Article

Influence variables for honey production using bees *Apis mellifera* in the Misantla region

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Abstract

Various notes of electronic portals, documentaries and to a lesser extent scientific articles have reported interest in improving the production yield of honey by beehive. Among these works, climatic, social and technological factors can be reported in their dimensional form, where experts and specialists recognize that they contribute to improving honey production. Supported by apicultural experts, the Delphi method and the MICMAC structural analysis, this article reports the influence and dependence of 22 variables and their direct and indirect relationship with honey production in the intermunicipal region of Misantla of the apicultural district no. 52. Variables based on MICMAC are classified as key, regulatory, lever and autonomous. On a strategic level, the 'location of the apiary' related to the 'diversity of honey flowering' and the 'time between the placement of the apiary and the honey harvest', represent the key variables with the highest strategic value of 75/79, 61/79 and 63/79, respectively. Although the 'flowering of honey species' is a key variable for honey production, the result also indicates that this variable is not a determinant for the beekeeper to decide the 'location of apiaries'. These results provide knowledge in four categories of influential variables in honey production so that the beekeeper reflects on his beekeeping practices and can design strategies and make decisions, to improve honey production yield.

Keywords: apiary, beehive, beekeeping production, honey, MICMAC.

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Introduction

Beekeeping in Mexico is a relevant activity of the livestock subsector, with volume of production that places it in sixth place worldwide and in America it is in third place in production and export (Magaña *et al*., 2016). This activity represents the third source of foreign exchange in the agricultural sector in Mexico (Ulloa *et al*., 2010; Luna *et al*., 2016). The Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) divides the Mexican Republic into five beekeeping regions, with different degrees of development and variety of types of honey according to their characteristics of moisture, color, aroma and flavor. These regions are: Plateau, Pacific, Gulf, North and Yucatan Peninsula.

Due to its geographical location, the beekeeping region in the state of Veracruz is located in the Gulf region. According to the Agri-Food and Fisheries Information Service of the Government of Mexico (SIAP), said state occupies third place as a honey producer nationwide, with 4 704 091 t year^{-1}, which represents 9.21% nationwide, with value estimated 2 190 411 million pesos. The state of Veracruz has 12 beekeeping districts, within which, district no. 52 Martinez de la Torre is made up of 22 municipalities and in this district, they stand out as honey producers, the municipalities of Papantla, Martínez de la Torre, Tlapacoyan, San Rafael and Misantla.

The municipality of Misantla is located in the central mountainous region of the state of Veracruz, on the slope of the Gulf of Mexico, between the Sierra Madre Oriental and the Sierra de Chiconquiaco, bordering the municipalities of Yecuatla, Colipa, Nautla, Tenochtitlan, Martínez de la Torre, Atzalan and Vega de Alatorre.

Misantla presents natural characteristics that favor the development of beekeeping, such as the types of climates: warm tropical, subhumid warm, humid temperate and warm thermal regime; with rainfall varying from 2 036.4 mm per year on average and annual average temperature ranging between 22.7 °C with relative humidity of 35% to 40%. Also, the type of vegetation such as chalahuite (*Inga vera*) and intensive coffee (*Coffea arabica*), grapefruit (*Citrus maxima*), persian lime (*Citrus latifolia* Tanaka), tangerine (*Citrus reticulata*) crops, are natural flora components in this region.

Consequently, the honey produced in the intermunicipal region of Misantla according to the type of flowering are citrus honey and multiflora honey, with by-products such as pollen, wax, and propolis. At least 85% of beekeepers in the study region carry out the traditional exploitation focused on the production of honey, wax and cores (Luna *et al*., 2016), in contrast to the so-called integral exploitation that seeks to obtain additional income from the obtaining other products such as royal jelly, apitoxin, mono-floral honey, organic honey, in addition to pollination services.

