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The Beekeeping Areas of the State of Yucatán, for the Promotion of their Rational Use and the Transition Towards Organic Honey Production and Botanical Certification

Batllori Sampedro Eduardo Adolfo*

Department of Human Ecology, Center for Research and Advanced Studies of the IPN, Mérida Unit, Yucatán, Mexico.

***Correspondence:**
Batllori Sampedro Eduardo Adolfo, Department of Human Ecology, Center for Research and Advanced Studies of the IPN, Mérida Unit, Yucatán, Mexico.

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ABSTRACT

Bees play a crucial role in nature as pollinators, enabling the reproduction of most wild and cultivated plants. They are considered an environmental regulatory service, indirectly benefiting food production, biodiversity conservation, and integrated environmental protection. This work analyses data from the state project on Biodiversity and Human Development, proposing a beekeeping zoning plan for Yucatán.

Keywords

Apiculture, Organic honey production, Botanical certification.

Introduction

In the Yucatán Peninsula, the indigenous Maya groups have harnessed the natural resources of their environment through the agroforestry system known as "milpa," which has been and continues to be the cornerstone of their subsistence. The milpero system is a complex method of resource appropriation involving the diversification of activities and, consequently, the products obtained, through which rural families trade and exchange goods with other groups. The milpa is a polycultural agricultural system that involves not only the planting of maize but also other species and varieties such as squash, beans, and chili, and incorporates a range of complementary agricultural, forestry, and extraction activities, including post livestock farming and beekeeping. Within the milpero system, beekeeping has been one of the traditional activities of farmers to utilise the biodiversity of various ecosystems and obtain diverse bee products such as honey, wax, and pollen for self-consumption, exchange, and sale. Various authors also note that beekeeping has been one of the primary activities providing monetary resources to farming families.

Meliponiculture, like beekeeping, has been and continues to be an important part of the history, tradition, and economy of the Yucatán Peninsula [1]. Before the colonial period, the Maya of the peninsula worked with native stingless bees from the genera Melipona and Trigona, which are typical of the tropical and subtropical regions of Mexico. The species Melipona beecheii Benett, known in the Maya language as X unáan kàab or X ko'olel kàab (Lady of the honey, woman of the honey, respectively), was widely used for honey and wax production. These products were used both for local consumption and for trade with other Mesoamerican peoples. During the colonial period, the Spanish imposed a tax on the Maya of this region in the form of honey and wax (cerumen), which was satisfactorily met through the production of native bees. The demand of the Spaniards living in the central part of the country was met by products coming from the port of Campeche. As a result, the wax came to be known as "Cera de Campeche."

With the introduction of Apis mellifera to the Yucatán Peninsula (around 1911), beekeeping began to be promoted; it is considered that this initiation took place in the state of Yucatán, where beekeeping was practised as a hobby without technique. It was from 1930 onwards that beekeeping became more formally established in the Peninsula. Local Yucatecans imported genetic material and beekeeping technology. It was not until 1954 that Mr.

Felipe Martínez López made a significant contribution to queen rearing technology by designing a plastic cup-cell, replacing the artificial wax cup-cells. Between 1965 and 1971, Yucatán exported nearly 61,000 tonnes of honey. By 1973, President Luis Echeverría inaugurated the Southeast Beekeeping Promotion Centre for the manufacturing and sale of beekeeping equipment and supplies. This centre was coordinated with the Regional Laboratory of Animal Pathology (now SAGARPA) for disease control.

In 1985, the federal government, state government, and the University of Yucatán signed a coordination agreement for the establishment of the State Advisory Committee for the prevention and control of Africanised bees. During the period from 1992 to 2000, the mite Varroa destructor was detected in Yucatán, leading to the indiscriminate use of unauthorised substances for its control. Beekeeping research groups were consolidated in various institutions across the Peninsula, developing projects on the biological and technical aspects of beekeeping [2]. By 2009, research continued to manage the certification of Yucatán honey based on its botanical and geographical origin.

In 2012, commercial permits were granted for the cultivation of genetically modified (GM) soybeans in the Yucatán Peninsula, as well as in Chiapas and the Huasteca Plain, with a total of 13,075,000 kg of seeds allocated to 253,000 hectares (two hundred and fifty-three thousand hectares) starting from the spring-summer cycle (P-S) of 2012, with indefinite validity. The European market is highly demanding regarding honey quality and imposes restrictions on its commercialisation if the honey shows any contamination, including traces of genetically modified material. Therefore, honey traders aim to avoid indicating that their product contains GM ingredients, as this could have a very negative impact on their sales. The overlap between beekeeping areas and GM soybean cultivation raises questions about the possibility of coexistence between the two. The only existing study up to that year showed that, out of 36 honey samples collected from regions with GM soybean crops, 100% contained pollen from this plant, with 97% of the samples having more than 3% of this pollen and 3% of the samples having between 3% and 15% of this pollen.

Among the main environmental services provided by nature is undoubtedly pollination, which is carried out through the activities of bees, wasps, flies, beetles, butterflies, ants, bats, birds, and some mammals, as well as the wind. However, of the total flowering plants pollinated by insects, 80% are pollinated by bees, which require nectar and pollen for their nourishment, thus establishing a symbiosis between plants and pollinators.

For a flowering plant to reproduce sexually, it is necessary for pollen to be transferred from the anther of one flower to the stigma of another flower, a process known as pollination [3]. To achieve this, plants require an agent to transfer pollen from the male organ of the plant to the female organ. Bees represent a crucial link in nature and, as pollinators, enable the reproduction of most wild and cultivated plants, thus being considered an environmental regulatory service (Ecosystems and Human Well-being: A Framework for Assessment, Report of the Working Group on the Conceptual Framework of the Millennium Ecosystem Assessment). According to Moritz [4], bees are valuable for recovering and stabilising damaged or endangered ecosystems. For the state of Yucatán, the pollination service provided by various species is illustrated in Figure 1, showing the potential distribution of bats and bees across the state. Figure 2 depicts the current status of regulatory services in general within the state of Yucatán and their trends.

Humans, recognising the value of this environmental service, have developed an activity that involves the breeding, improvement, and rational exploitation of bees, both sedentary and migratory, which is now known as beekeeping. This practice leverages a derived product, honey, which is the naturally occurring sweet substance produced by bees from the nectar of flowers or other living parts of plants. Bees collect, transform, and combine this nectar with specific substances of their own, storing it in honeycombs. For this reason, beekeeping, in addition to its productive function, provides indirect benefits by contributing to food production, conserving biodiversity, and serving as a vital support in the integrated protection of the environment.

