Article

Evaluation of the sustainability of corn cultivation in Villaflores and La Trinitaria, Chiapas

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Abstract

Today, major environmental events have had an impact on the population at different economic and social levels and above all, on agricultural production. Hence, sustainability is a priority given the need for development that not only involves natural resources, but is also interrelated with economic and social aspects. The objective of this research lies in the interest of measuring the sustainability of the corn production system, in order to determine the levels of sustainability of the productive system, and formulate alternatives that contribute to the design of the sustainable system that benefit productivity with social equity, the conservation of natural resources and the decision-making of the productive units for the year 2018. For this reason, it was evaluated through the framework of evaluation of management systems incorporating sustainability indicators. From the results, it is shown that the sustainability values for the municipalities of Villaflores and La Trinitaria are 3.78 and 4.81, respectively, with a limited sustainable level prevailing. It is concluded that the sustainability of the production system may be maintained in optimal and stable conditions, as changes are made in economic benefits, self-reliance, participatory equity in the production process and in decision-making, implementation of agro-ecological techniques and adoption of sustainable practices and the sustained management of the corn crop to preserve and conserve the natural resource in an integral way.

Keywords: agroecological techniques, agro-ecosystem, MESMIS methodology, sustainable development.

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Introduction

Today, it is necessary to ensure sustainable development patterns in agricultural production systems, promoted as sustainable agroecosystems from an environmental and sociocultural point of view (Astier *et al*., 2002). Population growth, environmental deterioration and the intensive agriculture model have generated interest in society about the creation of new strategies aimed at sustainable development, which achieve food production without affecting natural ecosystems (ONU, 1992).

Which leads to generating sustained long-term yields through the use of technologies and practices that improve the efficiency of the production system; and not high short-term returns. In other words, the optimization of the system is sought through the interactions of biotic and abiotic components (Altieri, 1994). On the other hand, major environmental events have had an impact on the population at its different economic and social levels and, above all, on agricultural production. Human activity implies maintaining contact with the environment, which leads to the need to identify the region in which it operates, to produce better and cooperate more efficiently with the development of society (Bassols, 1984).

Thus, sustainability in the context of agricultural systems, considers the creation of productive systems of natural resources, stable and adaptable, that distribute costs and benefits equitably, generating self-managing processes among other beneficiaries (Masera *et al*., 2000). For their part, Edwards *et al*. (1990) refer that sustainable agriculture not only refers to an agriculture that tries to provide sustained long-term yields, but has also promoted the need to make adjustments in conventional agriculture so that it becomes environmentally, socially, and economically viable and compatible.

Likewise, it is necessary to change growth patterns, consumption habits, investment in infrastructure and technology that counteract the problem of environmental deterioration in order to achieve conservation and sustainable development. In this sense, in order to measure the sustainability of production systems, it is necessary to identify and evaluate the social, economic and ecological variables involved in development, through integrative processes that generate indicators that are holistic to analyze and evaluate the state of the environment and ecological functions, as well as the impact and consequences of development on natural resources (Torres *et al*., 2000).

The design of sustainable systems should be oriented to small producers with scarce economic resources, reducing production costs and increasing benefits, such as productivity, conservation of traditional knowledge related to agricultural management, as well as access to inputs, food and markets (Astier *et al*., 2008). Hence, sustainability is a priority given the need for development that not only involves natural resources, but is also interrelated with economic and social aspects.

Therefore, the objective of this research work lies in the interest of measuring the sustainability of the agricultural production system with greater importance in the region of the state of Chiapas, which constitutes the cultivation of corn, through the framework of evaluation of systems of management incorporating sustainability indicators (MESMIS), in order to determine the levels of sustainability of the productive system, and formulate alternatives that contribute to the design of the sustainable system, benefit productivity with social equity, the conservation of natural resources and the of decisions of the productive units.

Materials and methods

This research work is of a mixed type, since it has an observational, exploratory, descriptive, non-experimental and transversal scope. On the other hand, regarding the sampling frame, it was determined by selecting producers from the municipalities of Villaflores and La Trinitaria, Chiapas, using the Proagro Productivo beneficiary list for the 2017 agricultural cycle.

