IJANR
International Journal of Agriculture and Natural Resources

Int. J. Agric. Nat. Resour. 50(2):23-45. 2023
www.ijanr.cl

FOOD TECHNOLOGY

DOI 10.7764/ijanr.v50i2.2375

REVIEW

A review of local-scale agricultural sustainability in the coffee regions of Mexico

Jesús Gómez-Velázquez[1], Alfonso Vásquez-López[1], Juan Regino-Maldonado[1], and Silvia N. Jurado-Celis[2]

[1]Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional (CIIDIR) Unidad Oaxaca del Instituto Politécnico Nacional. Hornos 1003, Col. Noche Buena, Santa Cruz Xoxocotlan, C. P. 71230, Oaxaca, Mexico.

[2]Escuela Superior de Turismo, Instituto Politécnico Nacional. Miguel Bernard 39. Col. La Purísima, Ticomán. Alcaldía Gustavo A. Madero, Ciudad de México, México. C.P. 07630.

Abstract

J. Gómez-Velázquez, A. Vásquez-López, J. Regino-Maldonado, and S. N. Jurado-Celis. 2023. A review of local-scale agricultural sustainability in the coffee regions of Mexico. Int. J. Agric. Nat. Resour. 23-45. The concept of sustainability aims to integrate diverse aspects of human needs through the analysis of the environmental, social, and economic dimensions. Although there is a marked consensus on the concept of sustainability, there are local conditions that define the production patterns and their actual sustainability conditions. This paper aims to integrate a research review of sustainability in the agriculture systems of Mexico with a local-scale approach, highlighting the local perspectives of each region to provide a clear view of the whole country's agriculture systems and to find the thresholds of sustainability research in the coffee regions of Mexico. To integrate the review, several databases and quotes from selected papers were used from 2012, with some baseline references from 2002, and the paper structure was developed under a narrative technique. As a result, we show a view of the sustainability research approaches at different local scales in the agriculture systems of Mexico, emphasizing coffee systems and showing the thresholds of sustainability research with these approaches.

Keywords: Agroforestry systems, agroindustries, coffee systems, sustainability, sustainable agriculture, sustainable development.

Introduction

The scientific foundations of the concept of sustainability have generally been ascribed to the Brundtland Report in 1989. This concept has evolved through the international discourse toward the reduction of the environmental impacts and the point of assuring "the future generations to meet their needs (Brundtland, 1987). The concept of sustainability comes from environmental criticism foundations, which turned into action proposals in public policies and agreements worldwide.

The 2030 Agenda for Sustainable Development stimulates actions in areas of critical importance for humanity and the planet (UN, 2015). The 2030 Sustainable Development Goals (SDGs) illustrate the ways in which agriculture, particularly food value chains, is positioned to holistically address the social, economic, and environmental dimen-

Received Oct 26, 2021. Accepted Jun 19, 2023
Corresponding author: jgomezv1700@alumno.ipn.mx

sions of sustainable development and represents a base for fostering sustainable economic growth, reversing harmful environmental trends, and enhancing resilience, tracing some of the most potent pathways for agriculture policies (Omilola & Robele, 2017).

While sustainability assessment is a growing concern worldwide, with United Nations' Agenda 2030 being implemented as it considers the environmental, social and economic issues in light of cultural, historic and institutional perspectives, appropriate tools are needed to ensure the complete coverage of these aspects (Villeneuve et al*.,* 2017). On the other hand, the agroecology perspective seems to be an alternative to reach the 2030 Agenda objectives, as it can effect systemic change, which is needed to provide sustainable food for everybody, as stated in the Agenda (Ching, 2018).

The sustainability assessment from agroecology focuses on the definition of a degree of sustainability with participatory methodologies and a multidisciplinary approach of the production units in a certain context (De Ataide et al., 2015). Sustainability programs such as the Assessment Framework for Management Systems with Sustainability Indicators (MESMIS) aim to evaluate production units as agroecosystems according to their sustainability threshold (Jiménez-Ortega et al., 2022).

The sustainability assessment from the agroecology perspective allows the evaluation of multidimensional variables of the production units to establish a degree of sustainability based on their local approaches with participatory methodologies. This is important for linking the theoretical assumptions to the local realities (Astier et al., 2012).

As coffee production has been designed as an example of sustainable production (Perfecto & Vandermeer, 2015), it is important to highlight the sustainability research on these particular agriculture systems to illustrate a good example of sustainability from the sustainability perspective in the Latin American context. To properly illustrate the differences among regions, we performed a review by regions of our country (Mexico) as an example of the perspectives and heterogeneity of studies related to sustainability.

This is why this paper aims to explore the background of sustainability research from several concept applications within the Latin American context with local-scale examples and experiences in agriculture systems. Then, explain particularly those of coffee production. This paper contributes to the sustainability perspective in agriculture studies with an emphasis on coffee systems.

Search Methods and Inclusion Criteria

To build this review, we used several databases: Dialnet, SCielo, Redalyc, JSTOR, ScienceDirect, and Scopus. Not only were the reference lists in several papers used to integrate the background, but the paper quotes found in Google Scholar replying to baseline papers were also used.

In the review, there were included papers from 2012 to date with some baseline papers in the period 2002–2012. Only indexed or at least peer-reviewed articles and a few relevant thesis documents (only those found by Google Scholar quotes) in Spanish, English and Portuguese were considered.

Papers with both qualitative and quantitative scopes were integrated into the discussion. The references were ordinated by the regions of Mexico, even for sustainability agriculture studies in general and those of coffee systems in particular. No criteria were used to evaluate the validity of the studies.

To summarize this literature review, a simple narrative technique was used to express the findings and the regions of Mexico, and the emphasis on coffee production allows us to appreciate the heterogeneity among different regions as well as

the performance of a so-called agriculture system with high potential for sustainability: coffee.

Sustainability: From the concept to the local-scale realities

There is a large difference between the global perspectives of sustainable development and those of the local communities trying to perform it. It is important to take participatory approaches, setting the context for sustainability assessment at local scales (Reed et al., 2006).

While the most common definition of sustainability lies at the intersection of environmental, social, and economic dimensions (Elkington, 1997), there is also a marked difference between sustainable development and sustainability concepts, and the significance of the distinction will depend on one's perspective.

According to Clift (2003), the concept of sustainability can be referred to as the process of achieving sustainable development. Therefore, Sikdar (2003) suggests that the metrics of sustainability allow quantification in the realization of sustainable development.

Within the discussion on the economic perspectives of development, there was a notion that environmental and developmental issues did not merge strongly (Mebratu, 1998). Since the World Conservation Strategy was formulated in 1980, the concept of sustainability has been brought into this debate. Then, the operation, quantification, and variable treatment of the sustainable development approach seem to be executed under the concept of sustainability, but with the element of time within the environment and development discussion, it was possible to synthesize what was previously a diffuse idea of sustainable development (Khosla, 1995).

In contrast to the fields of application of the sustainability concept, some researchers have focused on the endorsement of the environmental concept of sustainability within the empirical scopes in production research (Sarkis & Zhu, 2018), even from the business corporate perspective (Lozano, 2015), as well as for performance in manufacturing companies (Harik et al., 2015). Moreover, there is a rising concern about the biophysical and social measurement of climate change within sustainability issues (Fenichel et al., 2016).

On the other hand, researchers look to explain local sustainability programs by linking the theoretic framework to empirical models (Owen & Videras, 2008), even considering community-based resource management with a cultural and community approach (Keitumetse, 2014), proposing locally adapted projects (Winther, 2017), or applying sustainability assessment frameworks to local-scale cases (Jiménez-Ortega et al., 2022).

Dietz et al. (2018) suggest that there are normative, methodological, and philosophical considerations in choosing a certain definition of sustainability. There are also local conditions that need to be comprehensively analyzed to obtain a holistic view of sustainability in specific locations (Ravichandran et al., 2021).

The Voluntary Sustainability Standards (VSS) is an example of a sustainability assessment framework of agriculture from the certification standards perspective, of which recent findings suggest that the best practices in conducting robust evaluations for addressing sustainability trade-offs and measuring environmental outcomes could be improved through credible research measuring VSS impacts (Traldi, 2021).

On the other hand, the Framework for Evaluation of Management Systems with Sustainability Indicators (MESMIS) represents a baseline to perform participatory methodologies in local contexts to assess agriculture systems in terms of sustainability (Jiménez-Ortega et al., 2022).

In sustainability studies, heterogeneity comes to the fore as a generalized condition of rural com-

munities (Winther, 2017), producers and growers in rural agriculture (Guadarrama-Zugasti, 2008), and membership heterogeneity in sustainability cooperatives (Elliott et al., 2018). Even in well-demarcated contexts, there is heterogeneity among social, economic, and environmental conditions.

Particularly in rural community contexts, multiple interpretations and weak definitions of sustainability lead to confusion and misunderstanding among both researchers and local people. Some proposals have tried to integrate holistic sustainable place-based rural community models to measure community sustainability particularities and illustrate this heterogeneity (Winther, 2017).

However, there are many different ways to define sustainability, even from philosophical, ideological or methodological aspects. At this point, the sustainability assessment comes to the fore to propose a multidimensional approach to evaluate agricultural systems (Pashaei Kamali et al., 2017). From this perspective, we have taken the concept of sustainability as the property that allows an agricultural system to maintain its permanence over time (Khalili et al., 2013).

Even though there are sustainability concepts and assessment tools formulated under certain conditions for methodological purposes, we consider that there are also heterogeneous local conditions that complicate sustainability assessment, measurement, and analysis. This is why we discuss in this paper a view of the Latin American sustainability perspectives in the case of Mexico, with an approach by regions to highlight this heterogeneity and the particular case of coffee systems that have shown potential for sustainability.

Local-scale sustainability: The importance of community-based practices and culture

To introduce to our local-scale approach of sustainability, we lead this discussion to the current conditions of environmental conservation, the perceptions of the local people and the importance of community-based practices.

