Revista Mexicana de Ciencias Forestales Vol. 15 (85)
Septiembre - Octubre (2024)

DOI: 10.29298/rmcf.v15i85.1473

Research article

Valor cultural de especies arbóreas con potencial para restaurar sistemas agroforestales con *Agave* en Oaxaca

Cultural value of tree species with potential to restore agroforestry systems with *Agave* in the state of *Oaxaca*

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Fecha de recepción/Reception date: 15 de marzo de 2024
Fecha de aceptación/Acceptance date: 1 de julio del 2024

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Abstract

The surface area cultivated with *maguey* in the state of *Oaxaca* has increased by more than 500 ha per year. In the "*mezcal* region", changes in land use are observed, as new *maguey* plantations are established as monocultures on land where there used to be natural vegetation, and, therefore, these ecosystems become less diverse and more fragile and liable to erosion. The objective of this work was to identify native tree species with the potential to restore areas cultivated with *Agave* in *Oaxaca*, and to estimate their cultural value from the perspective of the stakeholders. For this purpose, 108 interviews were conducted with *maguey* producers in the "*mezcal* region", and the Cultural Importance Index was determined to prioritize the species mentioned, as well as four taxa suggested by the authors, based on their importance for restoration. The results showed 23 species with potential use, among which the following stand out for their cultural value and potential to restore areas cultivated with *Agave*: *Pithecellobium dulce* (*camachile*), *Neltuma juliflora* (*mesquite*), *Dodonaea viscosa* (broadleaf hopbush) and *Eysenhardtia polystachya* (kidneywood), in addition to the four suggested species: *Bursera bipinnata* (*copal*), *Leucaena esculenta* (leadtree), *Amphipterygium adstringens* (*cuachalalate*) and *Bursera linanoe* (*linaloe*). The producers indicated that they were aware of the problem and suggested the possibility of associating trees with maguey in the crop contour.

Key words: *Agave angustifolia* Haw., species association, native tree species, Cultural Importance Index, prioritization of species, productive restoration.

Resumen

La superficie que se cultiva con maguey en Oaxaca se ha incrementado en más de 500 ha por año. En la "región del mezcal" se observan cambios en el uso del suelo, ya que las nuevas plantaciones de maguey se establecen como monocultivos en terrenos donde antes había vegetación natural, con la consecuente transformación de los ecosistemas hacia unos con menor biodiversidad y mayor fragilidad del suelo a la erosión. El objetivo del

presente trabajo fue identificar especies arbóreas nativas con potencial para restaurar áreas cultivadas con *Agave* en el estado de Oaxaca, y estimar su valor cultural desde la perspectiva de los actores. Para ello, se realizaron 108 entrevistas a productores de maguey en la "región del mezcal" y se determinó el Índice de Importancia Cultural para priorizar las especies mencionadas, así como cuatro taxa sugeridos por los autores, a partir de su importancia en la restauración. Los resultados mostraron 23 especies con potencial de uso, entre las que resaltan, por su valor cultural y potencial para restaurar áreas cultivadas con *Agave*, *Pithecellobium dulce* (guamúchil), *Neltuma juliflora* (mezquite), *Dodonaea viscosa* (jarilla) y *Eysenhardtia polystachya* (cuatle); además de las cuatro sugeridas: *Bursera bipinnata* (copal), *Leucaena esculenta* (guaje), *Amphipterygium adstringens* (cuachalalate) y *Bursera linanoe* (linaloe). Los productores indicaron estar conscientes del problema y plantearon la posibilidad de asociar árboles con maguey en el contorno del cultivo.

Palabras clave: *Agave angustifolia* Haw., asociación de especies, especies arbóreas nativas, Índice de Importancia Cultural, priorización de especies, restauración productiva.

Introduction

In the state of *Oaxaca*, the *Agave* spp. (*mezcal maguey*) is one of the emblematic crops due to its tradition and culture, as it is the raw material used to produce the spirit drink called *mezcal*, which has an economic boom not only in the state, but also nationally and has become the third most exported product, after beer and coffee (Palma *et al.*, 2016). This situation has contributed to the growing involvement of individuals and companies in the production of *Agave* L. and its transformation into *mezcal*.

