Agricultura, Sociedad y Desarrollo

SUSTAINABILITY OF THE PERSIAN LIME PRODUCTION SYSTEM IN MARTÍNEZ DE LA TORRE, VERACRUZ

Ana Maryury **Franco-Valderrama***[1], Ignacio **Caamal-Cauich**[1], Verna Gricel **Pat-Fernández**[1], Javier Jesús **Ramírez-Hernández**[2]

[1]Universidad Autónoma Chapingo, Km 38.5. Carretera México-Texcoco. Chapingo, México. 56230. [2]Centro de Estudios e Investigación en Desarrollo Sustentable Universidad Autónoma del Estado de México. Matamoros núm. 1007, Col. Universidad, Toluca, México. 50120.

*Corresponding author: mareducacion2020@gmail.com

ABSTRACT

Sustainability is a process that has the objective of finding balance between the economic, social and environmental areas. The agricultural sector in Mexico has undergone a series of changes for years, and these changes have been reflected directly in the environment, since conventional agriculture has an impact on natural resources. The study was carried out in the Municipality Martínez de la Torre, Veracruz, since it is the most important in Persian lime production (*Citrus latifolia Tanaka*). The objective of the study was to evaluate the sustainability in the conventional production of Persian lime, using the framework for the evaluation of management systems of natural resources incorporating sustainability indicators (MESMIS). The economic area was evaluated with the result being that it is the one most strengthened because during the year there is Persian lime production, the benefit-cost obtained is economically acceptable, and the environmental area resulted in farmers conducting very few actions for the conservation of natural resources. The social area was the weakest of its indicators, which is why it derives to a large extent in a lack of technical training, low family participation, and lack of women's integration in agricultural practices.

Keywords: attributes and indicators, conventional agriculture, surface, yield.

Citation: Franco-Valderrama AM, Caamal-Cauich I, Pat-Fernández VG, Ramírez-Hernández JJ. 2022. Sustainability of the persian lime production system in Martínez de la Torre, Veracruz.
Agricultura, Sociedad y Desarrollo
https://doi.org/10.22231/asyd.v19i2.1376

ASyD 19(2): 213-228

Editor in Chief:
Dr. Benito Ramírez Valverde

Received: November 11, 2020.
Approved: February 16, 2021.

Estimated publication date:
October 14, 2022.

INTRODUCTION

In Mexico, citrus production is considered one of the main activities of the primary sector, with lime being one of the most important citruses due to its production volume. Three species of lime are cultivated in Mexico: key lime (*Citrus aurantifolia*), Persian lime (*Citrus latifolia*) and Italian lime (*Citrus limón*) (Servicio de Información Agroalimentaria y Pesquera [SIAP], 2018). A large part of the national territory has the adequate soil-climate conditions for lime production. Among the 5 main entities that are producers of key lime and Persian lime, the following stand out: Michoacán with 29 percent of the production volume, since this state has a higher production in key lime, and Veracruz with 27 percent of the volume of Persian lime production, followed by the states of Oaxaca and Colima with 10 percent of the production, and Tamaulipas with 4 percent (SIAP, 2020). Regarding the main producing states in Persian lime at the national level, the first place is occupied by Veracruz with 53 percent of the production, followed by Oaxaca with 14 percent, the state of Jalisco with 7 percent, Tabasco with 6 percent, and Yucatán with 4 percent of the production (SIAP, 2020). Concerning the municipal level, the 5 most representative municipalities for Persian lime in the state of Veracruz are: Martínez de la Torre, which occupies the first place with a production of 49 percent, followed by Atzalan with 17 percent, San Rafael with 15 percent, Tlapacoyan with 13 percent of the production, and Papantla with 6 percent (SIAP, 2020).

In Mexico, agriculture is an activity where the environment is the most affected; agricultural systems are predetermined to create an increase in economic resources, but also cause a direct impact on the environment, and it should be highlighted that the conventional system does not develop sustainable agricultural practices so it goes against sustainable development, understood as "development that satisfies the needs of the present without endangering the capacity of future generations" (Organización de las Naciones Unidas [ONU], 2020). It is unavoidable to address the needs for elaborating and implementing new sustainable agricultural development models, which are focused on mitigating the environmental damage caused by conventional agriculture.

Conventional agriculture has exerted great pressure on the environment, placing at risk the resources and the future production of quality foods. The great expansion of the cultivated surface goes hand in hand with the increase in the use of external inputs, with fertilizers and pesticides standing out, and resulting in soil degradation, loss of habitats, among others (Andrade, 2016).

"Organic agriculture is a form of sustainable production, decreasing the use of fertilizers and pesticides, since the basic rules of organic production are the use of natural inputs and the prohibition of applying synthetic inputs, although in both cases there are exceptions" (Soto, 2008; Quezada, 2018). Crop rotation is also essential in organic production, which strengthens soils with techniques of interspersed crop management, covering with an organic layer, and integration of agriculture and livestock production as a fundamental element. Compound organic fertilizers are inexpensive and can be obtained locally, giving as a result the reestablishment of the soil structure, improving water retention, and with time also improving the yields because they contain a wide variety of nutritional elements (Quezada, 2018).

Regarding sustainability, it is built on the duty of current human behavior with regards to future generations; that is, to ensure that the economic, social, cultural and environmental development of today will be equal or better in the future. Ideally, sustainability is the condition or state that will allow continuity that is healthy, safe, productive and in harmony with nature (Sarandon, 2009). "Sustainability implies reaching an equilibrium between the trend towards the entropic death of the planet, generated by the rationality of economic growth, and the construction of a neguentropic productivity based on the photosynthetic process of life" (Leff, 2018).

