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CONTRIBUTIONS TO THE SUSTAINABILITY OF THE RURAL MEZCAL SYSTEM: THE CASE OF THE QUERÉNDARO REGION IN MICHOACÁN, MEXICO

Contribuciones a la sustentabilidad del sistema rural mezcalero: El caso de la región Queréndaro en Michoacán, México

Contribuções à sustentabilidade do sistema rural mezcalero: O caso da região Queréndaro em Michoacán, México

David Orlando Ramírez-Naranjo
Universidad Michoacana de San Nicolás de Hidalgo
Universidad Nacional Autónoma de México
Morelia, México
ORCID 0000-0003-0047-1331
david.ramirez@umich.mx

Ricardo Musule-Lagunes
Universidad Veracruzana
Veracruz, México
ORCID 0000-0001-8248-355X
musuleiq@gmail.com

Dante Ariel Ayala-Ortiz
Universidad Michoacana de San Nicolás de Hidalgo
Morelia, México
ORCID 0000-0002-7331-3628
daao@fevaq.net

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ABSTRACT
The traditional Mexican mezcal socio-ecosystem has extensive biocultural and economic wealth presence in rural communities. However, in recent years an intense demand has been experienced in global markets generating processes of agro-industrialization of diverse traditional practices and thereby negatively impacting the sustainability of the system. Regarding this matter the research aims to characterize and typify the existing relationships between producers and their socio-environmental contexts, contributing elements to the construction of greater degrees of local sustainability within rural contexts, using the Queréndaro region, in the central north of Michoacán state, as a case study. Our results show that the sustainability of the analysis units varies between and intra diversed categories, while sustainability is not a characteristic of the type of mezcal, but of the producers. It is their traditional cultural relationships, their history and their association with nature the criteria which make this element to be created.

KEYWORDS
Rural economy, cultural diversity, agrarian structure, Environmental sustainability.

RESUMEN
El socioecosistema mezcalero tradicional mexicano posee amplia riqueza biocultural y económica, presentes en las comunidades rurales. Sin embargo, en los últimos años se está experimentando una atractiva articulación en los mercados globales, generándose procesos de agroindustrialización de las prácticas tradicionales diversas y con ello impactando negativamente a la sustentabilidad del sistema. Así, esta investigación tiene como objetivo caracterizar y tipificar las relaciones existentes entre los productores y sus contextos socioambientales, aportando elementos a la construcción de mayores grados de sustentabilidad local dentro de los contextos rurales, usando como caso de estudio la región Queréndaro, en el estado de Michoacán, México. Detectamos que la sustentabilidad de las unidades de análisis varía entre e intra diversas categorías, en tanto la sustentabilidad no es una característica del tipo de mezcal, sino de los productores, pues son sus relaciones culturales tradicionales, su historia y su relación con la naturaleza los criterios que hacen que este elemento se construya.

PALABRAS CLAVE
Economía rural, diversidad cultural, estructura agraria, conservación ambiental.

RESUMO
O socio-ecossistema mezcalero tradicional mexicano possui amplia riqueza biocultural e econômica, presentes nas comunidades rurais. Mas nos últimos anos está experimentando-se uma atrativa articulação nos mercados globais, gerando-se processos de agroindustrialização das práticas tradicionais diversas e com isso impactando negativamente à sustentabilidade do sistema. En este sentido, esta investigação tem como objetivo caraterizar e tipificar as relações existentes entre os produtores e seus contextos socioambientais, aportando elementos à construção de graus maiores de sustentabilidade local, dentro dos contextos rurais, usando como caso de estudo a região Queréndaro, no estado de Michoacán, México. Detectamos que a sustentabilidade das unidades de análise varia entre e intra diversas categorias, enquanto a sustentabilidade não é uma característica do tipo de mezcal, mas sim dos productores, pois são suas relações culturais tradicionais, sua história e sua relação com a natureza os critérios que fazen que este elemento seja construido.

PALAVRAS-CHAVE
Economia rural, diversidade cultural, estrutura agrária, conservação ambiental.

Introduction

Mezcal is the most typical and ancestral distilled beverage in Mexico, which is characterized by the diversity in its preparation from a great variety of agave species, mainly wild, which generate a wide range of particular flavors and aromas (Hernández López, 2018; Torres García, 2016). The production of traditional mezcal derives from a man-nature relationship within the current Mexican territory, which originates approximately nine thousand years ago (Delgado Lemus et al., 2021; Zuzumbo, 2009).

The relationship between the agaves and the human being is understood from the importance of these plants as crucial natural resources, through which multiple needs have been satisfied such as construction materials, textile fibers, living fences, medicinal resources, food, beverages, etcetera (Colunga et al., 2007; Torres et al., 2015a; Zizumbo y Colunga, 2008). About the last two uses of agaves (Zizumbo et al., 2009b) divide three main moments according to their use: first, their use as food; second, as raw material for obtaining fermented beverages; and third, as distilled beverages, this being what gives rise to mezcal.

Currently, a marked biocultural diversity associated with this crop is identified, which gives meaning to the forms and materials with which each mezcal is made, within the different regions and their respective rural communities in Mexico. For example, the particular case of the Queréndaro mezcal region, located in the north-central portion of the state of Michoacán, in western México, where the following localities stand out: Real de Otzumatlán, Río de Parras, and Cañada del Agua (Delgado Lemus et al. 2021; Torres García et al., 2015a), where the traditional uses of agave persist, representing not only cultural importance but also subsistence as an important source of monetary income.

The characteristics of mezcal are closely linked to the region of origin, which in turn is associated with different factors such as: ecological conditions, historical background, various socioeconomic contexts, the different species of agave used, and management, agricultural use of plants (for example, wild, unmanaged, or cultivated with different agricultural and domestication management), among other factors (Hernández López, 2018). For example, in the Queréndaro region, Michoacán, mezcal is made using pulque from *Agave salmiana* or *A. maximiliana,* as an inoculum and catalyst for the fermentation process due to the temperate to cold climatic conditions in the area that, under normal conditions, would delay the bioprocess; while the mezcaleros of Etúcuaro, Michoacán, do not use pulque to start the fermentation process (Delgado Lemus et al., 2021; Torres, García, 2015b).

This implies a wide ecological and social diversity of mezcal production, which has increased over the last thirty years, because an attractive articulation has been experienced in global markets, following in the footsteps of tequila (Hernández López, 2018). The attraction of the worldwide market about mezcal is due to the perception generated that it is a rustic product and its connection with an indigenous, rural, and ancestral basis, with a ritual dimension, small-scale production, and concern for the preservation of nature, contrasting with the perception of tequila as a highly industrialized product nowadays (Torres et al., 2019).

According to data from the Mezcal Regulatory Council, in 2020, more than 7,800,000 liters of mezcal were produced in Mexico. Approximately 8,000 rural families are directly engaged in this activity, generating 19,000,000 direct jobs and more than 58,000 indirect jobs, in nine

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states that are currently recognized as part of the Denomination of Origin (Consejo Regulador del Mezcal, 2021).

