Article

MicMac structural analysis to determine the strategic variables of the sugar agribusiness in Mexico

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Abstract

The matrix analysis software MicMac (Matrice d'Impacts Croisés Multiplication Appliqués à un Classement) matrix multiplication applied to a classification, is a tool to organize a collective reflection. It offers the possibility of describing a system with the help of a matrix that relates all its constituent elements, based on this description, this method aims to determine the main influential and dependent variables. In this case, it was used to determine the essential variables that will define the future of the sugarcane agribusiness in Mexico. This analysis was carried out in 2019 by a group of experts with experience, a high level of knowledge and decision-making from the sugar cane agribusiness, who are part of the National Commission for the Sustainable Development of Sugar Cane (CONADESUCA). Five strategic variables of greater mobility and influence and of greater dependence were identified that will define the future of the sugarcane agroindustry in Mexico: research, development, innovation and technology transfer (R+D+I+TT), diversification, production costs, productivity and competitiveness. By logical order, they define that as long as the sugarcane agribusiness in Mexico obtains or adopts and uses intelligent technologies (research plus development plus innovation plus technology transfer), diversify and offer products derived from sugarcane at competitive prices, then it will be able to increase your productivity, lower your production costs and as a consequence you will be more competitive. Failing to take these recommendations, the sugar cane agribusiness will not be competitive, becoming increasingly obsolete and will tend to disappear.

Keywords: collective reflection, CONADESUCA, relational matrix.

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Introduction

The sugar agribusiness in Mexico is a productive activity with a high social, economic and spatial impact. The 6th Statistical Report of the Agroindustrial Sector of Sugar Cane in Mexico, harvests 2009-2010-2018-2019 CONADESUCA, reports that sugar production in the 2018-2019 harvest was 6.4 million tons, from a milling of 57 million tons of crude cane, with an industrialized surface of 804 060 ha, reported from the 50 mills that are currently in operation, distributed in 15 states and 227 municipalities in the country, reaching a field yield of 70.94 t ha^{-1}. It generates 440 thousand direct jobs and has an indirect socioeconomic effect on around 12 million people, with contributions in manufacturing gross domestic product (GDP) of 2.1%, in agriculture of 8.6% and national of 0.35% (CONADESUCA, 2019).

Despite the importance of this agro-industry, in recent years numerous factors threaten its competitiveness, for example: the Mexican sugar industry is not recognized as competitive mainly due to stagnation of cane, low yield of sucrose, high fiber in stems per hectare and variability in the production process.

Average sugar cane yields range from 60 to 70 t ha^{-1}. The decrease in agricultural production of sugar cane has been defined as the loss of productive capacity of the monoculture sugar cane soils in the long term (Aguilar, 2012).

The drastic fall in international sugar prices can also be explained by the accumulation of final sugar inventories worldwide, coupled with the substitution of this sweetener in recent years by others such as high-fructose corn syrups (HFCS) (Morcillo, 1997). Sugar production in Mexico has been seriously affected by combining on one hand the severe internal crisis both in the field and in industry with the collapse of the international sweet market (Zavala, 2015).

The sugar agribusiness is currently facing changes in consumption patterns due to health issues. Mexico occupies the first place in soft drink consumption (Caravali *et al*., 2016) and consequently the first place in diabetes (Moreno *et al*., 2014) and an increasing substitution and consolidation of other sweeteners such as high-fructose corn syrup (HFCS) which is 1.5 times sweeter than sugar and cheaper. The soft drink industry used 3.5 million tons as a sweetener that is being replaced by HFCS, which means a reduction of approximately half of the current sugar production, which is 6.4 million tons.

Faced with this problem, there is a need for new technologies that guarantee, among other things, food security in this basic carbohydrate, increased productivity and its challenges in the face of climate change, as well as the efficient use of natural inputs: water, soil, sun, wind, among others (Aguilar, 2014).

It is clear then that the sugar cane agribusiness needs to build a different future that responds to new demands. In this sense there are several philosophical, theoretical and methodological currents such as future studies and their two currents of thought: The North American determinist (Forecasting) where the future is unique and the French voluntarist (strategic prospective), (Berger,

1967), where the future is multiple (Jouvenel, 1964), supported by the complexity theory presented by (Morin, 1990). For this document the French (voluntarist) current was used. This current of future studies is based on the identification of possible or future futures to choose the most convenient and build it from the present. For the future, the future will happen to the extent that we prepare it through precise actions.