When it comes to sustainability in agriculture, it can be addressed from two perspectives (Sánchez, 2009; Martínez *et al.*, 2012):

- Sustainability as an approach: "When it is approached from regulations in response to the impacts of conventional agriculture, regarding the environment, food quality, survival of rurality, and others through alternative approaches (organic agriculture, conservation agriculture, integrated production, etc.)".

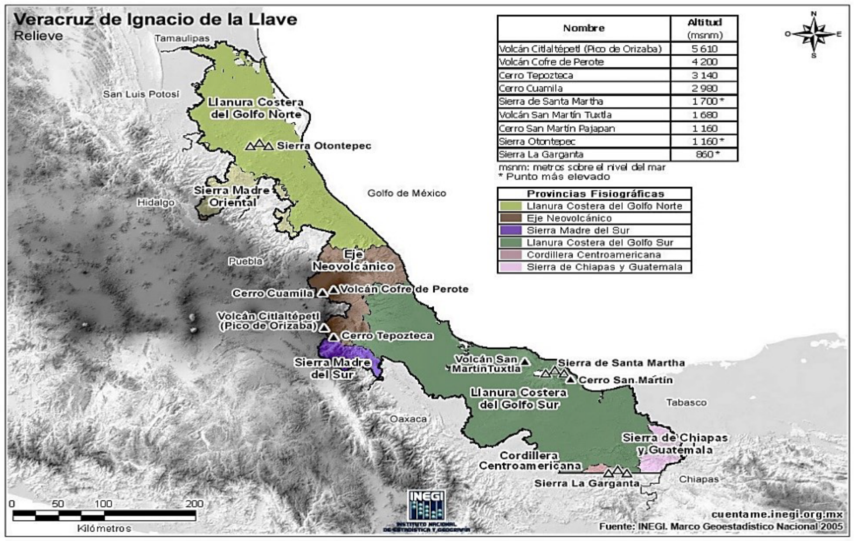
- Sustainability as property: "When its approach is of a positive (descriptive) type, by analyzing the capacity of agrarian systems to satisfy specific needs through time, interpreting a system as sustainable where the economic (income, socioeconomic stability), social (equity, coverage of basic needs), and environmental (protection of ecosystems or regeneration of natural resources) objectives reach acceptable values for the entire society".

The objective of the study was to evaluate the sustainability in conventional Persian lime production, using the framework for the evaluation of management systems of natural resources incorporating sustainability indicators (MESMIS). It is essential to conduct sustainable agricultural production of Persian lime, which is why the evaluation of sustainability in the economic, social and environmental spheres will allow identifying that its production in the conventional system is partially sustainable. The evaluation of sustainability has become one of the most useful tools to make the concept of sustainable development operative. Although not all the evaluations take into account the same principles, it is important to be clear about the objectives to be reached in order to design or base it on the most adequate objectives for the environment required (Prieto, 2011).