In 2021, *Oaxaca* registered 10 818 ha planted with *maguey*, with an average annual increase, in recent years, of 548 ha; the harvested surface area in that same year was 2 986 ha, with an average yield of 59.5 t ha^{-1} and an average rural price of MXN $3 283.00 per ton (SIAP, 2021).

The "*mezcal* region" consists of the districts of *Zimatlán de Álvarez*, *Tlacolula de Matamoros*, *San Carlos Yautepec*, *Sola de Vega*, *Ejutla de Crespo*, *Miahuatlán de Porfirio Díaz*, and *Ocotlán de Morelos* (Bautista and Ramírez, 2008). Due to the climatic and geographic conditions that characterize them, *maguey* thrives very well in all this

area, as its rainfall requirements are, on average, 600 mm per year, on soils with steep slopes of up to 100 % and low fertility; in addition, the cost-benefit that this crop generates is positive and highly profitable (Rodríguez *et al.*, 2022).

70 % of the farmers in the "*mezcal* region" make their living from subsistence farming, growing corn, beans, chili, and squash with low yields due to poor soils and water scarcity; therefore, the activity of cultivating *maguey* and producing *mezcal* in artisanal *palenques* allows them to receive and diversify their monetary income (Palma *et al.*, 2016).

The Mexican Regulatory Council for *Mezcal* Quality (Comercam, 2023) notes that *Oaxaca* currently allocates 12.9 million liters of *mezcal* per year to the market, which reflects the increase in the planted surface area, going from 8 077 ha in 2017 to 10 818 ha in 2021 (Moctezuma-López *et al.*, 2023). This condition is leading to a change in land use, transforming areas covered with low deciduous forest and thorny scrub into monoculture *Agave* plantations, with evident disturbances in the characteristic ecosystem of the region.

The most cultivated species is *Agave angustifolia* Haw., commonly known as *espadín maguey*, from which a *mezcal* of excellent quality is obtained; however, this type of *maguey* requires, for its good development, as much sunlight as possible (Bravo *et al.*, 2007). For this reason, in order to establish new plantations, producers need to clear the land, *i. e.* they eliminate the natural vegetation, thereby altering the ecosystem and rendering the soil more fragile to erosion.

The *maguey* cultivated under these characteristics has a twofold repercussion: on one hand, economic, as it benefits the local economy by promoting good development, production, employment, and family monetary income, which have represented a significant contribution to the state's gross domestic product. Secondly, it has implications for the environment, as it transforms ecosystems and

increases the risk of soil erosion, in addition to decreasing biodiversity; furthermore, after several years of *maguey* cultivation, soils become unproductive resources for agriculture, jeopardizing the sustainability of production (Moctezuma-López *et al.*, 2023).

Within this context, the need arises to look for alternatives to reverse this problem. One of these is productive restoration, *i. e.*, restoring certain elements of the structure and function of the original ecosystem while sustainably recovering productivity, mainly through the use of agroforestry and agroecological techniques that generate tangible economic benefits to the populations (Ceccon, 2013), as agroforestry systems make it possible to halt the deterioration of natural resources and at the same time exploit the *maguey* crops (Burgos *et al.*, 2016).

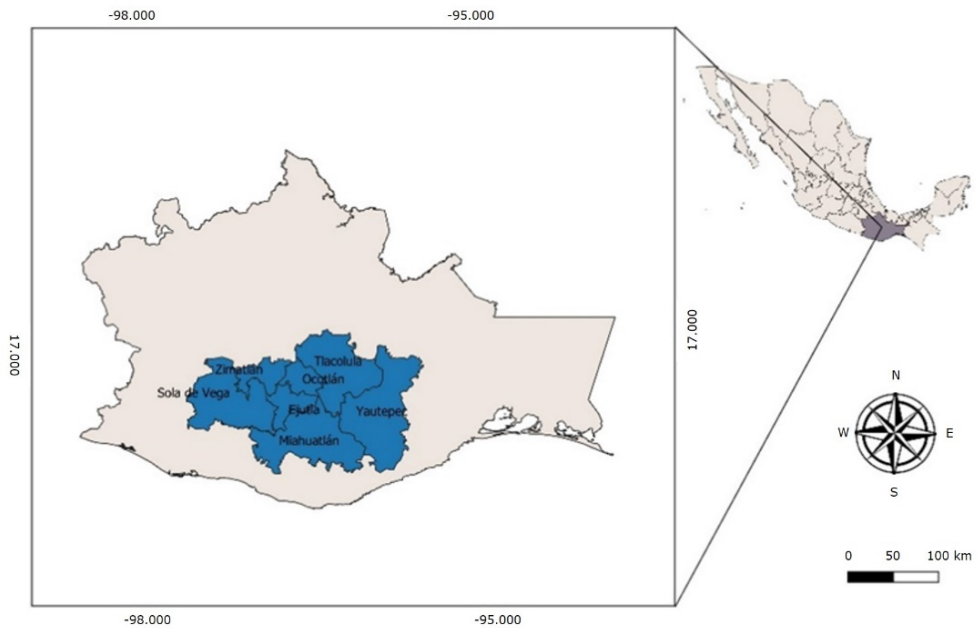
The Cultural Importance Index (*CI*) was utilized to identify, from the stakeholders' perspective, which tree species may have a potential for use as part of productive restoration systems and which are or have been part of natural ecosystems. The importance is determined by the value of their use and exploitation and was prioritized to ensure their success for restoration purposes in *Agave* plantations.