The prospective proposes that it is not necessary to suffer or suffer the future, but that it can be built and also shows that if it is analyzed, comparative advantages are acquired, simply because it is getting ahead of making decisions that others have not yet thought, in this way it is It is possible to win the lead and prevent being surprised by the future (Mojica, 2010).

The structural analysis (MicMac) has been used in different areas of knowledge, in higher education (Benjumea *et al*., 2016), ecotourism (Ariyani and Fauzi, 2019), solar energy in the rural sector (Sindhu *et al*., 2016), development of the agricultural system (Barati *et al*., 2019), transformation of a smart city in India (Kumar *et al*., 2019), among other areas.

In this work, the MicMac software that is part of the strategic foresight methodology of Ph. D. Francisco Josó Mojica was applied, which is a combination of the two currents of thought of future studies (Mojica, 2008), with the purpose to present the results of the structural analysis through the MicMac, which aims to identify the strategic variables that can counteract a defined trend and establish the future that the sugar sector will face later.

Materials and methods

The structural analysis (MicMac) was carried out at the facilities of the National Commission for the Sustainable Development of Sugar Cane (CONADESUCA), in Mexico City in July 2019. By a group of experts with experience, a high level of knowledge and decision-making of the sugarcane agribusiness. Initially, the group of experts, through a group reflection, selected 65 factors of change, these are the phenomena with which it is possible to begin to draw the profile of the agro-industry of sugar cane.

Using the technique of analyzing preconceived ideas or stereotypes, as a result, a draft list of 65 factors of change divided into five dimensions (economic, social, environmental, political and technological) was prepared. When weighing the factors of change by relevance, the experts selected 25, by the scoring method assigned the number 25 to the most important and relevant factor of change for the sugarcane agribusiness and so on until reaching number 1. Analyzed the information in a table in Excel.

The structural analysis software that Michel Godet designed with the name of the MicMac method was used and is a contribution to the strategic prospective toolbox (Godet, 2007). This software allowed prioritizing the most relevant variables and obtaining their disposition within a context where these elements are articulated according to their causal relationships. Structural analysis is a systematic method, in a matrix form, of analysis of the relationships between the constituent variables of the studied system and those of its explanatory environment (Godet and Durance, 2011).

The objective of the structural analysis is collective reflection, it describes a system with the help of a matrix where they interact in a relationship with all the variables, which impact each other. The MicMac method consists in raising the structural analysis matrix to a power of successive values, in this way thousands and millions of lines are analyzed in the majority of concrete systems. The three phases that were carried out in the investigation of the MicMac method are described below.

Stage 1. Identification of variables

At this stage, the experts, through collective reflection, made a homogeneous list of internal and external variables that characterize the sugarcane agro-industry, answering the following question: what are the political, economic, technological, social and environmental factors that Will they determine the evolution of the sugarcane agribusiness? Obtaining from the 65 factors of change, 25 variables the most relevant and important.

Stage 2. Describe the relationships between the variables

In a systemic approach, one variable only exists; through its interrelation with other variables. In addition, structural analysis allows you to identify these relationships between variables using a two-input table called a structural analysis matrix. The experts rated the matrix, the filling was qualitative. For each pair of variables, the following question is asked: Is there a direct influence relationship between variable *i* and variable *j*? if the answer is negative, they wrote down 0, in the opposite case, they asked if this relation of direct influence is, weak they wrote down (1) median they wrote down (2); and strong scored (3). This interrogation procedure not only makes it possible to avoid mistakes, but also to order and classify ideas by creating a common language within the group of experts. In addition, it allows, in most cases, to redefine certain variables and consequently, refine the analysis of the system (Godet and Durance, 2007).

Stage 3. Identify the strategic variables

The identification of strategic variables, through the MicMac, was done first, through a direct classification, later by an indirect classification (called MicMac for cross-impact matrices, applied multiplication for a classification). This indirect classification is obtained after the potential elevation of the matrix. The comparison of the hierarchy of the variables in the different classifications (direct, indirect and potential) is a rich teaching process. This allows us to confirm the importance of certain variables, but it also allows us to reveal certain variables that, due to their indirect actions, play a main role that were not revealed in the direct classification.