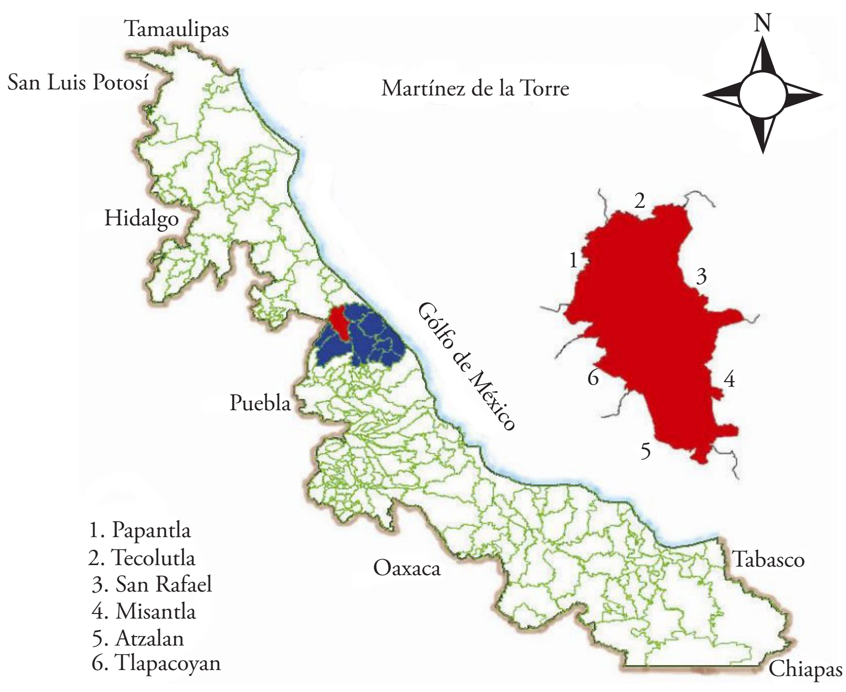
MATERIALS AND METHODS

Description of the study site

The state of Veracruz is located in the center-east of the Mexican United States, on the Gulf of Mexico coast. It has 212 municipalities and according to the population and Housing Census by the National Statistics and Geography Institute (INEGI, 2020) Veracruz has abundant water resources, the largest surface of grasslands, and an extensive coast on the Gulf of Mexico, which place it as the second state that contributes most to the agriculture, livestock and fishing wealth of the country, since in any of the sub-sectors it stands out. The state is leader in sugarcane (*Saccharum officinarum*), orange (*Citrus sinensis L.*), pineapple (*Ananas comosus*) and maize grain (*Zea mays*) production. Products such as Persian lime (*Citrus latifolia Tanaka*) and coffee (*Coffea*) are recognized internationally due to their quality and exported to more than 20 countries in the world (INEGI, 2020).
The most important municipalities of the state in agricultural production are: Tres Valles, Playa Vicente, Álamo Temapache, Coatepec and Isla; and when it comes to the production of Persian lime, the following: Atzalán, Cotaxtla, Cuitláhuac, Carrillo Puerto, Martínez de la Torre, Misantla, San Rafael, Tlapacoyan and Papantla (INEGI, 2011), (Figure 1).
The municipality of Martínez de la Torre is located in the northern zone of the state, on coordinates 20° 04' of latitude North and 97° 04' of longitude West, at an altitude of 151 meters above sea level. It limits north with Tecolutla, Papantla and San Rafael, east with Nautla and Misantla, south with Atzalán, Misantla and Tlapacoyan, and west with Papantla and the state of Puebla; it has a surface of 815.13 Km^2 and occupies 1.07 percent of the territory of Veracruz. It is located at an approximate distance of 101 Km from Xalapa, capital of the state of Veracruz (Ayuntamiento de Martínez de la Torre, 2019), (Figure 2).



Source: Prontuario de Información Geográfica Municipal de los Estados Unidos Mexicanos, 2019.
Figure 1. Map of the Municiaplity of Martínez de la Torre.



Source: prepared by the authors from field research, 2020.
Figura 2. Sustainability indicators.

The study zone is made up by conventional Persian lime producers, from the municipality of Martínez de la Torre in the state of Veracruz.

Research and sampling techniques

With regards to the research technique, a survey was used since it allows obtaining the data in the most efficient manner in a specific population, through the questions directed at the study subjects (López and Fachelli, 2015). Obtaining the data was done through the research instrument, which was the questionnaire; likewise, the interview technique with key producers from the municipality of Martínez de la Torre was applied, which allowed obtaining information about the establishment of the crop, and similarly was direct observation was a fundamental pillar in the research.

To determine the size of the sample, sampling was done by bi-stage conglomerate (Table 1), which consists in two phases, the first of which was the sample called localities formed by the primary units selected from the "stratum" population.

Each primary locality is in turn divided into smaller units called secondary localities (Table 2), where the size of the conglomerates is represented by the number of Persian lime producers from the municipality of Martínez de la Torre, according to which the result of the sample size was 49 producers.

Indicators, attributes and dimensions

The methodology used to calculate indicators, attributes and dimensions, as mentioned before, was the framework for the evaluation of natural resource management systems incorporating sustainability indicators (MESMIS). This constitutes an innovative tool to

Table 1. Phase I. Conglomerates selected.

Localities	Number of producers	Surface (ha)
Arroyo Blanco	90	397
Salvador Díaz y Mirón	61	185
La Piedrilla	47	232
Zapote bueno	13	48

Source: prepared by the authors with Epidat 4.2 software, 2020.

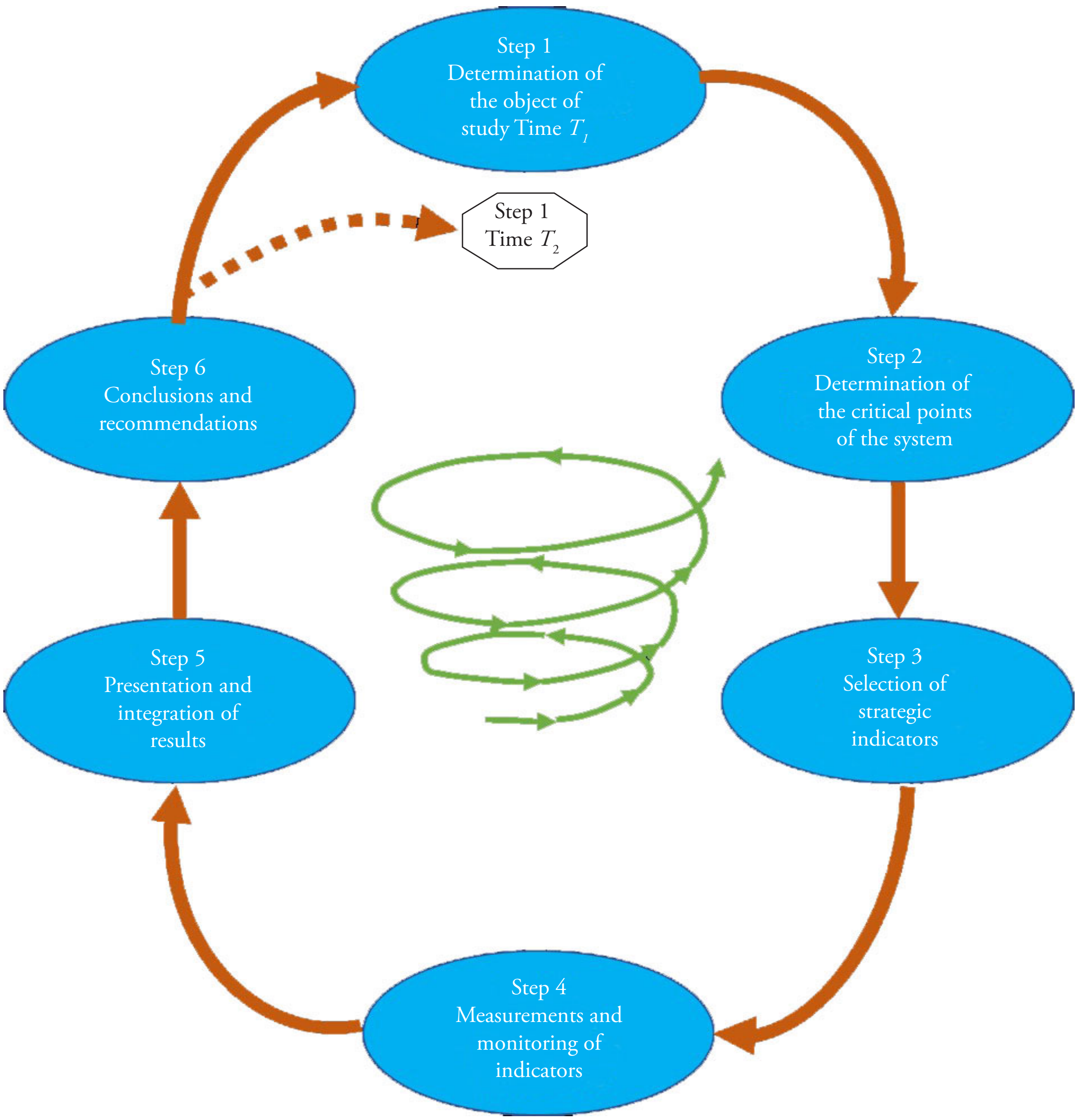
Table 2. Phase II. Number of producers selected by community**.**

