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Sustainability indicators for banana's farm evaluation in agricultural areas of Babahoyo, Ecuador

Indicadores de sustentabilidad para la evaluación de fincas de banano en zonas agrícolas del cantón Babahoyo, Ecuador

[1]Oscar Caicedo-Camposano
Doctorante de Agricultura Sustentable. Universidad Nacional Agraria La Molina, Perú; Profesor Investigador. Facultad de Ciencias Agropecuarias. Universidad Técnica de Babahoyo. Ecuador
ocamposano@utb.edu.ec
ORCID: 0000-0002-6020-0413

[2]Carlos Balmaseda-Espinosa
Profesor Investigador. Facultad de Ciencias Agrarias. Universidad Estatal Península de Santa Elena. Ecuador
cbalma59@gmail.com
ORCID: 0000-0003-2436-7993

[3]Dalton Cadena-Piedrahita
Doctorante de Agricultura Sustentable. Universidad Nacional Agraria La Molina, Perú; Profesor Investigador. Facultad de Ciencias Agropecuarias. Universidad Técnica de Babahoyo. Ecuador.
pcadena@utb.edu.ec
ORCID: 0000-0002-5532-7663

[4]Eleonora Layana-Bajaña
Profesora Investigadora. Facultad de Ciencias Agropecuarias y Ambientales. Universidad Técnica del Norte.
eleonora.layana@gmail.com
ORCID: 0000-0002-1573-9823

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Abstract

This assignment was carried out with the aim of constructing sustainability indicators for banana's farm evaluation in Babahoyo, Ecuador. For it, a workshop was held in the area of study, in which a group of experts in banana cultivation participated. The methodology is an adaptation of Professor Santiago Sarandón's proposal, in which he considers the three dimensions of sustainability; the labor presents a list of important indicators and formulas to calculate the value of environmental, economic and sociocultural indicators, as well as to obtain the general sustainability index. Through the Kendall Coefficient and the Cronbach's alpha, a satisfactory internal consistency was obtained with respect to the designed instrument. It is concluded that the development of the indicators, the sub-indicators and the categories for each of the dimensions of sustainability is appropriate to detect critical points of it, to establish causes and propose medium and long term solutions. The methodology involves an activity that is applicable to a wide range of farms in a series of contexts, as long as some indicators are replaced by others that are relevant to the farms to be evaluated. In addition, according to the methods to measure the agreement, the designed instrument was understood by the surveyed.

Keywords: Banana, methodology, multicriteria analysis, ranch.

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Resumen

Este trabajo se efectuó con el objetivo de construir indicadores de sustentabilidad para la evaluación de fincas bananeras en Babahoyo, Ecuador. Para ello, se realizó un taller en la localidad de estudio, en el que participó un grupo de expertos en el cultivo de banano. La metodología es una adaptación de la propuesta del profesor Santiago Sarandón, la cual considera las tres dimensiones de la sustentabilidad; el trabajo presenta una lista de indicadores importantes y fórmulas para calcular el valor de los indicadores ambiental, económico y sociocultural, así como para obtener el índice de sustentabilidad general. Mediante el Coeficiente de Kendall y el alfa de Cronbach se obtuvo una consistencia interna satisfactoria respecto al instrumento diseñado. Se concluye que el desarrollo de indicadores, subindicadores y categorías para cada una de las dimensiones de la sustentabilidad es adecuado para detectar puntos críticos de la misma, establecer sus causas y proponer soluciones a mediano y largo plazo, la metodología involucra una actividad que es aplicable a una amplia gama de fincas en una serie de contextos, siempre y cuando, se reemplacen algunos indicadores por otros que sean relevantes para las fincas a evaluar. Además, según los métodos para medir la concordancia, el instrumento construido fue comprendido por los encuestados.

Palabras clave: Banano, metodología, análisis multicriterio, fincas.

Introduction

The banana's exporting production is a technological and economical activity different from the production of conventional bananas, which, in countries such as Ecuador, remains the main non-oil export product. (Pro Ecuador, 2016).