In the interpretation of structural analysis two concepts converge: motor skills and dependency. Motor skills are the impact that one variable has on the others. Dependency is defined as the subordination of one variable with respect to the others.

The results in terms of influence and dependency of each variable are represented on a plane (the axis of abscissa corresponds to dependence and the axis of ordinates to influence). This cartesian plane allowed us to determine which are the most influential factors and which are the most dependent. The strategic or key variables are finally those that contain the highest ratings of influence and dependency.

Results and discussion

Expert connoisseurs of the sugarcane agribusiness with decision-making capacity chose 65 factors of change divided into five dimensions (Tables 1, 2, 3, 4 and 5).

Table 1. Change factors of the economic dimension.

	Economic phenomena
1	Competitiveness (substitutes, quality and prices)
2	Market (production chain)
3	Productivity (field and factory)
4	Production costs (field and factory)
5	Diversification (by-products, co-products)
6	International sugar prices (by-products, co-products)
7	Transportation costs
8	Profitability
9	Financial resources (economic return)
10	Globalization
11	Subsidies
12	Low yields (field and factory)
13	Infrastructure (Efficiency of mills)
14	Input price
15	Highly productive field management
16	Budget for Conadesuca
17	Suspension agreements
18	Nutritional labeling
19	Raw material payment system
20	Competition with other crops

Table 2. Change factors of the social dimension.

	Social phenomena
21	Education (basic, middle and higher)
22	Culture
23	Social welfare (low income) (producer)
24	Implementation of services
25	Social responsibility (factory and field)
26	Social Security
27	Poverty and marginalization indices
28	Cutters situation
29	Equity and gender
30	Child labor
31	Migration
32	Field unionization
33	Negative campaigns on cane sugar

Table 3. Change factors of the environmental dimension.

	Environmental phenomena
34	Sustainability
35	Energy (cogeneration of energy)
36	Climate change
37	Land use (soil degradation)
38	Organic products
39	Pollution (soil, water and air) (field and factory)
40	Water management (field and factory)
41	Good farming practices
42	2030 Agenda

Table 4. Change factors of the political dimension.

	Political phenomena
43	Regulatory framework
44	Union organizations impact (factory)
45	Differentiated inclusive public policies
46	New institutional arrangement
47	Impact cane organizations (field, free cane)
48	Bargaining power (alliances)
49	Trade Agreement (T-MEC)
50	Conflicts
51	Informality in contractual relationships
52	Executive-legislative relationship
53	Law of Sustainable Development of Sugar Cane

Table 5. Change factors of the technological dimension.

	Technological phenomena
54	Research, development and innovation technology transfer (R + D + I + TT)
55	Connectivity (communications) (roads)
56	Equipment (factory, field and market)
57	Automation (factory and market)
58	Precision agriculture (sensors, drones)
59	Training (factory, field and market)
60	Information technologies (Internet of things, Big Data)
61	Emerging technologies (biotechnology, nanotechnology)
62	Information platform
63	Interoperability
64	Technology adaptability
65	Research infrastructure (experimental field)

As a result of the collective reflection made by the experts in Table 6, the 25 most relevant and important variables that determine the future of the sugarcane agroindustry are shown, along with its abbreviation that was used in the matrix for its analysis. These represent the social, political, economic, environmental and technological phenomena of the environment of the sugarcane agro-industry.

Table 6. Most relevant and important variables of the sugarcane agribusiness in Mexico, with its abbreviation used in the matrix.

	Change factors
1	Research, development and innovation and technology transfer (R + D + I + TT)
2	Diversification (DIVERSIFIC)
3	Competitiveness (COMPETITIVE)
4	Market (MARKET)
5	Law of Sustainable Development of Sugar Cane (LDSCA-SANC)
6	Precision agriculture (AGRIC-PREC)
7	Production costs (COSTS-PROD)
8	Contamination (CONTAMINAC)
9	Highly productive field management (ORDER-TERR)
10	Productivity (PRODUCTIVI)
11	Sustainability (SUSTAINABI)
12	Emerging technologies (TECNOL-EME)
13	Information technologies (TECNOL-INF)
14	Research infrastructure (INFRA-INVE)
15	Trade Agreement (T-MEC)
16	Automation (AUTOMATIZA)
17	Climate change (CAMB-CLIMA)
18	Public policies (POLIT-PUBL)
19	Infrastructure (INFRAESTRU)
20	Globalization (GLOBALIAZA)
21	International sugar prices (PREC-INTE
22	Nutritional labeling (ETIQ-NUTRI)
23	Raw material payment system (SIST-PAG-M)
24	Water management (WATER-MANAGEMENT)
25	Regulatory framework (MARC-NORMA)