Michoacán is the fourth largest producer of mezcal nationwide, with a volume that has grown steadily over the last thirty years. In fact, in recent years it has increased from 234,000 liters produced in 2019 to 468,000 liters in 2020 (Chavez Parga, 2016; Consejo Regulador del Mezcal, 2016). The foregoing has generated the incorporation of three determining elements in the metabolism of this socio-ecosystem: (i) the frame of Denomination of Origin (DO) for mezcal in 1994, as a mechanism of intellectual protection for Agave distillates and other schemes for certification and regulation; (ii) the rise of modern agronomic techniques for its cultivation and mass production; and (iii) the use of biotechnology (for example cloning), to guarantee efficient and massive growth of the agaves. All of the above has been promoted by some large producers who saw tequila as a path to follow, since until a few years ago the demand for mezcal remained very low and local (Plascencia de la Torre and Peralta, 2018).

This highlights the complexity of the system and, therefore, the need to analyze how these production relationships should be treated to contribute to the construction of sustainability between cultural traditions and the mezcal boom of contemporary dynamics of the market for which the characterization of the socio-ecosystem relationships within this product is fundamental, as well as the typification of the rural units of mezcal production.

Thus, the present study has as a central goal to characterize and typify the existing relationships between rural mezcal producers and their socio-environmental contexts, using the Queréndaro region in Michoacán state as a case study. The purpose is to provide some elements in order to support greater degrees of local sustainability within rural contexts, as a starting point to improve the actors involved conditions, including producers, families, and workers of the system, together with their knowledge, consumers of traditional mezcal, and immersed ecosystems as suppliers of raw materials.

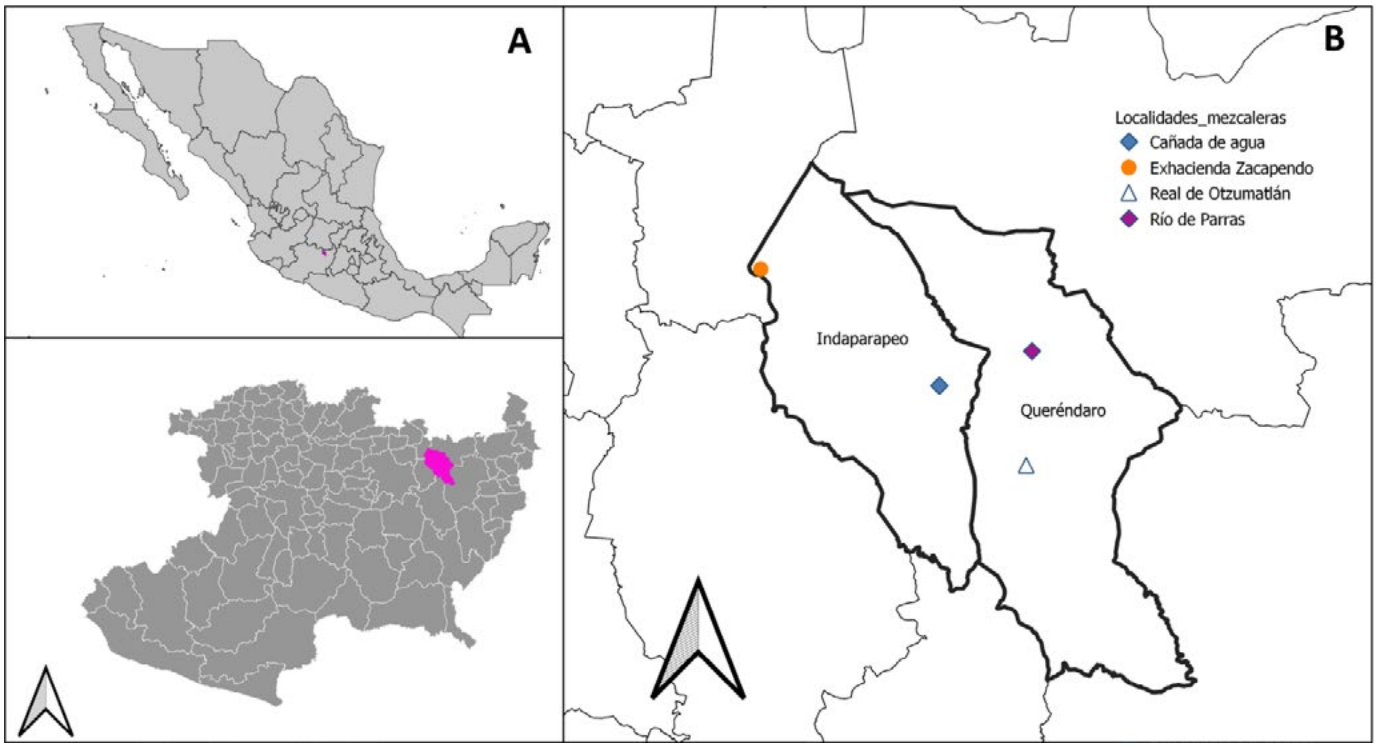
Materials and methods

Study area

Four communities located in the north of the state of Michoacán, Mexico were studied (Figure 1). These are part of the Queréndaro mezcal region, known for the production of mezcal and the use of the wild maguey species *Agave inaequidens*, and cultivated *A. cupreata*, and *A. tequilana*.

The climate of the study region is temperate subhumid with summer rains, with average temperatures ranging between 10 °C and 22 °C, and a rainfall range of between 600 mm and 1.500 mm per year. Its land use is mainly forest, agriculture and pasture, which promotes an economy based on primary activities (INEGI, 2020).

Figure 1. (A) In top left, Mexico, and bottom left, State of Michoacán de Ocampo. (B) Study area. Location of the communities and their municipalities
Figura 1. (A) En parte superior izquierda, México, y en parte inferior izquierda, Estado de Michoacán de Ocampo. (B) Área de estudio. Localización de las comunidades y sus municipios



Source: own elaboration. Fuente: elaboración propia.

Methods and data collection

Identification of the study system

An initial search for information on the mezcal production system was carried out through a review of the main databases such as Scopus and Google Scholar, university repositories where work on the subject has been developed (National Autonomous University of Mexico, Universidad Michoacana de San Nicolás de Hidalgo and the Center for Biological Research of the Northeast) and other important sources such as publications of civil organizations dedicated to the study and defense of the production of traditional mezcal.

The search was conducted in Spanish and English using the following keywords: "mezcal elaboration", "mezcal production", "mezcal preparation", "mezcal manufacturing", "maguey", "agave". Subsequently, after consulting local experts, the Queréndaro region in the state of Michoacán was selected, since it has the largest number of diverse analysis units, which means that different ways of making mezcal can be found in the same region. This first approach, besides the reviewed literature, allowed the identification of four traditional mezcal-producing localities in the region (Figure 1).

