traditional knowledge carried out by ethnobiologists and ethnoecologists, a scientific field that has achieved noteworthy importance in Mexico (Toledo et al., 2018; Pulido-Silva and Cuevas-Cardona, 2021). This parallel field reinforced the idea of a dialogue between forms of knowledge, which is a basic agroecological principle. The convergence of these 2 fields is not exclusive to Mexico. In a bibliometric analysis, Costa-Santos (2020) recorded 661 publications worldwide obtained from the Web of Science that relate agroecology to traditional ecological knowledge (TEK). These studies were published between 1991 and 2018 and were conducted by more than 2,000 authors from 878 institutions in 102 countries, confirming the outstanding role played by culture in agroecology.

The recent scaling-up of Mexican agroecology is due to a progressive government that rolled back 3 decades of neoliberal governments and modified environmental, agricultural, and livestock-raising policies. The shift was radical. As described in the section about the Department of Agriculture, priority was given to small-scale farmers and agroecology was held as a central objective. A new office of agroecology and bioculturality was created in the Mexican Department of the Environment. Similarly, CONAHCyT (the National Council of Humanities, Science, and Technology) created programs supporting these fields and 2 presidential decrees were issued in order to avoid the entry of genetically modified corn into the country, as well as the gradual substitution of glyphosate, the herbicide considered cancer-producing by the WHO. In summary, these 5 factors seem to explain the evolution of agroecology in Mexico. New studies on these issues may or may not confirm these conclusions.

Data accessibility statement

All data used in this article are publicly available in historical archives, the SCOPUS database, and government and scientific records. For sources that are harder to access, the authors may be contacted for copies.

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