In Los Ríos' province, the banana cultivation represents a very important item in economic terms; therefore, it requires large infrastructure investments such as irrigation, drainage, packing plants, cable track, among others. Of the 637,000 ha of land with agricultural aptitude, about 10% of that area is planted with banana (Instituto Nacional de Estadísticas y Censos, 2011).

The conventional procedures used to assess the results achieved in agricultural production systems such as cost-benefit are not sufficient to evaluate their long-term activity, since they do not consider social and environmental situations in the analysis, the same as today, they are very important elements within the production systems (Flores & Sarandón, 2004).
Banana's production pollutes not only the area of their plantations, but the agrochemicals applied there are washed away by tributaries and rivers to the sea or ocean, where they kill corals and fish (Maldonado *et al*. 2007).

Among the practices of banana's production in some tropical countries, there is a wide variation. Currently, the purpose of public and private companies in banana's producing countries is to identify alternative systems that combine high productivity and profitability with less dependence on agro toxics. (Bellamy, 2013)

For a sustainable agricultural production system to exist, strategies must be defined that lead to achieve a balance between the productive, economic and social aspects, as it is illustrated in figure 1, since, if the development of only one of them is prioritized, it is likely that the other two are affected and take restrictions (Müller, 1994).

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To Chiappe y Sarandón (2002), the adoption of a broad approach to sustainable agriculture includes both environmental and ecological aspects, as well as social and economic aspects, allows a more adequate approach to the formulation of alternative agricultural strategies.

The resilience of communities depends on the resources available in them. These resources can be interpreted as the existence of different forms of capital (Flora *et al*. 1995 and distinguish four types of capital: physical-financial capital, human capital, natural capital, and social capital. The figure 2 illustrates the forms of capital existing in a community and the interrelationships that exist between them.

The authors themselves manifest that human capital refers to the training's level of the members of a community, for example, the education and skills with which workers perform their job.
Physical capital consists of public, private goods and financial assets (the assets used in the production process), that is, everything that is monetarized or that is convertible to monetary terms. Natural capital is made up of the quantity and quality of the available natural resources: water, soil, air, biodiversity and landscape.

According to Putnam *et al*. (1994) mention that social capital is constituted by aspects of social organization that facilitate coordination and cooperation for mutual benefit.

The methodology of Altieri & Nicholls (2002) has not been used because it does not comprehensively address this type of studies. But the methodology developed by Sarandón *et al*. (2006) is better adapted to the sustainability analysis of agricultural systems or farms where annual crops are worked. For work on farms with perennial crops, it is advisable to reformulate it, but always considering the three dimensions of sustainability.

As part of the design of numerous investigations, it is necessary to consult people who participate as experts. However, to convert the conglomerate of knowledge possessed by the specialists in scientific information, needs the controlled application of a method for obtaining the information, that method is the Delphi. This method differentiates and adjusts particular opinions and arguments expressed by experts and allows decisions to be made, which should not be taken unilaterally by researchers. (García & Suárez 2013).

The Delphi is a qualitative research method that, when publishing research results, requires studies that use it and the details of its phases are explicitly described, which are: 1) preparation phase where the experts are selected; performs the preparation of the instrument, and the route of the consultation is decided; 2) consultation phase, the consultation rounds are carried out, the statistical processing is executed successively, and the feedback; 3) the consensus phase is built and the result is reported. For more than four decades the Delphi method has been the subject of multiple applications worldwide and continues being used by researchers who analyze complex problems (Astigarraga 2008).

The Kendall Coefficient of Concordance is used to determine the degree of agreement among several judges (experts), or the association between three or more variables, that is, it is especially useful when the experts are asked to establish ranges for the items. The minimum value assumed

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by the coefficient is 0 (zero) and the maximum value is 1 (one); However, the rating given to each item should always be reviewed, since there may be a high correspondence in the aspects, an example would be that the item is not appropriate. Unreasonably, in this case it must be excluded or completely modified, until it fits the measurement objectives appropriately (Escobar-Pérez & Cuervo-Martínez 2008).