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After this, during the period from April to September 2020, a second information search about the mezcal production system in Michoacán was carried out, including mezcal sales businesses, companies, marketing brands, civil organizations, cooperatives, and associations. Based on the foregoing, two mezcal associations, two regulatory and certifying bodies, a civil association, and 48 mezcal producers in the region were found. It is worth mentioning that many of the producers were identified during the application of interviews, following the "snowball" method (Creswell and Creswell, 2018), which is a sampling technique to find the study subject, where a person interviewed gives the name of another who, in the same way, provides the name of a third person, and so on until the theoretical saturation point is reached; in this case, the subject study was mezcal producers in this region.

Information collection

Throughout twelve visits to the study area, 22 in-depth interviews with a semi-structured script were applied: 16 to producers and 6 to link representatives (with an approximate duration of 1 to 2.5 hours for each interview). The appropriate number of interviews was determined from the theoretical saturation point (Creswell and Creswell, 2018), that is, the moment at which the data and information captured began to become repetitive (Table 1). The aspects addressed in the interview were: (i) identification information of the producer or link representative, (ii) information on the phases of the mezcal production process, and finally, (iii) relevant aspects of the system's sustainability.

Table 1. Ecological and economic aspects and number of mezcal producers interviewed by locality
Tabla 1. Aspectos ecológicos y económicos y número de productores de mezcal entrevistados por localidad

Community	Municipality	Code	Ecological and economic characteristics of the communities	Number of analysis units interviewed
Río de Parras	Queréndaro	PR	Scrubland/rural: Agriculture (corn, beans and squash), livestock, mezcal production	3
Real de Otzumatlán	Queréndaro	RO	Mountainous/rural: Agriculture (apple, plum and peach orchards), resin extraction, mezcal production	6
Cañada de agua	Indaparapeo	AC	Mountainous/rural: Agriculture (corn, beans and squash), cattle ranching, pine felling, mezcal production	5
Ex Hacienda Zacapendo	Indaparapeo	ZA	Scrublandl/rural: Agriculture (corn/ strawberries), mezcal production	2

Source: own elaboration. Fuente: elaboración propia.

In addition, through the participant observation technique (Creswell and Creswell, 2018), guided tours were carried out in each phase of the mezcal production process, from the maguey *jima* on the hill to the actual marketing of the finished product, mezcal. In some cases, elaboration activities were observed and participated in, such as: piecework in the mountains, selection of magueys, transfer on foot and by mule from the hill to the mezcal vinata, among others. To record the information, video recordings, photographs and field notes were taken.

Characterization and typology of the study system

From the qualitative analysis software ATLAS. Ti 8.4, the fully transcribed interviews and the recorded observations were processed, the above through abductive coding (Fernández et al., 2020), which refers to generating codes through interaction between inductive and deductive coding.

In this way, the codes were classified into two groups: the first of which refers to the elements or processes related to the social, economic, and ecological characteristics identified and which contributes to the understanding of the object of study (characterization). In this case, through Atlas.ti 8.4, a scientific software development GmbH, a scheme composed of elements grouped into subsystems and related to each other was built (networks).

In the second group, relevant mixed variables were identified for the operation of the study system, with the aim of building a typology to distinguish differences between an apparently homogeneous set of mezcal producers (López and Fachelli, 2015). Thus, variables that describe the region's mezcal socio-ecosystem were generated. The values of the quantitative variables were extracted from the interviews and observations, while the qualitative variables were extracted from the application of surveys. In the case in which the producers did not have a record of the variables, these were measured *in situ* (Table 2).

Table 2. Identification categories of subgroups or particular differentiation
Tabla 2. Categorías de identificación de subgrupos o diferenciación particular

Code	Category	Variable	floating rate	Unit/description
A	Species of maguey used	Idem	Numeric	No species/producer
B	Mezcal production	Idem	Numeric	Liters/year
C	By-product management	Idem	Numeric	Number of handlings/producer
D	Production season	Idem	Numeric	Month/year
E	Producer experience	Idem	Numeric	Year/producer
F	Employees	Idem	Numeric	Number of employees/producer
G	Income diversification	Idem	Numeric	Number of activities/producer
H	Cooking capacity	Oven size	Numeric	Ton/furnace
I		Number of ovens	Numeric	Number of ovens/producer
J	Retail price	Idem	Numeric	$/Liter
K	Management of the maguey	Planted plants	Numeric	Plants planted/year
M-Yes		Planted land	Categorical	If the producer performs some type of replacement, planting, wild care or has a nursery, in order to maintain the replacement cycle of the maguey that is used
M-No				
N-Yes		Nursery	Categorical	
N-No				
L-Own	Holding the "vinata"	Idem	Categorical	Not all producers have their own factory, some must rent a space within the communities of the region
L-Rented				

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Code	Category	Variable	floating rate	Unit/description
O-Yes	Mezcal making process	Pulque Use	Categorical	The use of pulque is traditional in the region, as a fermentation initiator, and stills distiller made of oyamel wood logs. However, some producers no longer do it this way
O-not				
P-Yes		Oyamel alembic use	Categorical	
P-No				
Q-Purchased	Obtaining the maguey	Idem	Categorical	Some producers have their own land, others extract the magueys from wild ejido land or buy them from communities and municipalities surrounding the region
Q-Purchased/Own				
Q-Ejido/Purchased				
Q-Own				
R-Yes	Certification	Idem	Categorical	Mezcal certified by a certifying body
R-No				
S-Yes	Use of agrochemicals	Fertilizer use	Categorical	The use of fertilizers or pesticides is not common even in the presence of pests, however, some units do
S-No				
T-Fly		Plague	Categorical	
T-Weevil				
T-Weevil/bacteria				
T-No				
U-Yes		Pesticide use	Categorical	
U-No				
V-State	Sale range	Idem	Categorical	Geographic range in which the producer's mezcal is marketed, which varies from state (Michoacán), national (two or more states of the Mexican Republic), and international
V-National				
V-International				

Source: own elaboration. Fuente: elaboración propia.

These categories were analyzed with an exploratory multivariate statistical analysis or mixed Principal Component Analysis (PCA). Taking into account quantitative and qualitative variables, in order to reduce the multidimensionality of the set of categories and obtain subsets, through linear combinations of uncorrelated factors (Díaz and Cárdenas, 2010). In other words, the data structure (variables) was summarized and an automatic classification of the interviewed and surveyed mezcal producers was carried out, using the XLSTAT software.

