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IDENTIFICATION OF CANE PRODUCER CAPITAL IN TAMAULIPAS AND THEIR PERCEPTION OF CULTIVATION, APPLYING A MULTIDIMENSIONAL SCALE

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ABSTRACT

Sugar cane production in Mexico has declined in the rural sector and factory over the last decade, so the farmer must employ optimal practices to improve profitability of this crop and accrue capital. This research sought to apply multidimensional scaling, in order to identify which aspects of knowledge, experience, perception and agricultural practices, employed by sugarcane producers in Tamaulipas, determine how their capital is structured, in accordance with Bourdieu's neoclassical economic theory. A questionnaire with dichotomous and polytomous Likert-type scales were applied and responses were assembled from direct interviews with 546 sugarcane producers from 6 municipalities in the south of the state, to create a sample obtained in two stages (by strata and by conglomerates) and the recommended statistical tests with SPSS© were applied. The structure of capital owned by Tamaulipas sugarcane producer appears to be quite cohesive and is augmented by cultural capital; that is by the knowledge and experience obtained when managing the crop and to a lesser extent as a result of invested economic resources; while social capital appears to be more dispersed among local producers. A main conclusion indicates the dissimilar perceptions of farmers concerning the yield and profitability of sugarcane, as well as resistance to changing the seed variety, as three out of four producers plant the CP 72-2086 variety.

Keywords: agricultural capital, multidimensional scaling, sugar cane, Tamaulipas.

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INTRODUCTION

Sugar cane (Saccharum officinarum) is thought to be native to New Guinea and from there it was brought to India and China in 4500 BC. It was introduced to Mexico by the Spanish colonizers at the beginning of the 16th century and by the second decade of that century, the first sugar mills already existed in the country, (Comité Nacional para el Desarrollo Sustentable de la Caña de Azúcar-CONADESUCA, Servicio de Información Agroalimentaria y Pesquera-SIAP, 2016), Pérez Vidal. "Ingenio", was the term used to designate sugar cane mills in 16th century Spain: an "ingenio" denotes nothing more than a simple hydraulic mill, whereas "trapiche" is the word for a mill powered by animal traction" (1971, as cited by López de Coca, 1987). Sugar cane represents an important crop in several regions of the world and can become an instigator of economic development, if it is carried out with good agroecological management, intensive technology and adequate organization of the productive sector.

Due to its importance, this crop is considered essential to the national economy and popular consumption; the value chain of this agroindustry generates more than 460,000 direct jobs including day laborers, harvesters, transporters, suppliers and workers, as well as hundreds of thousands of indirect jobs, among contractors pertaining to sugarcane organizations, purveyors of sugar mills and others involved in the distribution and trade of final products (CONADESUCA-SIAP, 2016; Gómez *et al*. 2017). Mexico occupies ninth position in terms of the largest sugar producers worldwide, due to the cultivation of cane that is carried out in 16 states of the country, among which, Tamaulipas presents itself in third place in the crop location index and in terms of economic specialization (Alvarado and Bustamante, 2022). The industrialization of sugar cane generates an important economic benefit for the country, for the more than 190 thousand sugar cane producers and the more than 267 sugar cane municipalities, where this plant is grown (CONADESUCA, 2021).

Despite the importance of the crop, sugarcane producers represent the weak link in the productive chain of the sugar agroindustry, where they face inadequate mechanization of agricultural tasks and high dependence on credit, inputs and technical assistance, as well as difficulties related to limited land ownership, in many cases. Even so, these farmers continue to carry out their productive activities, while assimilating knowledge and practices that will help them in the pursuit of better yields in order to survive competition with larger producers. This understanding and perception is useful for small producers according to Vaccaro (2010), who stated that the attitudes and decisions of sugarcane producers have not been well documented; hence, our interest in identifying the characteristics of this sector in our research. The objective of this descriptive and transversal research was to assess the growing capital of producers in the sugarcane producing areas of Tamaulipas, Mexico, based on similarities in their knowledge, perception and agricultural practices, using non-metric multidimensional scaling (MDS). Our hypothesis is that the sugarcane producers of Tamaulipas have developed strong agricultural capital during the time that cultivation has been undertaken in the northeastern sugarcane area.

THEORETICAL FRAMEWORK

Sugar cane is a protected crop in Mexico and is of interest to several government organizations, particularly considering results from the last decade: a decrease in productivity is apparent, both in the rural sector and factory (CONADESUCA, 2016, 2021). For these reasons, it is desirable that –to increase the value and profitability of the crop and increase its capital– the sugarcane producer must implement optimal practices in the field (Fideicomisos Instituidos en Relación con la Agricultura-FIRA, 2010; Gómez *et al*. 2017), which include soil preparation, planting and cultivation work, irrigation and fertilization, the use of technological packages, pest and weed control, as well as pre- and post-harvest activities (burning and regrowth). The strategic importance of the crop lies in the large capital investments necessary for production and the level of employment it generates (CONADESUCA-SIAP, 2016). This means that knowledge about the rural sector can serve as a strategy for achieving sustainable agricultural development, whose benefits can go directly to the farmer or the sugarcane sector.