Another method to know the reliability of the instrument is the Cronbach's Alpha, which is a coefficient that serves to measure the reliability of a scale of measurement, and whose Alpha name was made by Lee Joseph Cronbach in 1951. To determine the Alpha coefficient of Cronbach, the researcher calculates the correlation of each reagent or item with each of the others, resulting in many correlation coefficients. Something that must be taken into consideration is that the value of the Alpha is the average of all the correlation coefficients (Lind, Marchal, & Wathen, 2012). For this to be easier, it is preferable to have a similar scale in all the reagents proposed.

Bójorquez, López, Hernández, & Jiménez (2013) indicate that this coefficient requires a single administration of the measuring instrument and produces values that oscillate between 0 (zero) and 1 (one). Its advantage is that it’s not necessary to divide the measurement instrument into two halves, the measurement is simply applied, and the coefficient is calculated.

According to the literature of Streiner (2003), it holds that the limit value for accepting a Cronbach's alpha is 0.7. For its part, Malhotra (2008) indicates that "there is unsatisfactory reliability of internal consistency when the coefficient adopts a value equal to or less than 0.6". This assignment was carried out with the aim of constructing sustainability indicators for banana’s farm evaluation in Babahoyo, Ecuador. For it, a workshop was held in the area of study, in which a group of experts in banana cultivation participated.

Methodoly

For the construction of sustainability indicators, a workshop was held in Babahoyo, in which several experts participated in the cultivation of bananas domiciled in this city, workers from public and private institutions, with experience in the different edges of the banana growing chain. They followed the steps proposed by Sarandón *et al*., (2006), the same ones that were:

a) Establish a conceptual framework: What was understood as sustainable agriculture was discussed and defined.
b) Define the objectives of the evaluation: The objective was to evaluate the banana’s farm sustainability.
c) Characterize the farms to be evaluated: In the area, the banana is grown in monoculture.
d) Analyze existing information: Publications on edible banana production and sustainable agriculture were reviewed, by using in a comprehensive manner, the methodology of Sarandón & Flores (2009) and Altieri & Nicholls (2002).
e) Define the dimensions of the analysis: It was agreed to consider the three dimensions of sustainability.
f) Define sub-indicators for each dimension: it refers to indicate the parameters directly related to each dimension of sustainability.
g) Define range of values for sub-indicators refers to giving a numerical value to each of the parameters directly related to each dimension of sustainability.

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h) Define formulas to calculate the indicators: It was analyzed, discussed and proposed by Sarandón & Flores (2009) to measure the indicators of each dimension of sustainability and the pertinence of making changes.
i) Define formulas to calculate the general sustainability index: It was considered, discussed and proposed by Sarandón & Flores (2009) to calculate the general sustainability index and the pertinence of making changes in it.
j) Design of the format to collect the information in the field (survey). To analyze each of these items, it was necessary to use a minimum time of 30 minutes for the presentation and discussion of the proposals. The final proposal was defined by a vote in which the entire panel of experts participated.

Using the methodology of the State Committee of Science and Technology of Russia, developed in 1971 by Oñate Ramos & Díaz (1998), the competence of the experts was determined and then the processing of their criteria and opinions was applied by the Delphi method; finally, to verify the degree of coincidence of the evaluations made by the experts, the Kendall's concordance coefficient test was used.

When consulting experts, indicators, sub-indicators and assigned categories were validated. For this, 32 experts were evaluated who, among other things, work in the banana production and, in other cases, they were people linked to the teaching of this crop in the universities of Los Rios' province, the Delphi method was applied. It was detected that only 15 are experts, with a competence coefficient (K) $0.8 \leq K \leq 1.0$, which gives them a K = High; the model of the Kendall concordance coefficient statistical test was used, which helped to verify the degree of coincidence of the evaluations carried out by the experts (Reguant-Álvarez & Torrado-Fonseca, 2016; EcuRed, 2018).