Results

Characterization of the traditional rural mezcal socio-ecosystem

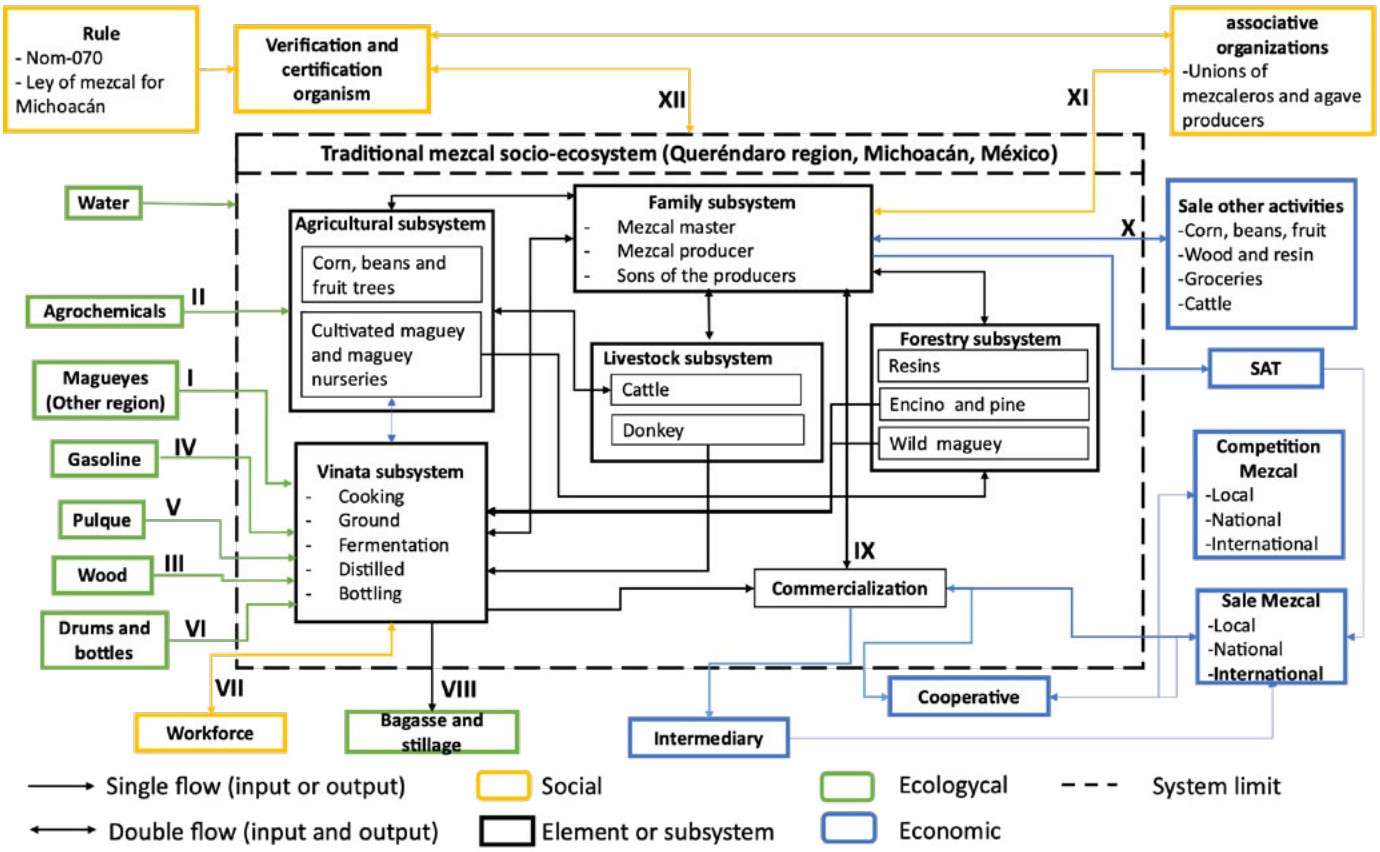
Figure 2 shows the identified subsystems (family, agricultural, vineyard, livestock, and forestry), as well as the processes and elements associated with them. In such a way that the traditional mezcal socio-ecosystem in the study region is a complex network of structured relationships that allow its functionality.

This functionality depends on the relationship that the production units (for example, producing family/family subsystem), have with the natural environment that surrounds them, in the sense that it requires the appropriation of part of nature for the production of mezcal

and its own subsistence.

The main raw material, the magueys (I, in Figure 2), essentially flow from three relationships: first, when the production unit extracts the wild magueys (Agave inaequidens) from the forest subsystem; second, when the unit production on their land jima the cultivated magueyes (mainly *A. inaequidens, A. cupreata, A. angustifolia* and *A. tequilana*); and third, when the production unit buys the magueys from neighboring communities (mainly *A. inaequidens, A. cupreata , A. angustifolia*). For all cases, the use of the mule or donkey (element of the livestock subsystem) is required to carry out the transfer from the place of jima to the vinata subsystem. The use of pickup trucks owned by the production unit is also required.

Figure 2. Traditional rural mezcal socio-ecosystem of the Queréndaro region, Michoacán
Figura 2. Socioecosistema mezcalero rural tradicional de la región Queréndaro, Michoacán



Source: own elaboration. Fuente: elaboración propia.

The first input used in mezcal production processes are agrochemicals (II), which flow from the outside to the agricultural subsystem where the maguey cultivation process or other cultivation activities are carried out. Another input is wood (III), which plays a fundamental role in the cooking and distillation processes, providing the required thermal energy. In cooking, green oak wood is used, which can come directly from the forestry subsystem, in cases where the production unit has land with pine-oak forests, or it can be purchased at sawmills or from neighbors in the same region. In the case of pine wood, normally bark (residue), is used in the distillation, which is purchased at sawmills in the region.

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Gasoline (IV), another input, is used by some producers in the sleeve shredder to grind the cooked maguey, or for the chainsaw with which the maguey is chopped in the jima process. This element flows from the outside into the vinata subsystem. Pulque (V) is also used as an inoculum for the fermentation process, which flows from outside (Ucareo community, Zinapécuaro municipality, or Tarímbaro municipality) to the vinata subsystem. Finally, there are the glass and plastic containers (VI), used to store the mezcal that flows from the outside to the vinata subsystem. Although it is not an input, labor is an input (VII), which is frequently required from the outside in both the processes that occur in the agricultural subsystem and in the vinata subsystem.

From all the processes described above, there are two flows in the opposite direction, from the vinata subsystem to the outside, which is, on the one hand, bagasse and vinasse (VIII), as by-products, which are left in the soil for decomposition or recirculated as organic fertilizer for the agricultural subsystem. On the other, there is the finished mezcal (IX), which can take three paths: first, the production unit sells it in bulk to intermediaries who label it with another brand and, later, it is resold to the consumer; second, that the production unit, in cooperation with external agents, promotes and sells a brand of mezcal to the consumer; and, third, that the production unit sells its own brand of mezcal directly.

The sale of mezcal occurs at all scales, but the intermediary and cooperative route tends to be national and international scales. Similarly, for those cases in which certifications from the regulatory bodies or labels of the fiscal entity are required (for example, the Mexican Tax Administration Service, SAT), for the production unit the need arises to have a relationship via federal tax for the sale of its maguey wines and, therefore, it becomes an outflow of money abroad.