Localities	Number of farmers interviewed
Arroyo Blanco	13
Salvador Díaz y Mirón	19
La Piedrilla	10
Zapote bueno	7
Total	49

Source: prepared by the authors with Epidat 4.2 software, 2020.

face several of the questions suggested in the evaluation area of sustainability since its objective is to evaluate the sustainability of different natural resource management systems at the local scale (community, farm, plot), from identifying critical points that are key to defining criteria and indicators, since they reflect the degree of sustainability of the system; this evaluation includes six steps (Figure 3), (Masera, *et al.*, 2005; Masera, *et al.*, 2008).

1) Determination of the object of evaluation. The characterization of the system was carried out through field visits to the different conventional Persian lime production units,



Source: Masera *et al.*,1999.
Figure 3. Evaluation cycle.

which allowed obtaining information on the conventional techniques that are used. In the municipality under study, the lime crop is established as monocrop, although some producers have trees in their plots such as cedar (Cedrela odorata L), avocado (Persea americana Mill), mango (Mangifera indica L), zapote (Manilkara zapota), in addition to fruit trees for self-supply and as a barrier to limit plots providing double benefit. It should be highlighted that most of the establishment of Persian lime production is done through hired workforce, which is why family participation is lower. Another point of utmost importance is that most of the Persian lime production goes to the international market, with the main commercial partners being the United States, Europe and Japan, thus being positioned as the citrus capital.

2) Identifying the critical points of the management system. This step implied the recognition of positive and/or negative aspects of the system in time. The critical points of the system were obtained in the first visit through direct observation and the interview with key people, which allowed identifying the strengths and/or weaknesses of the production system.

3) Selecting strategic criteria and indicators. The diagnosis criteria were determined and the most significant indicators were derived based on the above information. In relation to the study area, the social, economic or environmental aspects were evaluated. The diagnosis criteria described the general attributes of sustainability, that is, they constitute the necessary link between attributes, critical points and indicators. This process is supported with the review of similar studies and with field information through the application of the semi-structured questionnaire. For this study, 14 indicators were selected (Table 3).

4) Measuring and monitoring the indicators. Once the summary table with the final list of environmental, economic and social indicators was obtained, the procedure that will be used for measuring and monitoring was discussed. In this stage, the measuring instrument was designed for each indicator according to the methodology attributes (MESMIS). It should be mentioned that once the sustainability indicators were selected, the next step was the field information, thus obtaining the information from each Persian lime producer.

5) Integration of results. In this stage of the evaluation cycle, the results obtained from monitoring the indicators must be summarized and integrated through the AMIBA graph. The indicators were analyzed through descriptive statistics, using the IBM software Statistical Package for Social Science (SPSS), Version 25. Arithmetic means and standard deviation were also used.

6) Conclusions and recommendations. The first objective of this last step of the evaluation cycle is to present a series of clear conclusions regarding the management systems analyzed. For this purpose, the valuation must be particular; that is, of the type: "the system seems to be more sustainable in certain indicators and attributes of sustainability, but problematic or less sustainable in others".

RESULTS AND DISCUSSION

Analysis of the sustainability indicators

Attribute: Productivity

a)Persian lime yield: For this indicator the total production in a hectare of Persian lime was considered, in a period of one year (year 2020). The maximum yield value obtained

Table 3. Indicators for the analysis of the evaluation of sustainability in Persian lime production in Martínez de la Torre, Veracruz.

Attribute	Diagnostic criteria	Indicators	Areas of evaluation	Measurement
Productivity	Efficiency	Lemon yield	E	Performance index per ha
		Benefit/Cost Ratio	E	Ratio B/C
		Production	E	Production rate per ha
Stability; resilience; reliability	System fragility	Pest and disease control	A	Types of control for pests and diseases
	Resource conservation	Conservation practices	A	Opinion on conservation practices
		Management of natural resources	A	Opinion care of natural resources
		Vegetative diversity index	A	Type of vegetative species and use in the agricultural plot
	Risk distribution	Access to credits	E	Opinion for credit application
	Permanence	Degree of satisfaction of producers with the system	S	Level of satisfaction of producers
Adaptability	Strengthening the learning process	Technical training	S	Opinion on the trainings
Equity	Distribution of costs and benefits	Job creation	S	Number of wages
		Family participation in agricultural work	S	Field activities carried out by family members
Self-dependence (self-management)	Self-sufficiency	Dependence on external inputs	E	Dependence on external inputs
	Organization	Organization level	S	Organizations in the community

Source: prepared by the authors, 2020.

in the municipality of Martínez de la Torre was 30 tons per hectare, although the average production obtained from the application of 49 surveys was 18 tons.