Next, stratified sampling was used since, in this type, the population is divided into strata, and it tends to be more precise than in comparison to simple random sampling. In this sense, according to Vivanco (2005) to determine the size of the sampling strata, they were assigned according to the stratum of belonging, taking into account the criterion of the concentration of 80% of corn producers in the localities of the municipalities from Villaflores and La Trinitaria, Chiapas.

Finally, the stratification comprised six and five localities, for each of the municipalities. Regarding the allocation used for the stratified sampling, proportional allocation was determined. According to Vivanco (2005), this allocation has the advantage that a self-weighted sample is generated characterized by the same sampling fraction in all strata.

Subsequently, the following statistical formula was applied that represents the proportional allocation stratified sampling (Vivanco, 2005).

Total sample size

$$n = \frac{\Sigma_{i=1}^{I} N_i P_i Q_i}{NE + \frac{1}{N}\Sigma_{i=1}^{I} N_i P_i Q_i} \qquad E = \frac{d^2}{Z_{1-\alpha/2}^2}$$

Size of each stratum

$$n_i = n\left(\frac{N_i}{\Sigma_{i=1}^{I} N_i}\right) = n\left(\frac{N_i}{N}\right) = n(W_i)$$

The confidence percentage for this investigation is 95% and a precision error of 10%. Where: N= population size is 844 producers for the municipality of Villaflores and 992 producers corresponding to the municipality of La Trinitaria; N_i= size of the stratum population; P_i= expected proportion of 20%; Q_i = 1-P_i (1-0.2= 0.8); d = absolute error or precision of 10%; $Z_{1-\alpha/2}$ = 95% confidence level, therefore $Z_{1-\alpha/2}$ = 1.96^2; NE= product of the population size and the estimation error; n= total sample size; and n_i= size of each stratum.

Then, the sample size *n* estimated in the case of the municipality of Villaflores and La Trintiaria was 57 and 58 surveys, respectively, which represents the total of the target population of the study area. In another sense, the size of each stratum was determined by means of the corresponding formula on proportional allocation, obtaining the sample for each conglomerate.

Regarding the collection of field information, a semi-structured survey was carried out aimed at the heads of the maize crop production unit, where questions related to general data on the producer, production, socioeconomic and environmental aspects were included. Regarding the design of the research, it was carried out through the implementation of the framework for MESMIS, since it is a methodological model or non-static dynamic reference matrix, which evolves according to the immediate needs to enrich its performance and is in accordance with the object of study of analysis by its scale of evaluation and specificity of the same (Astier *et al*., 2002).

In this sense, the framework proposes six general steps that arise from the intersection of environmental processes with social and economic factors. Therefore, to achieve the expected objectives, the following were applied: definition of the system, determination of critical points of the system, diagnostic criteria and use of economic, social and environmental indicators, measurement and monitoring of indicators, presentation and integration of results, as well as conclusions and recommendations.

Derived from the above, once the system to be evaluated has been defined as part of the diagnosis of the corn production system, as suggested by Masera *et al*. (2000) in order to identify the vulnerable points that had an impact on the maize agro-ecosystem in relation to sustainability, the critical points on the productive system were distinguished. Subsequently, the diagnostic criteria and indicators for the measurement of sustainability were determined. For the selection of indicators, aspects of the economic, social and environmental fields, of evaluation and monitoring in the participating production units were related according to the information obtained in the field; these are 21 criteria and 23 indicators, as shown in Table 1.

Table 1. Diagnostic criteria and indicators to measure the levels of sustainability in corn production in the municipalities of Villaflores and La Trinitaria, Chiapas.

Ambit	Category	Criteria	Indicators	Evaluation parameters for the optimum
Economic	Economic benefit	Productivity	Yields	R= 4 t ha^{-1} Villaflores R= 1.84 t ha^{-1} La Trinitaria
		Income	Production costs	CP < IT-IN
			Net income	IN > IT-CP
			Source of income from other non-agricultural activity	No. of economic activities

