UNIVERSIDAD AUTÓNOMA DE BAJA CALIFORNIA

LATIN AMERICAN JOURNAL OF APPLIED ENGINEERING

Proposal of a Model to Determine the Sustainability and Profitability of the Differentiated Coffee Production Chain

Propuesta de un Modelo para Determinar la Sostenibilidad y Rentabilidad de la Cadena Diferenciada de Producción de Café

Nicolás Riaño Calderón [a,]*, **Campo Riaño Luna** [a,]**, **Fernando Muñoz Peña** [b,]***

[a]*Escuela de Ciencias Básicas, Tecnología e Ingeniería, Universidad Nacional Abierta y a Distancia, Bogotá D.C, Colombia.*

[b]*Facultad de Ingeniería, Universidad Militar Nueva Granada, Bogotá D.C, Colombia.*

**Corresponding author: nicolas.riano@unad.edu.co*

*** Corresponding author: campo.riano@unad.edu.co*

**** Corresponding author: fernando.munoz@unimilitar.edu.co*

***Abstract*—** Economic globalization has forced the coffee sector to become more efficient and innovative. Due to the complexity of the subject matter, the contribution of experts in coffee research and sustainable production chains from different areas and disciplines is important. To this end, the sustainable variables derived from the MESMIS method (Framework for the Evaluation of Management Systems with Sustainability Indicators) were synthesized to evaluate sustainability as recommended by various authors. Sequentially, we worked with the information gathered from a coffee environment and with economic, statistical and multi-criteria tools for decision making. These were the Delphi methods, the Hierarchical Analysis Process (AHP), the principal components analysis (PCA), the method of response surfaces (MSR) and the equilibrium point analysis. With the sequential application of the work tools and the data reported for the selected variables, a statistical model of linear regression is proposed to estimate the production, sustainability and profitability of a differentiated coffee production unit (UPCD) taking into account 10 variables of sustainability correlated among themselves and selected by experts in the coffee industry. The ranking of 3 sustainable coffee producing units is also presented.

***Keywords*—** Coffee production chain, Delphi method, hierarchical analysis process, response surfaces, sustainable production model for coffee.

***Resumen*—** La globalización económica ha obligado al sector cafetero a ser más eficiente e innovador. Debido a la complejidad de la temática, es importante la contribución de expertos en las investigaciones cafeteras y en cadenas productivas sostenibles de diferentes áreas y disciplinas. Para el efecto, se realizó una sinterización de las variables sostenibles derivadas del método MESMIS (Marco para Evaluación de Sistemas de Manejo con Indicadores de Sustentabilidad) que permiten evaluar la sustentabilidad como lo recomiendan varios autores. Secuencialmente se trabajó con la información recopilada de un entorno cafetero y con herramientas económicas, estadísticas y multicriterio para la toma de decisiones. Estas fueron, los métodos Delphi, el Proceso de Análisis Jerárquico (AHP), el análisis de componentes principales (ACP), el método de superficies de respuesta (MSR) y el análisis del punto de equilibrio. Con la aplicación secuencial de las herramientas de trabajo y los datos reportados para las variables seleccionadas se propone un modelo estadístico de regresión lineal para estimar la producción, la sustentabilidad y la rentabilidad de una unidad productora de café diferenciado (UPCD) teniendo presentes 10 variables de sustentabilidad correlacionadas entre sí y seleccionadas por expertos en la temática cafetera. Igualmente, se presenta la jerarquización realizada a 3 unidades productoras de café sustentable.

***Palabras Claves*—** Cadena productiva de café, método Delphi, proceso de análisis jerárquico, superficies de respuesta, modelo de producción sustentable para café.