Benefit/Cost Ratio

To obtain the result from the benefit/cost indicator, the following equation was implemented,

$$B / C = \frac{\text{Total revenus}}{\text{Total costs}} \quad (1)$$

where *B*: benefit, *C*: cost.

This indicator is obtained by dividing the total income of the production system by the total costs. In relation to the cost, it was estimated through the analysis of all the costs implicated in Persian lime production, considering land rental and the costs for the maintenance before production in a period of one year and the maintenance expenses in production phase; it is important to point out that the cost of investment per tree is $94 MX pesos on average.

To calculate the income, the total of tons per hectare from the communities surveyed was considered; on average, a hectare of Persian lime has a yield of 18 tons, at a rate of 422 plants. The average price obtained was $7,000 per ton; the price in Martínez de la Torre stays in constant change during the year, although the best prices are obtained in the winter period. Once the costs and the benefits were obtained, the benefit/cost ratio was calculated (Table 4). Considering the cost with rental/without rental, the conclusion is reached that for each peso invested the producer obtains a benefit cost of $3.03 MX considering rental, and $3.36 MX without rental. This indicator proves that the Persian lime production in Martínez de la Torre is economically profitable.

b) Production: It is obtained through the total production yield per year, which was 18 (ton) and per surface harvested, obtained from the study population which was on average six hectares. The production of reference was the maximum value found in the municipality of Martínez de la Torre, and a producer obtains 108 (ton) per year on average in a surface of six ha.

Attribute: Stability, reliability and resilience

a) Control of pests and diseases: Table 5 shows the main pests and diseases detected; 100 percent of the Persian lime producers expressed that they control them with agrichemicals,

Table 4. Benefit/Cost Ratio.

	Ratio B/C		B/C
	Costs	Benefit	
With rent	41,528	126,000	3.03
No rent	37,528	126,000	3.36

Source: prepared by the authors from field research 2020.

Table 5. Pests and diseases in the Persian lime crop.

Pests	Diseases
Spider mite (*Tetranychus urticae*)	Gummy (*Phytopthora parasítica* Dastur)
White mite (*Polyphagotarsonemus latus* Banks)	Gummy (*Diaporthe citri* Wolf)
Citrus plougher (*Phyllocoptruta oleivora*)	Antracnosis (*Colletotrichum acutatum* J.H. Simmonds)
Leaf miner (*Phyllocnistis citrella* Station)	Greasy stain (*Mycosphaerella citri* Stenella)
Aphid (*Aphis citrícola* Van der Goot)	
Diaphorina (*Diaphorina citri* Kuw.)	
Snow Scale (*Lepidosaphes gloverii* Pack.)	

Source: prepared by the authors from field research, 2020.

where three fumigations per year are necessary, applying a large variety of products such as fungicides, insecticides and acaricides, depending on the pest or disease that is detected. The producers are committed to avoiding an outbreak of pests, because it is the sole sustenance for the family. It is essential to highlight the damage that the use of pesticides causes when entering in contact with humans through all the possible exposure paths: respiratory, digestive and dermic, since these can be found in function of their characteristics, in the air inhaled, in the water, and in foods, among other environments (del Puerto Rodríguez *et al*., 2014).

b) Conservation practices: The practices for conservation of natural resources, such as natural fertilizer (animal or plant manure), green fertilizer sowing, establishment of agricultural barriers, sowing trees in deforested areas, and capturing rainwater are of great importance, since this way a sustainable management plan in Persian lime production could be carried out. However, in Martínez de la Torre producers are not trained to implement a sustainable agricultural production system, and 86 percent indicated that they do not conduct any practice for the conservation of natural resources. When it comes to the results (Table 6), it is observed that the average is 1.23, with a standard deviation of 0.602, indicating that very little is being done as conservation practices. It can be observed that

Table 6. Descriptive statistics of the practices of resource conservation.

Natural resource conservation practices	Minimum	Maximum	Mean	Standard deviation	*Evaluation
	Statistical	Statistical	Statistical	Statistical	
Application of natural fertilizer	1	3	1.18	0.527	Very little
Fertilizer planting of green	1	3	1.27	0.670	Very little
Manures establishment of agricultural barriers	1	4	1.35	0.779	Very little
Planting trees in deforested areas	1	3	1.20	0.456	Very little
Rainwater harvesting	1	4	1.14	0.577	Very little
Average	1	3.4	1.23	0.602	Very little

Source: prepared by the authors from field research, 2020.
*Note: the evaluation was characterized in the following way: 0.00-0.99 = nothing; 1.00-1.99 = very little; 2.00-2.99 = little; 3.00-3.99 = much; 4.00-4.99 = sufficient.

the practice of establishment agricultural barriers stands out with a statistical mean of 1.35 and standard deviation of 0.770, which indicates that if this practice were used by most of the producers, it could be the most beneficial for the conservation of natural resources. Finally, the conservation practices of natural resources are not frequently established.