According to Ayala-Arcipreste [7], beekeeping provides direct benefits to humans in the form of products that can be consumed and marketed. It is an economically and socially important activity that utilises the floral resources of various ecosystems without depleting them [8,9]. Sihag and Singh [10] argue that the loss of pollinators would pose a severe threat to the environment, as it would impact the reproductive processes of a wide variety of wild and cultivated plant species across the globe. However, the destruction of these organisms' habitats, the use of toxic chemicals, and the addition of pollutants to the environment have led to a large-scale decline in their numbers.

Figure 3 shows the richness of faunal species that contribute to the environmental service of pollination, including the distribution of bees represented by apiaries, which are indicated as black dots scattered across the state and municipal boundaries.

According to data from the National Institute of Statistics and Geography, in the publication "The Food Sector in Mexico," 2011, nearly 40% of honey in Mexico is produced in the Yucatán Peninsula, with production potentially exceeding 17,000 tonnes. However, the state of Yucatán is the leading producer, with more than 8,000 tonnes per year, representing 14.9% of the national total.

The Beekeeping Protection and Promotion Law of the State of Yucatán states in Articles 1, 2, and 4, sections VI, XIV, XV, XVI, and XIX, that the provisions contained in this law and its regulations are of social interest, general observance, and mandatory throughout the territory of the State of Yucatán. Its objective is the organisation, protection, promotion, development, and modernisation of beekeeping activities in the State, particularly in areas deemed suitable for the growth and development of beekeeping. It also aims to strengthen producer organisations

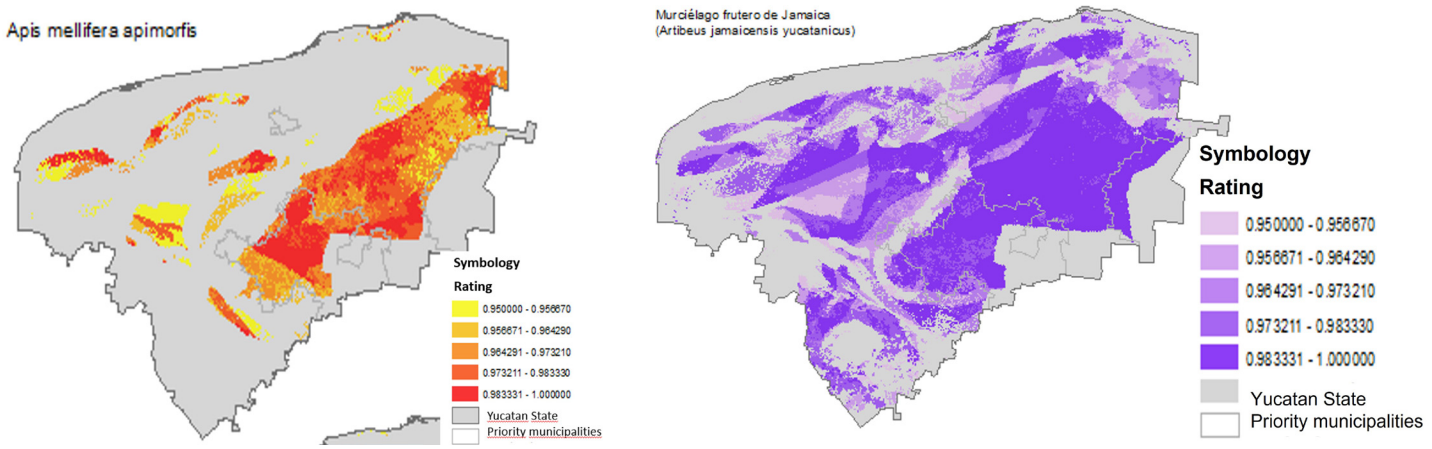


Figure 1: Potential distribution maps of bees (Apis mellifera) and bats (Artibeus jamaicensis yucatanicus) in the state of Yucatán. (Source: Seduma, 2016).

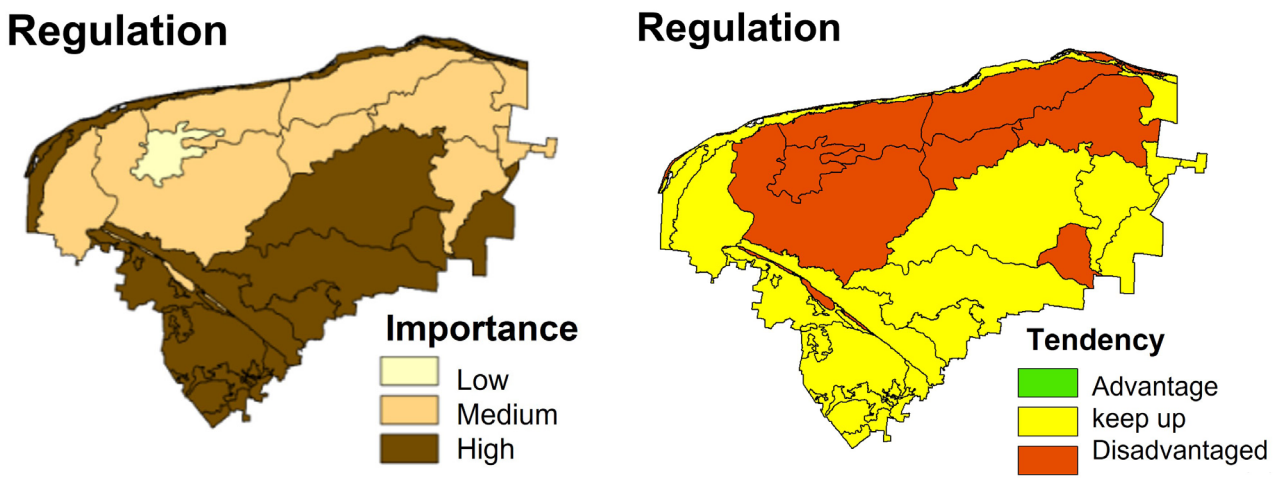
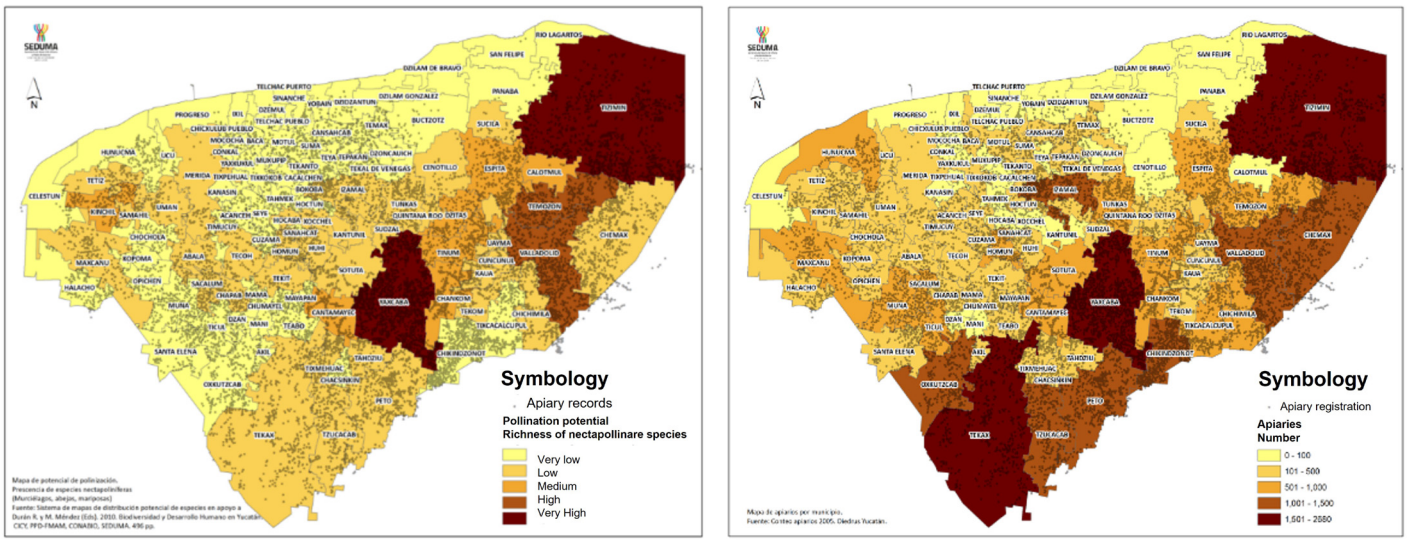