As previously mentioned, one of the fundamental characteristics of this system is the need for job diversification and, therefore, for their economic income (X, in Figure 2). This phenomenon occurs mainly because the income received from the commercialization of mezcal is not enough to maintain the requirements of the same unit. Therefore, the production unit flows some resources from the agricultural, livestock, and forestry subsystems (and also from the natural environment) to the outside through their own work. These resources are sold as surplus (v.gr. corn, beans, fruits, resins, wood, and earned) in order to supplement their income.

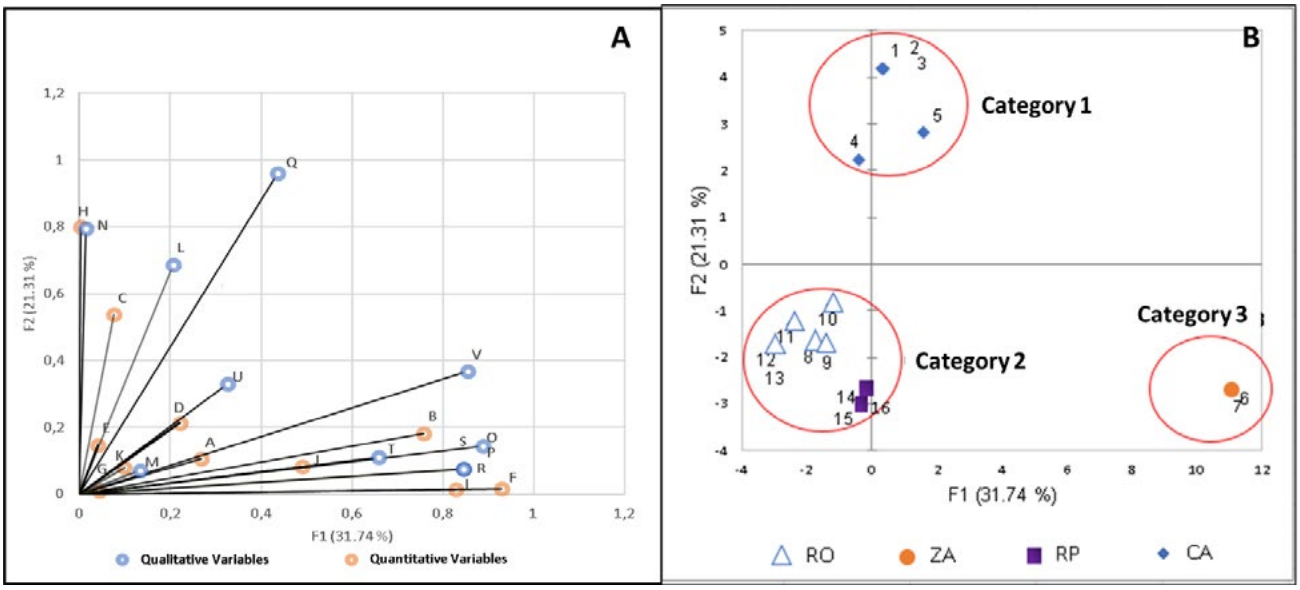
Finally, the production unit has two more relationships with the outside world: first, via associations or unions (XI), which are created by several mezcal producers, at the state level, in order to ensure the main interests of associates. These associations provide advice and training tools to members with the aim of supporting and improving their conditions. The second relationship is through the regulatory bodies responsible for the verification and certification of the mezcal production system (XII), guidelines framed in NOM-070-SCFI-2016, the current standard that regulates the production of mezcal in Mexico.

Typology (differentiation of the mezcal socio-ecosystem)

Appendix A shows the results of the 16 interviewed producers, which were classified into three categories built through a mixed PCA, as shown in Figure 3.

On the one hand, part A of Figure 3 shows the distinction between quantitative and qualitative variables, so that its length represents the eigenvectors where it was found that the variables with the greatest weight for F1 (Principal Component 1) are F, I, O and V, while for F2 (Principal Component 2) they are H, L and Q. Similarly, in Annex B the eigenvectors of the three main components used to analyze the classification of producers can be identified. This multidimensional instrument allowed, based on the categories or aspects identified, to classify the metabolism of the mezcal-producing socio-ecosystem in the Queréndaro region (Figure 3, part B).

Figure 3. (A) Squared saturations (F1 and F2 axis: 50.77%. (B) Producers classified by category according to mixed principal component analysis
Figura 3. (A) Saturaciones cuadradas (eje F1 y F2: 50.77%). (B) Productores clasificados por categorías de acuerdo con análisis de componentes principales mixto



The meaning of the letters is described in Table 2. Source: own elaboration. El significado de las letras es descrito en Tabla 2. Fuente: elaboración propia.

Each category is described below:

Category 1 (Traditional). In this category, all the producers maintain the use of pulque as raw material to start the fermentation process, as well as the use of oyamel stills for distillation, characteristic of the region. The production season is from eight to nine months (October-June). Although they work mainly with the species of *Agave inaequidens*, some mixed are also made at the request of clients with species such as the "chato" or "espadín". It is also characteristic of these producers that in addition to dedicating themselves to the production of mezcal, they also dedicate themselves to raising cattle and growing corn. The experience of the mezcal masters varies between 45 to 10 years, with an average of 20 years, although with a greater frequency towards 10 years.

Likewise, this category uses chemical fertilizers and pesticides to control the weevil and the white worm fly, mainly, which affect cultivated and wild maguey species. The establishment of nurseries and experiences of reintegration of maguey (*A. inaequidens*) into wild or conser-

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vation areas is very common. Their sales are mainly on a state and national scale, although much more tending to the state scale, in part because they do not have certification from any verification body, nor do they have a label from the SAT. Its production, which varies between 300 and 1,500 liters per year, is determined by the capacity of the ovens, which usually have a capacity of five tons and is consistent with the need for external labor to the family required, which ranges between four and six people. Finally, the price at which the product is sold to the public in these units ranges from $250.00 to $450.00 pesos, with an average of $350.00 pesos per liter.

Category 2 (Traditional hybrid). Producers in this category, like in Category 1, maintain traditional aspects of the region such as the use of pulque and oyamel alembic. However, in addition to producing mezcal mainly with the *A. inaequidens species,* it is very common for them to make mixes or distillates of mezcal from vipers, gamecocks, coyotes, fruits, quiote, chicken, cannabis, etcetera. They do not use chemical fertilizers or pesticides, despite the presence of pests such as weevils and a species of bacteria that has not yet been identified.

Like Category 1, they are dedicated to raising cattle and growing corn, but in a much more marginal way, because their basket of income is supplemented by the sale of mezcal creams, growing fruit trees, or taking advantage of the forest (wood and resins), in such a way that this category presents a higher level of diversification in economic income and use of natural resources in its context.