According to Bourdieu's (2018) economic theory, capital is accumulated work and can be studied from a social perspective, far removed from the neoclassical paradigm; in the analysis of the work of the French sociologist, Cerón (2019) states that Bourdieu expanded the concept of capital proposed by Marx, focusing on profitability or economic benefit, introducing the notion of economic capital, cultural capital and social capital. For Bourdieu, economic capital is a substantial asset that can be transmitted, either by donation, inheritance, purchase or exchange; it is the first factor that comes into play when investing in agriculture, as the producer must have land, while stockpiling seeds, fertilizers and work equipment, among other things; these factors, along with the other two types of capital and other "non-human" components [as Parral (2019) designates climate, available water or soil type], define the success of agricultural activity in different ways, according to Campos and Oviedo (2015)'s research.

Regarding cultural capital, Bourdieu (2011) refers to this as the set of possessions or "knowledge" of personal assimilation that the subject maintains while he lives and which dies with him; it can also be inherited, although more commonly, it is indicated as transmissible in the family context, to which can be incorporated other elements that the subject himself accepts as valid; Vaccaro (2010) considers in this typology, the education, empirical knowledge and skills of farmers; cultural capital is not an asset that can be transmitted instantly; but requires time to be incorporated and must be assimilated by the interested party. Bordieu (2018) also raises the possibility of reconverting economic capital into cultural capital, for example, when a farmer uses his profits to send his children to university, as they may then improve the value and profitability of the agricultural farm, incorporating technology or diversifying, thus promoting regional development (Gómez *et al*, 2017).

Finally, social capital is referred to by Bourdieu (2018) as "the totality of potential or current resources, associated with the possession of a lasting network of relationships… based on knowledge and mutual recognition"; Meier (2002, cited by Eslava, 2012) considers that social capital is a product of the individual's cultural knowledge, so this social capital is manifested in the relationships that a person establishes with others and that allow them to belong to social groups, in which real or symbolic exchanges can take place. For Vaccaro (2010), an agricultural producer increases his social capital, to the extent that he belongs to groups related to his economic activity such as sugarcane unions, credit unions or government networks, as these will allow him to test his beliefs, in order to improve his sowing strategy; this capital is essential for the economic development of any region, as in agri-food systems, producers with different outlooks participate, constituting social capital that must be prioritized, to give farmers an associative advantage.

The taxonomy of capital proposed by Bourdieu in his work is useful for carrying out this research. Cerón (2019) states that this makes it possible "to predict other properties related to factors still to be investigated", that is, the capacity to make conjectures and hypotheses, based on the economic, social and cultural characteristics of the agricultural producer.

Multidimensional Scaling

Multidimensional scaling (MDS) is a statistical technique that allows data about objects or their perception to be represented in a two-dimensional plane, in order to analyze their spatial representation and compare elements based on their differences or similarities (Alvídrez and Morales, 2014). As proposed by Torgerson in 1952, in its original version, and subsequently by Kruskal in 1964, in the non-metric model (cited by López and Hidalgo, 2010), it is a measurement related to multivariate analysis and cluster analysis, which is based on the randomness of all the variables analyzed, in order to interpret their combined effects, and attribute meaning to the results. MDS uses a representation of proximity data in a space with few dimensions and is considered by Ahumada and Escalante (2011) to be very useful for confirmation purposes, as it serves to "… transform the similarity or preference judgments implemented by a series of individuals on a set of objects or stimuli, at distances that can be represented in a multidimensional space". This makes it possible to generate perceptual maps, without having to previously define the attributes of the objects that are represented therein (Mejía, 2017).

MDS is widely used in the social sciences; in behavioral research, and works well with polytomous response forms. Furthermore, its use does not require the formulation of hypotheses (Elorza, 2008). This technique allows for the development of more robust methodological tools, because it can be implemented without the applied instrument meeting the requirements of validity and reliability, given that it serves for evidentiary purposes; however, its interpretation is restricted to what underlies the set of distance measurements or proximity of the analyzed objects, which can be of any type (Guisande *et al*. 2013). For Mejía (2017), MDS is a technique that does not require major methodological stipulations, in terms of data or concerning relationships between variables, and points out that each individual can have a different perception of things, which may vary in importance or they may change their judgment over time.

Examples of its use in some disciplines include: in work profile studies; Corrales (2006) used MDS to model the administrative management process in a private university, with help from a categorization system for job reports, internal self-assessment, while highlighting the usefulness of grouping the studied information on a two-dimensional plane, as it makes it easier to develop and understand the results. Likewise, Caicedo (2019) used MDS to identify the similarities and differences in studies about the quality of work life among Latin American health workers, performing a meta-analysis of the recent literature on this subject, while pointing out the importance of using instruments designed for the regional context.

In the business context, Ferreira *et al*. (2011) sought to identify consumer preferences in a study on the tourism business in Portugal and emphasized the ease of ordering data, identifying dimensions or criteria, obtaining positioning maps and grouping objects by attributes, in order to identify groups or sectors using this technique. Navarro *et al*. (2015) studied the influence of various factors on the competitiveness of countries that are members of the Asia Pacific Cooperation Forum and pointed out that MDS is a useful way to complement the results obtained using other techniques, such as cluster analysis. Similarly, Espino *et al*. (2021) studied the differences and similarities between entrepreneurs in a number of countries, who use financial services, based on multidimensional scaling, recognizing that this helps to organize large quantities of data that represent complex interpretation requirements, with the advantage of making effective comparisons between groups.