Figure 2: Map of the current importance of regulatory services in the state of Yucatán and trends in their development, by Environmental Management Units of the Yucatán Ecological Territorial Planning Programme [5].
Source: Batllori E, [6]. Ecosystem Services for Human Well-being. Secretariat of Urban Development and Environment (SEDUMA). Yucatán, Mexico.



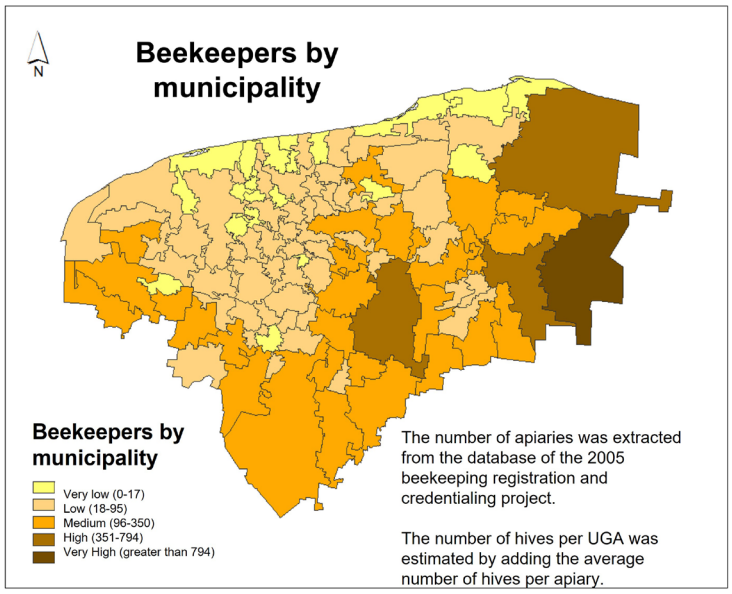


Figure 3: Potential Pollination Map. Presence of nectar-pollinating species (bats, bees, and butterflies in the left image) and Map of the number of apiaries located by each municipality for the year 2003 (right image), which contribute to the environmental service of pollination in the state of Yucatán. Distribution map of beekeepers (below).

Source: Distribution Maps System of species, with support from Durán, R., and Méndez, M. (Eds), 2010. Biodiversidad y Desarrollo Humano en Yucatán. CICY, PPD-FMAM, CONABIO, SEDUMA, 496 pp. And 2003 Census conducted by the Secretariat of Rural Development in the state of Yucatán. Certainly, Yucatán is recognised as the primary honey marketing hub in the country, exporting over 90% of its production to Europe, primarily to Germany. For this reason, the Congress of the State of Yucatán enacted the Beekeeping Protection and Promotion Law of the State of Yucatán through Decree No. 521, published in the Official Journal of the Government of the State of Yucatán on July 6, 2004.

and improve management and marketing systems for beekeeping inputs and products. For the purposes of the Beekeeping Protection and Promotion Law of the State of Yucatán, a "Beekeeping Zone" is defined as a region or area that, due to its natural or botanical conditions, is suitable for beekeeping development. Today, the international honey market has become more demanding due to increasing concerns about health and nutrition. Given that honey is a product intended for human consumption, it must be guaranteed for its safety, physicochemical quality, and traceability of its origin. For honey producers, it is crucial that beekeepers in the Peninsula offer a product with verified quality and safety, free from genetically modified organisms. This quality is linked to the botanical origin, which in some cases can indicate the geographical origin and is useful for honey certification.

Although the quality of Peninsula honey is recognised, it is often sold in bulk, as if only one type of honey were produced in the Peninsula [1]. In reality, the types of honey harvested in the region are diverse. Therefore, botanical characterisation would provide distinct identity to the honeys based on their floral origin and production area, linking them to their sensory characteristics perceived by the consumer [11].

Alfaro Bates et al. [12] state that the natural quality of honey is manifested through its organoleptic properties, including aroma, taste, and colour, which are attributed to the plant species in the area and confer its botanical origin. This quality is preserved and ensured by adhering to certain standards established in the Mexican Standard NMX-F-036-NORMEX-2006, CODEX STAN 12 [13], and the International Honey Commission [14] for honey as food and export product.

To meet these standards, routine physicochemical analyses and tests for potential contaminants are conducted to measure the quality and safety of the honey [2]. To a lesser extent, other types of analyses are used, such as sensory tests, which describe the characteristics of different honeys, and melissopalynological tests, which classify them by their botanical and geographical origin. Together, these three types of analyses allow for the interpretation and description of the complexity and variability of a type of honey [15], defining its reference framework [16].

There is a great diversity of honey types recognised by beekeepers in the Peninsula for their monofloral origin, such as ts'íits'ilche', ha'abin, and xtabentun, among others. However, this diversity is diluted when honey is mixed at collection centres for bulk sale and is labelled as multifloral honey. While these practices generate economic benefits for both producers and marketers, these benefits could be even greater by identifying honeys based on their botanical origin [12].