I. INTRODUCTION

THE coffee beverage (Coffea Arabica) is consumed in all countries of the world [1-2]. Colombia is recognized worldwide for the quality of its coffee, expressed in its flavor, aroma and body [3-4]. The international coffee organization commercially characterizes the coffee bean as conventional and differentiated (5). The latter, due to the way in which it is cultivated, presents quality characteristics different from the conventional one that make it desirable for gourmet consumers [6-9]. It is marketed at a higher price than conventional coffee (10). Among these selections is organic coffee, the starting point of this research. Organic coffee is defined as " a holistic system of production management that promotes and improves the health of agroecosystems, and in particular the biodiversity, cycles and biological activity of the soil, through practices that avoid the use of chemical synthesis products, as well as genetically modified organisms, wastewater, sweeteners and synthetic preservatives in processed products" as defined by several authors [11, 12). From the operational point of view " they are coffees cultivated using the clean production technique, without the need for agrochemicals, planted under trees of higher altitude for shade effects, preserving the environment, certified by specific environmental agencies, which makes them an exclusive bean in the world sphere [2, 3). However, for the small coffee grower the economic viability of producing differentiated coffee has been difficult to evaluate; since environmental, social, technical and economic variables must be considered as proposed by scholars on this subject [9,13, 14, 15).

Likewise, in [2] it is argued that agricultural development includes factors that affect community life that go beyond the increase in production and efficiency of the process. For example, in [11] it is argued that farms are cooperative learning environments where knowledge is transmitted following constructivist models.

The following methods were reviewed: MESMIS (Framework for Evaluation of Management Systems with Sustainability Indicators) [15], [17]; Delphi [19-20], AHP (Hierarchical Analysis Process) [21-23; equilibrium point; PCA (Principal Component Analysis) and MSR (Method of Response Surfaces). Also, CENICAFE publications [3], [18] and different databases on the topics to be addressed in this research.

The Delphi method is a consensus or cooperative learning method [27, 28, 29), it is based on group communication and has been designed to analyze and select the professional opinion of experts with respect to a particular problem in a structured and concerted manner [30-33).

Based on the above sources and procedures, academics and experts in the coffee industry were invited to participate in the research, who selected the most representative variables to characterize the coffee agroindustry, the scale to evaluate them_ rubric of easy applicability; a tool and process that was validated following parameters and indexes of pertinence and statistical confirmation [24]. After the above, this was used as a starting instrument to carry out the exercise of ranking 3 UPCD following sequentially the methods described in the previous paragraph.

II. METHODOLOGY

Theoretical perspective.

The Delphi method is essentially concerned with obtaining group consensus and statistical estimation from qualitative and quantitative approaches [24]. In this method, anonymity of the participants is imperative to ensure the absence of bias in individual responses [20], [28], [35-36). The purpose of the methodology is to build a general group consensus with statistical processing of differences and concordances between the experts and the course of the rounds [20], [28], [35-36). For this purpose, two joint working groups are formed following three fundamental phases, as explained in Figure 1.

In the first phase, the expert evaluators should be selected according to: profession, position, years of experience, teaching category, scientific degree, membership in a certain guild or company, link with the activity, number of related national and international research projects, and number of publications on the subject [19], [30]. As shown in Tables I and II of the results. For this group it is necessary to: delimit the topic of study raised in the proposed research problem, obtain their collaboration and commitment to the study, interpret the partial and final results of the project, supervise the correct progress of the research by making the proposed corrections and additions, and implement the questionnaire. See figure 1.

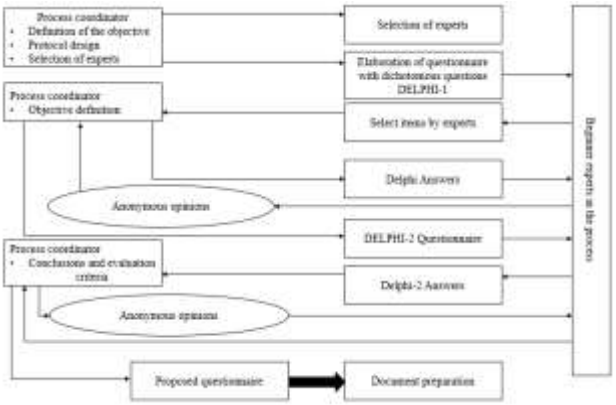

Fig. 1. Development scheme of the Delphi method. Adapted from (32).