Hernández *et al* (2016), who also used MDS in the educational context to study the self-perception of information competencies among future secondary school teachers in Spain; emphasized that this technique makes it possible to identify the weaknesses of the scales used, as well as those without adequate psychometric properties, identifying those that can be improved or the need to develop alternatives. Similarly, Jácome *et al*. (2021) carried out a study to associate characteristics of students in Ecuador, referring to intelligence typologies and socioeconomic level and found that MDS enables the representation of a large amount of data, with a smaller group of variables or constructing combinations of variables. Finally, Ahumada and Escalante (2011) analyzed the content validity of an instrument used in psychology to measure stress, called the Moos Coping Response Inventory, and they sate that MDS is an alternative when seeking to analyze the validity of instruments that have not been tested, either due to the characteristics of the instrument or because of scale, due to having small samples or for other reasons

MATERIAL AND METHODS

Geographical context

In Mexico, there are seven regions, where sugar cane is grown. Tamaulipas is located in the Northeast region next to San Luis Potosí and the north of Veracruz; the Tamaulipas sugarcane region covers an area of 67,358 hectares, representing 7.18% of the state, between the parallels 23°17’00” and 22°32’04” N and the meridians 99°20’09” and 98°36’00” west, consisting of eight municipalities: Antiguo Morelos, Gómez Farías, González, Llera, El Mante, Nuevo Morelos, Ocampo and Xicoténcatl. The region has mixed orography, consisting of abundant plains and mountainous areas pertaining to the Sierra Madre Oriental, with a warm humid and semi-humid microclimate, and abundant annual rainfall that exceeds 1,400 mm and an average temperature of 23.2 °C (CONADESUCA , 2019).

Sample description

The register for sugarcane producers in Tamaulipas, Mexico, was provided by the National Committee for the Sustainable Development of Sugarcane (CONADESUCA, 2019b), comprising 5,792 suppliers in the region in 2018, but lacked information about the municipalities of González and Llera. A representative sample was selected from this group with a confidence level of 98% and a margin of error of 5%, which was calculated for 546 subjects. Sampling was carried out in two stages (stratified and by clusters), as proposed by Johnson and Kuby (2014). During the first stage, the number of strata was determined, corresponding to the eight municipalities that make up the natural subdivisions of the geographical area in the study. As no information was reported for two municipalities, the final number of strata was six; dividing the total number in the register by the number of suppliers in each of the municipalities, to obtain the percentage per stratum, and using this data, we calculated the number of samples in each stratum. During the second stage, 145 communities that have a post code were identified (INEGI, 2020), to determine the sampling locations that represent the clusters. These were systematically selected, taking each *k-th* unit from the list of communities or settlements, sorted by zip codes. In the end, surveys were only carried out in 76 localities or collection points, the number per stratum is shown in the last column of Table 1; limited by not having been able to carry out surveys in some communities considered unviable, because they were not planted with cane, as difficulties were encountered, or due to greater distance, rain or other obstacles.

Methodological instrument and procedure

In order to convey the multidimensional aspect of the sugarcane producer's capital, in this work a set of factors related to knowledge, experience and agricultural practice, as well as the producer's perception of sugarcane cultivation, were selected from the methodology applied by Paz (2019). This study took as reference, activities suggested in the Bulletin of Recommended Practices for the sugarcane sector in Mexico, from FIRA (2010); the final adapted methodology included a section for defining the profile of the sugarcane producer and another related to aspects of the study, based on seven questions with dichotomous answers (Yes, No) and 13 multifaceted 3-point Likert-type answers (1: nothing). , 2: little, 3: a lot) or 5 points (where 1 is the lowest value and 5 is the highest value on a scale); recommended methodology to improve MDS function (Elorza, 2008).

Semi-structured interviews were used as a data collection technique, applied personally to the sugarcane producers by the researcher with two assistants. This procedure enabled us to perceive similar data among the uni-dimensional responses that represent judgments on the part of respondents (Mejía, 2017). Information collected was presented in a table

Table 1. Determination of stratified and cluster sampling.

Municipality / strata	Total suppliers ¶	Percentage of total	Locations/ Clusters §	Collection points	Samples obtained
Antiguo Morelos	538	9.3 %	11	8	51
El Mante	1,480	25.6 %	60	33	139
Gómez Farías	542	9.3 %	19	7	51
Nuevo Morelos	486	8.4 %	4	4	46
Ocampo	1,551	26.8 %	24	10	146
Xicoténcatl	1,195	20.6 %	27	14	113
Total	5,792	100.0 %	145	76	546

¶ using information provided by CONADESUCA (2019b) § According to INEGI (2020).
Source: self-elaborated.

of rows (cases) and columns (responses) and then converted into a matrix that was used in the SPSS© (Statistical Package for the Social Sciences) version 28. Once the data was obtained, statistical tools were used to determine the central tendency parameters (mean, median, mode) and other data, such as coordinates and normalized stress.

MDS does not require assumptions of normality or linearity for its implementation; however, it requires determining the goodness of fit of solutions obtained (Alvídrez and Morales, 2014). A strength of this study lies in sample size, which meets the requirements for validating the internal consistency of the scales; that is, more than 20 subjects per item and no less than 400 individuals for a 25-item instrument (Campo and Oviedo, 2008). Although it is not a requirement in this technique, the reliability of the instrument must be improved by paying attention to the wording of its statements, as well as the meaning and number of the items, in order to generate valid and objective information (Hinojosa and Rodríguez, 2014).