Understanding the diversity of honeys in the region would have the following advantages: Recognising honey as a product from a unique meliferous flora of the Yucatán Peninsula's biogeographic province, and The possibility of obtaining a quality designation benefiting the beekeeping chain.

The botanical origin can no longer remain a hidden parameter in the analysis of commercialised honeys. It should be integrated into physicochemical analyses, alongside sensory evaluation, so that a honey can be certified as monofloral from a specific species. This would ultimately allow consumers to recognise it through informative labels [17].

Objective

The general objective of this work is to analyse the information generated by Durán, R., and Méndez, M. (Eds), 2010, and to contribute to beekeeping activities by proposing a zoning plan through the use of the Potential Species Distribution Maps System from the Secretariat of Urban Development and Environment [18].

Specific Objectives

1. Establish a solid planning foundation to create guidelines, strategies, and actions related to the management of nectar-pollinating natural resources, aiming to enhance beekeeping activities in the Beekeeping Zones of the State of Yucatán, while adhering to national, state, and municipal laws and regulations.
2. Provide recommendations for sustainable alternatives that ensure the maintenance of environmental services provided by ecosystems within the Beekeeping Zones, and ensure that these benefits are distributed as widely as possible among the population.

Methodology

To determine the potential distribution of the most important nectar-pollinating flora species, information from the State Biodiversity System was utilised and analysed using the Biomain program [18]. This program allows for the correlation of physical and environmental factors with records and helps identify the potential spatial distribution of living organisms. Using maps of vegetation, temperature, soil types, geomorphology, land use, and precipitation in the state of Yucatán, an environmental matrix was constructed. This matrix utilised viable attributes to establish potential habitats for each group of organisms based on species, order, class, and family.

According to studies for the forestry strategy, a spatial analysis of potential habitats has been conducted based on records and environmental conditions for 71 species identified as most significant for nectar-pollinating production in beekeeping. By combining or overlaying each potential distribution map, a synthesized map is generated that illustrates the richness and potential distribution of species across the state territory. This map is then compared with the potentialities and limitations, leading to the establishment of a policy system that ensures the rational exploitation and conservation of the state's natural and human resources in the medium and long term.

In the ecological zoning model for the state of Yucatán [5], eighteen environmental management units are presented (1B, 1.2A, 1.2B, 1.2D, 1.2E, 1.2F, 1.2G, 1.2H, 1.2I, 1.2J, 1.2K, 1.2L, 1.2M, 2A, 2B, 2C, 3A, and 3B), in addition to Protected Natural Areas (PNAs), where beekeeping is proposed as a compatible use. These units are distributed along the coast and in the eastern, western, and southern parts of the state. The foundation of beekeeping activity is the sustainability of different land uses, including the conservation and protection of natural resources, as well as forestry, agricultural, and livestock utilisation. Beekeeping is included in over 80% of the proposed Environmental Management Units (UGAs), with some restrictions in coastal wetland areas and industrial and urban zones. Additionally, it aligns with the General Ecological Zoning Program of the Nation and the Sustainable Rural Development Law regarding conversion in forest and high-margin areas. Therefore, the proposal to establish beekeeping zones is feasible.

Subsequently, to develop the proposed Beekeeping Zoning, it is divided into units aimed at achieving the set objectives. These units describe activities that promote the enhancement of environmental services, primarily regulatory services, but also provisioning, supporting, and cultural services for the sustainable use and management of nectar-pollinating natural resources in each area. These activities will be carried out in accordance with the laws, standards, and regulations related to beekeeping and indigenous peoples. The criteria used to designate Zones and Subzones of Management are:

a) **Representativeness of Environmental Services**, particularly supporting and regulatory services.
b) **Contribution of Environmental Services**, particularly provisioning and cultural services.
c) **Vulnerability of Environmental Services,** to anthropogenic disturbances.
d) **Distribution of Environmental Services,** and equity for human well-being.
e) **Tendential Situation of the Potential,** of environmental services.

Results

The following maps display the values of richness or potential distribution index for important nectar-pollinating species in beekeeping (Figure 4). Darker colors represent areas with a higher index of potential distribution for the species, indicating locations with environmental conditions suitable for the species' habitat.

In this manner, the procedure was followed for 71 species identified as the most significant for nectar-pollinating production in beekeeping. By combining or overlaying each potential distribution map, a map is generated that synthesizes species richness and their potential distribution across the state territory. Table 1 lists the 71 species, and the indicative map is presented in Figure 5.