Ambit	Category	Criteria	Indicators	Evaluation parameters for the optimum
	Economic efficiency	Net income	B/C ratio	>1
	Self-sufficiency	Physical-economic	Independence from external inputs	Minimum external origin of the materials and services used in the production process
		Government support unit	Degree of dependence on government support	Null support
		Credit	Access to credit	No access
Social	Participation	Job creation	Employed labor	Minimum hiring of wages per hectárea
		Degree of participation of women at UPF	Participation of women in agricultural activities	>1
	Change and Innovation	Scholarship	Level of education in the municipality	High level
		Capacity and knowledge generation	Recovery of traditional techniques/technical assistance	>0
		Technology development and application	Incorporation of machinery and equipment; as well as adoption of practices	(%) of adoption of adoption of practices
	Organization/control	Management level	Who makes productive and commercial decisions	Equality in social organization
		Training to organization or productive association	Membership of an association or organization	10

Ambit	Category	Criteria	Indicators	Evaluation parameters for the optimum
Environmental	Productive diversification	Agricultural and livestock production	Number of species and breeds cultivated and managed	> 1
	Biological vulnerability	Existence of pests and diseases	Type of pests and diseases	No incidence
		Weather events	Presence of weather events	No presence
	Conservation and protection of natural resources	Plant biodiversity	Abundance or existence of other non-agricultural plant species	10
		Organic matter balance	Incorporation of OM	Yes it incorporates
		Chemical control	Pesticide and fertilizer use	Null use
		Soil conservation practices	Incorporation of soil conservation and management practices	High presence
		Generated externalities	Degree of deterioration of the natural resource	No level of impairment

Elaboration based on Astier *et al.* (1994).

Likewise, to estimate the reliability of the 23 indicators, it was carried out through Cronbach's alpha coefficient. The value obtained was 0.925 out of a maximum of one; where the closer the alpha value is to one, the greater internal consistency of the items analyzed. Therefore, according to the criteria of Gliem and Gliem (2003), an alpha value greater than 0.8, the measurement was considered excellent or reasonable. Regarding the measurement scales, they were obtained under a mixed approach. Once the field data were obtained, with the information processing the optimal values were determined, as well as the weighting and standardization.

In this way, the standardization of the indicators consisted of transforming the values obtained into dimensionless variables that contributed to their comparison through the construction of a Likert scale. According to Sarandon and Flores (2009), the indicators are direct: the higher the value, the more sustainable. In this case, the range from 2 to 10 was considered, with 2 being the least sustainable or unacceptable category, 4 limited, 6 moderate, 8 good and 10 the most sustainable or optimal. The optimal value is determined under the assumption that this level improves the system or maintains it in a balanced way.

Additionally, regarding the weighting of the indicators, descriptive statistics were used through weighted averages with Likert-type scales, where the calculation consisted of the frequency of each item and was multiplied by the value assigned within the standardized scale; and adding each of the products of the items, and then dividing by the number of the sample of each municipality (Levin and Rubin, 2004). Finally, the results were analyzed by integrating amoeba graphs, where the values obtained are indicated. The comparison of the maximum areas of each system determines the relative global sustainability between them (Sepulveda, 2008).

Results and discussion

Evaluation of the indicators of the economic dimension

The economic analysis was prepared based on the real conditions of spatial and temporal production of the production system and calculated by municipalities; shown below in Figure 1.

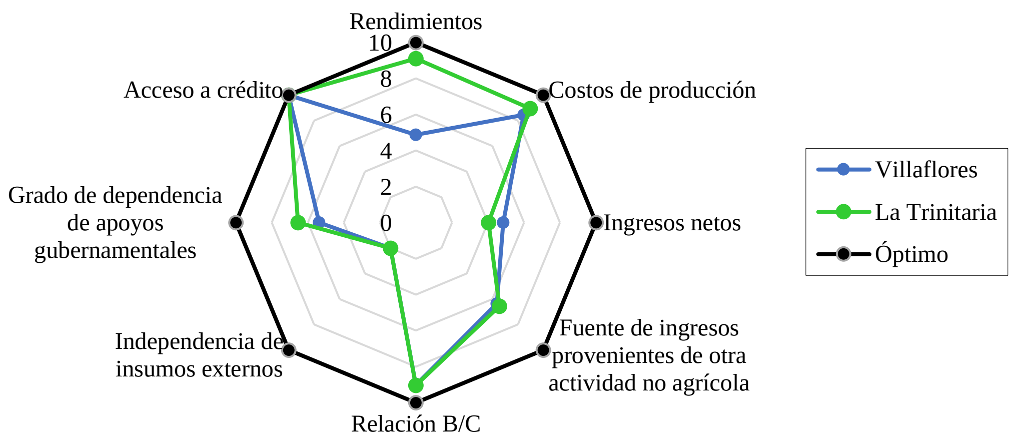

Figure 1. Radial of the indicators of the economic dimension.