The objective of this study was to identify and estimate the cultural importance of tree species with potential for use in potential productive agroforestry restoration systems with *maguey* in the "*mezcal* region" of the state of *Oaxaca*.

Materials and Methods

Study area

The scope of the study was the "*mezcal* region", which is located in the South-central part of the state of *Oaxaca*, geographically located between -96° and -98° W, and 16° and 17° N (Figure 1), at 800 to 1 700 masl, with an average temperature between 20 and 25 °C, and an annual precipitation ranging between 508 and 644 mm; the predominant climates are Bs, Bs_0 and (A)c (Bravo *et al.*, 2007; Amoroz, 2011).



Zimatlán = District of *Zimatlán de Álvarez*; *Tlacolula* = District of *Tlacolula de Matamoros*; *Yautepec* = District of *San Carlos Yautepec*; *Sola de Vega* = District of

Sola de Vega; *Ejutla* = District of *Ejutla de Crespo*; *Miahuatlán* = District of *Miahuatlán de Porfirio Díaz*; *Ocotlán* = District of *Ocotlán de Morelos*.

Figure 1. Location of the "*mezcal* region" in the state of *Oaxaca*, Mexico.

Research on *maguey* cultivation has been carried out in different communities in this region, including the works of Arredondo *et al.* (2001) and Espinosa *et al.* (2002).

Interviews

In 2023, 108 semi-structured interviews were conducted with *Agave* producers in the "*mezcal* region". The formula suggested by Boza *et al.* (2016) was utilized to determine the sample size, with the following expression:

$$n = \frac{N Z^2 \times p \times q}{e^2 (N-1) + Z^2 p \times q} \quad (1)$$

Where:

n = Sample size

N = Population size

Z = Confidence level, for 98 % equals 2.32

p = Proportion of the population that belongs to the group of interest, considered as 95 %

q = (1-p)

e = Level of precision, reflecting sampling errors, was considered to be 5 %

Based on information from Inegi (2022), the 16 municipalities of the "*mezcal* region" with the largest number of *maguey* producers were considered as the sampling frame, for a total of 1 764 producers, which constituted the total population to be sampled (N). The interviews were distributed proportionally among the municipalities (Table 1). With this information and the aforementioned Equation, a minimum n=97 interviews was obtained, with a reliability of 98 % and a precision of 5 %; to further reduce the error, the sample size was increased to 108, which meant a sampling intensity of 6.1 %.

Table 1. Distribution of interviews by municipality in the "*mezcal* region".

District	Municipality	Number of producers	Number of interviews
Miahuatlán	*Miahuatlán de Porfirio Díaz*	385	26
Miahuatlán	*San Luís Amatlán*	150	8
Tlacolula	*Santiago Matatlán*	187	9
Tlacolula	*San Pedro Quiatoni*	149	8
Tlacolula	*San Juan del Río*	105	3
Tlacolula	*San Lorenzo Albarradas*	84	3
Tlacolula	*San Juan Guelavía*	35	4
Yautepec	*Nejapa de Madero*	145	7
Yautepec	*San Carlos Yautepec*	134	5
Yautepec	*Santa María Ecatepec*	83	4
Yautepec	*San Pedro Totolapam*	42	3
Ejutla	*Ejutla de Crespo*	90	7
Ejutla	*La Compañía*	55	5
Sola de Vega	*Villa Sola de Vega*	60	4