The pressure on ecosystems within human-environment interactions creates a high vulnerability context. According to Eakin & Wehbe (2009), farmers' efforts to address their vulnerability can have implications for the sustainability of the social–environmental system.

Although more than 8.5 billion hectares of land around the world are property of rural communities under customary use and administration, there is no official recognition from formal laws (Wily, 2011). Some authors suggest that community-based resources reduce impacts on ecosystems (Barsimantov & Kendall, 2012), and in particular, those under proper indigenous community land management show the lowest ecosystem impacts (Nolte et al., 2013).

The indigenous population is significant in Latin America since it consists of approximately 50 million people who belong to 500 different ethnic groups. The largest populations (in absolute and relative terms) are in Mexico, Guatemala, Peru, and Bolivia (De Dios, 2020). In Mexico, approximately 92 percent of small farms are owned by indigenous community members (Jaffe, 2008).

Indigenous communities have articulated ideas of communal stewardship over land and a deep spiritual and emotional connection with the earth and its fruits (Anaya, 2005). To explore the meanings of nature, land, and sustainability in indigenous communities, it is necessary to acknowledge the traditional meanings of land, nature, and sustainability from their experiences, culture, and customs (Datta, 2015).

Since sustainability and development seem to be opposite terms, Martínez-Luna (2003) recognizes this diametrical antagonism under the premise that, despite their resistance, indigenous communities have learned to integrate the aspects

of development into their culture as a manner of adaptation.

The New Community Rurality approach focuses on the economic–ecological conditions of rural communities to explain sustainability in the socio-environmental context of Latin America. Peasant practices include heterogeneous processes of social appropriation of nature, and community-based sustainable resource management can be driven under communality principles (Fuente-Carrasco, 2009).

The commonality concept rises as a philosophical construct to integrate the community social dynamics performed over centuries and transmitted via oral tradition in the indigenous language. This way of organization based on an indigenous worldview has its essence, identity, and sense of belonging within a metaphorical sense of autonomy (Guerrero-Osorio, 2015), which is an expression of rituality.

The rituality in indigenous agriculture has been the foundation of agricultural cycles and materials in this kind of community (Romero-Contreras, 2004). Rituals have been described as an essential part of the culture, ideology, and relationship with the environment for agricultural activities (González-Jácome, 2003). Community embeddedness, identity, communality, and worldview contribute to sustainability as well as entrepreneurial projects (Molina-Ramírez & Barba-Sánchez, 2021). Community values, beliefs, and knowledge promote local sustainability and represent an opportunity to develop an adapted view of sustainable development (Vásquez-Arango et al., 2016). Community perspectives have been recognized as a way of transition to be contemplated within national legal frameworks for agroecology purposes (Domené-Painenao et al., 2015). Certain proposals, such as indigenous knowledge systems, have been proposed to express significant values and traditional knowledge to applicable strategies for local agricultural activities (Enock, 2013).

From community-based initiatives to theoretical community-based frameworks, there are expressions of community sustainability that are potentially applicable to agricultural system approaches. To develop sustainable agricultural practices and reach an adapted view of sustainability, it is necessary to have a local community perception and further investigate the agricultural system and its local context.

Duxbury & Jeannotte (2010) argue that the link between culture and sustainability comes from even conceptual and policy discourses, and cultural facts serve to develop planning frameworks not only in rural contexts but also in developed economies and societies. A research gap is found in tools suitable to the local context in developing countries such as Mexico, where data and skills availability could differ greatly between regions and municipalities (Calleros-Islas, 2019).

In the next section, the perspectives of agricultural production for sustainability issues in Mexico are shown. From the common characteristics to the heterogeneous ones, from the northeast to the southeastern regions of Mexico, the sustainability of agriculture and particularly of the coffee systems studies in Mexico is explained.

Sustainable agriculture in Mexico: A local-scale review

There is a wide difference between the geographic regions of Mexico in terms of socioeconomic factors and indigenous or nonindigenous populations (Rivera et al., 2003), where the north–south contrast comes to the fore in national terms. Even in a country, the conditions for sustainability are diverse. Therefore, we present a review of agricultural sustainability research along the regions of Mexico and highlight the main characteristics of each region.

Recent studies in Nuevo Leon are looking to develop waste management to reduce agroindustry impacts (Escalera-Chavez et al., 2015) as well as to orient farmers toward agro-industrial processes for a productive program and competitive conditions with a sustainable focus (Pantoja-Zavala & Flores-Vichi, 2018).

Particularly in the southeast region, research has recently focused on criticism of the industrialized food system and alternatives for local conditions. Bellante (2017) suggests that alternative food networks represent a livelihood strategy for the community economy, sustainable food governance from organic agriculture, and local commodity chains. There is also an idea of the heterogeneity of agricultural producers in context, where their attitudes, opinions, preferences, objectives, and risk perceptions have been analyzed (Sánchez-Toledano et al., 2017).

From the arid and industrialized north to the less developed southeast regions, Mexico is a diverse and heterogeneous country in terms of its socioeconomic and environmental conditions. To give an appropriate view of the research performed on agricultural sustainability in different regions of Mexico, a review by region was established under a socioeconomic criterion proposed by the Ministry of Tourism in Mexico SECTUR (2019):

In Figure 1, the regions of Mexico have been organized into eight state clusters for demographic and policy development purposes: i) Northwest, ii) Northeast, iii) West, iv) Central North, v) Central South, vi) East, vii) Southwest and viii) Southeast (SECTUR, 2019). These regions have been taken into account to create a view of sustainability in the different local contexts and the perspectives of agriculture production in Mexico. The research

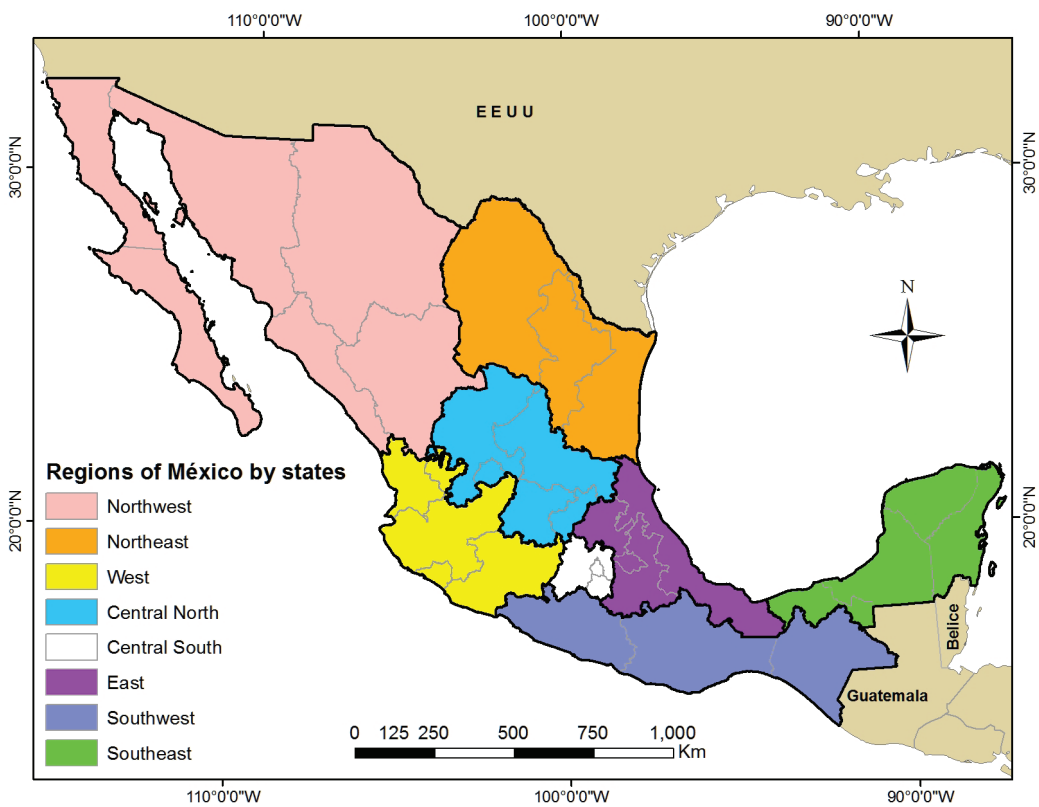

Figure 1. The regions of Mexico by state (SECTUR, 2016).
Source: Own elaboration.

background referred to each region to illustrate the perspectives of research on agricultural sustainability.

Case studies of agricultural sustainability in Mexico

Northwest Region

The northwest region includes Baja California, Baja California Sur, Sonora, Chihuahua, Durango, and Sinaloa. In this region of Mexico, the most relevant research problem has been related to water availability issues not only because this region is an arid zone with serious problems of water scarcity but also because the aquifers have been overexploited. The agricultural production of low-value and high water consumption has also been criticized (Salazar-Adams et al., 2012).

The water scarcity conditions worsen along the Baja California Peninsula. Nonetheless, the relevant agroecological sustainability indicators, such as environmental factors, water, soil, social factors, and production factors, have been evaluated (Alvarez-Morales, 2015). Hydroponic agriculture has been proposed as an alternative to the generalized arid conditions in Mexico under the premise that agriculture technology could contribute to improving the management of land and water resources and creating green environments while reducing emissions (De Anda & Shear, 2017).

Northeast Region

In the northeast region, which includes the states of Tamaulipas, Nuevo León, and Coahuila, agroindustries proliferate, and the business perspective is dominant over the research background. The understanding of sustainability from the agroindustrial perspective in Monterrey (Capital City of Nuevo Leon) has recently focused not only on its reduction of emissions and renewable energy development (Meneses-Jácome et al*.,* 2016) but also on organizational initiatives such as green supply chains and green human capital (Rodríguez-Pérez et al*.,* 2021).