Luna *et al*. (2016) mentions that the schemes of the beekeeping activity in Mexico are classified into three groups: technified, semi-technical and traditional, of which, in the intermunicipal region of Misantla 9% of beekeeping producers are technified, 36% are semi-technified and 45% use the traditional method. In this context, Misantla remains in fifth place. Based on data from the SIAP, the average production of this municipality is 80 tons per year, which represents 6.26% of the district's total production and 1.71% of Veracruz.

Beekeeping in the Misantla region faces a panorama of opportunities not only of economic type and infrastructure, but also of knowledge related to the factors that influence honey production. In this sense Magaña *et al*. (2016) mention that honey productivity is the result of the combination of several factors, including technology and the natural physical environment.

So too, Abou-Shaara *et al*. (2013) indicates that factors such as the density of honey and nectarine flora and minimizing the bee's path in its pecoreo influence yields. Magaña *et al*. (2016) adds that the productivity of honey per beehive is associated with various factors or natural physical events, among which are the africanization of the colonies, the deforestation of forests and forests, hurricanes and recently climate change.

In this sense, Medina-Cuellar *et al*. (2014) report as factors of variability in honey production to climatic fluctuations which impact on the phenology of plants, and consequently the source of nectar and behavior of bees. While, Roque *et al*. (2016) report as factors to improve honey production, topographic factors, climate, flowering density, as well as the location of the apiary, coupled with uncontrollable factors such as temperature, relative humidity, soil type, wind, sunlight, among others, among which the preference of the bee to certain floral species can be mentioned, due to the amount of nectar produced and the accessibility to the food source, as well as to the pollen composition.

Although these studies report dimensional factors in technology, climate and topography in which apiaries are based, they lack an analysis of the dependence influence of the variables that make up these dimensions. This article presents a study that uses structural analysis to determine the influence and dependence between variables on climatic, topographic, economic, technological and transhumance factors in the intermunicipal region of Misantla. In this sense, a categorization of the variables is also provided according to the dimension of the variables analyzed by the structural analysis.

Materials and methods

An exploratory type investigation is carried out based on primary and secondary sources. The primary information is collected through unstructured, face-to-face interviews and a diagnostic questionnaire with technicians and experts in the beekeeping sector, honey producers, representatives and former representatives of beekeeper’s associations in the study region.

From a population of 52 members in the Misantla Beekeepers Association (AAM), 30 beekeepers were interviewed, while those not registered in the AAM, were identified using the linear snowball technique during the period January to May of the year 2018 The study region includes the central-northern zone of the State of Veracruz, delimited to the municipalities of Misantla (19° 55’ 51.86’’ north latitude 96° 51’ 6.09 west longitude); Yecuatla (19º 51’ 57’’ north latitude 96º 46’ 36’’ west longitude; Colipa (19º 55’ 25’’ north latitude 96º 43’ 38’’ west longitude; Juchique (19º 50’ 25’’ north latitude 96º 41’ 41’’ west longitude) and Tenochtitlan (19º 48’ 27’’ north latitude 96º 54’ 39’’ west longitude.) The adjoining of these municipalities covers an area 1 159 km^2, with an approximate population of 65 996 inhabitants.

For this research, the structural analysis of Godet and Durance (2011) endorsed by the United Nations Educational, Scientific and Cultural Organization (UNESCO) is used for prospective studies and structural analysis at international level (Martínez, 2012). This methodology is commonly used as a tool for structuring and collective reflection, as well as to generate strategic information for decision-making, design, development and implementation of continuous improvement activities in work systems with the possibility of describing a system with help from a matrix that relates all its constituent elements (Godet and Durance, 2007; Ballesteros and Ballesteros, 2008; Quintero and López, 2010; Garza and Cortez, 2011).

The structural analysis is the first phase of the scenario methodology and its importance lies in the fact that it allows to clearly demonstrate the relationships between the variables that characterize the study system (Cely, 1999). This analysis described in Figure 1, comprises three phases of the MICMAC method as a matrix of cross-multiplication impacts applied to a classification (Godet and Durance, 2007).

Figure 1. Phases of the structural analysis methodology. Source: Godet and Durance (2007).