c) Management of natural resources: This indicator is established through the opinion of producers about the care of natural resources such as water and soil. The Persian lime producers consider that water is a scarce resource, which is why they take care of it sufficiently; when it comes to the soil, they consider that fewer herbicides are being applied and more labor is being hired to clean weeds that grow naturally. Table 7 shows that the mean is 4.30 with a standard deviation of 0.610, which indicates that Persian lime producers in Martínez de la Torre care sufficiently for the natural resources such as water and soil.

d) Vegetative diversity index: The Persian lime crop is a monocrop. However, 88 percent of the producers indicated that they have trees around the plot, resulting in a benefit for self-supply, in addition to being used for shade. Among the species there are cedar (*Cedrela odorata* L), avocado (*Persea americana Mill)*, mango (*Mangifera indica L*), zapote (*Manilkara zapota*), fig (*Ficus carica L*), bamboo (*Bambusoideae*), black pepper (*Piper nigrum*) and oak (*Quercus*). When it comes to the plant species that grow in the plots, 92 percent indicated that they are eliminated with manual tools such as “hoe, machete and de-weeder”, and with herbicides.

e) Access to credit: In the surveys applied with Persian lime producers, 100 percent pointed out that they have not requested credits, since access and negotiations to obtain them are very complicated. When it comes to the need for obtaining a credit, all the producers indicated that backing is important since it would be reflected in higher profitability in Persian lime production and credit would be used for inputs and implementation of technology f) Degree of satisfaction of producers with the system: Persian lime producers from Martínez de la Torre consider that production of the crop is sufficiently profitable, finding 100 percent satisfaction; the income obtained from this production is enough to cover their main needs such as food, housing, education, clothes, shoes and recreation.

Attribute: Adaptability

a) Technical training: Technical training is essential for Persian lime production, and this is why technical training, assistance and counsel are considered important requirements in

Table 7. Descriptive statistics of natural resource management.

Natural resources	Minimum	Maximum	Mean	Standard deviation	Assessment
Soil	3	6	4.22	0.654	Sufficient
Water	3	6	4.37	0.566	Sufficient
Average	3	6	4.30	0.610	Sufficient

Source: prepared by the authors from field research, 2020.
*Note: the evaluation was characterized in the following way: 0.00-0.99 = nothing; 1.00-1.99 = very little; 2.00-2.99 = little; 3.00-3.99 = much; 4.00-4.99 = sufficient.

their production, since with training the producer can achieve the control and adequate management of their plantations. This indicator was measured through three conditions: producers without training, producers with training, and institutions that provide technical assistance.

In the surveys applied, 88 percent indicated not having received any training for the management of Persian lime, and only 12 percent has ever received training, through the Agrotechnical service found in the municipal township; however, the training that producers require is in the management of pests, diseases and fertilization, yet only those who have an agreement with packinghouses receive training every three months.

Attribute: Equity

a)Employment generation: Employment generation is primordial in the productive process, and it is measured through the number of workdays that participate in the productive process. Day laborers carry out activities such as fertilization, application of herbicides and harvesting. It is important to highlight that the community that uses the most workdays is Salvador Díaz y Mirón (Table 8), representing 43 percent of the total, and this is because they are not applying herbicides and using more labor for weeding; in second place, the community of Arroyo Blanco with 26 percent of hiring day laborers.

b) Family participation in agricultural tasks: This indicator is crucial for the productive process, since this is how generational change around is guaranteed, where family heads of household transfer their knowledge to their children. However, in the surveys applied family participation is 10 percent and in combination with day laborers they represent 51 percent; just the day laborer represents 49 percent of the total, indicating the highest degree of participation in the Persian lime production process. In addition, in the farming tasks women have low participation, only 14 percent of the women carry out some management practice, such as reconditioning the land, planting, applying agrichemicals, managing the crop (pruning), and harvesting, and only 37 percent of the family men participate in agricultural tasks.

Attribute: Self-dependency

a) Dependency on external inputs: The dependency on external inputs is an essential indicator in the productive process of Persian lime. All of the producers (100 percent)

Table 8. Employment generation.

Communities	N° of jobs	%
Salvador Díaz y Mirón	468	43
Arroyo Blanco	288	26
La Piedrilla	195	18
Zapote Bueno	137	13
Total	1088	100

Source: prepared by the authors from field research, 2020.

indicated that they are dependent on the inputs of agrichemical origin, such as fertilizers for soil and leaf, herbicides, fungicides, insecticides and acaricides; these inputs are imports and they are necessary for the production of Persian lime. When it comes to the plants, there are those that are certified and those that are not; they are traded in nurseries of the municipality Martínez de la Torre, their valuation ranges from 12 pesos MX in non-certified plants to 35 pesos MX for certified plants.

b) Level of organization: The producers in their totality declared not belonging to any organization that improves the management of trade, production and inputs.