Calculation of multidimensional scaling (MDS)

Multivariate analysis was initiated, using the methodology suggested by Hair *et al*. (2007) and Mejía (2017). Proximities of data were constructed, based on the matrix created in SPSS; then the PROXSCAL function was used to create the initial model, the proximities were transformed into distances with the ordinal option; the most appropriate because it represents a non-metric scaling (Navarro *et al*. 2015). Concerning selection of dimensionality, no prior hypothesis establishes the number of dimensions for this data, so initially the two minimum and maximum dimensions proposed by the package were accepted. No restrictions were applied to the model and the interval measurements were maintained to create the Euclidean distances. As a result, Table 2 was obtained with the 20 variables used; in it, the closest objects can be identified, because they are at distances of less than 0.50 from each other, and the furthest objects are at distances exceeding 1.50 from each other.

To verify that the model obtained is valid, goodness of fit was corroborated with the stress and adjustment measures offered by the PROXSCAL procedure; 20 objects were found with 190 proximities. In this test, the aim is to obtain an S-Stress factor between the values of 0 and 1, with 0 considered a perfect value and 1 a null value; 0.025 is the excellent stress value, 0.05 is a good value and values less than 0.20 are acceptable (Ahumada and Escalante, 2011; Guisande *et al*. 2013). This indicator uses the stress formula proposed by Kruskal (1964, cited by Mejía, 2017), defined by:

$$\text{Stress} = \sqrt{\frac{\left(d_{ij} - \sim d_{ij}\right)^2}{\left(d_{ij} - xd_{ij}\right)^2}} \tag{1}$$

where xd_{ij}: the average distance on the map; $\sim d_{ij}$: distance obtained from similarity data; d_{ij}: original distances provided by respondents.

Table 2. Distances of objects

	ID4	ID6	ID7	ID8	ID9	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14	F15	F16
ID4	0.000																			
ID6	0.149	0.000																		
ID7	0.907	0.929	0.000																	
ID8	0.782	0.678	1.563	0.000																
ID9	0.372	0.268	1.183	0.412	0.000															
F2	0.659	0.569	1.479	0.140	0.301	0.000														
F3	0.411	0.323	1.245	0.371	0.067	0.249	0.000													
F4	0.534	0.423	0.768	0.849	0.553	0.799	0.619	0.000												
F5	0.543	0.430	1.316	0.251	0.171	0.174	0.154	0.625	0.000											
F6	0.254	0.364	0.708	1.032	0.620	0.913	0.664	0.595	0.789	0.000										
F7	0.225	0.374	0.895	0.974	0.578	0.843	0.605	0.717	0.749	0.192	0.000									
F8	0.836	0.928	0.461	1.605	1.194	1.491	1.242	0.976	1.357	0.582	0.711	0.000								
F9	1.352	1.500	1.478	2.044	1.686	1.905	1.697	1.779	1.850	1.189	1.127	1.018	0.000							
F10	0.392	0.445	0.520	1.119	0.713	1.014	0.767	0.511	0.869	0.198	0.390	0.500	1.285	0.000						
F11	1.088	1.195	0.690	1.868	1.456	1.748	1.499	1.268	1.623	0.836	0.929	0.292	0.869	0.784	0.000					
F12	0.626	0.770	0.915	1.372	0.983	1.237	1.006	1.044	1.153	0.451	0.405	0.541	0.739	0.571	0.643	0.000				
F13	0.132	0.149	1.030	0.661	0.262	0.534	0.290	0.571	0.432	0.384	0.317	0.967	1.429	0.520	1.215	0.721	0.000			
F14	1.070	1.189	0.806	1.851	1.442	1.725	1.480	1.313	1.612	0.826	0.889	0.364	0.717	0.810	0.153	0.554	1.191	0.000		
F15	0.926	0.831	1.724	0.161	0.563	0.267	0.515	1.008	0.409	1.179	1.108	1.756	2.151	1.274	2.015	1.499	0.801	1.992	0.000	
F16	0.597	0.508	1.421	0.196	0.241	0.062	0.187	0.753	0.134	0.850	0.781	1.429	1.850	0.953	1.685	1.177	0.472	1.663	0.329	0.000

Source: self-elaborated in SPSS®.

The value found for the first solution using function (1) was 0.01037, which is considered excellent (<0.025) and similarly, the Dispersion Accounted For (DAF) and Tucker's congruence coefficient comply with measurements, obtaining values of 0.99137 and 0.99567. These are both close to the recommended value of 1, and were shown to represent the best solutions (Table 3). The remaining stress measurements (normalized, I and II) indicate a good fit for the distances in the graph, which very accurately presents the scores of the interviewees. Next, stress decomposition was verified; a procedure that enables us to define which data contribute greater stress to the solution and which can be used to make corresponding decisions. In this case, there is only one source that generates stress (SRC_1), because the information was collected in a single attempt; in the graphic result for this solution, the objects in Euclidean space are easier to discern (Figure 1).