In the second or exploratory phase, the criteria or attributes to be evaluated were identified, as defined by the MESMIS methodology [19] and by (36, 37]. And in an opinion survey each participating expert was asked to indicate on a dichotomous scale (yes/no) which of the 10 criteria selected and contemplated in this survey would contribute appropriately to the correct selection of a farm producing differentiated coffee (FPCD). With the information gathered a first version of the evaluation questionnaire was constructed, thus initiating the last phase or round of validation of the selected experts to refine the attributes or criteria and determine an appropriate scale for the study [28], [34-38), reported in Table II. Next, inter-judge agreement was calculated. For this, Kendall's statistic was used to determine the degree of association between several sets (k) of N entities, using equation (1):

$$k = \frac{kc+ka}{2} \qquad \text{Equation} \qquad (1)$$

Where kc is the knowledge or information coefficient and ka is the argumentation coefficient, also called self-evaluation coefficient. The knowledge coefficient (kc) is found by the self-evaluation from 1 to 10 of each candidate at the moment of answering how much each one agreed with the criteria shown, data that were averaged and divided by 10 for normalization purposes; and the argumentation coefficient (Ka) is extracted from the evaluation of each expert according to the six sources of argumentation in a Likert-type scale [46].

Once the variables to be analyzed have been identified, we continue with the AHP, a multi-criteria technique belonging to the basic theory of decision making, which seeks to reduce the gap between subjectivity and objectivity when it comes to selecting or making a complex decision [39, 40). The decision problem is modeled by means of a hierarchy where the objective of the problem, equivalent to the goal to be achieved, is considered. At the base are the criteria with which the optimal decision can be made, these can also be hierarchized [41-43). At the levels are the alternatives to be evaluated. See figure 2.

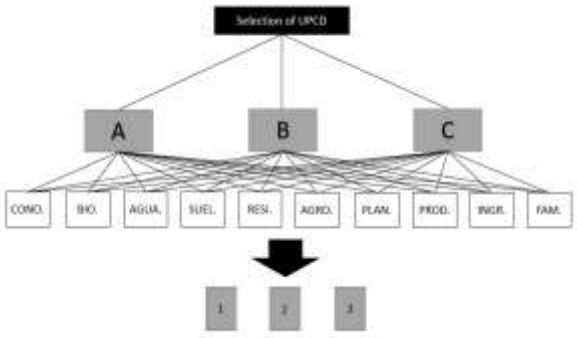

Fig. 2. Sequence and description for performing the AHP.

The break-even analysis in this research compares the direct economic relationship of the farms under study _A, B and C, whose corporate name is confidential in this study. For the process, the variables involved in the break-even analysis elucidated in [44] were measured and evaluated and applied to the three UPCD. In the PCA application stage, the objective is to transform the set of original variables collected from the MESMIS method, the AHP hierarchization and those identified from the economic variables at the break-even point [44], into a set of variables without having to lose the information or linear conjecture of the original ones, called principal components (factors).

For the calculation of the response surface, the factorial design 2^3 (two factors and 3 levels) was used, since several factors or variables _height, shade and plant density_ are involved to study the joint effect of these factors on a response variable, which was defined as productivity. We worked with 8 runs or executions for the construction of the block and its corresponding notation. The factorial design allowed expressing in a linear way the statistical model for the selection of UPCD based on productivity.

The sampling was non-probabilistic, 3 UPCD were taken and analyzed for convenience, the company name of each of these is confidential for the present study.

The type of research was descriptive, since the main characteristics of the UPCDs were analyzed. The data collection was mixed, of a qualitative nature, information was collected without numerical measurement, and from there, the pertinent attributes were identified to construct a model for the selection and evaluation of UPCD. The quantitative approach or orientation was supported to the extent that experts following the theoretical postulates posed by the Delphi method, gave a rating and the coordinators of the process calculated the reliability of the questionnaire to evaluate the selection model [34-35) and [37]. And the AHP, the break-even point and the linear regression equation or statistical model were consecutively calculated to determine how the productivity of a UPCD could be with the response surface methodology applying a factorial design, the above was worked with real data of the UPCDs taken from the sources consulted as references.

