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Article

Sustainability in prickly pear production in San Pablo Xúchil, Axapusco

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Abstract

The research aims to analyze the traditional and conventional production systems of prickly pear (*Opuntia albicarpa*) to identify their current sustainability, as well as the social, environmental, and economic relevance that this crop represents for the community. In the eastern region of the state of Mexico, several municipalities stand out for their deep-rooted tradition in the production of prickly pear. In the locality of San Pablo Xúchil, this activity has taken on a central relevance, not only economically, but also culturally. Nonetheless, production has been questioned in terms of its sustainability due to the adoption of practices that are harmful to the environment: monoculture and intensive use of agrochemicals. A questionnaire was applied to 44 prickly pear producers with the framework for the evaluation of natural resource management systems, incorporating sustainability indicators. Fifteen indicators were analyzed with the following dimensions: environmental, economic, and social. The results obtained show that both systems need to increase their sustainability, as a result of weak organization, low training, and high use of agrochemicals.

Keywords:

Opuntia albicarpa, community, MESMIS, sustainable development.

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Introduction

The production and use of prickly pear (*Opuntia albicarpa*) dates back to pre-Hispanic times in documents from the sixteenth century. Fray Bernardino de Sahagún in 'The general history of the things of New Spain', mentions how the Aztecs used nopales and prickly pears, their purposes, their physical and organoleptic characteristics, in a tree called *Nopalli* (Vela, 2019) and it is part of the biological legacy (Rzedowski, 2006).

Today, it continues to be an essential element in the life of many communities, not only because of its economic importance, but also because of its symbolism of identity and Mexicanity. Thus, the prickly pear not only represents agricultural development, but it also enriches the culture and heritage of the communities that grow it (Berber *et al*., 2012).

Some studies (Callejas *et al*., 2009; Berber *et al*., 2012; Ramírez *et al*., 2015; Domínguez *et al*., 2017) indicate that the production of prickly pear is economically profitable. However, they show vulnerability of the ecosystem, problems of soil degradation, technological dependence, and application of agrochemicals.

Producers face different situations that prevent them from adopting a more sustainable management of resources, largely due to the diversity of the existing production systems; some producers are characterized by the intensive use of agrochemicals and modern technologies to maximize production (conventional), whereas others use traditional techniques, prioritize reducing the ecological impact and the balance with natural resources, avoiding the use of agrochemicals (Berber *et al*., 2012).

Both prickly pear production systems play an important role. The traditional one, considered as a point of reference or guide for the development of other systems (Francis *et al*., 2003), is rooted in ancestral practices, such as the transmission of inherited techniques, pest control with natural methods, and incorporation of organic fertilizers. The conventional one incorporates new techniques, such as the application of synthetic fertilizers and pesticides, technified irrigation, and the use of specialized machinery, based on promoting productivity (Gliessman, 2002).

These forms of production are developed together, keeping the regional cultural identity alive. Therefore, to understand the vulnerability of prickly pear production systems, the concept of sustainability is taken, which focuses on the interaction of the environment with the economy and the social sphere (Amato, 2019), with the promotion of equitable relations between generations (Foladori, 1999), it considers the availability and durability of resources to meet the needs of the present without compromising the capacity of future generations (Bifani, 1999).

The studies focus on the economic viability and production of the crop, leaving aside the social and environmental importance. Ramirez *et al*. (2015); Domínguez *et al*. (2017); Hernández-Bonilla *et al*. (2020) investigated the economic importance of the prickly pear in the municipalities of Nopaltepec and Axapusco, the profitability of the crop, whereas other authors (Berber *et al*., 2012; Gallegos *et al*., 2013) analyze production.

The lack of social studies on prickly pear production limits the comprehensive understanding of its impact. Although economic and production reports provide valuable data on crop profitability and efficiency, it is essential to develop research that addresses social, cultural, and environmental aspects.

In this context, this research analyzes the sustainability of the traditional and conventional prickly pear production systems in San Pablo Xúchil, Axapusco, State of Mexico, identifies its current situation and the importance it has for the community, and proposes alternatives to improve the sustainability of the systems.

Materials and methods

The study area is San Pablo Xúchil, Axapusco in the east of the state of Mexico. It is located 16.1 km from the municipal capital, in a northwesterly direction (H. Ayuntamiento de Axapusco, 2022).