Coahuila has one of the most important dairy industries in the country. There, some sustainability evaluations of the production systems have been developed (Próspero-Bernal et al., 2015) as well as about the socioenvironmental impacts of water management in zones with water scarcity such as Cuatro Ciénegas. In González, Tamaulipas, the attitudes of farmers toward natural resource conservation were analyzed to develop efficient public policies and actions (Cruz-Delgado, 2020).

Western Region

The western region of Mexico includes Jalisco, Nayarit, Colima and Michoacan. Jalisco is the most important agave producer in Mexico. There, models of strategic planning with a sustainability approach have been proposed for El Grullo, Autlan, and El Limon Valley (Gómez-López et al*.,* 2018). Other authors have analyzed the driving forces of environmental pressures and responses in forest and agricultural management for sustainability in Cihuatlan municipality (Vásquez-Valencia & García-Almada, 2018) as well as a three-dimensional sustainability assessment tool to evaluate municipalities (Jalil et al*.,* 2020).

In the evaluation of agricultural practices, recent results in Michoacan showed that organic management shows the best results in soil quality and biodiversity management because of the practices and structure of its orchards (Ordaz-Gallegos et al*.,* 2020). Sustainability assessment was also explored in western Mexico through an adapted sustainability framework for proper application and interpretation (Calleros-Islas, 2019).

Central North Region

The central north region includes the states of Zacatecas, San Luis Potosí, Aguascalientes,

Guanajuato and Querétaro. Recent findings show the benefits of the organization's capacities for water management in the agricultural systems of southern Guanajuato (Mazabel & Caldera, 2018). Some others recognize that the implementation of an environmental management system would be beneficial for horticultural production in the semiarid context of Zacatecas (Padilla-Bernal et al., 2016).

The social conditions of the central north region of Mexico are more complex than those of the northern regions. The incorporation of the capitalist mode of agricultural production in rural areas has caused the loss of traditional activities. Community participation has been analyzed since the implementation of new public policies in Aguascalientes (Palafox-Muñoz et al*.,* 2016).

Central South Region

The central southern region of Mexico includes the State of Mexico, Morelos, and Mexico City. Although Michoacan is the most important producer of avocado in the country, recent research has focused on its production in Morelos. Under the premise that due to the exponential growth of the productive value of the avocado, it is urgent to create sustainable agriculture measures to maintain competitiveness, Gallegos-Hernández (2019) proposes a state-level development program for the avocado agriculture system.

More than 10% of the whole population of Mexico is located in the metropolitan area of Mexico City. In this urban and overpopulated context, certain initiatives of urban agriculture are still being performed, such as the *chinampas* systems, an ancient technique with agroecological implications, which have represented the foundations of local socioeconomic strategies (Torres-Lima et al., 1994). The economic, ecological, and social implications of urban agricultural development in Mexico City have also been evaluated (Dieleman, 2017).

Eastern Region

The eastern region of Mexico includes Hidalgo, Tlaxcala, Puebla, and Veracruz. From this point, tropical agroecosystems are located in the southern regions of Mexico. Coffee production has traditionally been recognized in Veracruz and recently in Puebla's Highlands. In Cuetzalan, Puebla and Huatusco and the Cordoba region of Veracruz, agroecosystems have been studied for their integration into organic and fair trade programs (Escamilla-Prado et al., 2005). Coffee rust (*Hemileia vastatrix*) has been one of the main reasons for the coffee production drop in Latin America. Public policy initiatives have been proposed to attend to both certification and coffee rust issues under the premise that planned actions promote agriculture sustainability (Renard-Hubert & Larroa-Torres, 2017).

Southwest Region

In the southwest region, coffee rust has also been identified as the core challenge to attaining sustainability. In Guerrero, the coffee rust management program for sustainability was developed under an organizational social responsibility approach (Hernandez-Polito & Lezama Ruiz, 2017). Recent studies have explored coffee growers' perception of sustainability from conceptual foundations to local factors and collective actions in the Sierra Madre of Chiapas (Merlín-Uribe et al*.,* 2019) as well as the implementation of sustainable practices in the planning of whole supply chains through knowledge creation and technology promotion (Contreras-Medina et al*.,* 2020).

In Oaxaca, cooperative production has been analyzed in terms of certification achievement and contributions to local sustainability (Montgomery, 2019), as well as provisioning measures by social organizations for sustainability and the promotion of local producers (Ortiz-Ayala et al., 2018).

The background previously detailed served to give an idea of the agriculture and coffee systems

approaches in sustainability in Mexico through a division by economic regions and further contrast these conditions to those of the regions where the coffee agroecosystems are located.

As stated before, the coffee production of Mexico is generally located in the southern and eastern regions, where there are common patterns of culture, worldview and indigenous communities as well as ecosystemic conditions that make possible the development of coffee production systems.

Southeast Region

The southeast region, which includes the Yucatan Peninsula states Quintana Roo, Yucatan, Campeche, and Tabasco, is characterized by a low-altitude landscape with a natural tropical forest (80% of the land cover) (Ramirez-Delgado et al., 2015). Due to the physiographic conditions in this region, the agricultural sustainability literature background relates to climate vulnerability and agricultural policies for maize production (Mardero et al., 2018), the sustainable management of coastal ecosystems (Herrera-Silveira et al., 2019) and private property land tenure impacts on deforestation and conservation strategies for forest cover (Ellis et al., 2017).

In this region, some authors have focused on the evaluation of palm oil agroecosystems under a local development and sustainability framework (Márquez et al., 2019) the negative impacts of transgenic soybean production and intensive glyphosphate use on local sustainability have also been analyzed (Rivera de la rosa & Ortiz-Pech, 2017), and the rural development policy for communities in natural protected areas for local environmental management has been implemented (Reyes-Grande, 2015). The agroecosystems in the southeast region have been analyzed with sustainability indices, diagnoses, schemes, and case study methodologies (Martinez-Castro et al., 2015).

The coffee systems in México

There is a great diversity of coffee (*Coffea spp*.) varieties in Mexico, of which *Coffea arabica L*. and *Coffea Canephora* are the most commercially important. For instance, there is a coffee collection at the Mexican National Bank of Coffee Germplasm where 87 accessions were genotypically characterized by the DArTseqTM method and SNP markers in Huatusco, Veracruz (Spinoso-Castillo et al., 2020). There are also mappings of green product development opportunities (Pérez-Hernández et al., 2021) and specialty coffee shop supply chains (Servín-Juárez et al., 2021).

Along with the huge ecosystemic and climate diversity of the Mexican territory, there are agroclimatic zones suitable for coffee production generally located in the southwest of the country, as well as on the border with Guatemala (Bunn et al., 2019). The coffee systems of Mexico are located only in the iii) west, iv) central south, v) central south, vi) east, and vii) southwest regions of Mexico, as shown in Figure 2:

The local-scale sustainability of the coffee systems in Mexico

Western Region

The agroecosystems of the western region are located from Talpa de Allende (Ruiz-Palomino et al., 2019) to Sierra de Manantitlán (Moguel & Toledo, 1999) in Jalisco, in Comala and Minatitlan, Colima (Perez et al., 2014), and in the coast region of Michoacan, where some reduction in coffee land cultivation has occurred (Nestel, 1995).

In Michoacan, the ethnoecological perspective suggests that local knowledge has the potential for the development of management strategies and conservation of the species (Castro-Sánchez et al., 2019). Recent studies suggest that the implementation of a planned supply chain with ecological and human dimensions could improve sustainability

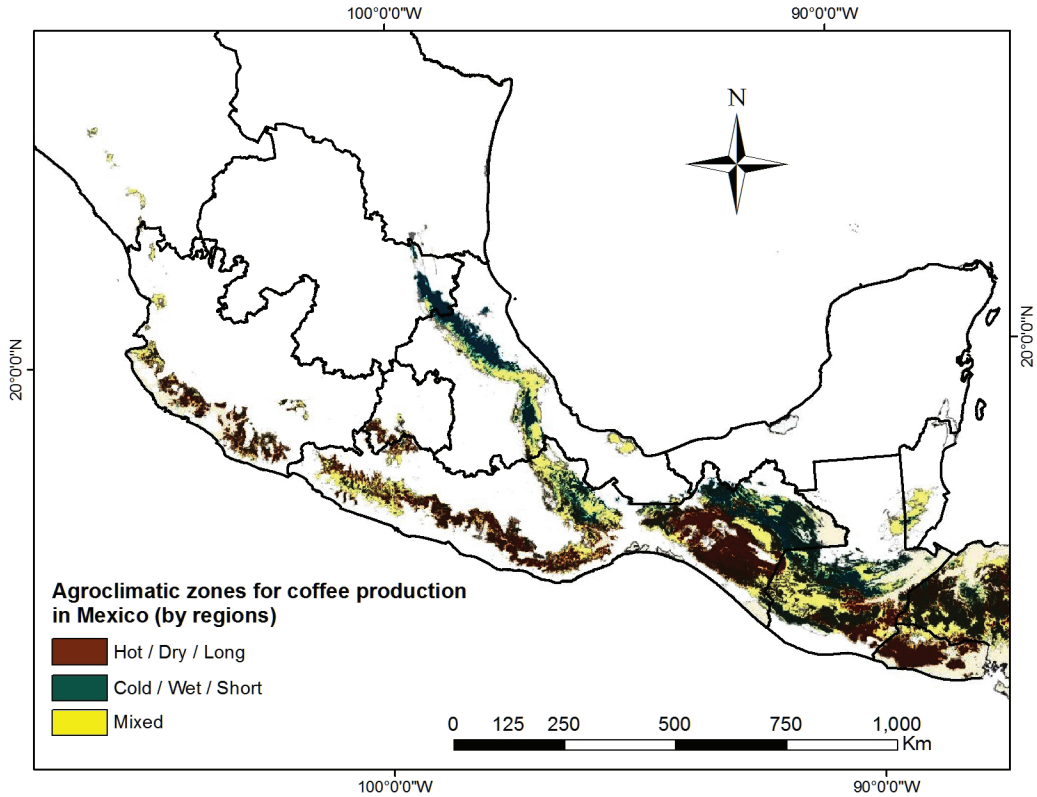

Figure 2. The agroclimatic zones for coffee production in Mexico (Bunn et al., 2019).