Ocotlán	*San Baltazar Chichicapam*	42	11
Zimatlán	*Zimatlán de Álvarez*	18	1
Total		1 764	108

The interview instrument considered the following groups of variables: general data about the producer, the characteristics of the property, the management and use of the property, perception of the problem, and a section on the perspective on the feasibility of transforming the *Agave* crop to a more sustainable agroforestry production system, in addition to free space for the suggestion of species with potential for association with *Agave*.

Likewise, due to their potential history and benefits in agroforestry systems, four timber species to be established in association with *maguey* were presented to the participants for their consideration: *Bursera linanoe* (La Llave) Rzed., Calderón & Medina (*linaloe*), *Amphipterygium adstringens* (Schltdl.) Schiede *ex* Standl. (*cuachalalate*), *Bursera bipinnata* Engl. (*copal*) and *Leucaena esculenta* (Moc. & Sessé *ex* DC.) Benth. (leadtree).

Linaloe is an ecologically and economically important timber species found in certain specific sites of the tropical deciduous forest in the Southern and Central states of Mexico (Castellanos-Bolaños and Gómez-Cárdenas, 2022). *B. linanoe* is distributed mainly at altitudes between 650 and 1 500 m (Rzedowski *et al.*, 2004); is the only species of *Bursera* whose essential oil, with a lemon-lime fragrance, is composed predominantly of linalyl acetate (Becerra and Noge, 2010). Stoniness is a condition that favors plant growth, apparently due to a high capacity of the root to absorb water from the soil quickly, in response to the sporadic and short rains that occur in the months of June to September (Cruz-Cruz *et al.*, 2009).

Copal is distributed from Southern *Chihuahua* and *Sinaloa* to *Morelos*, *Guerrero*, *Oaxaca* and *Chiapas* states; although chemically variable, the main volatile component of its fresh resin is *α*-pinene (Gigliarelli *et al.*, 2015). It is a dioecious

species, 6 to 10 m high, very resinous, with a pleasant and penetrating aroma; the trunk can measure up to 25 cm in diameter; it thrives in tropical deciduous forests and adjacent oak groves, as well as in secondary vegetation derived from them, at an altitude between 1 650 and 2 200 m. Its wood is used as firewood and to make poles and saddles; its resin is used as incense, and both its fruits and its bark are ascribed medicinal properties (Rzedowski *et al.*, 2004). *Copal* is a sacred tree, as it has cultural values that are deployed both in ceremonial uses and in medicinal applications (Martínez *et al*., 2020).

The leadtree is a semi-deciduous tree, ranging from highly branched shrubs less than 5 m tall to trees 8 to 20 m tall, with diameters at breast height of up to 50 cm and spreading crowns, with smooth gray or grayish-brown bark (Hughes, 1998). The plant blooms and fructifies during the season when foods are limited, *i. e.*, August to May. Due to its growth environment, it develops in poor soils (calcareous Regosols) (Peralta-Juárez *et al.*, 2017). In agroforestry systems it is used in windbreaks, shade for coffee plantations, live fences, cultivation in alleys, and in silvopastoral systems as a protein bank and for soil improvement through nitrogen fixation, which the genus *Leucaena* Benth. is capable of performing; it is also important as an ornamental tree, as a tutor, and for green compost (Olivares-Pérez *et al*., 2011).

Cuachalalate is endemic to Mexico and grows in the tropical deciduous forest, where it is dominant; it is a dioecious tree with ascending and twisted branches, reddish brown to dark brown in color; it reaches heights of 10 m and has a diameter at breast height of up to 40 cm (Pennington and Sarukhán, 2005). Its distribution is restricted to the Pacific slope, where a warm sub-humid climate predominates, with a precipitation coefficient of less than 40 mm and an average annual temperature of 24 °C (Solares and Gálvez, 2002). The species presents indicators of scarcity, as well as intensive and destructive exploitation because its bark has been used since pre-Hispanic times in traditional medicine. Among the ailments for which it is recommended are gastritis,

elimination of stomach ulcers, and wound healing, which is why it is one of the most important species in Mexican herbal medicine (Solares *et al.*, 2012).