In the first phase, people with proven and current experience as a beekeeper are used and through open interviews, the variables that influence the honey production system are selected and defined. In this phase, in accordance with the beekeeper's trajectory-time criteria, the beekeeping work system demonstrated by the beekeeper and the size of the beekeeper, an expert panel is integrated with five honey producers.

In the second phase, supported by a panel of experts, the structural matrix is constructed to evaluate the influence that each of the variables of the production system exerts on each other. The panel of experts assigns a value according to the degree of influence: zero (0); weak (1); medium (2); and strong (3). Subsequently, these interrelations are processed using the MICMAC software. As shown in Figure 2, the result of the calculation of the structural matrix is the classification of the variables according to the location in a plane of influence-dependence. Table A1 details the interpretation of each of these variables in the production system.

The third phase consists of identifying the key variables, their influence and their dependence. First, through a direct classification, and finally, by an indirect classification.

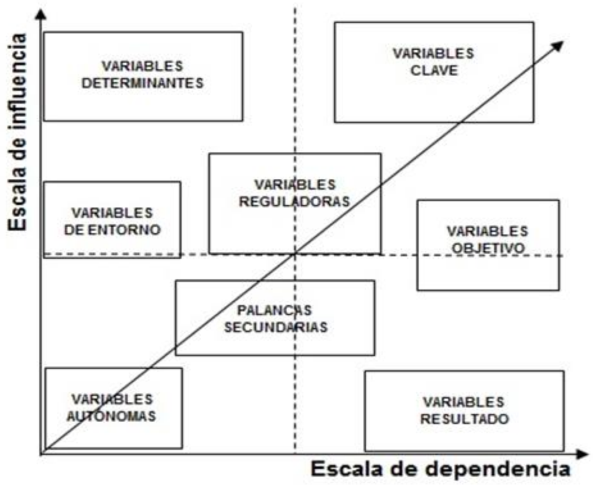

Figure 2. Strategic plane of influences-dependencies of double entry MICMAC. Source: Ambrosio *et al*. (2011).

Results and discussion

Phase I

Through an open face-to-face interview with beekeepers, the variables that influence honey production are collected, and in consensus with the panel of experts, 22 variables are identified and defined. Table 1 describes 22 variables in a long title and a short title. The latter is used in the MICMAC program.

Table 1. Variables that affect honey production.

Num.	Long title	Short title	Description
I	Time dedicated to the activity	Time (Ti)	Time that the beekeeper dedicates to the activity, can be part time or full time.
2	Deforestation of apicultural species	Deforests (D)	Increased deforestation of honey species that are important for beekeeping.
3	Pesticide use	Pesticides (P)	Use of pesticides and insecticides in places of beekeeping importance or in the areas of pecoreo.
4	Increase in agricultural areas	Agropecuar (A)	Increase in areas dedicated to livestock and crop areas not suitable for beekeeping.
5	Population growth	Population (Po)	Increase in urban stain in areas suitable for beekeeping.

Num.	Long title	Short title	Description
6	Phenology of honey species	Phenology (Fe)	Phenology of honey species suitable for beekeeping.
7	High temperatures inside the beehive	Tempera (Te)	Temperature greater than 35 °C inside the beehive.
8	Excess moisture inside the beehive	Humidity (H)	Excess moisture greater than 18% inside the beehive.
9	Access to flowering areas	Access (Ac)	Accessibility to flowering areas.
10	Distance to flowering areas	Dist-flora (Df)	Distance between the flowering zone and the apiary.
11	Distance between apiaries	Dist-apia (Da)	Distance between each apiary.
12	Excess of rain in the producing region	Rain (Ll)	Excess of rain that does not allow the pecoreo or that wash the nectar of the flowers.
13	Age of the queen bee	Age (E)	Age at which the queen bee is considered productive.
14	Morphology of honey species	Morphology (M)	Structure and shape of some honey species, which are not suitable for collecting nectar.
15	Beehive theft	Stole (Ro)	Theft of beehives in apiaries or during transhumance.
16	Location of eligible sites	Location (U)	Location of suitable areas of pecoreo.
17	Potential predators	Predator (De)	Animal species that are honey or bee consumers.
18	Care during transhumance	Care (C)	Preventive measures given to beehives during transhumance.
19	Periodic reviews	Revision (Re)	Time lapse provided for the review of beehives, which can be daily, weekly, biweekly.
20	Harvest time	T- harvest (Tc)	Time between apiary placement and harvest.
21	Transhumance to other regions	Trashuman (Tr)	Transhumance of beehives to areas suitable for honey production.
22	Flowering of honey species	Flowering (Fl)	Flowering of honey species that are considered potential for beekeeping.