Source: Own elaboration from Bunn, C et al., (2019) data. Climate Change Impacts on Coffee Production in Mexico and Central America.

in avocado production in Michoacan (Denvir et al., 2021), which is taking more relevance in this region than that of coffee.

In this region, there are examples of sustainability-focused initiatives, such as The Network for Sustainable Agricultural Alternatives (RASA in its Spanish acronym) founded in 1999, which gathers growers, indigenous people, women, consumers, technical advisors, NGOs, urban population, and universities throughout 20 localities and municipalities of Jalisco to encourage agroecology and popular education of rural households for sustainability (Toledo & Barrera-Bassols, 2017).

There is a difference between peasant and indigenous communities in terms of knowledge, community organization, and community institutional frameworks. In Michoacan, community organizations including both peasant and indigenous communities have generated alternative results in terms of solving contamination problems and the overexploitation of water (Sandoval-Moreno, 2015). The indigenous perspective of agriculture and sustainability strengthens in the southern and eastern regions of Mexico.

Central North Region

This region has a relevant agroclimatic zone in the Sierra Gorda of Queretaro and Guanajuato, as well as the Huasteca Region of San Luis Potosi. There are traditional agroforestry systems in Sierra

Gorda and Huasteca of San Luis Potosi developed from a local culture approach (Moreno-Calles et al., 2014) as well as a subzoning program management program for natural resources in the Sierra Gorda of Guanajuato (Pérez-Vega et al., 2016). The Biosphere Innovation System is part of a global project started by UNESCO, in which the Sierra Gorda, the Yayu coffee forest in Ethiopia, and the Lake Vänern archipelago in Sweden will develop models that can be applied in other parts of the world to promote societal entrepreneurship in biosphere reserves (Bergstrand et al., 2011).

Central South Region

In the central south region, which is Mexico City and surrounding states, there are climatic conditions for coffee production in the State of Mexico as well as Mexico City (Bunn et al., 2019). The wetlands of Xochimilco have been traditionally studied since this is one of the remaining sites where agricultural activities are still performed in the urban context of Mexico City. The *chinampas* traditional agricultural system has been analyzed in terms of environmental and socioeconomic sustainability (Merlín-Uribe et al., 2013), its potential for resilience by an adaptative cycle analysis for urban sustainability (Jiménez et al., 2020), and restoration practices for the ecosystem for water quality (Zambrano et al., 2020).

In Morelos, empirical studies acknowledge that the cultural diversity of traditional coffee plantations is important for agricultural production (Castro-Rodríguez, 2019). Coffee production seems to be more relevant in the south of the State of Mexico since the coffee of Temascaltepec was recognized as one of the best coffees in Mexico (Alliance for coffee excellence, 2018). Although there are records of nontimber forest product implementation to promote sustainability in these regions (Anastacio-Martínez et al., 2016), research on coffee agroecosystems and their sustainability factors seems to be weak in the region.

Eastern Region

This region, including Hidalgo, Puebla, Tlaxcala, and Veracruz, is gaining relevance due to its coffee production quality and particularities. The Xalapa/Coatepec region of Veracruz has been a regional leader in quality coffee worldwide, recognized by the Research Institute for Cocoa and Coffee (IRCC Acronym in French) and the Daily Subsistence Allowance (DSA) program, developing a project for the modernization of coffee production systems for intensification, diversification and commercialization improvement (Sallee et al., 1990). Recent studies have characterized the biophysical and structural composition of coffee agroecosystems (Ruiz-García et al., 2020), with carbon storage being a key point for adaptation and mitigation of climate change impacts in the region (Ortiz-Ceballos et al., 2020).

Recent investigations on sustainability have focused on coffee shade canopy plantations for forest management with native species in Hidalgo (Suárez-Islas et al., 2020), on environmental education through community programs in a high-diversity shade coffee-producing region, Cuetzalan (Andresen et al., 2020), and on the diversity of cropping systems and the agroecological transition in the Sierra Norte of Puebla, where diversity of farming management was identified, and local resources and sociotechnical practices lead to a favorable state of the agroecological transition (Espidio-Balbuena et al., 2020).

Southwest region

The southwest region of Mexico includes the states of Guerrero, Oaxaca, and Chiapas. In this socially and eco-systemically diverse context, the vulnerability of coffee systems comes to the fore as a core topic in sustainability analyses.

Recent findings suggest that the agroecological collective practices of indigenous organizations strengthen social capital, adaptability, and natural

resource conservation in Guerrero (Galicia-Gallardo et al., 2021). Other socioeconomic perspectives suggest that in Oaxaca, there are community-based responses to climate change. There are areas with high slopes and marginalization showing deforestation patterns and others with reforestation trends where local communities are a relevant bottom-up driver of change in natural resource conservation (Novotny et al., 2021). The suitability of the land to grow coffee is currently being analyzed in the Mixteca Alta region of Oaxaca to map the local knowledge perspectives on agriculture through geographic information systems (López-Carmona et al., 2021).

There are recent findings regarding traditional knowledge of edible plants from the indigenous communities of the Sierra Norte of Oaxaca, where this knowledge is essential for the conservation, use, and management of local plant diversity (Pascual-Mendoza et al., 2021).

There is statistical evidence that the coffee growers in Chiapas better adopt emerging technologies throughout a whole supply chain focus. This can improve sustainable practices such as resistant variety crops, pest management, soil analysis, water conservation and harvesting (Contreras-Medina et al., 2020).

In Chiapas, there are local supply chains of coffee looking for global expansion. Coffee entrepreneurs and their collective organizations have established alliances with transnational actors (Espinosa-Gallegos et al., 2021).

While the central north and central south regions have the least proper conditions for coffe production, they are developing several practices for sustainability and environmental protection. In the western region, producers are coping with expanding avocado systems, and some indigenous community organizations are trying to maintain coffee systems.

The only regions where coffee production is maintaining or expanding are the eartern and southwest regions, where we find more cases of sustainability studies and communities with coffee systems.

The thresholds of sustainability research at the local scale

The sustainability research perspectives applied to the coffee systems in Mexico are in continuous change because of the environmental, social, economic and cultural heterogeneity of the coffee-producing regions of Mexico. This review identifies five perspectives as the thresholds of research applied to coffee system sustainability:

1) Local knowledge and community-based coffee systems (Novotny et al., 2021), (Espinosa-Gallegos et al., 2021), (Castro-Rodríguez, 2019), and (Pascual-Mendoza et al., 2021); 2) supply chains for sustainable coffee production (Contreras-Medina et al., 2020), and (Servín-Juárez et al., (2021); 3) climate change resilience and adaptation of vulnerable coffee-producing regions (Bunn et al., 2019), (Ortiz-Ceballos, 2020) and (Galicia-Gallardo et al., 2021); 4) women's participation and gender equity in coffee production (Lyon 2019) and (Merlín-Uribe et al., 2019); and 5) coffee agroecosystems and agroecology (Ruiz-García et al., 2020) and (Espinosa-Gallegos et al., 2021). These research perspectives are detailed in Table 1:

The sustainability perspectives integrate diverse topics, including the economic, environmental, social, cultural and institutional dimensions of coffee production in Mexico.

Local knowledge relates to sustainability because the local rules for land planning and natural resource management bring out patterns of local governance and support for sustainable landscape change (Novotny et al., 2021). Sustainable practices can also improve the coffee supply chain based on certain emerging technologies (Contreras-Medina et al., 2020)

Table 1. The thresholds of sustainability research in the coffee systems of Mexico.

Perspectives (thresholds of sustainability research)	Region	Author and Location	Sustainability dimensions and factors	
1) Community-based Coffee Systems	Southwest	Novotny et al. (2021). Santa Catarina Tayata and San Cristóbal Amoltepec, Oaxaca	Land cover change/use	Changes from forest, cropland, grassland or bare soil.
			Socioeconomic	Marginalization index, migration and population
			Biophysical	Slope, elevation, temperature and precipitation
		Espinosa-Gallegos et al., (2021). Soconusco region, Chiapas	Diversification of the economic activities	Coffee production orientation, sale and distribution, and alternative activities (cafeterias and tourism).
		Pascual-Mendoza et al., (2021). Sierra norte region, Oaxaca	Sociodemographic factors that define the traditional knowledge of edible plants	Age, education and linguistic competence of the inhabitants.
	Central South	Castro-Rodríguez (2019). Xochitlán, Yecapixtla, Morelos	Cultural-based practices	Irrigation, pruning, organic fertilization and harvest
2) The supply chains for sustainable coffee production	Southwest	Contreras-Medina et al., (2020). Ángel Albino Corzo, Jaltenango de la Paz and La Concordia, Chiapas	Emerging technologies for sustainable practice improvement.	Expectations, current situations and actions.
	Southwest, East, West* and Northeast*	Servín-Juárez et al., (2021). Cities or Towns of Mexico City*, Guanajuato*, Jalisco*, Michoacán*, Nuevo León*, Oaxaca, Puebla, Tamaulipas* and Veracruz	Supply chains attributes for probability of purchasing.	Material attributes, symbolic attributes, coffee shop characteristics, owner's profile, socioeconomic context.
3) The climate change resilience and adaptation of coffee-producing vulnerable regions	East, Southwest, Central South, Central North and West	Bunn et al., (2019) Agroclimatic zones for coffee in Mexico (Baseline)	Climate change incremental, systemic and transformational adaptation.	Sustainable intensification, adaptation and mitigation.
	East	Ortiz-Ceballos et al., (2020) Xalapa-Coatepec Region, Veracruz	Carbon storage in coffee agroecosystems	Average carbon by tree, aboveground carbon density, and total aboveground carbon by ecosystem and by whole region
	Southwest	Galicia-Gallardo et al., (2020). La Montaña, Guerrero	Socioecological vulnerability - mitigation	Agroecosystem structure, certification and marketing, labor distribution, gender, migration, community organization, government programs, and cooperatives membership.
4) Women's participation and gender equity in the coffee production	Southwest	Lyon (2019). Oaxaca	Women's coffee program	Economic decision-making, coffee land ownership, organizational participation and access to gender equity programs.
		Merlín-Uribe et al., (2019). Sierra Madre, Chiapas.	Economic, environmental, social and institutional dimensions of sustainability	Conflicts and potentialities of each dimension.
5) The coffee agroecosystems and agroecology	East	Ruiz-García et al., (2020). Chocamán, Veracruz	Coffee agroecosystem classification.	Biophysical conditions and coffee system classifications.
	Southwest	Perfecto et al., (2019). Soconusco Region, Chiapas.	Coffee landscape biodiversity	Coffee intensification gradient, ecological interactions and landscape effects

Source: Own elaboration from the literature analysis. * Supply chains for coffee sales

The degree of climate change adaptation for sustainable coffee production in Mexico and Central America is related to the degree of climate change impact (Bunn et al., 2019).