Cultural Importance Index

The cultural value of tree species was determined through the Cultural Importance Index (*CI*), using the following mathematical expression (Burgos *et al.*, 2016):

$$CI = \Sigma(Iu + Fm + Tuv) \qquad (2)$$

Where:

CI = Cultural Importance Index, as the sum of the intensity of use, frequency of mention, and value of use

Iu = Intensity of use, number of uses of species *z*, expressed as a percentage of the total number of uses of all species

Fm = Frequency of mention of species *z*, expressed as a percentage of all interviews

Tuv = Total uses value of species *z*, expressed as the absolute number of uses for each species

For the registration of the species regarded as important by the producers in the interviews, 16 keys of uses were assigned based on the question analysis included in the interview itself, in which the producers could include the various uses that a tree

species has; each one was assigned a number for its synthesis during the survey: 1 firewood, 2 medicinal, 3 poles, 4 timber, 5 food, 6 charcoal, 7 fence poles, 8 manufacture of handicrafts/work tools, 9 ornamental, 10 ritual, 11 fodder, 12 shade, 13 ethnoveterinary, 14 green compost, 15 live fences, 16 others (specify).

The Cultural Importance Index of the taxa is made up of the intensity of uses, frequency of mention of each species, and the number of uses. For each mentioned species, the intensity of use was calculated based on the total number of uses, *i. e.*, 16 different uses corresponded to 100 %. The frequency of mention of species *z*, expressed as a percentage, was obtained from the number of times it was mentioned by the interviewees, regardless of the use they make of it. The total use value of species *z* is the absolute number of uses of each species.

The taxa reported by the producers were photographed, and botanical samples were collected for taxonomic identification and preparation of a list of species according to botanical family, scientific name, and common name; in addition, a database was generated in which the species were classified according to the highest value recorded for *CI*. The nomenclature of the taxa was verified in the World Flora Online platform (WFO, 2024).

Results and Discussion

Type of land and species

Based on the results of the interviews, the following data were obtained: according to the sample, a total of 613 ha were cultivated with *mezcal maguey*, of which 348 ha (57 %) were located on hillside lands, *i. e.*, lands with a certain level of slope, where a higher risk of erosion was observed due to the monoculture system and the way of planting (rows established parallel to the slope), and 264.7 ha (43 %) on flat land, where the risk of erosion due to slope is lower, but the soil is still uncovered.

Of the different types of *maguey* grown, it was confirmed that the predominant type is the *espadín maguey*, which was present in the plots of 104 producers (96 %), followed by *Agave potatorum* Zucc. (verschaffelt *agave*) with 36 mentions, in turn followed by *Agave rhodacantha* Trel. (*espadilla agave*) with 27, *Agave karwinskii* Zucc. (*cuishe agave*) with 25 mentions, and in a smaller proportion, the unidentified sub-species *Agave karwinskii* (*madrecuishe maguey*) with 17, *Agave americana* L. (American *aloe*) with 16, and *Agave karwinskii* subsp. *amatengo* (*barril maguey*) with 13. In addition, it was observed that the *espadín maguey* develops well in soils completely uncovered by vegetation and, therefore, with high luminosity —a situation that agrees with what was reported by Bravo *et al.* (2007).

Perception of restoration with tree species

According to the interviews, the producers showed different degrees of interest in the association of trees with *maguey* cultivation. A total of 86 producers (80 % of those interviewed) affirmed that it is possible to associate *maguey* with certain tree species and showed such interest that some also specified the type of association that would be ideal according to their experience and knowledge; while the rest (20 %) commented that this association —*i. e.*, planting trees with the *maguey* crop— is not

necessary. Of the producers in favor, 44 % indicated that they would plant trees as a living fence around the crop; 34 % were willing to plant trees in some association with the *maguey* crop, including as rows, as spaced trees, and with tree species that do not provide too much shade (Figure 2).