Integration of the sustainability indicators

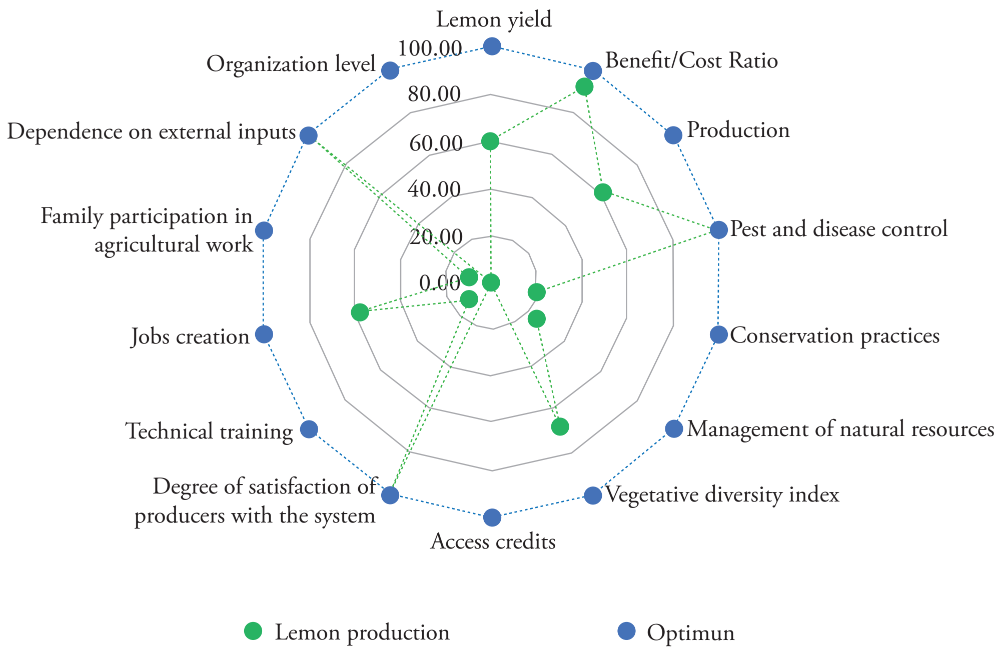
Once the 14 sustainability indicators were analyzed, their integration was started considering the attributes and the areas of economic, environmental and social evaluation, and each indicator was analyzed with regards to the optimal value (Table 9). Then, the indicators were integrated into the graph (AMIBA), which reflects the strongest found in the optimal point and the weakest that are near the center of the radial graph.

Figure 4 shows the indicators that most approach the optimal, with these indicators being the strongest: yield, benefit-cost ratio, production, incidence of pests and diseases, vegetative diversity index, degree of satisfaction of producers, employment generation, and dependency on external inputs. When it comes to the weakest indicators present, they are: natural resources conservation practice, management of natural resources, access to credit, technical training, family participation in agricultural tasks, and level of organization. It should be highlighted that the economic area was the one most strengthened, followed by the environmental area, while the weakest area according to the results obtained from the sustainability evaluation is the social one.

Table 9. Values of sustainability indicators.

Attribute	Indicators	Optimum	%	Value obtained	%	Evaluation areas
Productivity	Lemon yield	30.00	100	18.00	60	E
	Benefit/Cost Ratio	3.30	100	3.03	92.04	E
	Production	176	100	108	61	E
Stability; resilience; reliability	Pest and disease control	100	100	100	100	A
	Conservation practices	100	100	20	20	A
	Management of natural resources	100	100	25	25	A
	Vegetative diversity index	100	100	68	68	A
	Access to credits	100	100	0.00	0.00	E
	Management of natural resources	100	100	100	100	S
Adaptability	Technical training	100	100	12	12	S
Equity	Job creation	468	100	272	58	S
	Family participation in agricultural work	100	100	10	10	S
Self-dependence (self-management)	Dependence on external inputs	100	100	100	100	E
	Organization level	100	100	0.00	0.00	S

Source: prepared by the authors from field research, 2020.



Source: own elaboration of field research 2020.
Figura 4. Sustainability indicators.

DISCUSSION

For a production system to maintain a balanced or near-balanced relationship in the evaluation areas of sustainability, it is necessary to provide technical training and backing (inputs) to producers, or else to strengthen the areas that present most weakness after being evaluated, with the aim of ensuring the profitability of the crop through time.

Such is the case of the study by López *et al.* (2019), carried out in the state of Oaxaca, Papaloapan region, which had the study object of evaluating the competitive performance of producers of that region in lime growing; results showed that only 33.3 percent of survey respondents answered that they had received technical assistance through agrichemical companies, while for the benefit/cost indicator they obtained on average 1.87, concluding that the profitability obtained will depend on the type of producer (small, medium or large). Something similar happened with the study carried out in Martínez de la Torre (2020), since when comparing the same indicators, technical training and benefit/cost, it showed that both studies found a low level of technical training regardless of the agency that imparts them; the result in Martínez de la Torre for the first indicator was 12 percent, while for the second indicator it resulted in a cost/benefit of 3.03, with this last result showing a higher profit margin than the study by López, since for each peso invested, the benefit/cost in the profit is tripled.

Finally, it was found that both studies are related by the production of Persian lime which proves to be economically profitable independently of the state where it is conducted. It should be highlighted that these production systems were not evaluated under the same methodology, showing that the identification and measurement of indicators will ensure showing the nearest approximation to the sustainability of a productive system in reality.

CONCLUSIONS

The evaluation of sustainability is primordial to identify the interactions in evaluation areas such as the economic, social and environmental, since if there is a balance between them it can be concluded that it is a sufficiently productive, economically viable, socially acceptable, and environmentally sustainable agroecosystem in the local, regional and global sphere, which will manage to ensure the future of the next generations. Given what was studied, the methodological consideration is definitive to obtain the results, when we refer to evaluating the sustainability in productive systems.

In relation to the indicators measured, the conclusive results for each area evaluated were: the economic area was the one most strengthened, even when there are no credits for their production, and because in one hectare a producer can obtain up to 40 tons. However, for an entire year the production has a fluctuating price, although this can help to obtain an economically acceptable benefit/cost.