Results

The group of experts considered that the methodology used by the multicriteria analysis to evaluate the sustainability of banana farms (Sarandón *et al.* 2006; Sarandón & Flores 2009), unlike the proposal of Altieri y Nicholls (2002), is better to evaluate banana plantations, since it considers the three dimensions of sustainability and approaches it holistically and systemically (Mendoza & Prabhu, 2000; Evia & Sarandon, 2002). But this had to be reformulated and adapted for the analysis of banana farms. Having into account these considerations, the task of constructing indicators showed the following results:

Analysis of the economic dimension.

A. To assess whether the systems were economically sustainable, the following indicators and sub-indicators were established:
B. Food self-sufficiency: this is fundamental for the sustainability of the banana farm. The following variables were considered:

- Diversification of production: (4) More than four products; (3) Four Products; (2) Three Products; (1) Two Products; (0) A product.
- Percentage of the total area devoted to self-consumption: (4) More than one hectare; (3) Up to one ha; (2) Up to half a ha; (1) A quarter of a hectare; (0) Zero ha.

C. Economic income: The system is sustainable if it can meet the economic needs of the family group.

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- Crop yield. - The system is sustainable if it remains the same or higher than the average of the area. (4) Greater than 4000 boxes; (3) Between 3000 to 4000 boxes; (2) Between 2000 to 3000 boxes; (1) Up to 2000 boxes; (0) Less than 2000 boxes.
- Cost of production. - The cost of production must guarantee a margin of profit for the system to be sustainable. (4) Less than 4.25; (3) Between $ 4.25 and $ 4.50; (2) Between $ 4.50 and $ 4.75; (1) Up to $ 4.75; (0) Greater than $ 4.75
- Net income. - These revenues were evaluated in dollars per year. (4) Greater than $ 7000; (3) Between $ 6300 and $ 7000; (2) Between $ 4200 and $ 6300; (1) Up to 3100; (0) Less than $ 3100

D. Economic risk: A system will be sustainable if it minimizes economic risk, ensuring stability in production for future generations.

- Reduction during the process. - In order for the production on the farm to be sustainable, the reduction must be up to 5%. (4) Less than 5%; (3) Between 5% and 10%; (2) Between 10% and 15%; (1) Up to 15%; (0) Greater than 15%
- Marketing channels. - Commercial diversification decreases economical risk (4) plus 3 contracts; (3) Up to 3 contracts; (2) Up to 2 contracts; (1) 1 Contract; (0) Spot.
- Dependence on agrochemicals and other inputs. - A system with a high dependence on inputs is unsustainable over time. (4) Very low; (3) Low; (2) Moderate; (1) High; (0) Very high.
- Self-financing of production. - The production system is sustainable if its yields give the ability to self-finance. (4) self-financing; (3) average self-financing; (2) partial self-financing; (1) Self-financing with severe restrictions; (0) It is not self-financing.

E. Conversion (ratio): if the ratio in the farm is higher than 2, the system is sustainable and reduces the economic risk. (4) Greater than 2.6; (3) Between 2 to 2.6; (2) Between 1.5 to 2; (1) Between 1a 1,6; (0) Less than 2

$$(IE) = \frac{\left(\frac{A1 + 2A2}{3}\right) + 2\left(\frac{B1 + B2 + B3}{3}\right) + \left(\frac{C1 + C2 + C3 + 2C4}{6}\right) + 2D}{4}$$

<u>Analysis of the environmental dimension.</u>

A. To assess whether the systems were economically sustainable, the following indicators and sub-indicators were established:

B. Conservation of soil life: a system is sustainable if agricultural practices maintain or improve life in the soil.

- Vegetable cover in the soil. - It provides the soil with protection against climatic agents and reduces the risk of erosion. (4) 100% coverage; (3) 75% coverage; (2) 50% coverage; (1) 25% coverage; (0) bare floors
- Management of the cultivation system. - The sustainable management of the system is achieved with certified organic practices. (4) Organic with double certification; (3) organic with a certification; (2) Organic with Application for Certification; (1) In transition with substitution of inputs; (0) Conventional monoculture.
- Crop diversity. - The diversity of plants in the system ensures its sustainability. (4) Association of Crops; (3) Intercalated culture; (2) Monocultures with the presence of spontaneous vegetation; (1) Monoculture surrounded by other crops; (0) Monoculture Surrounded Partially by Spontaneous Vegetation.

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- Incorporation of organic matter. - The incorporation of organic matter in the soil improves the physical and chemical conditions of this, which makes the system sustainable. (4) Very common; (3) Frequent; (2) Less Frequent; (1) Uncommon; (0) Null.

C. Erosion risk: A system is sustainable if it manages to minimize or avoid soil loss due to erosion (water in this case).

- Relief of the soil. - a system is sustainable if the relief of the soil favors the same. (4) Plane; (3) Plane with slight Ripples; (2) Moderately Wavy; (1) Wavy; (0) Irregular
- Leveling the soil. - (4) From 0 to 1%; (3) From 1% to 5%; (2) From 5% to 10%; (1) From 10% to 15%; (0) Greater than 15%
- Irrigation system. - (4) Drip; (3) Spray + Fertigation; (2) conventional spray; (1) Superficial; (0) Precipitation
- Drainage system. - (4) Subsoil with pumping station; (3) Superficial with pumping station; (2) Subsurface or surface without pumping station; (1) Without maintenance; (0) None

D. Biodiversity's management: Biodiversity is important for the regulation of the system, since, among other functions, it provides habitats and ecological niches for natural enemies. The diversity of plants is the basis of heterotrophic diversity.

- Cultivated varieties. - (4) More than 4; (3) From 3 to 4; (3) From 2 to 3; (2) From 1 to 2; (0) 1
- Integrated pest management. - (4) Very frequent; (3) Frequent; (2) Less Frequent; (1) Uncommon; (0) Null
- Origin of plant material. - (4) Imported; (3) Meristematic Certificate Laboratory; (2) Non-certified meristematic laboratory; (1) Vivarium Propagation with Corms; (0) Unknown
- Incidence of pests and diseases. - (4) Null; (3) Grade 1; (2) Grade 2; (1) Grade 3; (0) Greater than grade 3.
- Frequency of agrotoxic applications. - (4) Bimonthly; (3) Monthly; (2) Biweekly; (1) Weekly; (0) Daily intervals
- Detrimental climatic factors for production. - (4) None; (3) precipitation; (2) Temperature; (1) Relative humidity); (0) Precipitation, Temperature, Relative Humidity

$$(IA) = \frac{\left(\frac{A1 + 2A2 + 2A3 + A4}{6}\right) + \left(\frac{B1 + B2 + B3 + 2B4}{5}\right) + \left(\frac{2C1 + C2 + C3 + C4 + 2C5 + C6}{8}\right)}{3}$$

<u>Analysis of the social dimension</u>

- To assess whether the systems were economically sustainable, the following indicators and sub-indicators were established:
- A. Satisfaction about basic needs: A sustainable system is one in which farmers have their basic needs completely assured. It includes housing, education, health, services.
- Housing. - (4) Housing with 2P finishes; (3) Homes with 1P finishes; (2) Unfinished homes 2P; (1) Unfinished homes 1P; (0) Without accommodation
- Access to education. - (4) Superior; (3) Secondary; (2) Primary and Secondary / Restrictions; (2) Primary: (0) Without access
- Access to health. - (4) Hospital; (3) Sub-center; (2) Surgeries of the Ecuadorian Social Security Institute; (0) It does not exist