Source: own elaboration from MICMAC in Ambrosio *et al*. (2011).

Phase II

In Phase II, a double-entry information matrix is constructed, in which the variables that were selected by the panel of experts are fixed, using the Delphi method, rounds of consultation between the experts are executed on days 28, 29, October 30 and 01, 2018, to identify the influence of the variables described in the information matrix. For each pair of variables, the following question was asked: is there a direct influence relationship between variable *i* and variable *j*? If such influence exists, to what degree does it exist? (Perez and Alfonso, 2016). Experts assess the direct influence between all variables and their intensity, as follows: strong (3); medium (2); weak (1); and zero (0) or potential (P).

Based on Del Río and Cárdenas (2018), the structural matrix, described in Figure 3, is entered into the MICMAC database. This matrix is understood as follows: humidity (H) maintains a “strong” influence with temperature (Te) and so on. The evaluation of the matrix through MICMAC is reflected in the cartesian plane of influences/dependencies, by means of two classifications: direct and indirect.

Variables	1 : Ti	2 : D	3 : P	4 : A	5 : Po	6 : Fe	7 : Te	8 : H	9 : Ac	10 : Df	11 : Da	12 : Ll	13 : E	14 : M	15 : Ro	16 : U	17 : De	18 : C	19 : Re	20 : Tc	21 : Tr	22 : Fl
1 : Ti	0	0	0	0	0	3	0	0	0	0	0	0	0	0	2	3	3	1	3	1	3	0
2 : D	0	0	2	3	3	0	0	0	0	3	3	0	0	0	0	3	0	0	0	3	3	3
3 : P	0	2	0	3	1	0	0	0	0	1	1	0	0	0	0	3	0	0	0	0	2	3
4 : A	0	3	3	0	0	0	0	0	1	2	3	0	0	0	0	3	0	0	0	0	2	3
5 : Po	0	3	1	0	0	0	0	0	0	0	1	0	0	0	0	3	0	0	0	0	2	3
6 : Fe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	2	0	3	3
7 : Te	0	0	0	0	0	0	0	3	0	0	0	1	0	0	0	0	0	1	0	0	0	0
8 : H	0	0	0	0	0	0	3	0	0	0	0	2	0	0	0	0	3	1	0	0	0	0
9 : Ac	0	1	0	0	0	3	0	0	0	3	0	2	0	0	0	3	0	0	3	2	1	2
10 : Df	0	2	2	2	0	0	0	0	3	0	3	0	0	0	0	3	0	0	0	3	0	2
11 : Da	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	2	0	0
12 : Ll	0	0	0	0	0	2	0	2	0	0	0	0	0	0	0	0	1	1	0	2	0	2
13 : E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14 : M	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
15 : Ro	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0
16 : U	0	3	3	3	3	3	0	0	3	3	3	0	0	1	3	0	0	0	0	3	3	3
17 : De	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	1	0	0	1	0	0	0
18 : C	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	0	0
19 : Re	2	0	0	3	0	0	0	0	3	0	0	0	0	0	1	1	1	0	0	0	1	0
20 : Tc	3	3	0	0	0	3	0	1	2	3	3	3	2	0	3	3	2	2	2	0	3	3
21 : Tr	2	1	0	3	3	2	0	0	3	0	0	0	0	0	2	2	0	3	0	3	0	2
22 : Fl	0	3	3	3	0	3	0	0	3	3	3	2	0	0	0	3	0	0	0	3	3	0