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Fifty point zero six percent of its territory is used for agriculture, mainly rainfed crops (fodder oats, white grain corn, beans, sorghum), 22.1% for livestock activities and 21.82% for forestry and grazing (Secretaría del Campo, 2023).

The study population is 52 prickly pear producers, which was obtained from the register of producers in the community. The sample consists of 44 farmers: 16 producers in a traditional way and 28 conventionally, which were selected by simple random sampling (Santos *et al*., 2003); information is obtained through the mixed approach: qualitative and quantitative (Hernández and Mendoza, 2018).

The method applied is the ethnographic method, social research techniques (Quecedo and Castaño, 2002). The quantitative method, a questionnaire (74 questions), data analyzed with descriptive statistics and frequency distribution with Excel and Rstudio programs.

The approach of sustainability and use of natural resources in prickly pear production uses the framework for the evaluation of natural resource management systems incorporating sustainability indicators (MESMIS, for its acronym in Spanish), it considers the attributes: productivity, stability, resilience, reliability, adaptability, equity, and self-dependence, and allow us to analyze the changes in the quality of resources and their efficiency. Based on the evaluation, modifications are proposed to improve the level of sustainability of each component (Masera *et al*., 1999).

The following were established: general attributes, critical points, and sustainability indicators linked to the following areas of evaluation: economic (E), social (S), and environmental (En). The information obtained is integrated through a multi-criteria analysis and thus, a critical evaluation of the management systems is issued and recommendations for their improvement are offered.

Object of the evaluation: traditional and conventional prickly pear production system. The difference in their production methods considers the basic unit of analysis. The systems are analyzed on a cross-sectional scale, comparing both systems. Based on the data obtained with the questionnaire applied, critical points of the system that limit or strengthen prickly pear production were identified (Table 1).

Table 1. Critical points of the prickly pear produc on system.

Attributes	Critical points
Productivity	Increased production costs Low crop yield
Stability, resilience, reliability	Degraded natural resources Excessive use of agrochemicals Growing interest from new generations
Adaptability	Availability of resources Resistance to the adoption of new ways of producing Low or no training for producers
Equity	Evolution of jobs
Self-management	Dependence on external inputs Little or no community organization

Selection of diagnostic criteria and strategic indicators

These criteria describe the general attributes of sustainability, connect critical points with indicators, and must consider economic, social, and environmental dimensions. Table 2 shows the attributes, diagnostic criteria and indicators, their form of measurement, and the dimension to which they belong.

Table 2. Diagnostic criteria and strategic indicators.

Attribute	Diagnostic criteria	Indicator	Measurement	Dimension
Productivity	Efficiency	Crop yield	Number of t ha^{-1} produced	E
	Profitability	B/C ratio	Cost/benefit analysis	E

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Attribute	Diagnostic criteria	Indicator	Measurement	Dimension
Stability, resiliency, and reliability	Caring for system resources	Ethics in the management of natural resources Conservation practices Ethics in the use of agrochemicals	Opinion on environmental damage Opinion on conservation practices Opinion on the damage from the use of agrochemicals	En En En
	System fragility	Use and transmission of traditional practices Incidence of pests	Transmission of local knowledge to new generations Opinion on the evolution of pest damage	S En
Adaptability	Strengthening the learning process. Capacity for change and innovation	Training Willingness to change	Opinion of the training of prickly pear producers. Opinion on adapting production changes	S S
Equity	Socioeconomic vulnerability	Main income-generating activity Income usage Evolution of jobs	(%) of income provided by the sale of prickly pear. Income use opinion. Number of daily wages required by the system	E S E
Self-management	Self-sufficiency and organization	Dependence on external inputs Community Organizing Self-financial capacity	Opinion on dependence on chemicals and inputs and external money Opinion on the organization for prickly pear production and sale (%) of producers who finance their production	En S E

Masera *et al*. (1999).

Results and discussion

Based on the indicators, strengths and weaknesses were identified in the conventional and traditional prickly pear production systems in San Pablo Xúchil, which are presented below.

Productivity

Crop yield. Its measurement considers the maximum production, 25 t ha^{-1} in the conventional system and 16 t ha^{-1} in the traditional system. The average production is 19.96 t ha^{-1} (conventional) and 11.2 t ha^{-1} (traditional). Conventional production (79.84%) shows greater efficiency in terms of gross yield compared to traditional production (70.5%).