From this list of variables, a logical structure of causality was sought, verifying the influence that one of the phenomena has on others, with this effect a structural analysis was performed, a technique proposed under the name of MicMac that allows configuring a perception systemic grouping the factors into three levels, according to the way in which some influence others. For this, a double-entry matrix was generated showing the ratings that the experts made under the

criteria of the following question: Is there a direct influence relationship between variable *i* and variable *j*? if the answer is negative, they wrote down 0, in the opposite case, they asked themselves if this relation of direct influence is, weak they wrote down (1) median they wrote down (2) and strong they wrote down (3) (Figure 1).

	1 : I+D+I+TT	2 : DIVERSIFIC	3 : COMPETITIV	4 : MERCADO	5 : LDSCA-SANC	6 : AGRIC-PREC	7 : COSTS-PROD	8 : CONTAMINAC	9 : ORDEN-TERR	10 : PRODUCTIVI	11 : SUSTENTABI	12 : TECNOL-EME	13 : TECNOL-INF	14 : INFRA-INVE	15 : T-MEC	16 : AUTOMATIZA	17 : CAMB-CLIMA	18 : POLÍT-PUBL	19 : INFRAESTRU	20 : GLOBALIAZA	21 : PREC-INTER	22 : ETIQ-NUTRI	23 : SIST-PAG-M	24 : MANJO-AGUA	25 : MARC-NORMA
1 : I+D+I+TT	0	3	3	2	1	3	3	2	3	3	3	3	3	3	2	3	3	2	3	2	1	2	2	3	2
2 : DIVERSIFIC	3	0	3	3	1	3	3	2	3	3	3	3	2	3	2	3	3	2	3	3	3	2	3	3	2
3 : COMPETITIV	3	3	0	3	2	3	2	3	3	3	2	2	2	3	3	3	2	2	2	3	2	3	2	3	2
4 : MERCADO	2	2	3	0	1	2	2	2	2	3	2	2	2	2	3	2	2	2	2	2	3	2	2	2	2
5 : LDSCA-SANC	2	2	2	2	0	2	2	2	2	2	2	2	2	1	2	2	2	3	2	2	2	2	3	2	3
6 : AGRIC-PREC	3	2	3	2	1	0	3	2	3	3	3	2	3	2	1	2	2	2	2	2	1	1	1	3	2
7 : COSTS-PROD	3	3	3	3	1	3	0	2	3	3	3	3	3	3	1	3	2	2	3	2	2	3	2	2	2
8 : CONTAMINAC	2	2	2	2	2	2	2	0	2	3	3	2	2	2	1	2	3	3	2	2	2	1	1	3	2
9 : ORDEN-TERR	2	3	3	2	2	3	3	2	0	3	3	2	2	2	1	2	2	3	2	2	1	1	2	2	3
10 : PRODUCTIVI	3	3	3	3	1	3	3	2	3	0	3	2	2	3	2	3	3	2	3	2	3	2	3	3	2
11 : SUSTENTABI	2	3	2	2	1	2	2	2	2	2	0	2	2	3	2	2	3	3	2	2	2	2	2	2	2
12 : TECNOL-EME	3	3	3	2	1	3	3	2	2	2	3	0	2	2	2	2	2	2	2	2	1	1	1	2	2
13 : TECNOL-INF	3	2	3	2	1	3	2	1	2	2	2	3	0	2	1	2	2	2	2	2	1	1	2	2	2
14 : INFRA-INVE	3	3	3	2	2	3	2	2	2	3	3	2	2	0	2	3	2	2	2	2	1	1	1	2	2
15 : T-MEC	2	2	2	3	2	1	2	2	2	1	1	2	2	2	0	2	1	3	2	2	3	2	2	1	3
16 : AUTOMATIZA	3	2	3	2	1	3	3	3	2	3	2	2	2	2	1	0	2	1	3	2	1	1	2	2	2
17 : CAMB-CLIMA	2	2	2	2	2	2	2	2	2	3	2	2	2	2	1	2	0	3	2	2	2	1	1	3	2
18 : POLÍT-PUBL	2	2	2	3	2	2	2	3	3	2	2	2	3	3	3	2	3	0	2	3	2	3	2	3	3
19 : INFRAESTRU	3	3	3	2	1	2	3	2	3	3	2	2	2	2	1	3	2	1	0	1	2	1	2	2	2
20 : GLOBALIAZA	2	3	3	3	2	2	2	2	1	2	2	2	2	2	3	1	2	2	2	0	3	2	1	1	2
21 : PREC-INTER	2	3	2	2	2	2	2	2	1	2	2	2	2	2	3	2	1	2	2	3	0	1	2	1	2
22 : ETIQ-NUTRI	2	1	2	2	2	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	0	1	1	2
23 : SIST-PAG-M	2	2	2	2	2	1	2	1	2	2	2	2	2	1	2	2	1	2	2	2	3	1	0	1	3
24 : MANJO-AGUA	3	2	2	1	2	3	3	3	2	3	3	2	2	2	1	2	2	2	2	1	1	1	1	0	2
25 : MARC-NORMA	2	2	2	3	3	2	2	3	3	2	3	2	2	2	2	2	2	3	2	2	2	2	2	2	0