The processes described above were carried out using the advantages of information and communication technologies (ICT), It means that we used the electronic mail and through there we attached the filed, consisting of the description, introduction, methodology, phases in which the process was found, instructions for completing the questionnaire followed by the instrument for validation as proposed by several authors [19],[45].

III. RESULTS

Seven experts were selected; teachers, coffee extensionists, area and program coordinators and coffee growers with secondary education, with training in coffee and therefore all of them knowledgeable about coffee manuals and primers. Table I presents the score calculated for each of the six sources of argumentation evaluated for the participants as recommended in [47]. The above concertedly identified 10 factors for analyzing a UPCD. The result in agreement with the survey experts is presented in Table III.

TABLE I. Likert-type scale for calculating the argumentation coefficient of the selected experts.

Sources of argumentation	**Degree of influence of each of the sources on their criteria**		
	High	**Medium**	**Low**
	(H)	**(M)**	**(L)**
1.Theoretical and/or experimental research related to the subject.	0,3	0,2	0,1
2. Experience obtained in professional activity (undergraduate and postgraduate teaching received and/or taught).	0,5	0,5	0,2
3. Analysis of specialized literature and publications of national authors.	0,05	0,05	0,05
4. Analysis of specialized literature and publications of foreign authors.	0,05	0,05	0,05
5.Knowledge of the current state of the problems in the country and abroad.	0,05	0,05	0,05
Intuition.	0,05	0,05	0,05
Total	1	0,9	0,5

Table II shows the knowledge coefficient Kc, argumentation coefficient Ka, competence coefficient k and the evaluation of the degree of competence for the expert participants who collaborated in the research.

TABLE II. Determination of the competition coefficient k and average K (Kp).

Experts	**Kc Knowledge coefficient**	**Ka Argumentation coefficient**	**K**	**Valuation**
1	0,92	1	0,96	High
2	0,84	1	0,92	High
3	1	1	1	High
4	0,94	0,9	0,92	High
5	0,82	0,8	0,81	High
6	1	1	1	High
7	1	1	1	High
Kp			**0,94**	**High**

Table III shows the model of the dichotomous survey for the 10 criteria selected and to be evaluated for the classification of the UPCD.

TABLE III. Dichotomous scale of the MESMIS criteria selected for this research.

	Nombre del indicador	**Abreviatura del criterio**	**Concepto**	**¿Estás de acuerdo con este criterio? Si/No**	
1	Application of acquired knowledge	COND.	Number of agroecological practices, knowledge and experiences applied on the farm to advance in the sustainability process.	Yes	No
2	Biodiversity	BIO.	Number of animal and/or plant species in the farm's ecosystem.	Yes	No
3	Water availability	AGUA.	Number of water sources, quality, availability and use of water resources on the farm.	Yes	No
4	Implementation of soil conservation practices	SUEL.	Number of soil conservation practices implemented.	Yes	No
5	Solid and liquid waste management practices.	RESI.	Number of waste management practices carried out at the farm level.	Yes	No
6	Agro diversity	AGRO.	Number of agricultural and livestock species established in association at the farm level.	Yes	No
7	Planning and records	PLAN.	Tools needed to organize, measure and evaluate farm activities.	Yes	No
8	Coffee productivity	PROD.	Coffee kilograms per hectare produced on the farm.	Yes	No
9	Diversified income	DIGR.	Number and quantity of products obtained on the farm that are marketed.	Yes	No
10	Integration of the family into the process.	FAM.	Number of family members who participate in the project by following up and making decisions.	Yes	No

The reliability and homogeneity or statistical correlation (Cronbach's Alpha) for the degree of association between the selected variables, was 0.87.

Table IV shows the results of the ranking of the coffee farms according to the criteria selected by the experts and analyzed with the AHP. Figure 3 frames the comparison of the UPCD.

TABLE IV. Ranking matrix of the farms in terms of the selected criteria.