Benefit/cost ratio. It integrates average expenses generated in the production of prickly pear per ha during a season (April-July), mainly daily wages and input used. The total costs in conventional ($24 544.00 MXN) and traditional ($13 978.00 MXN) production make up the average profit ($58 300.00 MXN conventional, $30 600.00 MXN traditional).

Costs in the conventional system increase due to the intensive use of inputs. Traditional benefit/cost ratio is 2.19, indicating that for each peso invested, they earn 2 pesos and 19 cents when marketing the production; conventional 2.36, it means that for each peso invested, they earn 2 pesos and 36 cents. In their studies of the profitability of prickly pear cultivation, Callejas *et al*. (2009); Jolalpa *et al*. (2011); Domínguez *et al*. (2017) agree that the benefit-cost ratio is 3.16.

When comparing this value with data obtained, conventional production presents 75.94%, whereas traditional production reaches 69.3%, indicating the level of profitability of each method.

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Stability, reliability, and resiliency

Ethics in the management of natural resources. Prickly pear producers' perception of the environmental impact is due to monoculture and the use of agrochemicals; it is reported as negative. There is knowledge about the adverse effects that these agricultural practices generate on the environment.

Conservation practices. The excessive use of agrochemicals is the main problem faced by the conventional production system, aggravated by a lack of conservation practices: incorporation of organic matter, living barriers, omission of soil tillage. In this system, 7% of producers adopt conservation actions; and in the traditional one, all producers develop sustainable practices to mitigate the effects of monoculture, reflecting a more responsible approach to the natural environment.

Ethics in the use of agrochemicals. Prickly pear production involves agricultural practices that are harmful to the environment, use of agrochemicals. Producers were asked about the environmental damage it causes them, they perceive the damage to the soil and pest resistance.

The average of each aspect evaluated in Tables 3 and 4 was calculated with the ecological sensitivity. Questions evaluated with the rating: 0-0.99 not at all; 1-1.99 very little; 2-2.99 little; 3-3.99 a lot; 4-4.99 too much.

Table 3. Ecological sensitivity: conventional producers.

Aspect assessed	Min	Max	Mean	Typical error	Standard dev.	Evaluation
Chemical fertilizer	1	5	2.6	0.678	1.517	Little
Herbicides	1	5	3	0.707	1.581	A lot
Pesticides	1.5	3.5	3.1	0.40	0.894	A lot
Fungicides	1	5	3	0.707	1.581	A lot
Acaricides	2	4	3	0.44	1	A lot

Ecological sensitivity =2.6+3.0+3.1+3.0+3.0 =14.7 (14.7 /5) =2.94, ecological sensitivity in percentage =(2.94*100)/5=58.8 %.

Table 4. Ecological sensitivity: traditional producers.

Aspect assessed	Min	Max	Mean	Typical error	Standard dev.	Evaluation
Chemical fertilizer	1	5	3	0.63	1.41	A lot
Herbicides	1.5	5	3.2	0.66	1.48	A lot
Pesticides	1.5	5	3.2	0.66	1.48	A lot
Fungicides	1.5	4.5	2.6	0.6	1.34	Little
Acaricides	1.5	5	3	0.63	1.41	A lot

Note: ecological sensitivity= 3.0+3.2+3.2+2.6+3.0 =15 (15/5=3), ecological sensitivity in percentage =(3*100)/5=60 %.

The ecological sensitivity obtained is 58.8%, it states concern of producers about damage caused to the environment (excessive use of agrochemicals); in practice, they are not taking measures to mitigate it. This demonstrated a lack of coherence between opinion and effective actions to conserve and protect the environment.

It is 60% in the traditional system, indicating a high ecological sensitivity. The traditional method opts for production free of chemical inputs. They carry out actions in favor of the environment in a manner consistent with their principles.

Use and transmission of traditional practices. It considers the inheritance of knowledge directly to family members. In conventional production, 94% share their knowledge with direct relatives (children) and in the traditional system, 86%. This practice not only ensures the continuity of prickly pear production but also strengthens the intergenerational bond.

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Pest incidence. In the conventional method, they assure that the appearance of pests has increased (93%), the traditional method shows a lower incidence (56%), indicating a greater resilience of practices against pests.