Women's participation in coffee production promotes organizational governance (Lyon, 2019) and is very relevant in organizations with self-management, organizational capacity, and solidarity to address sustainability (Merlín-Uribe et al., 2019).

The agroecology perspective has a lack of information regarding biophysical and physiographic factors of the arboreal structure and soil composition, which define agroecosystem management, improvement and conservation (Ruiz-García et al., 2020).

Conclusions

The objective of this paper was to integrate a review of relevant research to identify the different local-scale approaches of agriculture sustainability in different regions of Mexico to finally apply this investigation to coffee systems as a system with sustainability potential (Perfecto & Vandermeer, 2015).

Although the thresholds of sustainability research on coffee systems have common factors of analysis, because they generally start from the intersection of environmental, social, and economic factors (Elkington, 1997), there will always be different local conditions that define sustainability studies beyond the available theoretical or conceptual considerations in the literature. Additionally, to determine the proper definition of sustainability for a certain context, it is necessary to consider normative, methodological and philosophical considerations (Dietz et al*.,* 2018), as well as the heterogeneity of the producers' conditions in each context (Guadarrama-Zugasti, 2008).

This paper illustrates the sustainability of Mexico's agriculture from the perspective of each region of the country through the particularities of the coffee systems. This analysis also allows us to acknowledge that the three spheres of environmental, social and economic factors are valid and represent the base for the most recent investigations on coffee system sustainability. Social factors seem to be the most complex and discussed considerations in the analyzed literature because Latin American environmental thinking acquires its identity from the cultural heritage of its peoples (Leff, 2012).

As we can see, the environmental, social and economic conditions allow coffee system development in six of the eight regions of Mexico. In the northern regions, where physiographic conditions do not allow coffee production, there are agroindustries and capital. Meanwhile, in the southern and eastern regions, social, economic and cultural factors allow the development of social and rural collective organizations for coffee production.

Although there are common characteristics and conditions throughout Mexican coffee production systems, it is necessary to recognize the relevance of local knowledge to improve agricultural practices in each context, even in areas with high levels of ecological degradation (López-Carmona et al*.,* 2021). Local knowledge is an expression of growers' thinking, and it is important for the interpretation of the local processes of agriculture. It represents a key point to integrate working hypotheses formulation into coffee system sustainability research.

Although there are political agreements and sustainability assessment frameworks, most of these approaches are integrated from theoretical interpretations, and local communities establish drivers of change for natural resource management (Novotny et al*.,* 2021). The explicative potential of the local factors lies not only under the premise that there is a close relationship between agriculture and the natural environment but also on the local heterogeneity of the environmental, social, economic, institutional and cultural factors.

The thresholds of sustainability research on coffee systems in Mexico go further than the three spheres of the sustainability concept, particularly with local-scale approaches. Local knowledge, community-based strategies and women's participation integrate a cultural sphere of sustainability. The organization for production and adaptation to climate change would be part of the social sphere, while the agroecosystem definition and analysis would be integrated within the environmental issues of sustainability.

The agroecology perspective is relevant because it seeks to integrate agroecosystems from the close interaction of agriculture and ecosystems. It is very important to consider the local culture in terms of knowledge, community-based practices, and land tenure, among other conditions, to develop an appropriate sustainability assessment. An agroecology perspective with an appreciative sense of local heterogeneity would enhance mainstream sustainability research for better interpretation and evaluation.

This analysis allows defining Mexican coffee systems as heterogeneous, with generalized community-based and traditional management oriented to supply chain development, gender equality, climate change adaptation, and agroecosystem development.

The thresholds of sustainability research in coffee systems of Mexico are defined under the heterogeneity of conditions with a high potential to develop further investigations. The agricultural transition and sustainability assessment of coffee systems need to be performed under a contextual view of the phenomenon.

The southwestern and eastern regions are those where the highest number of sustainability studies are being developed. These regions showed an orientation toward community-based systems, the creation of supply chains with a sustainable emphasis and the application of agroecological practices. With these findings, we were able to identify three of the five thresholds of sustainability research.

The climate change resilience and the womens' participation research lines were also identified in these regions but at a lower scale, with fewer cases than those stated before. It is recommended to develop these research lines in coffee regions, as they are relevant in sustainability studies along other regions in the central and northern regions.

Local-scale sustainability studies are prolific in the central and southern regions, including the western and eastern regions. Due to the local heterogeneity of agricultural systems and their environmental, social and economic factors, local-scale approaches and case analysis are the best way to explain sustainability realities and assess their multidimensional factors. Therefore, we recommend following up with research on a local scale and being careful of the local heterogeneity factors, where qualitative studies and study case methodologies are good choices to perform sustainability studies in agriculture and coffee systems.

Resumen

J. Gómez-Velázquez, A. Vásquez-López, J. Regino-Maldonado, y S. N. Jurado-Celis. 2023. Una revisión de la sustentabilidad agrícola a escala local en las regiones cafetaleras de México. Int. J. Agric. Nat. Resour. 23-45. El concepto de sostenibilidad pretende integrar diversos aspectos de las necesidades humanas mediante el análisis de las dimensiones medioambiental, social y económica. Aunque existe un marcado consenso sobre el concepto de sostenibilidad, existen condiciones locales que definen los patrones de producción y sus condiciones reales de sostenibilidad. Este trabajo pretende integrar una revisión de la investigación sobre sustentabilidad en los sistemas agrícolas de México con un enfoque de

escala local, destacando las perspectivas locales de cada región para ofrecer una visión clara de la totalidad de los sistemas agrícolas del país y encontrar los umbrales de la investigación sobre sustentabilidad en las regiones cafetaleras de México. Para integrar la revisión se utilizaron diversas bases de datos y citas de artículos seleccionados a partir de 2012, con algunas referencias de referencia de 2002, y la estructura del artículo se desarrolló bajo una técnica narrativa. Como resultado, se muestra una visión de los enfoques de investigación en sustentabilidad a diferentes escalas locales en los sistemas agrícolas de México, haciendo énfasis en los sistemas cafetaleros y mostrando los umbrales de la investigación en sustentabilidad con estos enfoques.

Palabras clave: Agricultura sustentable, agroindustrias, desarrollo sustentable, sistemas agroforestales, sistemas cafetaleros, sustentabilidad.

References

Alliance for Coffee Excellence (2018). *Cup of excellence winning farms – national winners*. https://cupofexcellence.org/mexico-2021/

Alvarez-Morales, Y. (2015). *Evaluación de indicadores de sustentabilidad agroecológica en sistemas de producción agrícola de Baja California Sur, México* [Tesisdoctoral, Centro de Investigaciones Biológicas del Noroeste]. Repositorio digital del Centro de Investigaciones Biológicas del Noroeste. dspace.cibnor.mx:8080/handle/123456789/460

Anastacio-Martínez, N. D., Franco-Maass, S., Valtierra-Pacheco, E. & Nava-Bernal, G. (2016). Aprovechamiento de productos forestales no maderables en los bosques de montaña alta, centro de México. *Revista mexicana de ciencias forestales*, *7*(37), 21-38.

Anaya, J. (2005). Indigenous peoples' participatory rights in relation to decisions about natural resource extraction: the more fundamental issue of what rights indigenous peoples have in lands and resources. *Arizona journal of international and comparative law*. L., 22, 7.

Andresen, E., López-del-Toro, P., Franquesa-Soler, M., Mora, F. & Barraza, L. (2020). Teenagers' Awareness about Local Vertebrates and Their Functions: Strengthening Community Environmental Education in a Mexican Shade-Coffee Region to Foster Animal Conservation. *Sustainability*, *12*(20), 8684. https://doi.org/10.3390/su12208684

Astier, M., García-Barrios, L., Galván-Miyoshi, Y., González-Esquivel, C. E. & Masera, O. R. (2012). Assessing the sustainability of small farmer natural resource management systems. A critical analysis of the MESMIS program (1995-2010). *Ecology and society*, *17*(3). http://doi.org/10.5751/ES-04910-170325

Barsimantov, J. & Kendall, J., (2012). Community forestry, common property and deforestation in eight Mexican states. *Journal of Environment and Development*, *21*, 414-437. https://doi.org/10.1177/1070496512447249

Bergstrand, B. O., Björk, F. & Molnar, S. (2011). Biosphere Entrepreneurship: A Pilot Study on social entrepreneurship in the biosphere reserve Lake Vänern Archipelago and Mount Kinnekulle, Sweden. p. 1-16.