Based on the above, we decided to carry out a second test, increasing the number of dimensions, in order to three to discern whether a better solution exists, as recommended by Hair *et al*. (2007) and Mejía (2017). The test resulted in a solution with an S-Stress of 0.00906, a counted dispersion index of 0.99180 and a Tucker coefficient of 0.99589. These values did not register any modification to the two-dimensional map from the second solution and complicated its three dimensional interpretation. We thus decided to maintain the values from the original two dimensional test. The result of the decomposition of the normalized gross stress is shown in Table 4, with a description of the 20 final factors for the second solution.

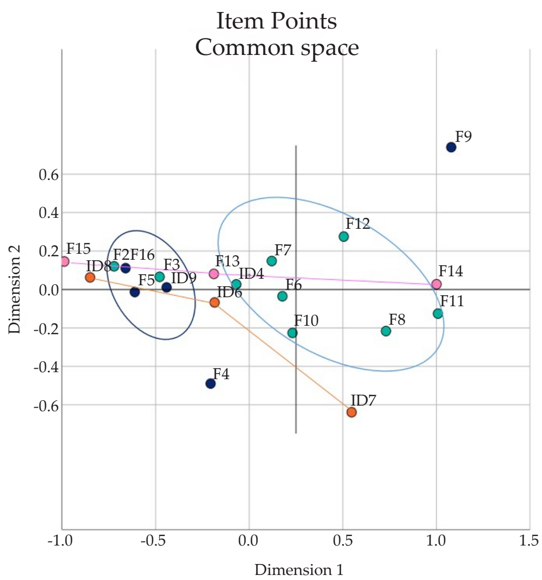
The ultimate solution offered two perspectives that express most of data variance, representing proximities that concern opinions of sugarcane producers about the practices and perceptions of sugarcane cultivation. The calculated model shows a clearer distribution of the objects than the initial model, based on an excellent stress index, meaning that this configuration presents distances between the objects that are more like the original ones (Hair *et al*. 2007); thus, it was approved.

In order to validate the perceptual map, the method of divided or multiple samples was used, carried out with the following procedure: the sample was divided into group A of 280 values and another group B of 266 values; for each of these, an MDS analysis was

Table 3. Measurement of stress and fit.

Initial solution with 20 objects.	
Normalized gross stress	0.00863
Stress-I	0.09291[a]
Stress -II	0.18559[a]
S- Stress	0.01037[b]
Dispersion Accounted For (D.A.F.)	0.99137
Tucker's congruence coefficient	0.99567

Source: self-elaborated in SPSS®.



ID4: level of education, ID6: member of sugarcane group, ID7: mill to which the sugarcane is delivered, ID8: belongs to the support network, ID9: owner of the property, F2: knowledge about soil, F3: knowledge about seed, F4: money invested per Ha, F5: cost control, F6: Frequency of soil digging F7: Frequency of fertilizer application, F8: Frequency of tillage, F9: how many tons are produced, F10: type of cane cutting , F11: regrowth occurs after cutting, F12: burns the straw when cutting, F13: cane yield, F14: the crop is still profitable, F15: wants to change seeds, F16: has an irrigation system.
Source: self-elaborated in SPSS®.
Figure 1. Perceptual map of sugarcane producers' capital in Tamaulipas.

Table 4. Decomposition of normalized gross stress.

Object	Factor	Origin SRC_1	Media	Object	Factor	Origin SRC_1	Media
ID4	Maximum education level	0.212	-0.026	F7	Frequency of fertilization	-0.089	-0.093
ID6	Sugarcane cooperative	-0.382	-0.008	F8	Frequency of soil tillage	0.277	-0.135
ID7	Mill where cane is delivered	0.188	0.153	F9	Production in tons	0.938	-0.628
ID8	Member of sugarcane group?	-0.61	0.106	F10	Manual, mechanized or mixed cutting?	-0.064	-0.219
ID9	Owner or landlord?	-0.401	0.006	F11	Instigates regrowth?	0.393	-0.116
F2	Soil texture	1.425	-0.332	F12	Burns the straw or incorporates it?	0.049	0.218
F3	Does he recognize the seed?	0.656	1.683	F13	Perception of production	-0.106	-0.588
F4	How much money does he invest?	-0.308	0.009	F14	Perception of profitability	-0.052	-0.032
F5	Keeps track of costs?	-0.488	0.054	F15	Desire to change seeds?	-0.735	0.035
F6	Frequency of tillage	0.106	-0.03	F16	Does he own an irrigation system?	-0.584	-0.056
	Media	0.0003	0.0003		Media	0.0003	0.0003

Source: self-elaborated in SPSS®.

performed, which yielded acceptable S-Stress values of 0.00873 for group A and 0.01327 for group B, and two perceptual maps manifesting very similar patterns, however not identical to the map of the ultimate solution. Both maintain the same distances from the objects, which corroborates the validity of the map obtained using all the values. Finally, we present the coordinates for all the items delivered by the two-dimensional plane model (Table 5).

RESULTS

The result of multidimensional scaling is presented in Figure 1, where a perceptual map is presented with the 20 points that represent all the objects with their proximities in Euclidean space (the ellipses and colored lines that join the points were delineated by the author to clarify interpretation); this complies with Mejía‘s recommendation (2017), to establish at least nine objects for a two-dimensional solution, as using fewer objects may result in a mismatch.