Its production capacity, on average, is greater than category 1 (between 400 and 9,000 liters per year), which is explained by the size of the ovens, which range between five and ten tons. Although it has higher productions, this category hires less labor than category 1 (between one and five employees), this is explained by the fact that many of the producers in this category have more experience (average 35 years), while their age is older, and they have family labor in their children and grandchildren who are also dedicated to the production of maguey wine.

This category also has nursery processes, but tends to plant in areas destined for monoculture, which has led to greater pest problems, especially one that is known as "Bacteria". Although they sell their mezcal on all three scales (regional, national and international), their main market is on the national scale, explained in part because, although they are not certified, many producers do have a label from the SAT. Finally, the mezcal sold in these units ranges from $250.00 to $330.00 pesos, with an average of $290.00 pesos per liter.

Category 3 (Semi-industrial). This category groups the smallest number of producers, but at the same time the most different from the former categories. These, unlike the previous categories, do not use pulque or oyamel alembic, characteristic of the traditional production of the region. Likewise, the most common and traditional species used to produce mezcal in this region, the *Agave inaequidens,* is not used due to its low sugar yields, while the cultivated species of agave "espadín" and "azul" are used, with some mixed of *A. cupreata*.

The production capacity of this category is much higher than the others (between 10,000 and 60,000 liters per year), which is explained by its infrastructure and level of technology, oven capacity, and the number of hectares used for the monoculture of "espadín" and "azul" agaves, enhanced with chemical fertilization and pesticides. Like the other categories, this

presents diversification of economic activities but focused on tourism of the tequila-type landscape of its properties. The experience of mezcal masters in this category is fifteen years on average, the shortest among all categories.

A relevant aspect is that this category is certified and uses the SAT label, which allows it to market mezcal more easily in national and international markets. Finally, the average price per liter sold to the public is $400.00 pesos, the most expensive among the categories, ranging from $300.00 to $500.00 pesos.

Discussion

Characterization of the traditional rural mezcal socioecosystem

This research coincides with Delgado Lemus et al. (2021) reports, regarding (i) two of the localities analyzed (Río de Parras and Real de Otzumatlán); (ii) the use of "maguey alto" (*A. inaequidens*), "maguey chino" (*A. Cupreata*), and "maguey azul" (*A. azul spp*.); (iii) use of pulque to accelerate the fermentation, alembic made from a large hollowed-out fir tree trunk and huinum to cover the agaves in the oven, (iv) significant presence of fruit trees, characteristic of the mezcal of this region.

However, although Delgado Lemus et al. (2021) carried out the first characterization of the Queréndaro region, compiling the particularities of mezcal production in the state of Michoacán, when we compare it with the data found for this study, made specifically for one of the mezcal regions of the state, it was possible to register another six characteristics of the Queréndaro region, which are discussed below.

First, the fact that there are four towns that produce traditional mezcal in the region (Río de Parras, Real de Otzumatlán, Cañada del Agua and Ex Hacienda Zacapendo). Second, in addition to the already mentioned magueys species, in recent years experiments have begun with the *A. angustifolia*. Third, that the cultural socio-ecosystem of traditional mezcal production is made up of five closely related subsystems: family subsystem, agricultural subsystem, livestock subsystem, forestry subsystem, and vinata subsystem.

Regarding this last aspect, it is important to highlight the production of mezcal in this region as an interaction between the family production units (the producing families) and the natural environment that they take advantage of, it is only understood to the extent to which the complete elements and processes are incorporated to the metabolic structure that at first appear separate. A first general approach to this complex understanding of the subsystems was mentioned by Zizumbo et al., 2009a for the traditional agricultural production of mezcal wine in southern Jalisco, and by *Agave* genus in the agroforestry systems of Mexico (Torres García, 2019).

These elements and processes for the Queréndaro region are: the cultivation of the milpa, fruit trees, and the cultivated magueys themselves; the raising of cattle, males, and farm animals; grocery stores, restaurants, or small businesses; the exploitation of the forest in terms of extraction of wood, huinumo, resins and the wild magueys themselves; as well as the workforce of family members and the transformation processes that occur in the forest, the farmland and the vinata (mezcal factory).

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The region above was exposed, in a general way (Torres et al., 2015a; Torres et al. 2019) when it identified that many of the mezcal communities with a centuries-old tradition have diverse practices in cultural and economic terms that give them their own identity.

A fourth relevant element found here is that the Family Production Units carry out management of the *Agave inaequidens*, which can be: (i) leaving some mature individuals so that they can spread their seeds naturally, (ii) spreading of seeds collected in areas conducive to germination, (iii) clearing the vegetation that competes with the maguey in the forest, and (iv) germination of seeds in nurseries for the subsequent return of the seedling to the forest or in areas delimited in a manner monoculture. Torres García and Hernández López (2016) identified some of these managements for the towns of Real de Otzumatlán and Río de Parras, which he categorized into three levels: wild harvesting, on-site management, and off-site management.

The fifth aspect to highlight refers to the ways in which the region's mezcal is marketed and its different relationships with the outside of the socio-ecosystem or social environment (MAS). Relationships that are relevant when understanding the differences in economic and social terms, for example, selling the mezcal to an intermediary or selling the mezcal directly to the local, national, or international consumer.

And finally, the sixth aspect, coinciding with those previously identified by Arreola et al. (2018), it is emphasized that the external actors in the socio-ecosystem, which are in charge of regulating the system of sale and commercialization of mezcal, immersed within the Industrial Protection Law and NOM-070-SCFI-2016, are the producer organizations (UMM and the UEPAMM), the Secretary of Economic Development of the state of Michoacán and the verification and certification bodies (CRM and CIDAM).

So, on the one hand, in general terms and referring to the institutional aspects in which the cultural socio-ecosystem of the Queréndaro region is framed, there are no differences with the already found by Arreola et al. (2018), except for the notorious decrease in mezcal unions, going from six to two in the last three years, and the recognition of CIDAM as a verification and certification body. The foregoing is perhaps due to the increase in the homogenization of the frameworks themselves that fail to perceive the socio-ecological and cultural diversity of regional and national mezcal productions. Such homogenization is accelerating the transition from traditional, diverse processes with their own biocultural identity to typical and highly commercial industrial processes, like those of the tequila industry.

Now, comparing the characteristics found in the study region with other studies carried out for Michoacán state and other states of the Mexican republic, it is possible to identify certain characteristic features within their metabolic structures, again highlighting the fact that each region mezcal is particular and distinctive, even more so at the federal level. The following characteristics were identified:

In the first place, an increase in the demand and consumption of mezcal, evidenced in this work by the increase in specialized establishments ("mezcalerías"), the continuous appearance of mezcal brands, advertising, and continuous marketing with the direct participation of even high-ranking *influencers'* impact on social networks, and the constant promotion of festivals around mezcal at different levels; a situation that has already been reported by

literature (Delgado Lemus et al., 2021; Plascencia de la Torre and Peralta, 2018; Red Temática Productos Forestales No Maderables, 2018; Torres García, 2015; Torres García and Hernández López, 2016).