Adaptability

Training. In both production systems, most producers reported not receiving training. In the conventional system, 25% of producers have received training to increase production by the extension service of the state of Mexico, compared to the 12.5% in the traditional one.

Willingness to change. Producers were questioned if they made changes in their agricultural practices. It was observed that 11% of conventional producers are willing to make changes and in the traditional system, they (100%) showed resistance to modifying their production practices. In this case, the higher the value of the negative response, the more appropriate it is, which is considered inversely when making the graph.

Equity

Main income-generating activity. For both producers, the main family income is the sale of prickly pear; the conventional system reports 57% and the traditional one 69%. The importance of continuing with production is justified. In the conventional system, 18% of producers obtain their income from the sale of nopal; in the traditional one, it is lower (6%). Both systems supplement their income with other activities (employees, masons, others).

Use of income. The income allocated to labor and inputs. Conventional system, the mean of the average is 2.9, according to evaluation criteria (1-1.99 not at all, 2-2.99 little, 3-3.99 regular, 4-a lot), it indicates that the use of their income is considered low, representing 58% of the total, weakening the system. In contrast, the traditional one presents an average of 2.2, it is little (44%), the use of income towards inputs and payment of labor strengthens the system.

Evolution of jobs. Work carried out by family members and salaried day laborers in both systems. Conventional production requires more labor, an average of 5.5 days of work per season: the traditional one, an average of 4.25. The measurement takes as reference the maximum value of contracted days of work: five in the traditional system and six in the conventional one. The proportion of days of work is 85% and 91.6%, respectively.

Self-management

Dependence on external inputs. A high degree of dependence is one of the factors that most weaken sustainability. Its measurement considers the opinion of traditional and conventional producers on the dependence of their prickly pear production on the different inputs used in their production system.

In the traditional system, the mean of the average reflects a value of 3, according to evaluation criteria (0-0.99 not at all, 1-1.99 too little, 2-2.99 little, 3-3.99 a lot, 4-4.99 too much), there is dependence on external inputs, equivalent to 60%, which weakens the system. A production system with greater dependence on external inputs weakens its sustainability. In the conventional system, the meaning of the average is 3.5, indicating high dependence on external inputs (70%). This situation negatively affects the system, making it more vulnerable.

Community organization. The results obtained consider the opinion of the producers, there is very little or no community organization for the production and sale of prickly pear. The traditional system has no organization (0%), whereas in the conventional one, it is minimal (10.7%); in the field, it is observed that they are only organized for production. This is one of the indicators that substantially affects the system.

Self-financial capacity. One hundred percent of the producers of both production systems have the capacity to finance their production; through the sale of prickly pear, they generate the necessary income to reinvest in their productive activities.

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Presentation and integration of results

The results are integrated by obtaining the values of the 15 indicators in the dimensions of economic, social, and environmental sustainability; thus, a criterion on the evaluated system regarding its sustainability is issued. A mixed methodological approach was used, which allows the combination of a graphic presentation with numerical information (Masera *et al*., 1999) (Table 5).

Table 5. Values of sustainability indicators.

Attributes	Indicators	Conventional production system	Traditional production system	Dimension
Productivity	Crop yield	79.84%	70.5%	E
	B/C ratio	75.94%	69.3%	E
Stability, resilience, reliability	Ethics in the management of natural resources	100%	100%	En
	Conservation practices	7%	100%	En
	Ethics in the use of agrochemicals	58.8%	60%	En
	Use and transmission of traditional practices	94%	86%	S
	Pest incidence	93%	56%	En
Adaptability	Training	25%	12.5%	S
	Willingness to change	11%	0%	S
Equity	Main income-generating activity	57%	69%	E
	Income usage	58%	44%	S
	Evolution of jobs	91.6%	85%	E
Self-management	Dependence on external inputs	70%	60%	En
	Community organization	10.7%	0%	S
	Self-financial capacity	100%	100%	E

Masera *et al*. (1999).

The MESMIS methodology recommends the use of an AMEBA diagram to present the indicators that are represented in axes including their units. The analysis is cross-sectional; this approach simplifies the comparative evaluation between traditional and conventional prickly pear production systems (Figure 1). The optimal state of each indicator (100%) was used as a reference system.