Description of the Tamaulipas sugarcane producers' capital

Based on the literature (Bourdieu, 2018; FIRA, 2010; Vaccaro, 2010), we presented factors that form part of the capital pertaining to the Tamaulipas farmer, presented in Figure 1. For the economic capital, which includes assets that can be transformed into money, factors were proposed as follows: ID9 [owner or renter of the property], F4 [money invested per hectare of agricultural planting], F5 [cost control], F16 [has an irrigation system] and F9 [how many tons it produces] (represented with blue dots); and for cultural capital, representing the knowledge accumulated by the farmer that he uses to improve his agricultural practice and maintain his agribusiness, factors include ID4 [education level of the producer], F2 [knowledge about soil], F3 [knowledge about the plant], F6 [how often the soil is tilled], F7 [how often it is fertilized], F8 [how much work goes into

Table 5. Coordinates of final data

Object	Factor	Dimension		Object	Factor	Dimension	
		1	2			1	2
ID4	Education	-0.069	0.026	F7	Num_fertilizer applications	0.120	0.148
ID6	Cooperatives	-0.185	-0.068	F8	Soil_prep	0.731	-0.217
ID7	Mill	0.547	-0.639	F9	Tons	1.079	0.740
ID8	Cane pattern	-0.850	0.063	F10	Harvest	0.231	-0.226
ID9	Owner	-0.441	0.011	F11	Regrowth	1.008	-0.126
F2	Texture	-0.722	0.120	F12	Burn	0.505	0.275
F3	Seed	-0.479	0.066	F13	Perc_production	-0.189	0.081
F4	Money	-0.206	-0.490	F14	Profitability	1.001	0.027
F5	Costs	-0.611	-0.013	F15	Change seed	-0.988	0.146
F6	Tillage	0.177	-0.035	F16	Watering system	-0.660	0.111

Source: self-elaborated in SPSS®.

soil preparation], F10 [type of cane harvest], F11 [instigates regrowth when cutting] and F12 [burns the straw when cutting] (represented with light blue dots); social capital refers to the alliances that the farmer can make and that facilitate his decision-making; factors include ID6 [membership of cane cooperatives], ID7 [mills that receive their harvest], and ID8 [being a member of a government support network] (represented with orange dots); lastly, and not included in capital, factors relating to the producer's perception of sugarcane cultivation are: F13 [what is the cane yield], F14 [whether the crop is still profitable] and F15 [whether they consider changing seeds] (represented with pink dots).

Interpretation of the perceptual map

Multidimensional analysis aims to represent the characteristics of objects or their perception on a smaller scale -of 2 or more dimensions-, in order to compare them, on the basis of their differences or similarities and it is necessary to discern meaning in the results, in order to reach an overall interpretation. This is a difficult and subjective task, restricted by what underlies the perceptual map generated using this technique. We followed Hair *et al*. proposal (2007), in order to identify the dimensions of this exercise; they recommended that the researcher should apply their judgment and describe these in terms of their known characteristics (subjective method) or determining attributes (objective method). A combination of these methods may be more accurate, so we proceeded to physically inspect the map.

In Figure 1, a first dimension is observed in the horizontal plane of the perceptual map, delimited with a light blue ellipse in the middle zone, which seems to represent the agronomic practice of the sugarcane producer, as within it, the proximity between factors ID4, F6, F7, F8, F10, F11, F12, which represent the cultural tasks and agro ecological practices of sugarcane cultivation (light blue points), that is, the number of times soil is fertilized and prepared, and for the cane cutting method, whether regrowth is instigated when cutting and whether straw is burned or reintegrated. The greater proximity of these factors indicates similarity in terms of the responses of the interviewees, reflecting the homogeneous characteristics of each object.

A little further from the center, to the left, are the factors F2 and F3, whose distances from the other objects in their category indicate that knowledge of the soil and seeds does not comply with other agronomic practices. This is understandable, because the producer may not have remembered the name of the variety of the seed planted in the last cycle or the typology of the soil texture (sandy, loam, clay, etc.) when interviewed; however they repeatedly carry out agronomic activities to improve the productivity of their crop; undertaken in each agricultural cycle.

Likewise, in Figure 1, a second dimension is observed in the vertical plane of the perceptual map, delimited by a blue ellipse in the left quadrants, which apparently represent the business profile of the sugarcane producer, as the ID9 factors [owner or renter of the agricultural property], F5 [take control of expenses] and F16 [own an irrigation system] are concentrated. All of these can be monetized to support the producer as a receiver of credit (blue dots); similarly, factors F2 and F3 appear very close here, which means that this agronomic knowledge influences the producer's economic decisions, such as renting a property instead of buying it or using a particular type of irrigation system. The economic factors F4 appear at a considerable distance, in the lower left quadrant [money invested per hectare in agricultural planting] and F9, in the upper right quadrant [tons of cane per hectare], whose distance from the other aspects of the business profile, may be due to the fact that the economic decision to invest and productivity are more related to other factors, such as the type of land and agro-ecological labor to produce the crop.

Also appearing at a distance are the ID6 factors [cane cooperatives to which the producer belongs], ID7 [mill to which the cane is delivered] and ID8 [being a member of a government support network], which represents the social capital that the producer mobilizes to facilitate the tasks of agricultural planting (orange dots); these appear somewhat dispersed. In the region, there are two sugarcane cooperatives and six sugar mills; however, many producers are not members of any networks; this can result in several possible combinations and explain the distances between these factors.