First, the corn crop yield indicator expresses significant variability between municipalities, given the agro-climatic conditions, the adaptability of the productive system in the area, the type of technology and seed used, differing in the expected yields. It is noteworthy that high yields are derived from the implementation of technology and the use of agrochemicals that enhance crop production.

Although the implementation of technology, fertilizers and pesticides, affects the increase in yields, it also increases the production costs of corn due to the high price of inputs and variable costs such as the rental, maintenance and renewal of machinery. Furthermore, the proposals of Cruz *et al*. (2004), state that production costs are higher in tractor technology. Thus, it agree with Sangerman *et al*. (2009) where it expresses that the use of technologies is an essential factor for greater profitability and a trend of increase in production costs is glimpsed, as more developed technology is used and decreasing in less developed technologies.

As for the indicator of net income from production sales, a limited income is reflected despite a good profitability of production. Therefore, economic resources are insufficient to support the family, hence the need to diversify the economy. In the same way, Arias (2009) indicates that agricultural production is no longer sufficient, which is why producers find it necessary to diversify their sources of income through pluriactive activities. Additionally, Carvalho and Moesch (2013) state that the benefits of the diversification of non-agricultural activities in rural areas consist of the increase in economic resources, which encourages economic, social and environmental development.

Thus, both production costs and the benefit-cost ratio have a level of 9.02 for Villaflores and 9.03 for La Trinitaria. Which shows approaching the optimum of the indicator. However, it is necessary to generate higher income from production by increasing the population density of planting and diversifying the market for the sale of production; to make this indicator sustainable. With regard to the self-dependence of the system, it is shown to be low, due to the high use of external inputs. According to Astier *et al*. (2003), indicated in research, results with dependence on the outside between 55 and 70% approximately in the systems that contemplated machinery, equipment and agrochemicals.

Regarding the intervention of government institutions in granting support or subsidies, there is a limited and moderate degree of dependence on the government support received, with a level of 5.37 and 6.55 for Villaflores and La Trinitaria, respectively. Thus, there is a minority of producers that receive federal support from Procampo, a program to promote agriculture, and from the state such as the Amanecer program; aimed at the production and improvement of the quality of life of the adult population in situations of poverty, vulnerability and social exclusion.

Along these lines, according to Reyes *et al*. (2003), a negative effect of subsidies on production is evidenced, because the support programs generate a dependent economic sustenance, causing negative and unsustainable behavior in the production units. In this sense, as Garcia (2017) points out, not having access to credit favors producers not to undercapitalize and reduce their production due to lack of liquidity. The foregoing agrees with the author given that the contracting of credit entails a payment for financing at high and sometimes non-preferential rates, which contributes to the production of corn being unprofitable and sustainable. Therefore, the vision of Gonzalez *et al*. (2018), which state that it is essential for agriculture to be more competitive, driven through the integration of small corn producers in value chains, linked to more profitable markets and innovation in the use of optimal technology for production.

Evaluation of the indicators of the social dimension

Based on the information in Figure 2, there are seven indicators that determined the level of sustainability of this dimension. According to what has been observed, some producers in Villaflores hire labor for wages compared to producers in La Trinitaria who resort to the participation and integration of family work in production processes. In this regard, as Manzano (2009) points out, hiring personnel for this type of agriculture implies a significant cost for the producer and at the same time, causes a process of intensification and modernization of agricultural holdings, with a business nature and with less motivation for the work that the farmer himself.