Figure 1. Matrix of expert ratings for factors of change.

With the MicMac software, the strategic variables were identified. In this phase the essential variables for the development of the system are obtained initially, it is carried out through an indirect classification (MicMac or Matrice d' Impacts Croisés Multiplication Appliqués à un Classement). This indirect classification is obtained after increasing the power of the matrix. Compare the hierarchy of variables in the different rankings (direct, indirect, potential). This analysis confirmed how important some variables are and revealed the variables that play a more dominant role, given their indirect action, something that did not appear in the direct classification.

In the interpretation of structural analysis two concepts converge: motor skills and dependency. Motor skills are the impact that one variable has on the others. Dependency is defined as the subordination of one variable with respect to the others. Based on these two principles, the influence and dependence of each variable are represented on a plane (the abscissa axis corresponds to dependence and the ordinate axis to influence). The most influential and most dependent variables are chosen as strategic variables (Figure 2).

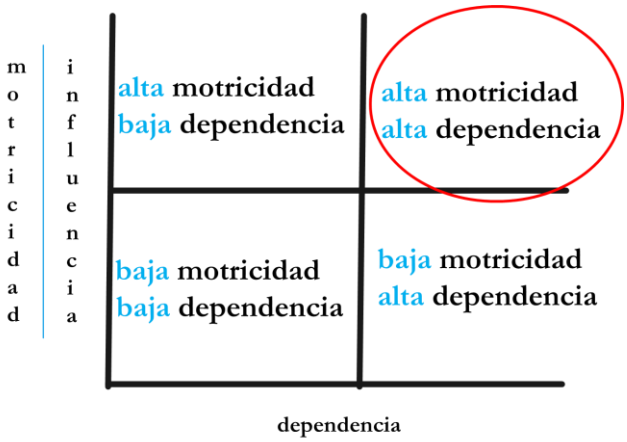

Figure 2. Dependency influence plane to choose the strategic variables.

At this moment, we can already speak of strategic variables, assuming that one variable is a phenomenon that is modified by virtue of another. In (Figure 3) the red variables with the highest values in influence and dependence can be seen in the red circle. A Pareto of 20% of the 25 initial variables was selected and the five strategic variables that will serve as a prop and support to carry out the exploration of the future of the sugarcane agribusiness were defined.