DISCUSSION

Analysis of the Tamaulipas sugarcane producers' capital

In the context of economic capital, investment in the harvest [F4] is taken into account by the majority of producers (77%), comprising an amount of up to $30,000.00 per hectare, a value similar to that calculated by CONADESUCA (2019) for the northeastern region: up to 48,200 pesos, if it is irrigated cane and 21,000 pesos, if it is from rain-fed "resoca" (resprouted plants); averaging 31,100 pesos. This result closely resembles factor F5 [cost control applied], which implies that the Tamaulipas producer does know how much he invests in his crop, because he monitors his finances, personally organizes his outgoings and relies on local accounting firms. Producers in the region face high production costs and yields below the national average (CONADESUCA, 2019), which is why their perception of some economic factors does not appear to be consensual (see objects F13, F14 and F15); however they do not base all their planting decisions on costs and profits.

Regarding cultural capital, the preparation of crop lands in the Tamaulipas sugarcane region is almost entirely mechanized; it consists of one or two subsoil layers, two fallow periods and a harrowing session (CONADESUCA, 2019); work that is usually carried out by third parties, due to lack of machinery owned by the producer. Similarly, subsequent cultural tasks require additional work, and secondary jobs are generated for day laborers and cane cutters (CONADESUCA-SIAP, 2016). The harvest is mainly manual (49%), semi-mechanized (19%) or mechanized (32%), a decision which affects how dirty or damaged the cane is when delivered to the mill, resulting in monetary set-backs for the producer. Mechanized harvesting is increasing, as it has demonstrated a positive increase concerning the sucrose content of the cane, which is economically favorable for the producer (Campo and Oviedo, 2008). After cutting the cane, the straw is burned to facilitate harvesting and reduce subsequent work, but consequential damage to the environment and public and private infrastructure have caused its prohibition in various parts of the world. This explains the distance of the ID7 factor [mill to which the cane is delivered], as only one mill requires the cutting of green cane, whereas the others permit burning.

Regarding social capital, farmers in the region must link up with sugar mills and producer associations, as these represent an opportunity to obtain first-hand information about the crop, technological advances and access to sugarcane credit, which – due to the small size of their plots – allows them to plan the agricultural cycle and generate economies of scale. Besides this, they must remain registered in support networks, as the existence of social capital in agriculture reduces migration from the countryside to urban areas and encourages alliances with other participants to achieve common objectives (Parral, 2019).

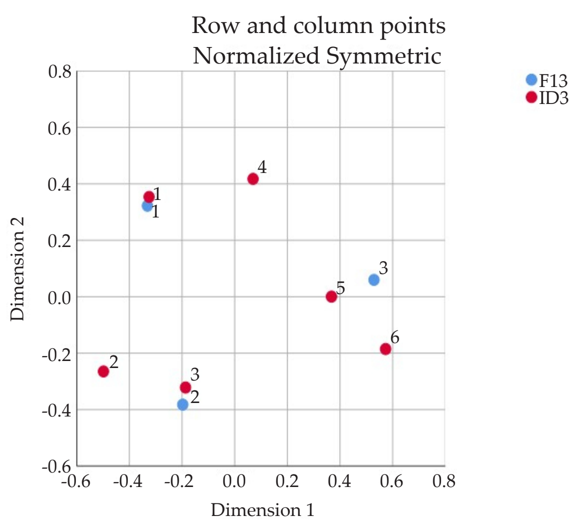
According to Vaccaro (2010), the capital gains for the agricultural producer are reflected in his economic, cultural and social capital; use of multidimensional scaling enabled us to identify that the capital of the Tamaulipas sugarcane producer is quite cohesive, meaning the characteristics of those who carry out the agricultural activity are fairly homogenous, although they differ concerning attitudes to cane cultivation; three factors were added to the instrument, in order to assess these opinions. The first factor measures the farmer's perception of the sugarcane yield in the field [F13] and appears in the perceptual map between economic and cultural capital, which denotes very varied producer opinion. This perception appears closer to F4 [money invested] than the other two perceptions and draws attention to the fact that many producers (73%) consider that their production has decreased, something that concurs with the average real production of the Tamaulipas sugarcane field in the 2017/2018 harvest, which was 69 tons per hectare, about 10 tons, below the national average (CONADESUCA, 2019). According to this latest report, yield in the field increases when technological packages are implemented, but decisions concerning these agricultural technologies can be affected by various factors attributable to the producer, such as their level of education, their experience in cultivation, their perception concerning degree of complexity and cost of implementation or may be attributable to the sugar mill (Parral, 2019), for example investment and innovation capacity, regardless of the geographic region where the crop is located.

Given that the structure of relationships between objects with non-metric attributes is analyzed, it is also possible to validate the result from the MDS, by implementing a simple correspondence analysis by municipality (Hair *et al.* 2007), which corroborates the opinion of the interviewees regarding the performance of their plot. Apparently, the producers from Antiguo Morelos (less irrigation) are those, who mostly perceive a decrease and those from Ocampo and Xicoténcatl (more irrigation), mostly perceive an increase (Figure 2).