Regarding the environmental evaluation area, Persian lime producers carry out the conservation practices of natural resources very scarcely, this being a fundamental indicator to ensure the conservation of resources; however, when it comes to diversity of species, whether fruit trees or timber trees, most declared having them which provides a direct benefit in self-supply.

For its part, the social evaluation area was the weakest, which derived to a large extent from the lack of technical training, low family participation, especially women's integration into agricultural practices, and the lack of organization as a community. As can be inferred, sustainability in Persian lime production in Martínez de la Torre is partially sustainable and economically viable, although there are weaker areas to address such as the environmental and social areas, for it to be possible to reach sustainable equilibrium and in this way for it to be sustainable in time. Caring for natural resources and social integration is crucial to ensure the future of the next generations and thus achieve sustainable agricultural development.

Finally, considering that the Persian lime production system in Martínez de la Torre has the potential to implement agriculture that is friendly with the environment; changing the type of production, that is, to organic production, could guarantee better fruit quality, higher yield per hectare, and a better care of natural resources. Organic agriculture should ensure food security for people, and at the same time support the sustainable management of the land, water and natural resources.

REFERENCES

Andrade FH. 2016. Los desafíos de la agricultura. (1a ed). (I. P. Institute, Ed.) Recuperado en febrero de 2021, de https://inta.gob.ar/sites/default/files/inta_los_desafios_de_la_agricultura_fandrade.pdf

Ayuntamiento de Martínez de la Torre. 2019. Martínez de la Torre 2018-2021. Obtenido de https://www.martinezdelatorre.gob.mx/municipio/historia/

INEGI (Instituto Nacional de Estadística y Geografía). 2020. Instituto Nacional de Estadística y Geografía. Obtenido de https://www.inegi.org.mx/datos/. 20 de febrero de 2020

Leff E. 2018. Pensar la complejidad ambiental. 7-53. Obtenido de https://www.researchgate.net/publication/328653293_PENSAR_LA_COMPLEJIDAD_AMBIENTAL

López Hernández WGB. 2019. Competitividad del limón persa en la región del Papaloapan, Oaxaca. Revista Mexicana de Ciencias Agrícolas, 15. Recuperado el 23 de Febrero de 2021, de https://cienciasagricolas.inifap.gob.mx/editorial/index.php/agricolas/article/view/408

López RP, Fachelli S. 2015. Metodologia de la Investigación Social Cuantitativa. Barcelona: Bellaterra. Recuperado en 2020, de http://ddd.uab.cat/record/129382

Martínez BL, Bello RP, Castellanos DÓ. 2012. Universidad Nacioanl de Colombia. Obtenido de Repositorio institucional Biblioteca digital: https://repositorio.unal.edu.co/handle/unal/10045. 29 de junio de 2012.

Masera O, Astier M, López S. 2005. Sustentabilidad y sistema campesino: cinco experiencia de evaluación en el México Rural. México: Mundiprensa,GIRA/Programa universitario de Medio Ambiente/Instituto de Ecología-UNAM,México. Obtenido de http://www.mesmis.unam.mx/

Masera O, Astier M, Lopez-Ridaura S, Galván-Miyoshi Y, Ortiz-Avíla T, García-Barrios LE, Speelman E. 2008. Sección I. La experiencia del marco MESMIS. En M. Astier, M. O. R., & Y. Galván-Miyoshi, Evaluación de sustentabilidad. Un enfoque dinámico y multidimensional. España: SEAE, CIGA, ECOSUR, CIECO, UNAM, GIRA, Mundiprensa, Fundación Instituto de Agricultura Ecológica y Sustentable. Obtenido de https://www.ciga.unam.mx/publicaciones/index.php/component/abook/book/12-coleccionesciga/12-evaluacion-de-sustentabilidad. 200 p.

ONU (Organización de las Naciones Unidas). 2020. Programa 21: Fomento de la Agricultura y del Desarrollo Rural Sostenibles. Obtenido de Departamento de asustos economicos y sociales - División de desarrollo sostenible: http://www.un.org/spanish/esa/sustdev/agenda21/agenda21spchapter14.htm. 25 de Noviembre de 2020.

Prieto EA. 2011. Recuperado el 23 de Noviembre de 2019, de http://oa.upm.es/9036/1/TFM._Esperanza_Arn%C3%A9s.pdf

Puerto Rodríguez AM. 2014. Efectos de los plaguicidas sobre el ambiente y la salud. Revista Cubana de Higiene y Epidemiología, 52(3), 372-387., 16. Recuperado el 23 de febrero de 2021, de http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S1561-30032014000300010&lng=es&tlng=es

Quezada UQ. 2018. Producción orgánica sostenible y su demanda en el mundo al 2030. Kuntur, 6(06), 11. Recuperado el 2020, de http://revistas.udaff.edu.pe/index.php/kuntur/article/view/40

Sarandon S. 2009. Evaluación de la sustentabilidad en Agroecosistema: Una propuesta metodológica. Agroecologia 4. Obtenido de https://revistas.um.es/agroecologia/article/view/117131

SIAP (Servicio de Información Agroalimentaria y Pesquera). 2018. Zumo de limón, zumo de bendición. Recuperado el 25 de 11 de 2020, de Gobieno de México: https://www.gob.mx/siap/es/articulos/zumo-de-limon-zumo-de-bendicion?idiom=es. 07 de 11 de 2018

SIAP. 2020. siap.gob.mx/gobmx. Obtenido de https://nube.siap.gob.mx/cierreagricola/. 28 de Octubre de 2020.