Farm	AHP Normalization	% Importance	Hierarchical Ranking
A	3,505	35,048%	1
B	3,390	33,905%	2
C	3,105	31,048%	3
	10	100%	

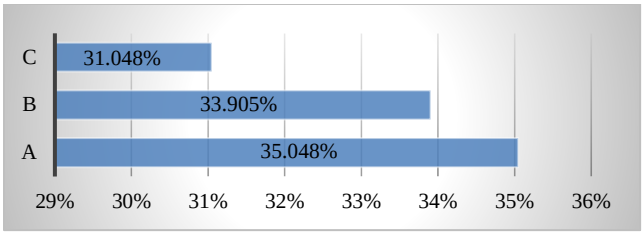

Fig. 3. Hierarchical ranking result of the FPCDs under study.

The geographical and cultivation characteristics of the UPCD allow for traceability and describe the conditions to be considered such as: planting density, the variety of coffee cultivated by the farmers on their farms, the altitude of the region and the area available for the cultivation and harvesting of coffee, as presented in table V.

TABLE V. Geographic and crop characteristics for each UPCD.

Name	Altitude	Total area (ha)	Coffee area (ha)	Plant/ ha	Coffee planted %	Variety
A	1602	1,3	1,3	3500	1	Col.
B	1600	6	1	6400	0,17	Col.
C	1932	0,9	0,8	3600	0,89	Col.

Once the process costs have been calculated [46], Figure 4 specifies the different values of the variables involved in the break-even point, for example, those of the UPCD identified for the work as A.

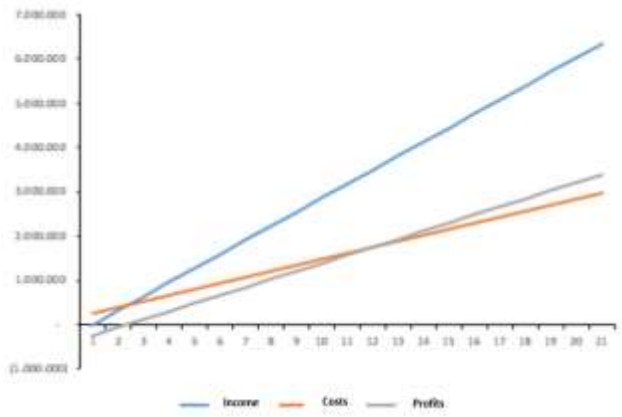

Fig.4. Break-even point calculated for the UPCD identified for the work as A.

TABLE VI presents the break-even analysis for each of the UPCDs.

TABLE VI. Break-Even point records calculated for each UPCD.

Name	A	B	C	
Equilibrium Cost (kg C.P.S/ha)	67	116	97	**Total**
Production Cost ($/ha)	$2.928.737	$2.950.466	$2.796.358	$8.675.560
Income ($/ha)	$6.281.352	$6.118.200	$5.710.320	$18.109.872
Profit ($/ha)	$3.352.615	$3.167.734	$2.913.962	$9.434.321
Total profit	35,536%	33,577%	30,887%	100%

With the geographic and crop characteristics of the UPCDs the PCA determines which of these are the most important and how they are correlated with each other, and which ones explain most of the variance in total as shown in Table VII and Figure 5.

TABLE VII. Principal component analysis.

Component Number	Eigenvalor	Percentage of variance	Percentage of variance Accumulated
1	2,0215	67,383	67,383
2	0,66642	22,214	89,597
3	0,312079	10,403	100,000

There are different tests to recognize whether the factorial model or the extraction of the factors is significant in their sets, among them the Kaiser, Meyer and Olkin test, the closer the coefficient is to one, the more direct the relationship between the variables [46]. For this case, a KMO index = 0.623 is shown in Table VIII.

TABLE VIII. Factorability test for UPCD selection.