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- Tenure of the land. - (4) Own; (3) Inheritance; (2) Possession; (1) In Expropriation Process; (0) Invasion
- Satisfaction with the agricultural system. - (4) Very satisfied; (3) Satisfied; (2) angry pleased; (1) Less satisfied; (0) Disappointed
- Level of acceptance of new practices. - (4) Very high; (3) High; (2) Average; (1) Low; (0) null
- Disposal of waste. - (4) Delivered to collection centers; (3) Store and remove them; (2) Store and deliver; (1) Delete frequently; (0) Burn it
- Dedication time to the farm. - (4) 12 h; (3) 8 h; (2) 6 h; (1) 4 h; (0) Less than 4 h
- Generation of Relay. - (4) More than 3 children; (3) From 2 to 3 children; (2) 1 to 2 children; (1) 1 child; (0) None

A. Social integration: The relationship with other members of the community was evaluated. - (4) Very high; (3) High; (2) Average; (1) Low; (0) Null

B. Ecological awareness

- Suitability of the soil on the property. - (4) Very Adequate; (3) Apt; (2) Moderately Fit; (1) Marginally Fit; (0) Do not know
- Irrigation water aptitude. - (4) Excellent; (3) Good; (2) Permissible; (1) Doubtful; (0) Not suitable

$$IS = \frac{2\left(\frac{A1 + 2A2 + A3 + A4 + 2A5 + A6 + A7 + A8 + 2A9}{12}\right) + B + \left(\frac{C1 + C2}{2}\right)}{4}$$

As can be seen, all the variables received values within the same scale ranging from 0 (less sustainable) to 4 (more sustainable). This standardization homogenizes the results and favors its interpretation. Sarandón and Flores (2009) recommend a scale with 4 or 5 values; one from 0 to 10 is so broad that it could make it difficult to define categories and lead to the assignment of coherent values to all categories. It is important to mention that the indicators that will be used must be selected before going to the field, not later, since the choice of an indicator indicates the role played by the indicator in the sustainability of the system to be evaluated. The same can be said for each of the variables to be used. Overall's sustainability index. To calculate this index, it was agreed that the formula would be the same as proposed by Sarandón *et al*. (2006). The three dimensions receive the same evaluation because, in an adequate vision of sustainability, they must have the same importance and, therefore, the same value. The proposed formula is the one shown below:

$$ISG = \frac{IE + IA + IS}{3}$$

In the process of validation of the indicators, sub-indicators and the assigned categories, it was obtained as results that only 15 of the 32 people selected, turned out to be experts, the same ones that with the Delphi method reached a coefficient of competence *(K)* $0.8 \leq K \leq 1.0$ which gives them a K = High; then; with the Kendall Coefficient of Concordance statistical test model and the Cronbach's alpha, the degree of coincidence of the assessments made by the experts whose values reached were 0.997 and 0.712 respectively.

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Conclusions

The development of indicators for each of the dimensions of sustainability is adequate to detect critical points of the same, establish its causes and propose medium and long-term solutions.

This methodology involves a participatory activity and it's applicable to a wide range of agroecosystems (farms) in a series of geographic and socioeconomic contexts, as long as some indicators are replaced by others that are relevant for the agroecosystem to be evaluated.

A coefficient of Kendall very close to one and a satisfactory Cronbach's Alpha were obtained, since the coefficient is higher than 0.6 which indicates a satisfactory internal consistency, which means that the constructed instrument was understood by the surveyed.

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Contribución de los Autores

Autor	Contribución
[1]Oscar Caicedo-Camposano [2]Carlos Balmaseda-Espinosa [3]Dalton Cadena-Piedrahita [4]Eleonora Layana-Bajaña	[1]Concepción y diseño, investigación, metodología, redacción y revisión del artículo. [2]Investigación, búsqueda de información, análisis e interpretación de datos y revisión del artículo. [3]Investigación, búsqueda de información, análisis e interpretación de datos y revisión del artículo. [4]Adquisición de datos, aplicación de Software estadístico, análisis e interpretación.

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