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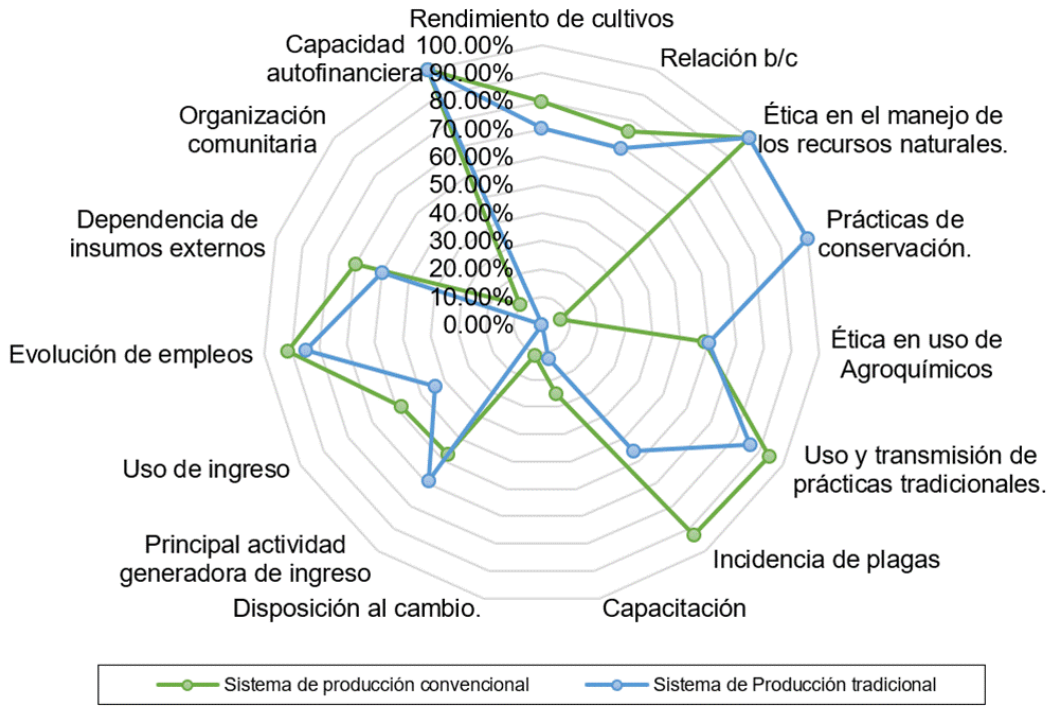
Figure 1. Comparison of sustainability indicators.



Conclusions

The conventional prickly pear production system maintains eight indicators with a high level of sustainability, it reports strength. Seven of them need to be strengthened to increase their sustainability. On the other hand, the traditional system has five in a high state of sustainability, it requires strengthening ten indicators to improve. The conventional system stands out in indicators related to production efficiency and economic aspects, whereas the traditional one obtains better environmental scores.

In both production systems, the economic dimension contributes more to their stability, whereas the social dimension weakens them more. The indicators that limit sustainability are training, community organization, practices on environmental conservation uses, and willingness to change.

It is necessary to develop and design programs oriented towards training, community organization, and adoption of sustainable practices for prickly pear producers in San Pablo Xúchil.

Bibliography

1 Amato, N. C. 2019. Revisión bibliográfica sobre sustentabilidad y ética organizacional: Actores relevantes. Ciencias Administrativas. 13:55-66.

2 Berber, S. R.; Torcuato-Calderón, C.; Almaguer-Vargas, G.; Colinas-León, M. T. y Khali Gardezi, A. 2012. El sistema productivo del nopal tunero (*Opuntia albicarpa* y O. *megacantha*) en Axapusco, Estado de México. Problemática y alternativas. Revista Chapingo. Serie Horticultura. 18(1):81-93.

3 Bifani, C. P. 1999. Medio ambiente y desarrollo sostenible. 4ª Ed. Instituto de Estudios Políticos para América Latina y África. Madrid, España. 121-123 pp.

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4 Callejas, J. N.; Matus, G. J.; García, S. A.; Martínez, D. A. and Salas, G. M. 2009. Situación actual y perspectivas de mercado para la tuna, el nopalito y derivados en el Estado de México. Agrociencia. 43(1):73-82.