Factorability test	
Medición Kaiser-Meyer-Oskin para muestreo idóneo KMO	0,623185

With the 2^k statistical treatment it is found that the statistical model for the productivity of a UPCD, can be equation 2 and its representation as a response surface plot in Figure 5.

$$Productivity\ of\ a\ coffee\ farm\ = 845.313 - 26.526\ Height + 17.1875\ Plant\ density - 45.312\ Shade - 23.437\ Height * Plant\ density + 39.062\ Height * Shade + 76.562\ Plant\ density * Shade. \quad (2)$$

The R^2 for this model is 92.576%

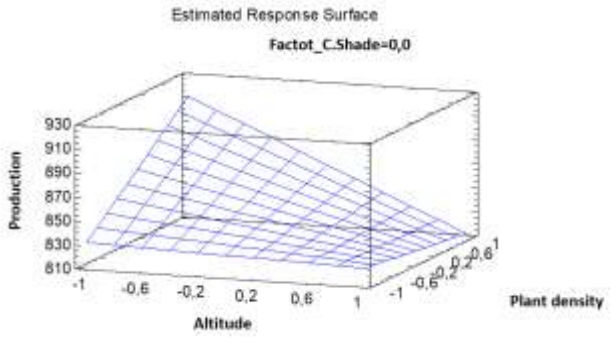

Fig. 5. Three-dimensional response surface for the linear UPCD model.

Table IX shows that there is a relationship between the results obtained in the AHP, break-even point and factorial design in the linear model.

TABLE IX. Comparison between the methods used to select and classify UPCD. Selection farm A.

		A	B	C
AHP		35,046%	33,577%	30,887%
Break-even Point	kg C.P.S/ha	67	116	97
	% Profitability.	35,536%	33,577%	30,887%
Height	m	1602	1600	1932
Seeding Density	Plants/(ha)	3500	6400	3600
Shadowy	Type of sun exposure	Sombra	Sombra	Semi-Sombra
	Incident astronomical radiation Wm^2	397,57	434,3	464,33
Productivity	kg C.P.S/ha	991,4	965,6	901,3
Variety		Colombia	Colombia	Colombia

It is evident from the above table that the best UPCD is the one identified as A for this research.

IV. Conclusions

The Delphi method is characterized by the cooperative work of people with previous training and experience that guarantee mastery with respect to a specific topic as stipulated in [34], the coffee actions are no stranger to this.

The final questionnaire or survey obtained 90% unanimity of the participants in the process.

Kendall's statistic for ordinal data was 0.94 respectively, which indicates that the concordance is excellent.

The reliability and homogeneity or statistical correlation (Cronbach's Alpha) for the degree of association between the selected variables was 0.87, which is high and indicates the effectiveness of the process followed as stipulated in [46].

The biophysical characteristics of the farms allow traceability and describe the conditions to be considered such as: planting density, the variety of coffee cultivated by the farmers in the UPCD, the altitude of the region and the area available for the cultivation and harvesting of coffee, as presented in Table IX.

The analysis of the break-even point determines that the UPCD identified as A is the best, since it presents a lower break-even point and has a higher percentage of profit within the total profit generated by the three organic coffee producing farms. This means that the working capital is recovered by producing 67 kg of dry parchment coffee with a profit of $3,352,615 per hectare of differentiated coffee planted, presented in tables VI and IX.

With the geographical and cultivation characteristics of the UPCD, the PCA determines which of these are the most important, how they are correlated with each other, and which explain most of the variance in total as shown in table VII and figure 5. These factors are described in three practical components, height, planting density and exposure to shade. The first two components explain 89.57% of the total variance.

The Kaiser, Meyer and Olkin _ KMO index was 0.623 which indicates a direct relationship between the variables and a factorization can be performed [46], see Table VII.

The statistical model to determine how the productivity of a UPCD could be, only considers agricultural variables and the R2 for this model is 92.576% and explains the percentage of variability in production or the quality of the model to replicate the results as shown in equation 2.

V. Acknowledgements

The authors express their gratitude to the Universidad Militar Nueva Granada, the Universidad Nacional Abierta y a Distancia and the Federación Nacional Cafeteros de Colombia for the advice provided. And especially to the professional experts who participated selflessly in the project PIE_ ECBTIPIE 092020_Diagnosis and characterization of the quality of the coffee production chain: Econometric model.