Figure 3. MICMAC structural matrix. Source: own elaboration with support from the MICMAC Godet and Durance program (2007).

he first classification is carried out through the sum of influence/dependence values for each of the variables and the second classification is through the application of the MICMAC method by means of raising the matrix to the second power, there being a correlation between the variables flowering of honey species and location of suitable areas of 1 520 interactions.

Figure 4 shows the plane of direct influences-dependencies resulting from the cross-impact matrix, product of the level of motor skills and dependence between variables. The motor skills and dependence of the variables depend on the location of the variables within the influence-dependence plane. The driving variables are the ones that exert the greatest influence on the rest of the variables that make up the system. The dependent variables are those that are influenced by the rest of the variables (Vázquez *et al*., 2017).

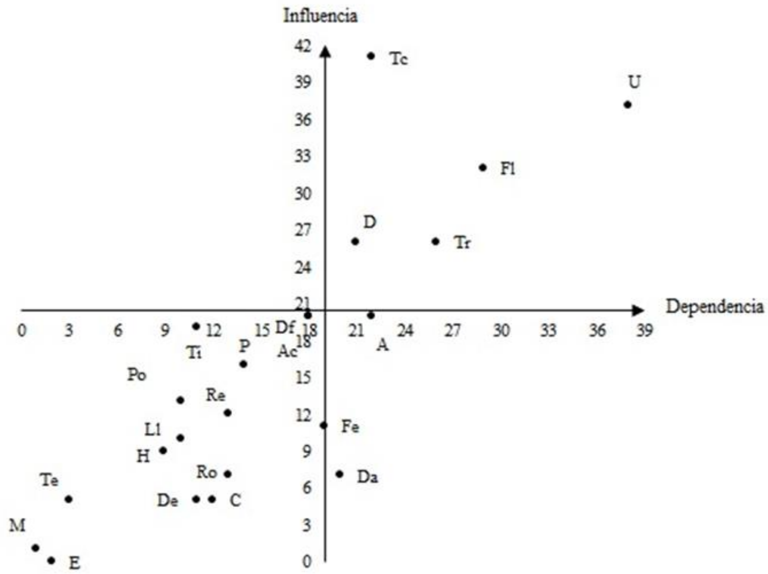

Figure 4. Plane of influences-dependencies. Source: elaboration with support from the MICMAC Godet and Durance program (2007).

As described in Figure 4, MICMAC makes a classification of the variables that make up the system based on their location in the plane of influences-dependencies. The result of this classification was as follows.

Key variables: location of suitable areas of pecoreo, flowering of honey species, harvest time.
Regulatory variables: transhumance, deforestation.
Secondary levers: time dedicated to the activity, distance to flowering areas, access to flowering areas, increase in agricultural areas, use of pesticides, phenology of honey species, distance between apiaries, periodic reviews.
Autonomous variables: theft of beehives, excess rainfall in the producing region, population growth, care for transport of the beehive during transhumance, excess humidity inside the beehive, elevated temperature inside the beehive, potential predators, morphology of the honey species, age of the queen bee.

The classification of the variables is a process that allowed identifying the importance of the variables and their strategic nature in the production of honey. The strategic value of the variables indicates the relevance that the variable has in the production of honey and in that degree, the care and attention that the beekeeper should keep in its product chain. In a broad sense, acting on them entails effects of evolution of the rest of the variables and, consequently, of the apicultural system of the study region.

In the Table 2 describes the classification of the variables resulting from the direct influence-dependence plane and their strategic value as a correlation of the magnitude of influence in honey production and since no determining variables, environment variables, objective variables and outcome variables were identified in the plane, its columns are omitted in Table 2. Where, the strategic value (E_n) of the variable is determined by the sum of its motor skills (m_n) and its dependence value (d_n).