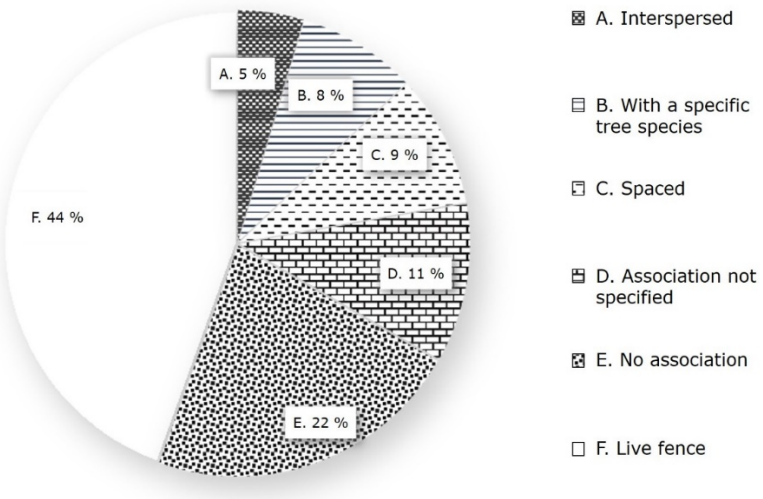


Figure 2. Type of association that *Agave* producers in the "*mezcal* region", *Oaxaca*, Mexico, are willing to implement.

Cultural importance of the mentioned species

The 23 species mentioned in the interviews had 16 uses; for 18 of them, the main use was to obtain firewood, three are utilized for food, and two for traditional medicine (Table 2).

Table 2. Uses of tree species, intensity of use (*Iu*), frequency of mention (*Fm*), total use value (*Tuv*), and Cultural Importance Index (*CI*).

Family	Scientific name/Common name	Use key	Mentions	*Iu*	*Fm*	*Tuv*	*CI*
Fabaceae	*Pithecellobium dulce* (Roxb.) Benth. (*camachile*)	1, 2, 4, 7, 8, 11, 12, 14, 15	71	0.56	0.66	9	10.22
	Neltuma juliflora (Sw.) Raf. (mesquite)	1, 4, 7, 8, 11, 12, 15, 16 (melliferous)	50	0.5	0.46	8	8.96
	Eysenhardtia polystachya (Ortega) Sarg. (kidneywood*)*	1, 2, 4, 7, 8, 11, 15	20	0.44	0.19	7	7.62
	Erythrina americana Mill. (Coral tree)	5, 7, 8, 9, 10, 15	8	0.38	0.07	6	6.45
	Vachellia farnesiana (L.) Wight & Arn (*huisache*)	1, 2, 11, 12, 15	21	0.31	0.19	5	5.51
	Piptadenia retusa (Jacq.) P. G. Ribeiro, Seigler & Ebinger (retuse piptadenia)	1, 7, 11, 15, 16 (dye)	16	0.31	0.15	5	5.46
	Lysiloma acapulcense (Kunth) Benth. (*tepehuaje*)	1, 5, 7, 11, 15	16	0.31	0.15	5	5.46
	Vachellia pennatula (Schltdl. & Cham.) Seigler & Ebinger (fern-leaf acacia)	1, 7, 8, 15	12	0.25	0.11	4	4.36
	Senna atomaria (L.) H. S. Irwin & Barneby (*flor de San José*)	1, 11, 12	10	0.19	0.09	3	3.28
	Haematoxylum brasiletto H. Karst. (Mexican logwood)	1, 2, 15	6	0.19	0.06	3	3.24
Cupressaceae	*Juniperus deppeana* Steud. (juniper)	1, 4, 7, 12, 15	4	0.31	0.04	5	5.35
	Taxodium mucronatum Ten. (Montezuma cypress)	1, 8, 12	5	0.19	0.05	3	3.23
Anacardiaceae	*Schinus molle* L. (Peruvian peppertree)	2, 10, 12, 15	11	0.25	0.1	4	4.35
	Spondias mombin L. (yellow mombin)	1, 4, 8, 12	2	0.25	0.02	4	4.27
Sapindaceae	*Dodonaea viscosa* Jacq. (broadleaf hopbush)	1, 2, 4, 7, 9, 12, 15	30	0.44	0.28	7	7.72
Malvaceae	*Ceiba aesculifolia* (Kunth) Britten. & Baker f. (*pochotle*)	1, 4, 9, 10, 12, 15	10	0.38	0.09	6	6.47
Bignoniaceae	**Jacaranda mimosifolia* D. Don. (*jacaranda*)	1, 4, 9, 10, 12	27	0.25	0.25	5	5.5
Convolvulaceae	*Ipomea murucoides* Roem. & Schult. (*cazahuate*)	1, 2, 12, 16 (insecticide for leaf cutter ants)	15	0.25	0.14	4	4.39
Zygophyllaceae	*Guaiacum officinale* L. (guaiacwood)	1, 2, 4, 12	8	0.25	0.07	4	4.32
Cactaceae	*Opuntia* spp. (*nopal*)	5, 7, 15	32	0.19	0.3	3	3.48
Rutaceae	*Citrus limon* L. Osbeck (lemon)	1, 5, 15	12	0.19	0.11	3	3.3
Boraginaceae	*Ehretia tinifolia* L. (*pingüica*)	1, 5, 12	8	0.19	0.07	3	3.26
Meliaceae	**Melia azedarach* L. (Chinaberry tree)	1, 10, 12	4	0.19	0.04	3	3.22