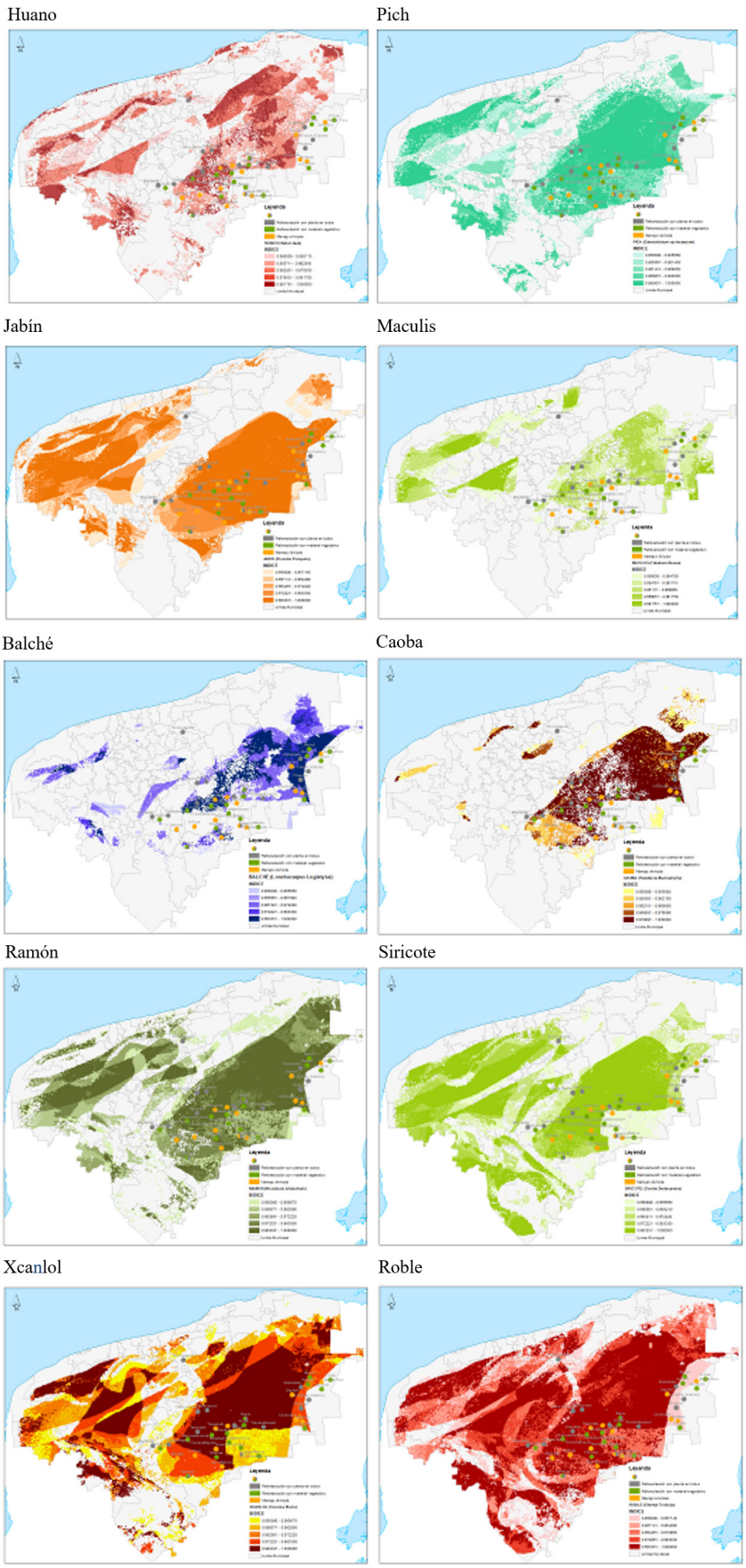


Figure 4: Potential Distribution of 10 Nectar-Pollinating Species. **Source:** Durán, R., and Méndez, M. (Eds), 2010, and SEDUMA, 2010.

Nectar-Pollinating Species					
1	*Acacia angustissima*	**25**	*Dendropanax arboreus.*	**49**	*Manilkara zapota*
2	*Acacia gaumeri*	**26**	*Diospyros cuneata*	**50**	*Metopium brownei*
3	*Allophyllus cominia*	**27**	*Dipholis salicifolia*	**51**	*Mimosa bahamensis*
4	*Astronium graveolera*	**28**	*Ehretia tinifolia*	**52**	*Nectandra coriacea*
5	*Brosimum alicastrum*	**29**	*Enterolobium cyclocarpum*	**53**	*Neomillspaughia emarginata*
6	*Bucida buceras*	**30**	*Eugenia mayana*	**54**	*Piscidia piscipula*
7	*Bursera simaruba*	**31**	*Eugenia yucatanensis*	**55**	*Pisonia acuela*
8	*Caesalpinia gaumeri*	**32**	*Exostema caribaeum*	**56**	*Pithecellobium platylobum*
9	*Caesalpinia violaceae*	**33**	*Exothea diphylia*	**57**	*Platymiscium yucatanum*
10	*Casimiroa tetrameria*	**34**	*Gliricidia sepium*	**58**	*Pseudobombax elipticum*
11	*Ceiba pentandra*	**35**	*Guazuma ulmifolia*	**59**	*Psidium sartorianum*
12	*Chrysophyllum mexicanum*	**36**	*Guettarda combsii*	**60**	*Simarouba glauca*
13	*Cissus sicyoides*	**37**	*Gymnanthes lucida*	**61**	*Spondas moman*
14	*Coccoloba reflexiflora*	**38**	*Gymnopodium floribundum*	**62**	*Swartzia cubensis*
15	*Coccoloba spicata*	**39**	*Haematoxylon campechianum*	**63**	*Tabebuia chrysantha*
16	*Cochlospermum vitifolium*	**40**	*Hampea trilobata*	**64**	*Tabebuia rosea*
17	*Coccoloba sp.*	**41**	*Havardia albicans*	**65**	*Talisia olivaeformis*
18	*Colubrina greggii*	**42**	*Heteropteris beecheyana*	**66**	*Thouinia paucidentata*
19	*Cordia gerascanthus*	**43**	*Lonchocarpus longistylus*	**67**	*Trema micrantha*
20	*Cornutia pyramidata*	**44**	*Lonchocarpus rugosus*	**68**	*Turbina corymbosa*
21	*Croton campechianus*	**45**	*Lonchocarpus xuul*	**69**	*Verbesina gigantea*
22	*Croton glabellus*	**46**	*Luehea speciosa*	**70**	*Viguiera dentata*
23	*Croton reflexifolius*	**47**	*Lysiloma latisiliqua*	**71**	*Vitex gaumeri*
24	*Dalbergia glabra*	**48**	*Machaonia lindeniana*		

Table 1: List of the 71 Most Important Nectar-Pollinating Species in Beekeeping Activity.

The flora of the Yucatán Peninsula is well-regarded for its significant contribution to beekeeping, as documented in various studies and research. These studies report numerous plant species visited by bees. According to the floristic database of the Yucatán Peninsula from the UADY Herbarium (BAFLOPY) and CONABIO [11], approximately 900 species out of 1,402 registered vascular plant species form the basis of the state's plant biodiversity [18]. About 250 types of pollen have been recorded from the species contributing to honey production in the beekeeping cycle. The identified pollen allowed for a geographical correlation of different types of honey produced in the Yucatán Peninsula, apparently in close relation to the distribution of potential vegetation and traditional human management.

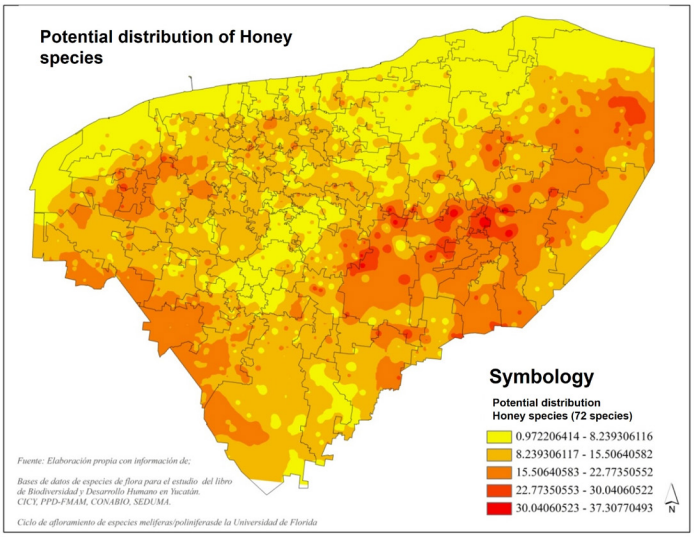


Figure 5: Potential distribution map of 71 bee-important species in the state of Yucatán. (Source: SEDUMA, 2010).