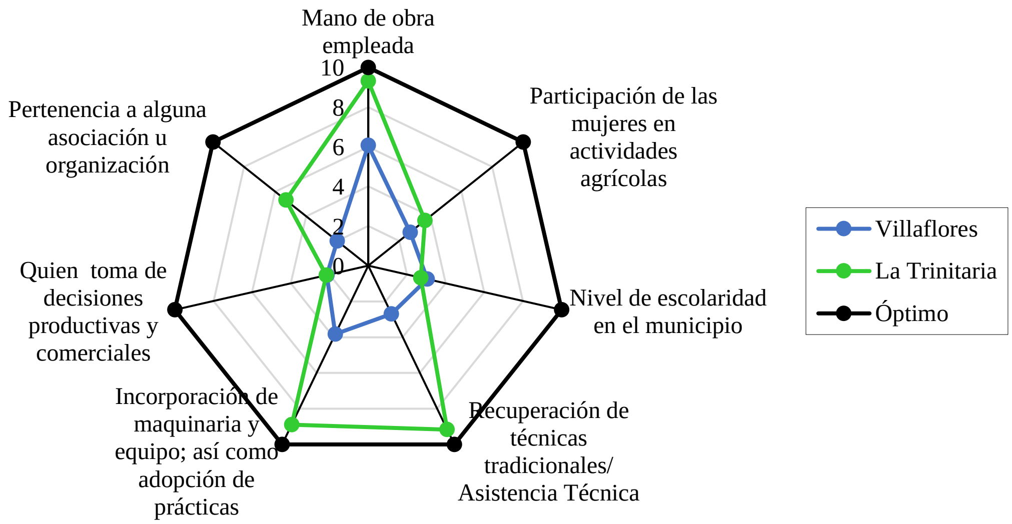

Figure 2. Radial of the indicators of the social dimension.

Regarding the participation of women in agricultural activities and making productive and commercial decisions, in both municipalities a limited equitable participation in the productive system is compared, as well as a low distribution of power in decision-making in agricultural activity. In this sense, as Vieyra (2004) infers, the work or participation of women is still marked in society as a passive entity, and little is said about the satisfactions that women obtain within the means of production, as an active contributor and participate in the decisions in the production system.

In a similar way, the degree of education of the producers shows a variability in this indicator, obtaining levels of 3.05 and 2.72 close to the unacceptable range for social sustainability. As shown by Bernal (2014), he highlights that education favors the autonomy of people and offers the possibility of self-managing their lives, through the generation of new capacities and personal and social enrichment; that allows establishing new opportunities for well-being and quality of life.

On the other hand, in La Trinitaria they apply traditional techniques and manual machinery (work animals, tools such as esqueque, sickle, hoe, scythe, etc.), which compared to Villaflores, which develops a technified practice (graders, seeders, tractor, etc.). Hence, Cruz *et al*. (2004) raise the need to use technologies with less use of capital and less intensity, but with greater development, because they result in higher yield using restrictive conditions and conserving natural resources.

To finish this dimension, the indicator belonging to an association or organization according to the results for the two municipalities, for Villaflores shows a lower value than is desirable. In contrast, some producers from La Trinitaria indicate that they are members affiliated with rural production societies and solid organizations such as the Emiliano Zapata Campesino Organization, the Tziscao Cinco Lagos Organization and the Popular Campesino Front; in which, they participate in member assemblies to make decisions, obtain benefits such as ensuring the sale of corn, allocation of government support and discounts on inputs.

Likewise, it is a clear example with the vision of Garcia (2000), where he states that the organization of agricultural producers constitutes a driving force and alternative to promote substantive improvements in agricultural activity, at the same time that they constitute one of the fundamental instruments for the achievement of the structural changes required in the process of social transformation of the countryside and a decisive way of incorporating the peasant into the process of social and economic development of the country.

Evaluation of the indicators of the environmental dimension

Regarding the evaluation of environmental indicators, eight indicators were considered that built the level of sustainability of this dimension, as seen in Figure 3.