*Introduced species

The taxa used for firewood also have other uses, *i. e.*, they are multipurpose species, and among them are for live fences, traditional medicine, shade, and poles; three taxa of the Fabaceae family stand out: *Pithecellobium dulce* (*camachile*), *Neltuma juliflora* (Sw.) Raf. (mesquite), and *Eysenhardtia polystachya* (Ortega) Sarg. (kidneywood), and one of the family Sapindaceae, *Dodonaea viscosa* Jacq. (broadleaf hopbush) (Table 2).

The species named, mainly for food use, were *Erythrina americana* Mill., Fabaceae (coral tree), *Opuntia* spp., Cactaceae (*nopal*) and *Citrus limon* L. Osbeck, Rutaceae (lemon). The taxa whose main use is medicinal were *Schinus molle* L., Anacardiaceae (Peruvian peppertree) and *Ipomoea murucoides* Roem. & Schult., Convolvulaceae (*cazahuate*).

Table 2 shows the Cultural Importance Index (*CI*) of the various species. The *camachile* stood out for having the highest value of *CI*=10.22, the result of the sum of *Iu*=56 % calculated as the percentage of nine types of uses out of a total of 16, plus 66 % corresponding to the frequency of mentions, plus a value of nine corresponding to the number of uses (Table 2). In this regard, Monroy and Colín (2004) agree with the importance of the *camachile* for its diversity of uses.

Cultural importance of the suggested species

Table 3 shows the species proposed by the authors of this research for validation by the producers.

Table 3. Suggested tree species, uses, intensity of use (*Iu*), frequency of mention (*Fm*), total use value (*Tuv*) and Cultural Importance Index (*CI*).

Family	Scientific name/Common name	Use key	Mentions	*Iu*	*Fm*	*Tuv*	*CI*
Burseraceae	*Bursera linanoe* (La Llave) Rzed., Calderón & Medina (*linaloe*)	2,7,10,13	14	0.3	0.1	4	4.4
	Bursera bipinnata Engl. (*copal*)	1,2,7,8,10,11,15,16	53	0.3	0.5	5	5.8
Anacardiaceae	*Amphipterygium adstringens* (Schltdl.) Schiede *ex* Standl. (*cuachalalate*)	2,4,5,10,16	99	0.5	0.9	8	9.4
Fabaceae	*Leucaena esculenta* (Moc. & Sessé *ex* DC.) Benth. (leadtree)	1,5,11,15,16	100	0.4	0.9	6	7.3

Amphipterygium adstringens (*cuachalalate*) stood out for having the highest value of *CI*=9.41, resulting from the sum of *Iu*=25 % obtained as the percentage of eight types of uses out of a total of 16, plus 12 % corresponding to the frequency of mentions, plus a value of eight corresponding to the number of uses (Table 3). *Leucaena esculenta* (leadtree) exhibited a *CI*=7.3, followed by *Bursera bipinnata* (*copal*) with a *CI*=5.8, and finally by *Bursera linanoe* (*linaloe*), with a *CI* of 4.37.

Prioritization of species

Figure 3 shows the ordered value of the *CI* of each one of the species mentioned and suggested; those with the highest *CI* may have the preference and a potential to become established as part of the productive restoration. In order of importance, they were *Pithecellobium dulce* (*camachile*), *Bursera bipinnata* (*copal*), *Neltuma juliflora* (mesquite), *Dodonaea viscosa* (broadleaf hopbush), *Eysenhardtia polystachya* (kidneywood) and *Leucaena esculenta* (leadtree).