For instance, in Yucatán state, where 70% of the vegetation has been transformed, tahonal and ts'íits'ilche' were characteristic species of the early and intermediate stages of lowland forest succession, and honey from these two species was predominantly harvested. In contrast, honey from pukte' (Bucida buceras) was representative of Campeche and Quintana Roo states and came from minimally transformed or non-transformed floodplain vegetation of the lowland subperennifolia and perennifolia forests [12].

Although a large number of plants contribute nectar for honey production in the Yucatán Peninsula, only a select number of species also provide pollen for the maintenance of hives during the beekeeping cycle. Among these species, the following are noteworthy: Vines (Convolvulaceae): These plants are known for their ability to provide both nectar and pollen to bees. Tahonal (Viguiera dentata): This shrub is significant in both monofloral and multifloral honeys and is well-represented in honey samples. Ts'íits'ilche' (Guaiacum floribundum): Although this species is nectar-producing, its pollen production is lower compared to other species such as tahonal and chakàah. Its presence in honey is less significant, appearing as secondary or minor, and predominates only in 3% of monofloral honeys in the Yucatán Peninsula. Chakàah (Bursera simaruba): This species is also relevant for its contribution of pollen and nectar. Ha'abin (Piscidia piscipula) and K'an Chunúup' (Thouinia paucidentata): These plants contribute to the beekeeping cycle by offering nectar and pollen to bees. Melisopalinological studies have allowed for the assessment of these species' representation in honey samples, demonstrating that while Ts'íits'ilche' is a nectar-producing species, its contribution to pollen is lower compared to species such as tahonal and chakàah

[12]. This highlights the importance of certain species in honey production and their role in bee nutrition. At this point, beekeepers agree that the use of herbicides and insecticides on pastures designated for cattle, as well as on soybean and mechanised corn crops and adjacent areas, causes the destruction of flowering plants important for beekeeping, such as the *Tajonal* (Viguiera dentata). This plant is not consumed by cattle and is considered invasive to pastures by ranchers [18]. Similarly, many farmers are beginning to replace traditional weeding methods with herbicides, resulting in the destruction of flowering plants, particularly *Tajonal*, which, along with *Tsitsilché*, are the most important sources of nectar in the region [12].

In the pollen spectrum of some monofloral honeys, pollen from non-nectariferous anemophilous species of the families Poaceae and Cyperaceae was found in abundance, likely used by bees as a supplementary protein source. This was observed in the honeys of *Wayúum* (Talisia oliviformis) from the municipality of Felipe Carrillo Puerto, Quintana Roo, which contained more Cyperaceae pollen than *T. oliviformis*, the latter being a nectar source. The presence of Cyperaceae could indicate that the apiary is near a savannah where these families are predominant. *Chakàah* (Bursera simaruba) proves to be very important as it provides nectar and pollen abundantly during much of the harvest period, suggesting that pollen from this plant is likely overrepresented in the analysed samples [12]. The presence of extra-floral honeys (honeydew or honeydew-like) has not been confirmed in the Peninsula, although it is highly likely to be found due to the abundance of Fabaceae in the region, a botanical family with species that have extra-floral nectaries [18]. The sugarcane areas in the states of Campeche and Quintana Roo represent exploitable spaces for beekeepers, who could potentially obtain extra-floral honeys.

The above provides an initial understanding of the beekeeping zoning related to nectar-pollen vegetation richness and the needs for conservation, restoration, and rational land use to enhance one of the main primary activities. This not only significantly impacts the Gross Domestic Product of the agricultural sector in the state of Yucatán but also contributes to foreign exchange earnings.

Landscape units, based on geomorphological foundations described in POETY [5], were used to contrast the potential distribution map of nectar-pollen species and to infer the environmental services provided by the various Environmental Management Units in their current state. These landscape units are described in Figure 6.

Subsequently, ecosystem services were identified according to the Landscape Units described in the Ecological Land Use Programme of the State of Yucatán [5] with potential for beekeeping. From this analytical perspective, the territorial area with beekeeping potential covers an area of **3,589,553.00** ha, based on the described socio-environmental characteristics.

Based on this, the proposed zoning outlines the necessary actions according to its specific characteristics, aiming to achieve compatibility between the objectives of conserving environmental services and the social development of beekeeping communities, particularly the Maya communities settled in the region and the users of natural resources.

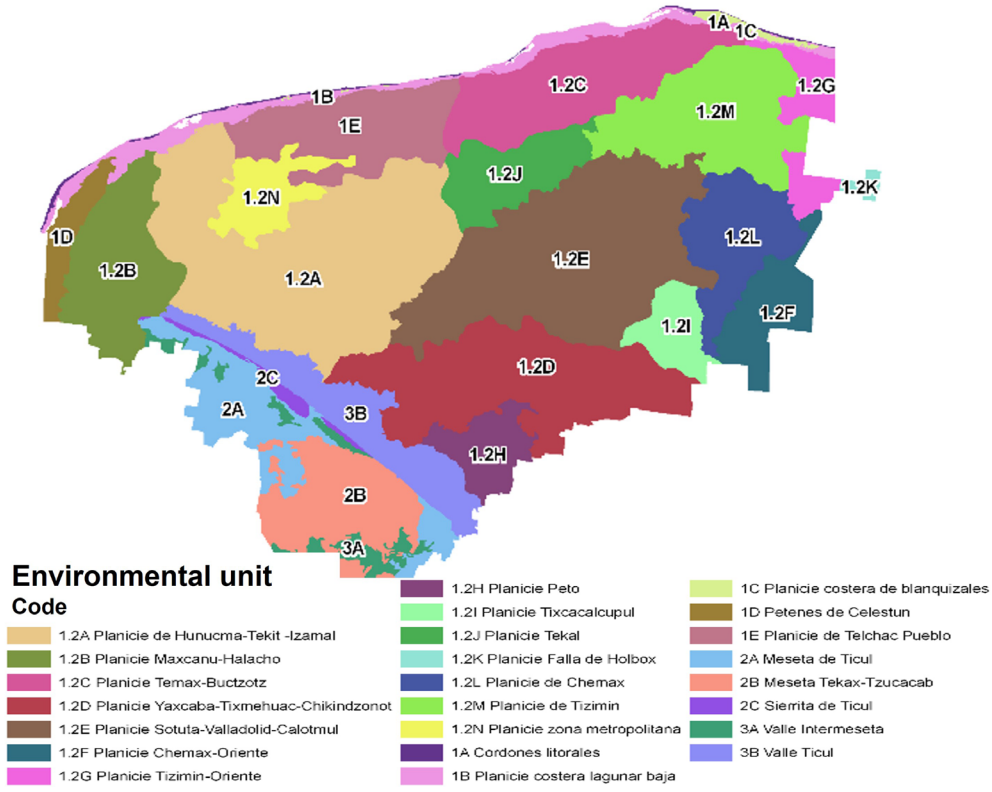


Figure 6: Landscape Units described in the Ecological Land Use Programme of the State of Yucatán [5]. (Source: POETY, 2007).