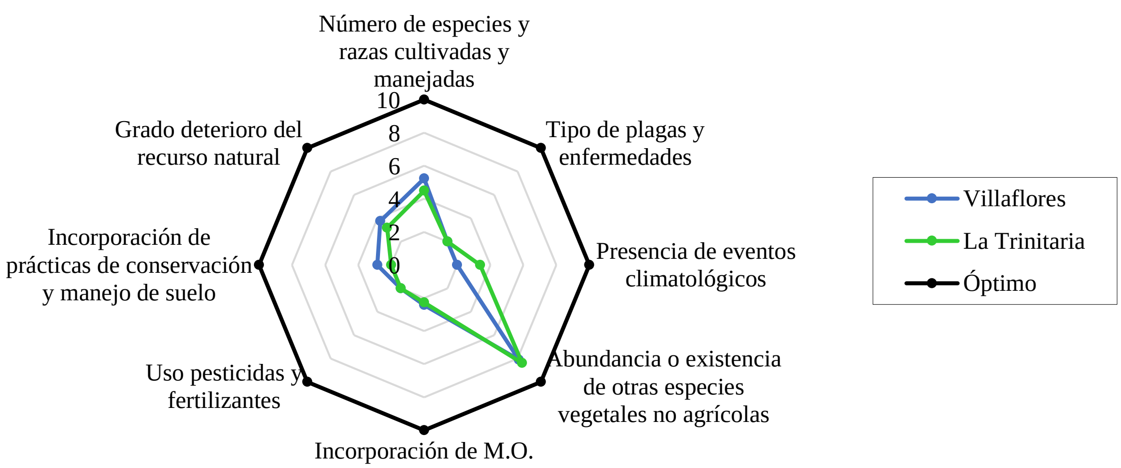

Figure 3. Radial of the environmental dimension indicators.

As a result of the environmental study, regarding the indicators of the number of species and breeds cultivated and managed, as well as the abundance or existence of other non-agricultural plant species, in the first case it is observed that both in Villaflores and La Trinitaria, the majority of corn producers have limited value, since most of them are dedicated to the monoculture of corn with little agricultural productive diversification.

According to Griffon (2008), they refer that monoculture is inherently unstable, so the richness of the elements in the system must be considered, in addition to taking into account the number of ecological relationships between the components of agrobiodiversity. For the second case, in the two municipalities a good level of different vegetative species is reflected to the agricultural ones present in the environment; which shows a high protection of the corn agro-ecosystem. Indeed, as they support where the biodiversity of species is a strategy that guarantees the sustainability of agro-ecosystems.

On the other hand, in relation to the presence of pests and diseases exhibited by the corn crop in the different municipalities, the most notable are blight, singe, fall armyworm, cutworm, corn worm, and corn leafhopper. Consequently, most producers resort to the use of agrochemicals such as urga, finale, fipol, ammonium sulfate and herbipol, to control the population densities of phytophages and phytopathogens in agriculture, together with the use of chemical substances such as fertilizers when necessary. intensive production. The use of these products causes soil and water contamination and alteration to the environment, making the maize production system biologically vulnerable and unsustainable as a system.

In this way, it is evident that the monoculture system requires opting for biological methods such as organic fertilizers and organic matter, which cause less economic and productive impact and that the systems are less dependent on agrochemicals, to maintain an ecological balance of biodiversity and positive effect on the conservation of the soil and natural resources.

Soil conservation avoids the loss of essential nutrients to improve the productive capacities of agricultural soils (Damian *et al*., 2010). Also, the incidence of climatological events and the alterations of natural cycles and processes, disturb the balance of the system that makes up the natural environment; causing direct economic damage and drop in productivity.

Maize crop sustainability assessment overview

Derived from the measurement of the indicators that measure sustainability in the three areas of the corn production system for the municipalities of Villaflores and La Trinitaria, Chiapas, the radial graph is shown below that shows the general vision of the evaluation to determine the sustainability profile, obtained from the approach of the optimal values passes each indicator, considering its ideal state (Figure 4).