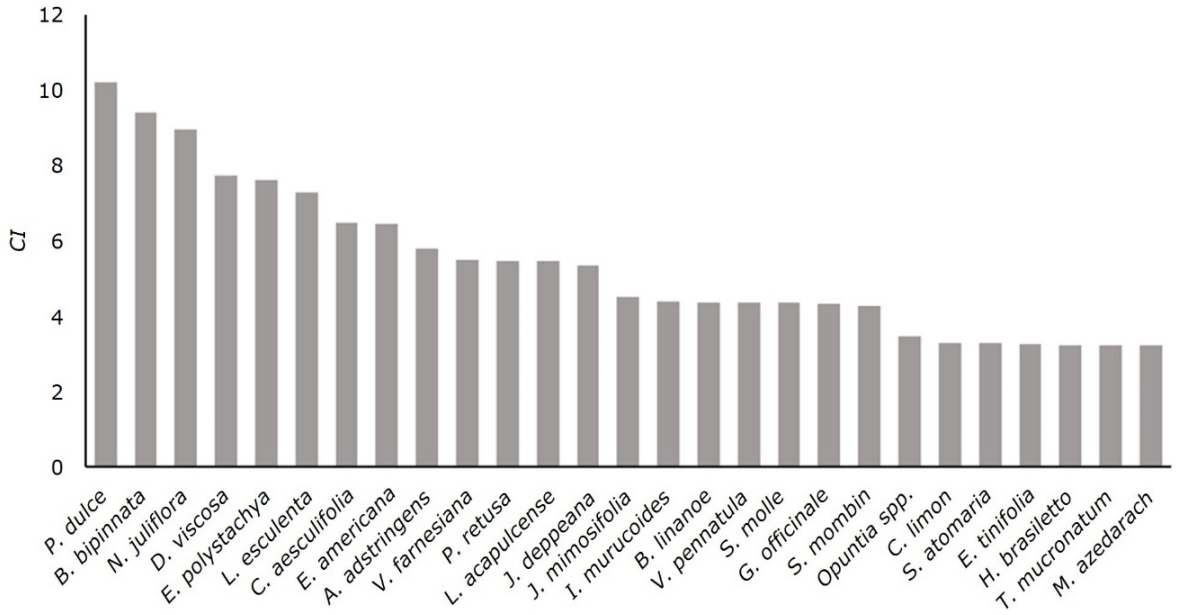


Figure 3. Prioritization of tree species according to their *CI*.

B. bipinnata (*copal*) ranked second as a suggested species; *L. esculenta* (leadtree) in the sixth place, *A. adstringens* (*cuachalalate*) ranked ninth and *B. linanoe* (*linaloe*) ranked 16th out of 27 species. Thus, the tree species mentioned by the producers were more important than some of those proposed by the researchers.

Conclusions

The association of tree species for the productive restoration of areas with *maguey* cultivation is possible according to the opinion of the producers, and the most feasible way to plant them is as live fences around the *agave* crop.

Based on the Cultural Importance Index, the promising species for the productive restoration of areas cultivated with *mezcal agave* are, in order of importance, *Pithecellobium dulce*, *Bursera bipinnata*, *Neltuma juliflora*, *Dodonaea viscosa*, *Eysenhardtia polystachya* and *Leucaena esculenta*, whose main uses are as firewood or food and in traditional medicine.

It is important to take into account the traditional knowledge of the producers and of the technical-scientific knowledge of researchers regarding the use and characteristics of the species to be established for productive restoration purposes.

Acknowledgments

The authors are grateful to the *maguey* producers of the various communities who were interviewed and enthusiastically collaborated providing information and points of view, and to the administrative and agrarian authorities of the communities for their valuable support.

Conflict of interest

The authors declare that they have no conflicts of interest with any company or institution related to the present study.

Contribution by author

Rafael Rodríguez-Hernández and Juan Francisco Castellanos-Bolaños: study idea, field data collection, analysis of the results and drafting of the manuscript; José Rafael Contreras-Hinojosa: field data collection and revision of the manuscript; Teresa Nashiely Ruíz-Ríos and Martha García-Sibaja: field data collection, coding of information and formulation of the database.

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