Brundtland, G. H. (1987). Our common future—Call for action. *Environmental Conservation. 14*(4), 291-294. https://doi.org/10.1017/S0376892900016805

Bunn, C., Lundy, M. & Castro-Llanos, F. (2019). *Climate Change Impacts on Coffee Production in Mexico and Central America*. International Center for Tropical Agriculture (CIAT), Cali, Colombia. 24 p.

Calleros-Islas, A. (2019). Sustainability assessment. An adaptive low-input tool applied to the management of agroecosystems in México. *Eco-*

logical indicators, 105, 386-397. https://doi.org/10.1016/j.ecolind.2017.12.040

Castro-Rodríguez, K.E. (2019). *La conservación de la diversidad biolcultural en xochitlán, municipio de Yecapixtla, Morelos* [Tesis de maestría, Universidad Autónoma del Estado de Morelos). Repositorio Institucional de Acceso Abierto. riaa.uaem.mx/handle/20.500.12055/1012

Castro-Sánchez, E. I., Moreno-Calles, A. I., Meneses-Eternod, S., Farfán-Heredia, B., Blancas, J. & Casas, A. (2019). Management of Wild Edible Fungi in the Meseta Purépecha Region, Michoacán, México. *Sustainability*, *11*(14), 3779. https://doi.org/10.3390/su11143779

Ching, L. L. (2018). Agroecology for sustainable food systems. *Environment and Development series*, Third World Network, Penang, Malaysia.

Clift, R. (2003). Metrics for supply chain sustainability. *Clean Technologies and Environmental Policy,* 5, 240-247 (2003). https://doi.org/10.1007/s10098-003-0220-0

Contreras-Medina, D. I., Contreras-Medina, L. M., Pardo-Nuñez, J., Olvera-Vargas, L. A. & Rodriguez-Peralta, C. M. (2020). Roadmapping as a Driver for Knowledge Creation: A Proposal for Improving Sustainable Practices in the Coffee Supply Chain from Chiapas, Mexico, Using Emerging Technologies. *Sustainability*, *12*(14), 5817. https://doi.org/10.3390/su12145817

Cruz-Delgado, D. (2020). La actitud de los agricultores hacia la conservación de los recursos naturales en González, Tamaulipas. *Agricultura, Sociedad y Desarrollo*. *17*(3), 457-472.

Datta, R. (2015). A relational theoretical framework and meanings of land, nature, and sustainability for research with Indigenous communities. *Local Environment*, *20*(1), 102-113. https://doi.org/10.1080/13549839.2013.818957

De Anda, J. & Shear, H. (2017). Potential of vertical hydroponic agriculture in Mexico. *Sustainability*, *9*(1), 140. https://doi.org/10.3390/su9010140

De Dios, M. (2020). *The situation of Latin America's indigenous population and the impact of COVID-19.* United Nations Development Programme. Latin America and the Caribbean.

Dieleman, H. (2017). Urban agriculture in Mexico City; balancing between ecological, economic, social and symbolic value. *Journal of Cleaner Production*, *163*, S156-S163. https://doi.org/10.1016/j.jclepro.2016.01.082

Dietz, T., Auffenberg, J., Chong, A. E., Grabs, J. & Kilian, B. (2018). The voluntary coffee standard index (VOCSI). Developing a composite index to assess and compare the strength of mainstream voluntary sustainability standards in the global coffee industry. *Ecological economics*, *150*, 72-87. https://doi.org/10.1016/j.ecolecon.2018.03.026

Domené-Painenao, O., Acuña Velázquez, I. R. & León, L. E. (2015). *Comuna y transición agroecológica: un caso de estudio en el Municipio Revenga, Estado Aragua Venezuela.* V Congreso Latinoamericano de Agroecología-SOCLA, La Plata, 2015.

Duxbury, N. & Jeannotte, M. S. (2010, August). *Culture, sustainability and communities: Exploring the myths*. 6th International Conference on Cultural Policy Research, Jyväskylä, Finland. pp. 24-27.

Elkington, J., 1997. *Cannibals with Forks: Triple Bottom Line of 21st Century Business*. Capstone Publishing Ltd, Oxford.

Elliott, M., Elliott, L. & Sluis, E. V. D. (2018). A predictive analytics understanding of cooperative membership heterogeneity and sustainability. *Sustainability*, *10*(6), 2048. https://doi.org/10.3390/su10062048

Ellis, E. A., Montero, J. A. R., Gómez, I. U. H., Porter-Bolland, L. & Ellis, P. W. (2017). Private property and Mennonites are major drivers of forest cover loss in central Yucatan Peninsula, Mexico. *Land Use Policy*, *69*, 474-484. https://doi.org/10.1016/j.landusepol.2017.09.048

Enock, C. M. (2013). Indigenous knowledge systems and modern weather forecasting: exploring the linkages. *Journal of Agriculture and Sustainability*, *2*(1), 98-141.

Escalera-Chávez, M. E., García-Santillán, A., Ríos-Álvarez, L., Zamora-Lobato, T. & Pozos-Texon, F. (2015). Financial Evaluation of the Technology Used for Waste Management in Swine Farms

in Mexico. *International Review of Management and Business Research*, *4*(1), 79-88.

Escamilla-Prado, E., Ruiz, O., Díaz, G., Landeros, C., Platas, D. E., Zamarripa, A. & González, V. A. (2005). El agroecosistema café orgánico en México. *Manejo Integrado de Plagas y Agroecología (Costa Rica)*. 76. pp. 5-16.

Espidio-Balbuena, J., Navarro-Garza, H., Flores-Sánchez, D. & Báez-Pérez, A. (2020). Diversity of cropping systems and agroecological transition: case study in Northern Sierra of the State of Puebla, Mexico. *Agroproductividad*, *13* (2). 23-29 https://doi.org/10.32854/agrop.vi.1530

Espinosa-Gallegos, M. I., Ocón, H. B. F. & Bonanno, A. (2021). Contendiendo en la globalización. Los empresarios cafetaleros del Soconusco y la organización de las cadenas de producción locales y globales. *Entre Diversidades: Revista de Ciencias Sociales y Humanidades*, *8*(1), 6-35. https://doi.org/10.31644/ED.V8.N1.2021.A01

Fenichel, E. P., Levin, S. A., McCay, B., Martin, K. S., Abbott, J. K. & Pinsky, M. L. (2016). Wealth reallocation and sustainability under climate change. *Nature Climate Change, 6*(3), 237-244. https://doi.org/10.1038/nclimate2871

Fuente-Carrasco, M. E. (2009). Nueva ruralidad comunitaria y sustentabilidad: contribuciones al campo emergente de la economía-ecológica. *Revista Iberoamericana de economía ecológica*, *13*, 41-55.

Galicia-Gallardo, A. P., Ceccon, E., Castillo, A. & González-Esquivel, C. E. (2021). Resisting socio-ecological: agroecology and indigenous cooperativism in La Montaña, Guerrero, Mexico. *Agroecology and Sustainable Food Systems*, *45*(1), 65-85. https://doi.org/10.1080/21683565.2020.1793871

Gallegos-Hernández, K. (2019). *Propuesta de competitividad sustentable del comité estatal del sistema producto aguacate en el estado de Morelos.* (Tesis de maestría, Universidad Autónoma del Estado de Morelos). www.riaa.uaem.mx/xmlui/handle/20.500.12055/939

Gómez-López, J. E., de Jesús Sandoval-Legazpi, J. & de Jesús Arellano-Panduro, A. (2018). Propuesta de un modelo en planeación estratégica como herramienta del desarrollo agrícola del valle El Grullo-Autlán-El Limón, Jalisco. *CIBA Revista Iberoamericana de las Ciencias Biológicas y Agropecuarias*, *7*(14), 32-52. https://doi.org/10.23913/ciba.v7i14.79

González-Jácome, A. (2003). Ambiente y cultura en la agricultura tradicional de México: casos y perspectivas. *Ciencia ergo-sum*, *11*(2), 153-163. https://doi.org/10.22201/iia.24486221e.2003.1.16738

Guadarrama-Zugasti, C. (2008). A grower typology approach to assessing the environmental impact of coffee farming in Veracruz, Mexico. *Confronting the coffee crisis: fair trade, sustainable livelihoods and ecosystems in Mexico and Central America.* MIT Press, Cambridge, 127-154.

Guerrero-Osorio, A. (2015). La comunalidad como herramienta: una metáfora espiral II. *Bajo el Volcán*, *15*(23), 113-129.

Harik, R., El Hachem, W., Medini, K., & Bernard, A. (2015). Towards a holistic sustainability index for measuring sustainability of manufacturing companies. *International Journal of Production Research*, *53*(13), 4117-4139. http://doi.org/10.1080/00207543.2014.993773

Herrera-Silveira, J. A., Lara-Domínguez, A. L., Day, J. W., Yáñez-Arancibia, A., Ojeda, S. M., Hernández, C. T. & Kemp, G. P. (2019). Ecosystem functioning and sustainable management in coastal systems with high freshwater input in the southern Gulf of Mexico and Yucatan Peninsula. *Coasts and Estuaries* (pp. 377-397). Elsevier. https://doi.org/10.1016/B978-0-12-814003-1.00022-8

Hernandez-Polito, A. & Lezama Ruiz, N. (2017). Responsabilidad social organizacional y sustentabilidad: Caso manejo de la roya del café en Guerrero, México. En Herrera-González et al. (1). *Propuestas de investigación. Una mirada a la forma de estudiar las organizaciones*. Grupo editorial Hess. Universidad de Guanajuato.

Jalil, F., Gómez, J. E., Hueso, E. J., Castañeda, A., Ramón, T. & Silva, R. B. (2020). Perfil de sustentabilidad tridimensional en el valle agrícola del municipio de Casimiro Castillo, Jalisco, México. *Idesia (Arica), 38*(2),

103-108. http://dx.doi.org/10.4067/S0718-34292020000200103.