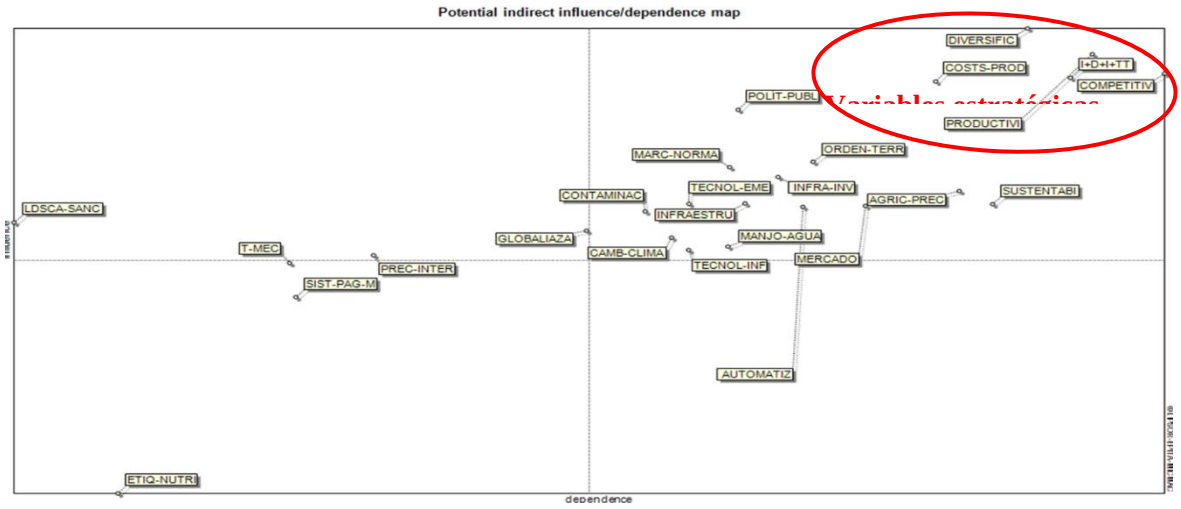

Figure 3. MicMac analysis result.

The results obtained through different classifications (direct, indirect, potential, dependency and classification), give a great variety of information and possibility of analysis, which allow the researcher to reflect on the functionality of the system (Veronica *et al*., 2014). The variables with the highest causality, which are found in the upper left quadrant and included in the circle, correspond to phenomena of very high importance for the life of the sugarcane agro-industry, they are: competitiveness, productivity, diversification, research plus development plus innovation plus technology transfer (R + D + I + TT) and production costs.

These variables that have been determined as strategic deserve to be read forming a systemic context of causality formed by themselves (Figure 4), in order to respect the principles of contextuality and complexity on which the strategic prospective rests. These conditions can be observed in the logical scheme of the strategic variables ordered according to the interrelationships of cause and effect, which appears below constituting a whole within which its elements are solidary and interdependent.

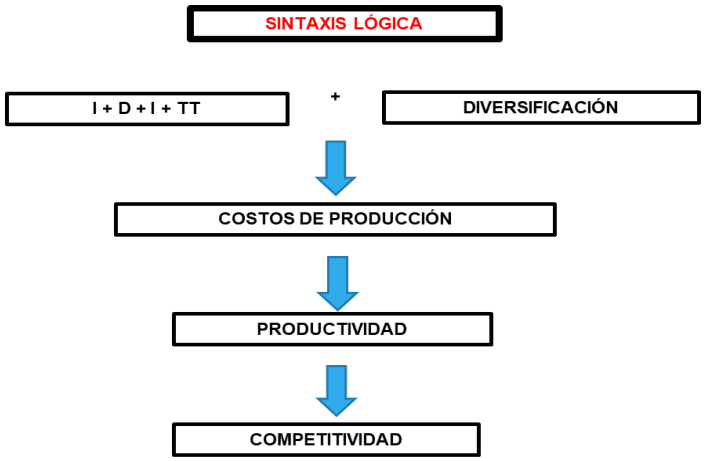

Figure 4. Logical syntax of the strategic variables.

Conclusions

It is vitally important since the experts are chosen, they really have experience, a high level of knowledge and decision-making, the MicMac being a mixed quantitative and qualitative method, which allows the decision maker to establish what those variables are that by its influence affect the entire system and based on this take the appropriate actions. This analysis also allowed comparing and confirming the importance of some variables over others, with the aim of planning in the future, thereby avoiding eliminating risks.

The MicMac software structural analysis identified five strategic variables according to their influence and dependence that defines the exploration of the future of the sugarcane agribusiness, these through their logical order define that while the sugarcane agribusiness in Mexico obtains or adopt and use smart technologies (research plus development plus innovation plus technology transfer), diversify and offer products derived from sugar cane at competitive prices, then you will be able to increase your productivity, lower your production costs and as a consequence you will be more competitive.

Failing to take these recommendations, the sugar cane agribusiness will not be competitive, becoming increasingly obsolete and will tend to disappear. The reading and interpretation of the results will be of utmost importance for the reflection of the studied system, as well as for decision-making based on the generation of information released by the MicMac.

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