The foregoing leads to an increase in the appropriation of resources necessary for the production of mezcal, especially in the extraction of magueys, as the second similar characteristic in the metabolisms of the country, perceived on the one hand, in the depletion of wild magueys and the increase in its domestication, generating the appearance or increase of pests, a case that is happening with *Agave inaequidens*, a species used in the Queréndaro region, reported by Figueredo et al. (2014) and Torres et al. (2015a); the same happens with other species of particular use for different regions of México, such as: Acateyahualco and Ahuacuotzingo, in Guerrero state (Illsley et al., 2018), the Tehuacán-Cuicatlán Valley, in Puebla state (Torres et al., 2015a) or some communities in the state of Yucatán (Colunga, 1996). On the other hand, it has also affected the appropriation of already domesticated species from other regions, thus causing the loss of diversity and biocultural identity of the regions where wild species are used (Colunga et al., 2017; Figueredo, 2014).

Finally, with the work carried out in the Queréndaro region and contrasted with the former said by literature (Colunga et al., 2017; Gaytán, 2018; Gaytán and Bowen, 2018), it was possible to identify that the march towards a mercantile transition from traditional forms of hundreds of years towards industrialized and homogenized processes, in part propitiated by the entry of large capitals that see in the rise of mezcal an opportunity to magnify their financial income, continues growing and apparently the political and regulatory frameworks are supporting these changes through the exclusion of the Family Units of traditional production, and therefore, of their diverse ways of relating to their natural context, with ecological, cultural, social and economic value.

Typology of the traditional rural mezcal socio-ecosystem

Through the characterization of the traditional mezcal socio-ecosystem of the Queréndaro region, three categories that describe patterns that group the diversities present in the study region at a local scale were found. These categories were constructed through the processing of multiple social, ecological, and economic variables that describe the features of the Family Production Units.

In this sense, in the literature there is only one classification where the attempt to differentiate mezcal production units is made; this classification is carried out by NOM-070-SCFI-2016, which refers to the Mezcal Denomination of Origin, defining three categories: Mezcal, Artisanal Mezcal and Ancestral Mezcal.

That classification is limited and reduced when it comes to understanding the diversity of expressions that exist between nature and family or business production units in Mexico, since the central criterion for making this differentiation lies in the use of materials and equipment (grades of technification), leaving aside the relevant ecological, social, cultural, economic and political processes and elements when it comes to giving identity to the processes themselves, as has been emphasized and shown in this work.

In such a way that the construction of the classification carried out by this research is inclusive and seeks to promote the defense of diversities in the elaboration of mezcal and its necessary relationships with its local ecological and social contexts, leaving aside the reductionism imposed by the Denomination of Origin (Consejo Regulador del Mezcal, 2021; Hernández López, 2018).

However, when we compare the categorization carried out by this study with that carried out by Torres et al. (2015a), who classified the perception of risk in five communities, within which three are located in the study region, for the species *A. inaequidens* in terms of its decrease in quality and quantity; both classifications coincide in three aspects: firstly, the use of the Principal Component Analysis (PCA), as a method to reduce the dimensionality of the variables taken into account for the categorization.

Second, the categories of identification of variables, since social, ecological, and economic variables were taken into account in order to achieve an understanding in terms of the socio-ecosystem of the communities analyzed, validating their relevance through the inductive analysis of the semi-structured in-depth interviews applied in Family Production Units.

The third and last aspect to coincide is related to the categorization itself, since, in the research carried out by Torres et al. (2015a), the patterns or categories, although they are not the same as those found by this research (product of its main objective), are similar to some degree, especially with the descriptive aspects found in the groups or categories C1 and C2. In this sense, Torres et al. (2015a), coincide with what was reported by this research in that C1, composed mostly of Family Productive Units of the Cañada de Agua locality, is a more vulnerable group in terms of unsustainability than the other communities, with intermediate extraction levels, between the categories and that carries out management practices for the species *A. inaequidens*.

In the same way, Torres et al. (2015b), coincide with this report regarding C2, composed mainly of Family Production Units from the towns of Río de Parras and Real de Otzumatlán, with the highest income from mezcal production compared to the town of Cañada of water.

Finally, and although the study carried out by Torres et al. (2015b) presents methodological coincidences and in their results, it is also clear that, because of the main objectives and the research approach, both studies separately present a previously unexplored section for traditional mezcal production systems, from their understanding as socio-ecosystems.

In this sense, the results obtained by this research revealed the ways in which the various forms of Family Production Units immersed in the socio-ecosystem of the Queréndaro region can be grouped, and are related to the processes and elements of nature and the rest of society, exposing the essential aspects that describe and give identity to the groups or categories. In such a way that C1 and C2 are systems that preserve the typical and ancestral traditions of the region; and that at the same time must coexist with expressions in the transition towards the industrial, such as the Business Production Units (C3).

This raises the question of whether it is possible to develop these systems in the same territorial space (the local), without generating conflicts, be they ecological, social, or economic; or conversely, if this particular region is moving towards industrial systems, as it happened with the tequila industry during the 19th and 20th centuries (Plascencia de la Torre and Peralta, 2018). Where big capital enters, commodifying the traditional knowledge and biocultural resources of the producing localities.

This could generate, on the one hand, the displacement of native species from the Queréndaro region, since they often do not have a competitive value in terms of industrial efficiency, due to their low sugar content compared to other highly intervened and domesticated species. On the other hand, it could decrease the degree of sustainability maintained by the alternately diversified systems (category 1 and 2), due to the loss of processes that sustain their ecological, social and economic wealth.

Conclusions

The rural social metabolism of the Queréndaro region mezcal socioecosystem, in Michoacán state, has relationships with its environment, built over hundreds of years that allow it to have its own identity in biocultural terms and diversity in its productive practices, which can be grouped into three categories or patterns that show the complexity in a single mezcal region. Categories 1 and 2 units conserve the traditional profile; but, at the same time, these groups must coexist with expressions in the transition towards the industrial, category 3.

Although the characteristics can be grouped, the units of analysis vary *inter* and *intra* categories, depending on the ways in which they are related to the natural environment. That is, not all units can be exclusively labeled since they belong to a category. This premise allowed us to indicate that sustainability is not a characteristic of the type of mezcal or category to which a unit belongs, but rather it is specific to each one and can vary according to cultural, historical, ecological, and social relationships, making this element be built specifically.

The existence of institutional frameworks that privilege and promote a specialized mezcal production system not only destroys nature and its resources, but also traditional practices. Originating a trend towards the commercial transition of the less specialized forms in a single productive activity, opens the question: can these systems be developed without generating ecological, social, or economic conflicts in the territorial space (the local)? Or, on the contrary, is this particular region inevitably moving towards industrial systems?