Jiménez, M., Pérez-Belmont, P., Schewenius, M., Lerner, A. M. & Mazari-Hiriart, M. (2020). Assessing the historical adaptive cycles of an urban social-ecological system and its potential future resilience: the case of Xochimilco, Mexico City. *Regional Environmental Change*, *20*(1), 1-14. https://doi.org/10.1007/s10113-020-01587-9

Jiménez-Ortega, A. D., Aguilar Ibarra, A., Galeana-Pizaña, J. M. & Núñez, J. M. (2022). Changes over Time Matter: A Cycle of Participatory Sustainability Assessment of Organic Coffee in Chiapas, Mexico. *Sustainability*, *14*(4), 2012. https://doi.org/10.3390/su14042012

Keitumetse, S. O. (2014). Cultural resources as sustainability enablers: Towards a community-based cultural heritage resources management (COBACHREM) model. *Sustainability*, *6*(1), 70-85. https://doi.org/10.3390/su6010070

Khalili, N.R., Ehrlich, D. & Dia-Eddine, K. (2013). A qualitative multi-criteria, multi stakeholder decision making tool for sustainable waste management. *Progressin Industrial Ecology, An International Journal*, *8*, 114-134. https://doi.org/10.1504/PIE.2013.055063

Khosla, A. (1995). *Foreword. In A Sustainable World*, T.C. Tryzna (ed). Sacramento: IUCN.

Leff, E. (2012). Latin American environmental thinking: a heritage of knowledge for sustainability. *Environmental ethics*, *34*(4), 431-450. https://doi.org/10.5840/enviroethics201234442

López-Carmona, D., Gallegos, Á., Palma, D. J., Martín-Morales, G., Barragán-Maravilla, M., Hernández-Vallecillo, G. & Bautista, F. (2021). Selección de tierras para el cultivo de café en zonas con información escasa: análisis espacial del territorio y conocimiento local. *Ecosistemas y Recursos Agropecuarios*, *8*(1). https://doi.org/10.19136/era.a8n1.2419.

Lozano, R. (2015). A holistic perspective on corporate sustainability drivers. *Corporate social responsibility and environmental management*, *22*(1), 32-44. https://doi.org/10.1002/csr.1325

Lyon, S. (2019). Business Anthropology's Lens into Gender Equity: Assessing the Impact of'Smart Economics' in the Coffee Sector. *International Journal of Business Anthropology*, *9*(2), 33-50.

Mardero, S., Schmook, B., López-Martínez, J. O., Cicero, L., Radel, C. & Christman, Z. (2018). The uneven influence of climate trends and agricultural policies on maize production in the Yucatan Peninsula, Mexico. *Land*, *7*(3), 80. https://doi.org/10.3390/land7030080

Martínez-Luna, J. (2003). Comunalidad y desarrollo. *Culturas populares e indígenas. Cultura indígena.* Gobierno del Estado de Oaxaca 2003.

Márquez, R. I., Ayala-Arcipreste, M. E., Sandoval-Valladares, J. L. & Sánchez-González, A. P. (2019) Sustentabilidad de las Plantaciones de Palma de Aceite a Pequeña Escala en Campeche, México. *Agroecosistemas Tropicales*, 48.

Mazabel, D. G. & Caldera, A. R. (2018). Self-Sustaining, Irrigated Agriculture and Sustainability. A Study in Southern Guanajuato, Mexico. *International Journal of Research in Sociology and Anthropology*, *4* (1) 24-35. https://doi.org/10.20431/2454-8677.0401004

Mebratu, D. (1998). Sustainability and sustainable development: historical and conceptual review. *Environmental impact assessment review*, *18*(6), 493-520. https://doi.org/10.1016/S0195-9255(98)00019-5

Meneses-Jácome, A., Diaz-Chavez, R., Velásquez-Arredondo, H. I., Cárdenas-Chávez, D. L., Parra, R. & Ruiz-Colorado, A. A. (2016). Sustainable Energy from agro-industrial wastewaters in Latin-America. *Renewable and Sustainable Energy Reviews, 56*, 1249-1262. https://doi.org/10.1016/j.rser.2015.12.036

Merlín-Uribe, Y., González Cabañas, A. A., Soto-Pinto, L., Contreras-Hernández, A. & Herrera, O. B. (2019). Sustainability: from concept to perception in organic coffee growers of the sierra madre de Chiapas. *Section: Social movements and rural culture*, (73). http://doi.org/10.5154/r.textual.2018.73.04

Merlín-Uribe, Y., González-Esquivel, C. E., Contreras-Hernández, A., Zambrano, L., Moreno-Casasola, P. & Astier, M. (2013). Environmental and socio-economic sustainability of chinampas (raised beds) in Xochimilco, Mexico City. *Inter-*

national Journal of Agricultural Sustainability, *11*(3), 216-233. https://doi.org/10.1080/14735903.2012.726128

Molina-Ramírez, E. & Barba-Sánchez, V. (2021). The Embeddedness as a Differentiating Element of Indigenous Entrepreneurship: Insights from Mexico. *Sustainability*, *13*, 2117. https://doi.org/10.3390/su13042117

Montgomery, M. C. (2019). *Adaptation Under the Canopy: Coffee Cooperative and Certification Contributions to Smallholder Livelihood Sustainability in Santa Lucía Teotepec, Oaxaca* (M.S. Thesis, University of Montana, Missoula, 2019). https://scholarworks.umt.edu/etd/11427/

Moreno-Calles, A. I., Galicia-Luna, V. J., Casas, A., Toledo, V. M., Vallejo-Ramos, M., Santos-Fita, D. & Camou-Guerrero, A. (2014). Etnoagroforestería: El estudio de los sistemas agroforestales tradicionales de México. *Etnobiología*, *12*(3), 1-16.

Nestel, D. (1995). Coffee in Mexico: international market, agricultural landscape and ecology. *Ecological Economics*, *15*(2), 165-178. https://doi.org/10.1016/0921-8009(95)00041-0

Nolte, C., Agrawal, A., Silvius, K.M. & Soares-Filho, B.S., (2013). Governance regime and location influence avoided deforestation success of protected areas in the Brazilian Amazon. *PNAS, 110* (13), 4956-4961. https://doi.org/10.1073/pnas.1214786110

Novotny, I. P., Fuentes-Ponce, M. H., Tittonell, P., Lopez-Ridaura, S. & Rossing, W. A. (2021). Back to the people: The role of community-based responses in shaping landscape trajectories in Oaxaca, Mexico. *Land Use Policy*, *100*, 104912. https://doi.org/10.1016/j.landusepol.2020.104912

Omilola, B. & Robele, S. (2017). *The central position of agriculture within the 2030 Agenda for Sustainable Development* (Vol. 1683). Internationall Food Policy Research Institute. New York, United States of America.

Ordaz-Gallegos, J., de las Nieves-Rodríguez, M., García-Cúe, J. L. & Pimentel-Equihua, J. L. (2020). Estrategias de manejo en huertas de mango y su efecto en la calidad del suelo y productividad en Los Cajones, Michoacán. *Revista Mexicana de Ciencias Agrícolas*, *11*(5), 1057-1068. https://doi.org/10.29312/remexca.v11i5.2127

Ortiz-Ayala, R., Hernández-Jiménez, A. & Valencia-Pérez, H. (2018). La sustentabilidad en el aprovisionamiento del café. El caso de Renovarte Café Coffee procurement sustainability. The case of Renov Arte Café. In Arrieta-Díaz, Delia, *Perspectivas de la gestión estratégica y la competitividad en las organizaciones*. 50. ECORFAN, Spain.

Ortiz-Ceballos, G. C., Vargas-Mendoza, M., Ortiz-Ceballos, A. I., Mendoza Briseño, M. & Ortiz-Hernández, G. (2020). Aboveground Carbon Storage in Coffee Agroecosystems: The Case of the Central Region of the State of Veracruz in Mexico. *Agronomy*, *10*(3), 382. https://doi.org/10.3390/agronomy10030382

Owen, A. L. & Videras, J. (2008). Trust, cooperation, and implementation of sustainability programs: The case of Local Agenda 21. *Ecological Economics*, *68*(1-2), 259-272. https://doi.org/10.1016/j.ecolecon.2008.03.006

Padilla-Bernal, L. E., Lara-Herrera, A. & Loureiro-García, M. L. (2016). Mecanismos de adopción voluntaria y los sistemas de gestión ambiental en unidades de producción hortícola de zacatecas, México. *Responsabilidad Social y Sustentabilidad*. Red Internacional de Investigadores en Competitividad, 10.

Palafox-Muñoz, A., Martínez-Perezchica, M. G. & Anaya-Ortiz, J. S. (2016). New rurality and social sustainability in the magical town of Calvillo, Aguascalientes. *Revista Iberoamericana de Turismo (RITUR), 6*(Especial), 64-81.

Pantoja-Zavala, G. M. & Flores-Vichi, F. (2018). The citrus sector of Nuevo León: characterization of the agri-food system as a platform for integration of the producer with agro-industry. *Región y sociedad*, *30*(71). https://doi.org/10.22198/rys.2018.71.a385

Pascual-Mendoza, S., Saynes-Vásquez, A. & Pérez-Herrera, A. (2021). Traditional knowledge of edible plants in an indigenous community in the Sierra Norte of Oaxaca, Mexico. *Plant Biosystems-An International Journal Dealing with all*

Aspects of Plant Biology, 1-22. https://doi.org/10.1080/11263504.2021.1887956

Pashaei Kamali, F., Borges, J. A. R., Meuwissen, M. P. M., de Boer, I. J. M. & Oude Lansink, A. G. J. M. (2017). Sustainability assessment of agricultural systems: The validity of expert opinion and robustness of a multi-criteria analysis. *Agricultural Systems*, *157*, 118-128. https://doi.org/10.1016/j.agsy.2017.07.013

Perez, E. M. C., Cornejo, N. E. S. & Ramírez, R. C. (2014). La ruta del café comala": una opción para diversificar la actividad turística. *Revista Turismo y Desarrollo Local (Turydes), 7*(17).