The second factor associated with perception [F14], indicated whether they consider that the crop is still profitable; most of the producers surveyed (90%) consider that sugarcane is still profitable and this factor is more associated with cultural capital. This means that the producer who carries out agronomic tasks for his crop knows that these increase productivity in the agricultural sector. This factor is located closer to F9 [production in tons] than to the other economic factors and this assessment is important, because it indicates that the sugarcane supplier is well-informed concerning the productivity of his property and the value of his harvest, he thus associates this with his agronomic practices. Producers seek to maximize their gains, requiring efficient production and employment of technological advances, not easy, because the costs of cultivation have been increasing and their profits have diminished compared to other years (CONADESUCA, 2021). In relation to the profitability of sugar cane cultivation, some agro businesses improve this aspect when they diversify their production, and this is already undertaken by 14.1% of the producers in the Tamaulipas countryside, who plant another crop in addition to sugar cane; recommended in order to avoid dependence on a single crop (CONADESUCA, 2021).

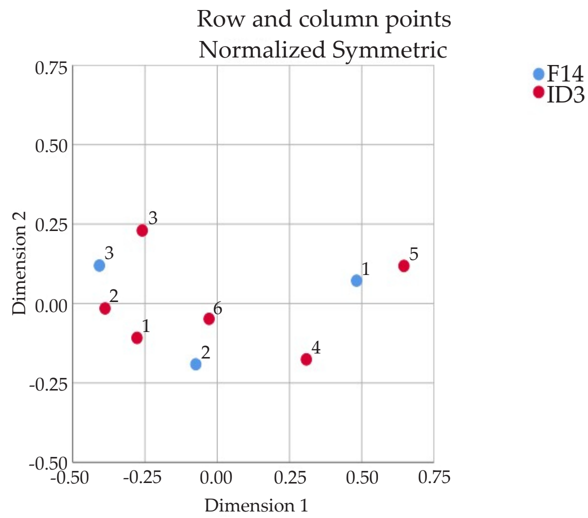
The second analysis of straight-forward answers by municipality (Figure 3) also confirmed results in relation to the producers' opinion on the profitability of the crop (F14): producers who most believe that it is profitable are those from Gómez Farías municipality (98%) and El Mante (94%), objects closest to point 3, whereas those who think that it is not profitable, are the objects closest to point 1, Nuevo Morelos (80%) and Ocampo (85%).

The third factor for measuring farmer's perception is F15, a question to assess whether they would like to change seeds in a future agricultural cycle, and this is depicted on the left side of the perceptual map, near only to some aspects of economic capital. In this regard, less than 20% of producers plan to make this decision soon; this would indicate certain recognition of the apparent monetary benefit derived from using the current variety. Change in seed variety, as well as in methods of fertilization and other innovations,



Source: self-elaborated in SPSS®. Objects in the figure: F13: Plot yield, 1: Has decreased, 2: Has remained the same, 3: Has increased, ID3: Municipality, 1: Antiguo Morelos, 2: El Mante, 3: Gómez Farías, 4: New Morelos, 5: Ocampo, 6: Xicoténcatl.

Figure 2. Correspondence analysis between municipalities (ID3) and performance (F13).



Source: self-elaborated in SPSS®. Objects in the figure: F14: Crop profitability, 1: Not profitable, 2: Somewhat profitable, 3: Profitable, ID3: Municipality, 1: Antiguo Morelos, 2: El Mante, 3: Gómez Farías, 4: Nuevo Morelos, 5: Ocampo, 6: Xicoténcatl.
Figure 3. Correspondence analysis between Municipalities (ID3) and Profitability (F14).

represent the easiest technological changes for the farmer, but greater crop productivity that does not translate into greater profits, may encourage the producer to replace his crop with another more profitable one or abandon the rural context, causing a reduction in agricultural capital. Diversification in the variety of cane seed may represent a good option for the regional producer; in this regard, Reyes *et al*. (2022), found that some sugarcane varieties have offered higher yields in the rural context than the most common variety in this region, CP 72-2086 (74.9%), confirming the CONADESUCA (2019) diagnosis.

CONCLUSIONS

This study provides statistical information for decision-making by economic agents in the agri-food sector; the results presented here offer a panorama of how the sugarcane producer faces decisions about his agribusiness, how he employs his economic, cultural and social capital, simultaneously identifying the knowledge accumulated from his resources, his experience and his agricultural practices.

The multidimensional scaling technique applied here, identified the attributes that determine the capital of sugarcane producers in the Tamaulipas rural sector. Many producers share very similar knowledge and experience about the crop, in particular, agronomic practices and business aspects. The two-dimensional graphic representation indicated that capital increased with cultural and economic factors, while social capital was more dispersed. All this accumulated capital enables the producer to face bigger competitors and remain in agricultural activity, with an average of 17 years in the region and exceptional cases of up to 75 years.

The perception of sugarcane producers concerning crop yield, in terms of agronomic practices and economic factors, was also validated through simple correspondence analysis. However, they have different opinions about crop profitability, which identified more with cultural capital. This last perception, related to changing the variety of the seed, seems alien to financial or rural knowledge, and it may be that the majority planting of one variety in almost the entire region has been caused by resistance to change. Therefore, we propose monitoring the evolution of the sugarcane system and identifying other factors that need to be included in future analyses.

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