We support the position of rural communities as sites that move towards the commodification of their biculturalism, to the extent that they are subject to market forces, then their dynamics are different in ecological and social terms (more sustainability). Inevitably, these rural communities face a clear disadvantage compared to expressions designed to function under the fierce competition of the global market, which is not interested in the value of the traditional, beyond whether it is a good business or not.

In this sense, government institutions must generate policies to support these units in disadvantage by the market, not only monetary, but also in actions that contribute to the strengthening of local institutions and authorities for the conservation and appreciation of the natural and cultural assets that they possess.

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Finally, this research leaves important perspectives to be explored, in terms of being able to respond to rural problems through sustainability processes, especially with: (i) the domestication and control of pests, which are increasingly resistant and diverse; (ii) the traditional knowledge of management and conservation of resources, which over time has given positive results to the units most attached to tradition; and (iii) the diversification of the units of analysis, since it is key to maintaining a balance a the basic dimensions of sustainability.

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Appendix

Appendix A. Ecological-economic aspects and number of mezcal producers interviewed by locality

No	Code Municipio	Species of maguey used	Mezcal production	By-product management	Prodction season	Producer experience	Employees	Income diversification	Cooking Capacity	Number of ovens	Retail price	Planted plants	Planted land	Nursery	Holding the "vinata"	Pulque use	Oyamel alambic use	Obtaining the maguey	Certification	Fertilizer use	Plague	Pesticide use	Sale range
1	CA	3	50	2	8	10	6	2	5	1	300	2000	Yes	Yes	Rented	Yes	Yes	Ejido/Purchased	No	No	Weevil/bacteria	Yes	State
2	CA	3	500	2	8	10	6	2	5	1	300	2000	Yes	Yes	Rented	Yes	Yes	Ejido/Purchased	No	No	Weevil/bacteria	Yes	State
3	CA	3	500	2	8	10	6	2	5	1	300	2000	Yes	Yes	Rented	Yes	Yes	Ejido/Purchased	No	No	Weevil/bacteria	Yes	State
4	CA	1	500	2	8	45	4	1	5	1	400	3000	Yes	No	Own	Yes	Yes	Ejido/Purchased	No	No	Fly	No	State
5	CA	3	1250	1	9	15	5	1	5	2	400	2000	Yes	Yes	Own	Yes	Yes	Ejido/Purchased	No	Yes	Weevil	No	National
6	ZA	3	35000	1	12	10	15	2	8	3	400	0	Yes	No	Own	No	No	Own	Yes	Yes	Weevil	Yes	National/international
7	ZA	3	35000	1	12	10	15	2	8	3	400	0	Yes	No	Own	No	No	Own	Yes	Yes	Weevil	Yes	National/international
8	RO	1	6500	1	8	40	3	2	8	1	260	5000	Yes	No	Own	Yes	Yes	Purchased/Own	No	No	Weevil/bacteria	No	National
9	RO	1	8000	1	7	50	4	3	8	1	300	6000	Yes	No	Own	Yes	Yes	Purchased/Own	No	No	Weevil/bacteria	No	National
10	RO	3	1750	1	12	16	2	0	6	1	250	1000	Yes	No	Own	Yes	Yes	Purchased/Own	No	No	Weevil/bacteria	No	National
11	RO	1	500	0	8	15	1	1	7	1	250	2000	Yes	No	Own	Yes	Yes	Purchased/Own	No	No	Weevil/bacteria	No	State
12	RO	1	500	0	8	10	1	1	7	1	250	1000	No	No	Own	Yes	Yes	Purchased	No	No	No	No	State
13	RO	1	500	0	8	10	1	1	7	1	250	1000	No	No	Own	Yes	Yes	Purchased	No	No	No	No	State
14	RP	3	4000	1	12	37	5	3	8	1	300	5000	Yes	No	Own	Yes	Yes	Own	No	No	Weevil/bacteria	No	National/international
15	RP	3	6000	1	12	50	3	2	10	1	300	6000	Yes	No	Own	Yes	Yes	Own	No	No	Weevil/bacteria	No	National/international
16	RP	3	6000	1	12	50	3	2	10	1	300	6000	Yes	No	Own	Yes	Yes	Own	No	No	Weevil/bacteria	No	National/international

Source: own elaboration. Fuente: elaboración propia.

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Appendix B. Eigenvectors of the first three Principal Component Analysis classifying the mezcal handlers' strategies of management in the communities studied

Variables	F1	F2	F3
A	0.51793244	0.32420571	0.41183225
B	0.87040714	-0.425811	-0.0616503
C	0.27412937	0.73301073	0.4889213
D	0.47058056	-0.460931	0.35774368
E	-0.2026721	-0.3837378	0.69845271
F	0.96376217	0.12904108	0.07385767
G	0.21015399	-0.0925811	0.57865571
H	0.04979313	-0.8945832	0.26923229
I	0.91073457	-0.1198611	-0.2300686
J	0.70015726	0.28554152	0.16637321
K	-0.3153911	-0.2798517	0.80135859
M-No	3.31492646	-0.9824622	-0.8725902
M-Yes	-0.2549943	0.07557402	0.06712232
N-No	3.31492646	-0.9824622	-0.8725902
N-Yes	-0.2549943	0.07557402	0.06712232
L-Own	-0.0476935	-0.9827919	1.79492886
L-Propia familiar	-0.8395558	-0.5952383	-1.3872757
L-Rented	0.09904594	1.53803334	0.13851038
O-No	-0.2549943	0.07557402	0.06712232
O-Yes	3.31492646	-0.9824622	-0.8725902
P-No	-0.8962162	-0.6550853	-1.760115
P-Yes	0.14936937	0.10918088	0.2933525
Q-Purchased	-0.8962162	-0.6550853	-1.760115
Q-Purchased/Own	-0.511302	-0.5187295	0.08952293
Q-Ejido/Purchased	0.13288103	1.29247664	0.1203553
Q-Own	1.0577451	-1.0257649	0.85345393
R-No	-0.3165115	-0.0038598	0.07702523
R-Yes	3.31492646	-0.9824622	-0.8725902
S-No	-0.3612064	-0.3631638	0.0457059
S-Si	0.90301607	0.90790945	-0.1142648
T-Fly	-0.1159442	0.81950355	0.237958
T-No	-0.8962162	-0.6550853	-1.760115
T-Weevil	1.89906896	0.02315871	-0.4621514
T-Weevil/bacteria	-0.2099735	0.04937217	0.4673972
U-No	-0.0780349	-0.564288	-0.0363819
U-Si	0.19508733	1.41071991	0.09095463
V-State	-0.3339248	0.52112696	-0.5011912
V-Nacinal/Internaciona	-0.0708456	-1.0474162	1.71647597
V-National	-0.2089404	-0.1426485	0.23699408
V-International	3.31492646	-0.9824622	-0.8725902

Source: own elaboration. Fuente: elaboración propia.