In Figure 7, the trends of ecosystem services across the various landscape units of the State of Yucatán are shown (including all supporting, regulating, provisioning, and cultural services). It outlines the intervention guidelines needed to ensure the long-term maintenance or improvement of these ecosystem services for human well-being (Batllori E. 2009. Ecosystem Services for Human Well-Being. Secretariat of Urban Development and Environment (SEDUMA), Yucatán, Mexico).

As shown, ecosystem services are highly disadvantaged in several units. In some cases, the ecosystems are close to threshold levels that could result in dramatic and irreversible changes, potentially leading to soil erosion and desertification, with the presence of xerophytic and spiny plants and contaminated groundwater.

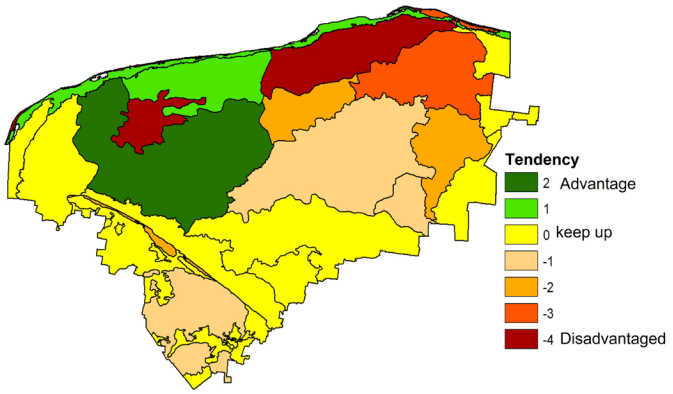


Figure 7: Current trends of ecosystem services in the state of Yucatán. (Source: Batllori Sampedro, E. (2009)).

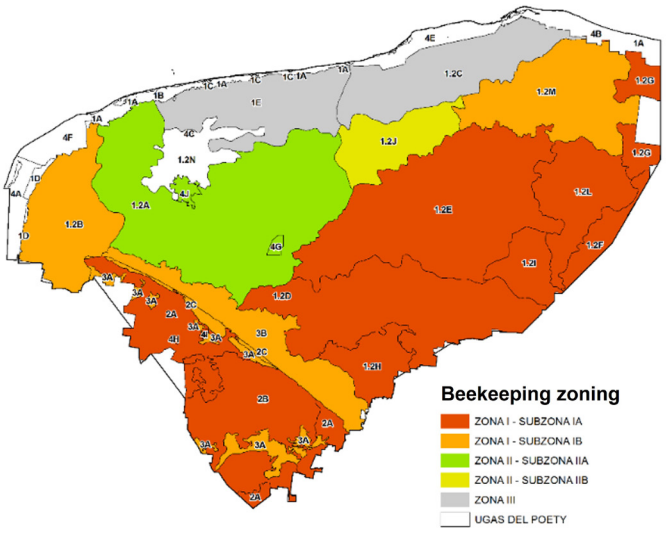


Figure 8: Map of Beekeeping Zones and Subzones in relation to the Environmental Management Units of the Ecological Land Use Programme of the State of Yucatán. (Source: Prepared by the autor).

For the appropriate management of the territorial area with beekeeping potential, a zone defined as Support and Regulation Services Zone (Zone I) was established. This is further subdivided based on its potential status into Support and Regulation Services Consolidation Subzone (Subzone IA) and Support and Regulation Services Stabilisation Subzone (Subzone IB), according to its specific characteristics. Another zone is defined as Provision and Cultural Services Zone (Zone II), which is subdivided into Provision and Cultural Services Consolidation Subzone (Subzone IIA) and Provision and Cultural Services Stabilisation Subzone (Subzone IIB) based on its potential status. Finally, another zone is defined as Productive Restoration and Environmental Services Promotion Zone (Zone III). The following table details the specific designation for each of these zones and is also referenced in the beekeeping potential territorial zoning map (Figure 8).

Table of Zoning for Beekeeping Areas

Zone	Category	Area (ha)	% Sub Zones	% Total Zones
I	Subzone IA: Consolidation of Support and Regulation Environmental Services	1,755,485	72%	68%
	Subzone IB: Stabilisation of Support and Regulation Environmental Services	695,079	28%	
	Total for Zone I	**2,450,564**	**100%**	
II	Subzone IIA: Consolidation of Provision and Cultural Environmental Services	581,974	82.5	20%
	Subzone IIB: Stabilisation of Provision and Cultural Environmental Services.	123,491	17.5	
	Total for Zone II	**705,465**	**100%**	
III	Zone of Productive Restoration and Promotion of Environmental Services	**433,524**		**12%**
	Grand Total	**3,589,553**		**100%**

Source: Prepared by the autor

Description of the Beekeeping Zoning

1) Beekeeping Zone I

This Zone covers an area of **2,450,564.00** hectares and is located within Environmental Management Units 1.2B, 1.2G, 1.2L, 1.2F, 1.2I, 1.2E, 1.2D, 1.2H, 1.2M, 2A, 2B, 2C, 3A, and 3B. It includes the best representation of services related to organic matter contribution via detritus, oxygen production, germplasm bank, wildlife habitat, aquifer recharge, microclimate control, pollination, carbon sequestration, sediment trapping, hydraulic gradient, erosion control, water purification, thermal regulation, windbreaks, sediment trapping, and flood control. This zone is characterised by the highest diversity of honey-producing tree species and pollinators, the greatest number of producers, apiaries, and hives, as well as the total honey production, although with low yields per hive. Given this, Beekeeping Zone I will focus its efforts on the consolidation and stabilisation of support and regulation environmental services.

Beekeeping Subzone IA: Consolidation of Support and Regulation Services

These are the Environmental Management Units where environmental services are maintained or enhanced due to the prevailing utilisation characteristics and cover an area of

1,755,485.00 ha. The UGA's in this subzone are: 1.2G, 1.2L, 1.2F, 1.2I, 1.2E, 1.2D, 1.2H, 2A, and 2B

Beekeeping Subzone IB: Stabilisation of Support and Regulation Services

These are the Environmental Management Units where environmental services are disadvantaged by human practices and need to be stabilised for optimal integrated use, covering an area of **695,079.00** ha. They include the UGA's: 1.2B, 1.2M, 2C, 3A, and 3B.

2) Beekeeping Zone II

This zone covers an area of **705,465.00** hectares, where it is essential to promote provisioning and cultural services. It includes the UGA's 1.2A and 1.2J. It requires the enhancement of forest and wildlife resources, reorientation of agricultural activities, sanitation and reduction of agrochemicals to ensure quality drinking and irrigation water, and improvements in landscape quality and historical heritage. This zone is characterised by the lowest diversity of honey-producing tree species, the most degraded forests and loss of biodiversity, and a lower number of pollinators. It has the fewest producers, apiaries, and hives, as well as the lowest total honey production; however, it shows the highest yield per hive.