VI. References

1. ABIC (Associação Brasileira da Indústria de Café). (2012). Indicators of the coffee industry in Brazil. Consultado el 15/10/15 en: http://www.abic.com.br/publique/cgi/cgilua.exe/sys/start.htm?sid=61#1389. 1

2. Fernandes, D., De Souza, A., Sun, Da., Nirdorff, S. & Yoko, E. (2014). Application of infrared spectral techniques on quality and compositional attributes of coffee: An overview. Food Research International. Volume 61, July 2014, Pages 23–32.

3. Camargo, L. & Campos, L. (2011). Evaluación del efecto sombra en la producción de café -Coffea arabica L.- dentro de un sistema agroforestal tradicional con árboles en Las Minas, El Paraíso, Honduras. (Tesis de pregrado). Zamorano, Honduras.

4. Ramos, L. & Criollo, H. (2017). Calidad física y sensorial de Coffea arábica L. variedad Colombia, perfil Nespresso AAA, en La Unión, Nariño. Revista de ciencias agrícolas, Volumen 34(2):83-97.

5. ICO. International Coffe Organization. (2006). Historical Data. Consultado el 15.9+.15 en: http://www.ico.org/historical.asp.

6. DaMatta, F. & Rodríguez, N. (2007). Producción sostenible de cafetales en sistemas agroforestales del Neotrópico: una visión agronómica y ecofisiológica. Agronomía Colombiana, 25(1), 113-123.

7. De Souza, R. & Benassi, M. (2012). Discrimination of commercial roasted and ground coffees according to chemical composition. Journal of the Brazilian Chemical Society, v.23, p.1347-1354, 2012. DOI: 10.1590/S0103-50532012000700020.

8. Varaschim, J., Guimarães, A., Marquetti, I., Dos Santos, M. & Bona, E. (2014). Geographical and genotypic classification of arabica coffee using Fourier transform infrared spectroscopy and radial-basis function networks. Chemometrics and Intelligent Laboratory Systems. Volume 135, 15 July 2014, Pages 150–156.

9. Aranda, J. (2014). Guía de buenas prácticas para café sustentable. Consultado el 15.10.15 en: www.alianza-mredd.org/uploads/ckfinder_files/files/coffee_production.pdf.

10. De Giovannucci, D. (2001). Encuesta sobre café sustentable. Recuperado de: http://www3.cec.org/islandora/es/item/1700-sustainable-coffee-survey-north-american-specialty-coffee-industry-es.pdf.

11. Ayalew, T. (2014). Characterization of Organic Coffee Production, Certification and Marketing Systems: Ethiopia as a Main Indicator: A Review. Asian Journal of Agricultural Research, 8: 170-180.

12. Pérez, P. (2009). Los espacios de producción de café sustentable en México en los inicios del siglo XXI. Revista Pueblos y Fronteras digital. Vol. 4, Núm. 7, Junio – Noviembre, págs. 116-156.

13. Cheng, B., Furtado, A., Smyth, H. & henry, R. (2016). Influence of genotype and environment on coffee quality. Trends in Food Science & Technology. Volume 57, Part A: 20-30.

14. Alvarado, B. & Laura, S. (2013). Evaluación de la sustentabilidad de la producción orgánica el café a través de la medición de eficiencia económica con variables ambientales. Natura@economía. Vol. 1, Nº 2: 91-110.Olmos, M. & González, W. (2013). El valor de la sustentabilidad. Ciencia y Agricultura, Vol. 10 - Nº. 1 Enero - Junio 2013, p.91-100.

15. Valderrama, R., L. Alcántara & D. Limón. (2016). The complexity of environmental education: teaching ideas and strategies from teacher. EDUHEM. Almeria, Spain

16. Peredo, S. & Barrera, C. (2016). Definición participativa de indicadores para la evaluación de la sustentabilidad predial en dos sistemas campesinos del sector Boyeco, Región de la Araucanía. IDESIA, Volumen 34, Nº 6. Páginas 41-49 Ospina, O., Duque, H. & Farfán, F. (2003). Análisis económico de la producción de fincas cafeteras convencionales y orgánicas en transición en el departamento de Caldas. Cenicafé. 54(3): 197-207.