Pérez-Hernández, C. C., Salazar-Hernández, B. C., Mendoza-Moheno, J., Cruz-Coria, E. & Hernández-Calzada, M. A. (2021). Mapping the Green Product-Space in Mexico: From Capabilities to Green Opportunities. *Sustainability*, *13*, 945. https://doi.org/10.3390/su13020945

Pérez-Vega, A., García, H. R., Nóguez, A. B., Gutiérrez, M. F., Álvarez, F. R. & Magaña-Cota, G. (2016). Valoración de la subzonificación del plan de manejo en la Reserva de la Biósfera de Sierra Gorda Guanajuato. *Acta Universitaria*, *26*(2), 45-61. https://doi.org/10.151774/au.2016.1538

Perfecto, I. & Vandermeer, J. (2015). *Coffee agroecology: a new approach to understanding agricultural biodiversity, ecosystem services and sustainable development*. Routledge. Taylor and Francis Group, London.

Próspero-Bernal, F., Salas Reyes, I. G., Fadul Pacheco, L., Heredia Nava, D., Albarrán Portillo, B. & Arriaga Jordán, C. M. (2015). Evaluación de la sustentabilidad de los sistemas de producción de leche en pequeña escala en dos zonas agroecológicas contrastantes del centro de México. *Estudios Socioeconómicos y Ambientales de la Ganadería*. Universidad Autónoma Chapingo.

Ramirez-Delgado, J. P., Christman, Z. & Schmook, B. (2015). Deforestation and fragmentation of seasonal tropical forests in the southern Yucatán, Mexico (1990–2006). *Geocarto International*, *29*(8), 822-841. https://doi.org/10.1080/10106049.2013.868039

Ravichandran, A. Diaz-Elsayed, N., Thomas, S. & Zhang, Q. (2021). An assessment of the influence of local conditions on the economic and environmental sustainability of drain water heat recovery systems. *Journal of Cleaner Production*, *279*, 123589. https://doi.org/10.1016/j.jclepro.2020.123589

Reed, M. S., Fraser, E. D. & Dougill, A. J. (2006). An adaptive learning process for developing and applying sustainability indicators with local communities. *Ecological economic*s, *59*(4), 406-418.

Renard-Hubert, M. C. & Larroa-Torres, R. M. (2017). Política pública y sustentabilidad de los territorios cafetaleros en tiempos de roya: Chiapas y Veracruz. *Estudios Latinoamericanos*, *40*, 95-113.

Reyes-Grande, F. (2015). ¿Sustentabilidad versus subsistencia? Un estudio de caso dentro del Área Natural Protegida Cañón del Usumacinta. *Relaciones. Estudios de historia y sociedad*, *36*(142), 261-305.

Rivera, J. A., Monterrubio, E. A., González-Cossío, T., García-Feregrino, R., García-Guerra, A. & Sepúlveda-Amor, J. (2003). Nutritional status of indigenous children younger than five years of age in Mexico: results of a national probabilistic survey. *Salud pública de México*, *45*, 466-476.

Rivera de la Rosa, A. R. & Ortiz Pech, R. (2017). Producción de soya transgénica y miel en Yucatán, México. Impactos en la sustentabilidad de productores en Tekax. *Revista de economía*, *34*(88), 45-81.

Rodríguez-Pérez, E. G., Daniel-Torres, R. A. & Mendoza-Gómez, J. (2021). Estudio exploratorio sobre la cadena de suministros "verde" y el capital humano "verde" en organizaciones del área metropolitana de Monterrey (Exploratory study on the" green" supply chain and" green" human capital in organizations in the metropolitan area of Monterrey). *Innovaciones de Negocios*, *18*(35). https://doi.org/10.29105/rinn18.35-7

Romero-Contreras, A. T. (2004). Rituales y actividades materiales en la antigua agricultura indígena. *CIENCIA ergo-sum*, *11*(1), 25-35.

Ruiz-García, P., Gómez-Díaz, J. D., Valdes-Velarde, E., Tinoco-Rueda, J. A., Flores-Ordoñez, M. & Monterroso-Rivas, A. I. (2020). Biophysical and structural composition characterization in agro-

forestry systems of organic coffee from Veracruz. *Tropical and Subtropical Agroecosystems*, *23*(2).

Ruiz-Palomino, P., Guatemala-Morales, G., Mondragón-Cortéz, P. M., Zúñiga-González, E. A., Corona-González, R. I. & Arriola-Guevara, E. (2019). Empirical model of the chlorogenic acid degradation kinetics during coffee roasting in a spouted bed. *Revista Mexicana de Ingeniería Química*, *18*(2), 387-396. https://doi.org/10.24275/uam/izt/dcbi/revmexingquim/2019v18n2/Ruiz

Salazar-Adams, A., Moreno Vázquez, J. L. & Lutz Ley, A. N. (2012). Agricultura y manejo sustentable del acuífero de la Costa de Hermosillo. *Región y sociedad*, *24*(SPE3), 155-179.

Sallee, B., Pasquis, R. G. & Berhocoirigoin, F. (1990). Research and development methodology in the Xalapa/Coatepec coffee basin, Mexico. In 13. *Colloque Scientifique International sur le Cafe, Paipa (Colombie),* 21-25 Aou 1989. ASIC.

Sánchez-Toledano, B. I., Kallas, Z. & Gil, J. M. (2017). Importancia de los objetivos sociales, ambientales y económicos de los agricultores en la adopción de maíz mejorado en Chiapas, México. *Revista de la Facultad de Ciencias Agrarias UNCuyo*, *49*(2), 269-287.

Sandoval-Moreno, A. (2015). Community Organization and Water Sustainability. *Ambiente y Desarrollo*, *19*(36), 9-24. https://doi.org/10.11144/Javeriana.ayd19-36.cows

Sarkis, J. & Zhu, Q. (2018). Environmental sustainability and production: taking the road less travelled. *International Journal of Production Research*, *56*(1-2), 743-759. https://doi.org/10.1080/00207543.2017.1365182

SECTUR (2019). *Sistema Nacional de la Información Estadística del Sector Turismo de México*. *Datatur*. Secretaría de Turismo, Mexico. http://www.datatur.sectur.gob.mx/SitePages/Inicio.aspx

Servín-Juárez, R., Trejo-Pech, C. J., Pérez-Vásquez, A. Y. & Reyes-Duarte, Á. (2021). Specialty Coffee Shops in Mexico: Factors Influencing the Likelihood of Purchasing High-Quality Coffee. *Sustainability*, *13*(7), 3804. https://doi.org/10.3390/su13073804

Sikdar, S. K. (2003). Sustainable development and sustainability metrics. *AIChE journal*, *49*(8), 1928-1932.

Spinoso-Castillo, J. L., Escamilla-Prado, E., Aguilar-Rincón, V. H., Ramos, V. M., de los Santos, G. G., Pérez-Rodríguez, P. & Corona-Torres, T. (2020). Genetic diversity of coffee (Coffea spp.) in Mexico evaluated by using DArTseq and SNP markers. *Genetic Resources and Crop Evolution*, *67*(7), 1795-1806. https://doi.org/10.1007/s10722-020-00940-5

Suárez-Islas, A., Capulín-Grande, J. & Mateo-Sánchez, J. J. (2020). Performance of Dalbergia palo-escrito Rzed. & Guridi-Gómez, a valuable timber tree, in a coffee plantation in Hidalgo, Mexico. *Bois & forets des tropiques*, *344*, 47-57. https://doi.org/10.19182/bft2020.344.a31899

Torres-Lima, P., Canabal-Cristiani, B. & Burela-Rueda, G. (1994). Urban sustainable agriculture: The paradox of the chinampa system in Mexico City. *Agriculture and human values*, *11*(1), 37-46. https://doi.org/10.1007/BF01534447

Traldi, R. (2021). Progress and pitfalls: A systematic review of the evidence for agricultural sustainability standards. *Ecological Indicators*, *125*, 107490. https://doi.org/10.1016/j.ecolind.2021.107490

Vázquez-Arango, M. D. L., Velázquez Sánchez, R. M. & Ramírez Castillo, E. A. (2016). Gestión comunitaria sustentable como elemento turístico en la comunidad de Capulálpam de Méndez, Oaxaca. *El desarrollo regional frente al cambio ambiental global y la transición hacia la sustentabilidad*. Asociación Mexicana de Ciencias para el Desarrollo Regional, A. C, México.

Vásquez-Valencia, R. A. & García-Almada, R. M. (2018). Indicadores PER y FPEIR para el análisis de la sustentabilidad en el municipio de Cihuatlán, Jalisco, México. *Nóesis: Revista de Ciencias Sociales y Humanidades*, *27*(53), 1-26. https://doi.org/10.20983/noesis.2018.3.1

Villeneuve, C., Tremblay, D., Riffon, O., Lanmafankpotin, G. Y. & Bouchard, S. (2017). A systemic tool and process for sustainability assessment. *Sustainability*, *9*(10), 1909. https://doi.org/10.3390/su9101909

Wily, L. A., 2011. *The Tragedy of Public Lands: the Fate of the Commons Under Global Commercial Pressure*. International Land Coalition. Canadian International Development Agency. The International Land Coalition.

Winther, A. M. (2017). Community sustainability: a holistic approach to measuring the sustainability of rural communities in Scotland. *International Journal of Sustainable Development & World Ecology, 24*(4), 338-351. https://doi.org/10.1080/13504509.2016.1224987

Zambrano, L., Rivas, M. I., Uriel-Sumano, C., Rojas-Villaseñor, R., Rubio, M., Mena, H. & Tovar-Garza, A. (2020). Adapting wetland restoration practices in urban areas: Perspectives from Xochimilco in Mexico City. *Ecological Restoration*, *38*(2), 114. https://doi.org/10.3368/er.38.2.114