5 Domínguez-García, I. A.; Granados-Sánchez, M. R.; Sagarnaga-Villegas, L. M.; Salas-González, J. M. y Aguilar-Ávila, J. 2017. Viabilidad económica y financiera de nopal tuna (*Opuntia ficus-indica*) en Nopaltepec, Estado de México. Revista Mexicana de Ciencias Agrícolas. 8(6):1371-1328.

6 Foladori, G. 1999. Sustentabilidad ambiental y contradicciones sociales. Ambiente & Sociedades. 5:19-34.

7 Francis, C. A.; Liebelin, G.; Gliessman, S. R.; Breland, T. A.; Creamer, N.; Harwood, R.; Salomonsson, L.; Helenius, J.; Rickerl, D.; Salvador, R.; Widenhoeft, M.; Simmons, S.; Allen, P.; Altieri, A. M.; Flora, C. and Poincelot, R. 2003. Agroecology: the ecology of food systems. Journal of Sustainable Agriculture. 22(3):99-118.

8 Gallegos, V. C.; Gallegos, M. S. y Mondragón, C. J. 2013. Los sistemas de producción comercial de tuna en México y su aplicación en el Altiplano. *In*: Producción sustentable de la tuna en San Luis Potosí. Gallegos, V. C.; Gallegos, M. S. y Mondragón, C. J. (eds.). Colegio de Postgraduados-Fundación Produce San Luis Potosí. San Luis Potosí, México. 37-48 pp.

9 Gliessman, S. R. 2002. Agroecología: Procesos ecológicos en agricultura sostenible. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE). Turrialba, Costa Rica. 359 p.

10 H. Ayuntamiento de Axapusco. 2022. Plan de Desarrollo Municipal de Axapusco 2022-2024 Gubernamental.

11 Hernández-Bonilla, B. E.; Ruiz Reynoso, A. M.; Ramírez Cortés, V.; Sandoval Trujillo, S. J. y Dávila Hernández, M. 2020. Análisis económico de productores y comercializadores de nopal en el Valle de Teotihuacán. Revista Iberoamericana de Contaduría, Economía y Administración. 9(17):72-108.

12 Hernández, S. R. and Mendoza, T. C. 2018. Metodología de la Investigación: las rutas cuantitativa, cualitativa y mixta 1ª Ed. Mcgraw-Hill, interamericana editores, SA de CV. Ciudad de México, México. 3-19 pp.

13 Jolalpa, J. L.; Aguilar-Zamora, A.; Ortíz-Barreto, O. y García-López, L. 2011. Producción y comercialización de tuna en fresco bajo diferentes modalidades en Hidalgo, México. Revista Mexicana de Agronegocios. 28:605-614.

14 Masera, C. O.; Astier, C. M. y López-Ridaura, S. 1999. Sustentabilidad y manejo de recursos naturales el manejo de evaluación MESMIS. Mundi-Prensa. México, SA de CV. 109 p.

15 Quecedo, L. R. y Castaño, G. C. 2002. Introducción a la metodología de investigación cualitativa. Revista de Psicodidáctica. 14:5-39.

16 Ramírez-Abarca, O.; Figueroa Hernandez, E. y Espinosa Torres, L. E. 2015. Análisis de rentabilidad de la tuna en los municipios de Nopaltepec y Axapusco, Estado de México. Revista Mexicana de Agronegocios. 36:1199-1210.

17 Rzedowski, R. J. 2006. Vegetación de México 1ª Ed. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO). México. 12-19 pp.

18 Santos, P.J.; Muñoz, A. A.; Juez, M.P.; Cortiñas, V.P. 2003. Diseño de encuestas para el estudio de mercado. Técnicas de muestreo y análisis multivariante. Centro de Estudios Ramón Areces, SA. Madrid, España. 728 p.

19 Secretaría del Campo. 2023. Información estadística agropecuaria por municipio: Axapusco. Secretaría del Campo, con base en el Servicio de Información Agroalimentaria y Pesquera (SIAP). Cierre Agrícola. Ciudad de México, México. https://secampo.edomex.gob.mx/estadisticas-agropecuario.

20 Vela, R. E. 2019. Cultivos Mesoamericanos: las especies que México dio al mundo. Arqueología Mexicana. (84):61-63.

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