Subzone IIA: Consolidation of Provision and Cultural Services

These are the Environmental Management Units where environmental services are being enhanced due to the abandonment of henequen cultivation and the prevailing utilisation characteristics, covering an area of 581,974.00 ha. This includes only UGA 1.2A.

Subzone IIB: Stabilisation of Provision and Cultural Services

These are the Environmental Management Units where environmental services are disadvantaged by human practices, particularly extensive livestock farming, and need to be stabilised for optimal integrated use, covering an area of 123,491.00 ha. This includes only UGA 1.2J.

3) Beekeeping Zone III: Productive Restoration and Promotion of Environmental Services

This zone covers an area of 433,524.00 hectares and requires the initiation of environmental restoration actions with a productive orientation to promote environmental services in general, including both regulatory and supportive as well as provisioning and cultural services. It includes the UGA's 1E and 1.2C. This area is severely affected and shows a negative trend in environmental services primarily due to livestock activities, with significant soil loss from erosion, high thermal fluctuations due to forest loss, and poor sediment retention and carbon sequestration. It requires the enhancement of forest resources through silvopastoral techniques, groundwater sanitation due to agrochemical presence, conversion to agroecological practices, and the use of compost to improve soils. It also needs to improve wildlife and pollinator habitats to encourage biological control recovery, address the significant loss of biodiversity and landscape quality, and enrich the hubche's. The zone has low numbers of beekeeping producers and hives, low honey production, average yield per hive, and low richness of honey-producing species. Therefore, there is a need to implement actions for productive restoration and the promotion of environmental services.

Recommendations

Considering that honey is a product intended for human consumption, its safety, physicochemical quality, and traceability must be guaranteed. Therefore, it is necessary for the Secretariat of Urban Development and Environment, in coordination with the Secretariat of Rural Development and other relevant agencies, to undertake the following activities:

1) Convene the Apiculture Product System Committee of the State of Yucatán, as the specialised governing body responsible for studying the state of beekeeping. The purpose is to support the implementation of programmes aimed at increasing the quality and productivity of apiculture.

2) Initiate actions to update the registry of beekeepers, organisations, companies, and institutions involved in apiculture. Provide inputs and equipment to beekeepers, particularly those focused on organic beekeeping. In this process, it is essential to avoid the use of prophylactic medicinal treatments, synthetic chemical agents, and genetically modified organisms. Additionally, ensure the recognition of an accredited entity for honey certification and the verification of the locations where this process takes place.

3) Coordinate with federal, state, and municipal authorities, within their respective areas of responsibility, for the execution of programmes on:

3.1) Prevention and control of diseases affecting bees.

3.2) Promote organic beekeeping, meliponiculture, and diversify the marketing of other beekeeping products such as pollen, propolis, royal jelly, and bee venom. Additionally, work to reduce the gender gap and strengthen salary equality between women and men.

3.3) Control of human activities that harm beekeeping, adhering to established standards, guidelines, and procedures. Urge the Ministry of Agriculture, Livestock, Rural Development, Fisheries, and Food, as well as the National Service of Health, Safety and Agro-Food Quality, the Ministry of Health, the Federal Commission for the Protection against Health Risks, and the State Ministry of Rural Development, to coordinate the reduction of agricultural pesticides that affect bees and other pollinators in Beekeeping Zones and negatively impact local beekeeping. This is in line with the work agenda of the Conference of the Parties on Biological Diversity. Additionally, strengthen the use of biofertilisers and biopesticides in agricultural production and promote agroecological practices for pest control, thereby protecting beneficial species for our environment. Furthermore, develop awareness-raising actions on the importance of protecting bees for agriculture, the pollination process, and the substances and conditions adverse to this vital insect, to ensure the survival of this crucial species.

3.4) Establish the necessary measures to protect the honey-producing areas and plants that form the ecosystem of the State of Yucatán. The main current threat stems from the excessive use of agrochemicals in traditional and technologically advanced agricultural crops, as well as those using genetically modified organisms, which are putting the activity in crisis due to risks affecting honey quality, bee survival, contamination, biodiversity and agrodiversity loss, and market restrictions. Therefore, it is necessary to promote compensation for individuals providing community pollination services in highly marginalised and impoverished areas, with special attention to the Maya community. This should aim at productive restoration, conservation, and sustainable use of natural resources, increasing natural capital, reducing deforestation, and encouraging reforestation with nectar and pollen-producing species. Continue with habitat protection and conservation actions, and the productive transition towards agroecological, silvopastoral, and agroforestry practices that ensure the quality of organic products and environmental services provided by the region's ecosystems. Vegetation is a crucial element for the survival of beekeeping, and bees are valuable for recovering and stabilising destroyed or endangered ecosystems.

3.5) Ensure that beekeeping processes, from production to marketing, comply with current safety, health, and hygiene standards, implementing biological control techniques and cooperating with legal authorities as required. This quality is associated with the botanical origin, which can indicate the geographical origin and is useful for honey certification. Therefore, it is necessary to recognise honey as a product of a unique honey flora from the biogeographic province of the Yucatán Peninsula.

3.6) Achieve certification of Yucatán honey's origin. For certification based on botanical origin, it is essential to strengthen fundamental research and generate more evidence to support verification, starting with the identification (through pollen) of the honey-producing plants in the region that contribute to honey formation. The aim is to obtain a quality distinction that benefits the beekeeping chain. The botanical origin should be integrated into physicochemical analyses, alongside sensory evaluation, so that honey can be certified as monofloral from a specific species, allowing consumers to recognise it through informative labels.

4) Research and technological development in the beekeeping sector should focus on:
   4.1) The management of meliponine and Africanised bees, disease prevention and control (such as varroosis and others), and support for segmented marketing;
   4.2) Strengthening technical aspects and equipment;
   4.3) Advisory and training services for beekeepers, particularly in organic techniques;
   4.4) Promoting research in areas such as acarology, genetics, biology, honey analysis, native bees, pollination, and honey flora. Additionally, research should cover environmental, socioeconomic, and cultural aspects, as well as the impacts of the coexistence between beekeeping activities and agricultural crops with genetically modified organisms.
5) Encourage the inclusion of beekeepers in organic honey production, rehabilitate, modernise, and implement new honey collection centres, consolidate the marketing of current products, and diversify the product offering based on botanical and organic origins. Promote the technical advancement of production, reduce the administrative procedures for project management, and supervise the process to ensure its proper functioning.

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