Table 2. Classification and strategic value of influence-dependence variables in honey production.

Regulator		Secondary levers		Key		Autonomous	
Variable	E_n	Variable	E_n	Variable	E_n	Variable	E_n
D	47	Ac	38	Tc	63	Ro	20
Tr	52	A	42	Fl	61	Ll	20
		P	30	U	75	Po	23
		Fe	30			C	17
		Da	27			H	18
		Re	25			Te	8
		Df	38			De	16
		Ti	30			M	2
						E	2

Source: elaboration with support from the panel of experts and Godet and Durance (2007).

Figure 5 shows the direct influence between variables provided by the MICMAC Cruz and Medina program (2015), in which the relationships between variables connected with arcs are observed, which are identified with the magnitude of the influence. For example, with weak influence (1); medium influence (2); important influence; and (3).

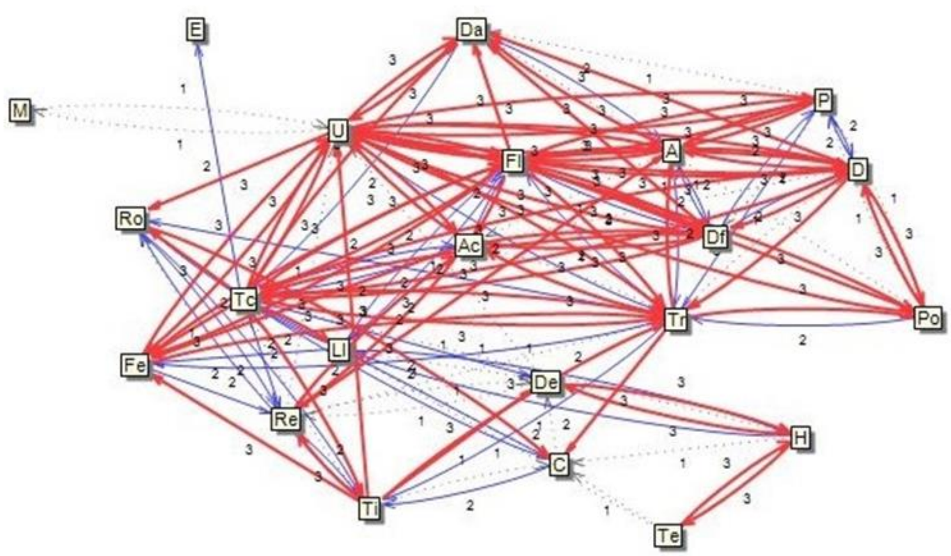

Figure 5. Graph of direct influences. Source: own elaboration with support from the MICMAC program Godet and Durance (2007).

It can be observed that the variables with the greatest interaction and influence within the system, in order of their strategic value, are: location of suitable areas of pecoreo (U_75), harvest time (Tc_63), flowering of honey species (Fl_61), transhumance (Tr_52), deforestation of apicultural species (D_47), increase in agricultural areas (A_42), distance to flowering areas (Df_38), access to flowering areas (Ac_38), phenology of honey species (Fe_30), distance between apiaries (Da_27), and population growth (Po_23).

In this way, the MICMAC program generates a diagram of indirect influences, in which the variables with an indirectly important degree of influence on honey production are observed. In this diagram it is observed that the 'flowering of honey species' maintains an important indirect influence with the 'location of suitable areas of pecoreo' for the apicultural practice. This is interesting, since these variables are identified as variables with greater interaction and influence and important for honey production in the direct influences diagram.

This shows that, although 'flowering of honey species' is important for honey production, this variable is not a determinant in the location of apiaries. However, there is a significant negative influence of the 'deforestation of honey species', the 'use of pesticides' and the 'increase of agricultural areas' with the activity of 'transhumance'.