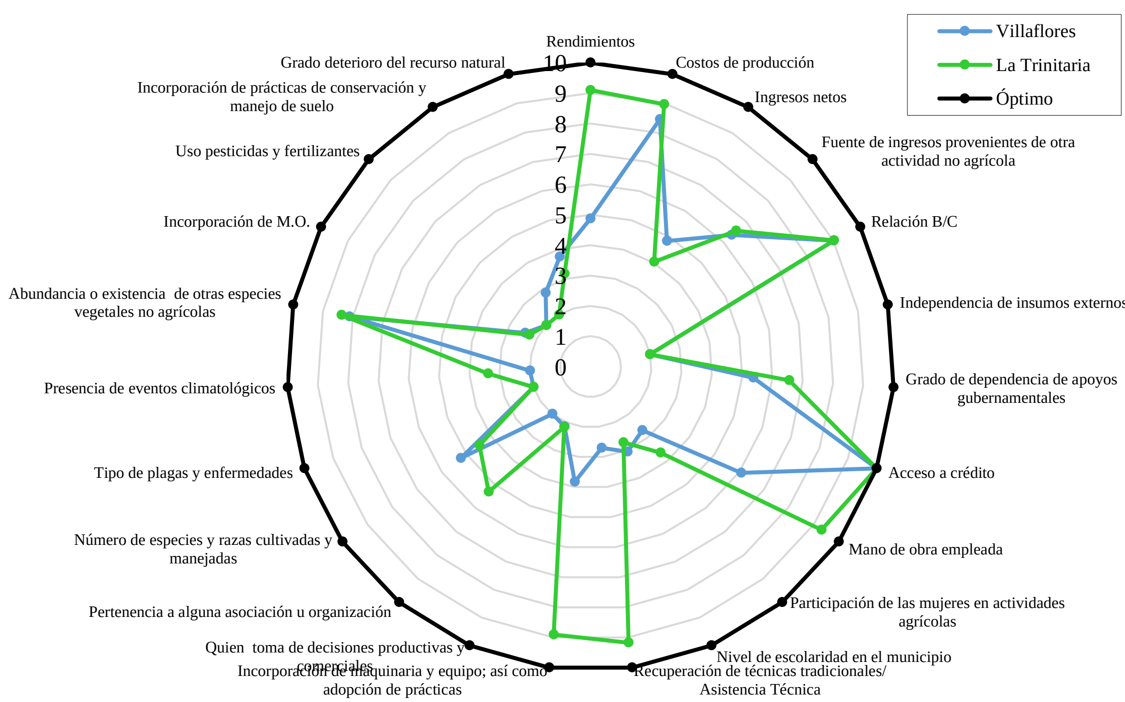

Figure 4. AMEBA type diagram: integration of sustainability indicators.

In this way, according to the results obtained in the evaluation for Villaflores and La Trinitaria, it stands out that in the economic dimension it is at a moderate sustainable level, with a score of 5.77 and 6.32, respectively. In this area, it is evident from the values obtained, fragile aspects such as net income from production, source of income from other non-agricultural activities, dependence on external inputs and degree of dependence on government support.

With regard to social indicators, values lower than 3.01 and 5.08 are reflected in the moderate average for the two municipalities. In the case of Villaflores, a vulnerable sustainable level is noted in the indicators of employed labor, recovery of traditional techniques and technical assistance, incorporation of machinery and equipment, as well as adoption of practices, and belonging of the producers to an association or organization.

Regarding the environmental dimension, a weak sustainable level stands out for Villaflores and La Trinitaria, with a score of 3.11 and 3.6 with respect to the optimum, based on the values obtained in all its indicators of this dimension, such as: cultivated species and breeds and improved (agrodiversity) in the cultivation of corn, type of pests and diseases, use of pesticides and fertilizers, presence of weather events, incorporation of organic matter, incorporation of soil conservation and management practices and degree of deterioration of the natural resource. Therefore, it is not fulfilled in an optimal and agroecological way given the presence of anthropogenic and environmental factors.

Finally, it should be noted that the sustainability values of the industrial estates for the municipalities of Villaflores and La Trinitaria are 3.78 and 4.81, respectively. Therefore, it should be noted that a limited sustainable level prevails in the economic, social and environmental sphere, which shows that corn production in these municipalities is far from the optimum of sustainability, as a result of a low integration between the dimensions.

Conclusions

From the significant results highlighted by the measurement, it shows a low level of sustainability in the agro-ecosystem. However, in the economic sphere, the productive system reflected a sustainable level strengthened in the categories of economic benefit and economic efficiency, but vulnerable and fragile in the social and environmental dimension, due to low levels of sustainability in equitable social participation, change and innovation, social organization, biological vulnerability and conservation and protection of natural resources.

Therefore, the evaluation of sustainability in the cultivation of corn for the municipalities of Villaflores and La Trinitaria, Chiapas, shows that the system is affected by different social, economic and environmental pressures that cause and accelerate changes in its socioeconomic and environmental structure; affecting a highly fragile scenario, a situation that makes maize cultivation vulnerable to the alterations it presents in the production system.

In addition, to mitigate the impact of agriculture on the environment, the application of agroecological techniques is required, which develop an environment-friendly exploitation and where the corn production process is stable and not be opposed to the sustainable development of production. agricultural.

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