This finding coincides with what was reported by Bellarby *et al*. (2008); Roque *et al*. (2016) and where he mentions that transhumance is closely linked to the environment and natural resources of the area that the producer uses to install his apiaries, which have been modified in the last decade by different factors, including clandestine logging or increased extension of intensive crops, which modify biotic systems with impacts on low yields of honey production per beehive.

It is important to highlight that within the 22 variables reported in this article, the panel of experts does not consider access to water sources as a variable that worries the beekeeper to increase the production of honey in the beehive. This consideration is justified by the panel of experts due to the goodness of the study area in that the beehive has unlimited access to water sources. However, in this investigation we have found that the 'water source' has an importance of 27%, between the criteria of access to the apiary, the height above sea level and the temperature of the area, for the 'location of apiaries' and to increase honey production, respectively.

In this context, the field investigation shows that the 'selection of the place of the nectarium', the 'selection of areas of the honey flora' and the 'transport of the beehive to the place of settlement of the apiary', are primary activities that should always take care in the practice of beekeeping to improve the production yield of honey in the beehive.

The first two activities are considered as key variables in this investigation with a strategic value of 75 and 61 respectively on a maximum scale of 79, while the activity of the 'transport of the beehive to the place of settlement of the apiary', is considered in this study as an autonomous variable with strategic value of 17, which, even though with its low strategic degree, it can interfere negatively in the production of honey, depending on the degree of its presence.

In congruence to these results, Simone *et al*. (2016); Alger *et al*. (2018) emphasize that the mobility of beehives, among other climatic factors and of traditional agricultural practices such as the application of pesticides, are elements that stress the beehive with an effect on the detriment of honey production.

Although three key variables and two regulatory variables with strategic value of 42/79 to 75/79 strategic units are suggested in the influence-dependency plane, it should be taken into account that the set of secondary lever variables are the variables that act on the regulatory variables and these in turn affect the evolution of the key variables. Strictly speaking, in coincidence with Contreras-Uc *et al*. (2018), the yield of honey production, depends largely on the beekeeping practices integrated to the opportunity and efficiency in the management of the colony.

In an order of strategic importance, the variables 'increase in areas dedicated to livestock and crop areas not suitable for beekeeping' have an important indirect influence with 'accessibility to flowering areas' and the 'distance between the area of flowering and the apiary'. Beekeepers in the study region warn that the effect of these variables does not manifest immediately and their behavior, sooner or later, to a greater or lesser degree, will impact on the level of flowering necessary for the beehive to perform its work of pecoreo.

Finally, the findings identified in Phase I of this research related to beekeeping practice are largely coincident with those reported by Contreras-Uc *et al*. (2018), such as the advanced age of beekeepers, the non-technical activity for honey production and that beekeeping is a complete form of economic income. This suggests that there is a relationship between the age of the beekeeper and the adoption of innovative processes in beekeeping practice, since, based on the results in this study, these components can be combined to trigger key variables and variables with strategic value to improve honey performance.

Conclusions

The structural analysis tool allowed to determine and analyze the influence and dependence of variables understood as activities that the beekeeper commonly performs as a practice in the production of honey and that in the literature are only reported in the dimension of factors that affect the production of honey from bee. The results show that the variables reported here, not only directly, but also indirectly, influence the production of honey from the key activity of finding areas suitable for the settlement of apiaries to meet the supply needs of nectar or pollen from the beehive.

In this way, the selection of the place of the nectarium, the selection of the area of the honey flora and its accessibility and transport of the beehive to the place of settlement of the apiary, strategically represent the beekeeper's decisions, which are under his control. In this sense, we consider relevant in this article to report the variables that influence the production of honey, as well as the degree of influence/dependence of the variables reported in order to improve the compression of the honey production system.

In this investigation, the Delphi and MICMAC method have been used in order to reduce the subjectivity bias of experts to determine and identify the influence of variables on honey production. This knowledge will help the beekeeper to define their actions and decisions, as well as design strategies to improve honey production performance. With this objective, studies aimed at determining location criteria and sizes of apiaries that maximize honey production deserve attention.

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