17. Hsu, Ch. & Sandford, B. (2007). The Delphi Technique: Making Sense of Consensus. Practical Assessment Research & Evaluation, 12(10).

18. Iljaž, RJ, Megliè, M. & Svab, I. (2011). Building consensus about eHealth in Slovene primary health care: Delphi study. BMC Med Inform Decis Mak.11:25.

19. Arnés, E. & Astier, M. (2018) Sostenibilidad en sistemas de manejo de recursos naturales en países andinos. UNESCO. recuperado de:
https://www.ciga.unam.mx/publicaciones/images/abook_file/MESMIS.pdfOsorio, J. & Orejuela, J. (2008). El proceso de análisis jerárquico (AHP) y la toma de decisiones multicriterio. Ejemplo de aplicación. Scientia et Technica. 14 (39), 247-252.

20. Cabala, P. (2010). Using the analytic hierarchy process in evaluating decision alternatives using the analytic hierarchy process in evaluating decision alternatives. USA.

21. der Gracht, H. (2012). Consensus measurement in Delphi studies: Review and implications for future quality assurance. Technological Forecasting and Social Change. Vol 79, 1525-1536

22. Toledo, Víctor M. «¿De qué hablamos cuando hablamos de sustentabilidad? Una propuesta ecológico-política.» Interdisciplina 3, no 7 (2015): 35-55.

23. Andreu, R., Canós, L. & De Juana S., (2016). evaluación de la calidad docente en el ámbito universitario: la experiencia de una red de la Universidad De Alicante. Encarnación Manresa Departamento de Organización de Empresas Universidad de Alicante. Vol 16. 1-18.

24. Jacobs, G. (2008). Cooperative Learning: Theory, Principles, And Techniques. JF New Paradigm Education. Consultado el 15.11.14 en: http://www.georgejacobs.net.

25. Humphrey, S., Varpio, L., Gonsalves, C. & Wood. T. (2016). Using consensus group methods such as Delphi and Nominal Group in medical education research. Medical Teacher, 39(1):1-6

26. Gorina, A., Sánchez, I. & Berenguer, A. (2017). Perfeccionando el procesamiento de la información en investigaciones pedagógicas desde una relación metodológica cualitativa-cuantitativa. Encuentros Vol. 15 No. 02 :189 – 206

27. Linstone, H. & Turoff, M. (2011). Delphi a brief look backward and forward. Technological Forecasting and Social Change, 78(9):1712-1719

28. Reguant, M. & Torrado, M. (2016). El método Delphi. REIRE, Revista d'Innovació i Recerca en Educació, 9 (1), 87-102.

29. López Gómez, E. (2018). El método Delphi en la investigación actual en educación: una revisión teórica y metodológica. Educación XX1, 21(1), 17-40

30. López, F. & Calvo, A. (2019). Diseño y validación mediante Método Delphi de un cuestionario para conocer las características de la actividad física en personas mayores que viven en residencias. Retos, 36, 515-520.

31. Garcia, M. & Suarez, M. (2013). El método Delphi para la consulta a expertos en la investigación científica. Rev Cubana Salud Publica vol.39 no.2.

32. Charro, E. (2017). Investigando en Educación: el método Delphi. Revista Atlante, cuadernos de Educación y Desarrollo, 1-12.

33. Cruz M. & Martinez M. (2012). Perfeccionamiento de un instrumento para la selección de expertos en las investigaciones educativas Revista Electrónica de Investigación Educativa Vol. 14, Núm. 2.

34. Steurer J. (2011). The Delphi method: an efficient procedure to generate knowledge. Skeletal Radiol. 40(8):959-61.

35. Bruner, J. (2005). A Delphi method of teaching applied phylospphy. Teaching philosophy, 8 (3), 2007-220.

36. Tezanos, J. (2016). Tendencias científico-tecnológicas. retos, potencialidades y problemas sociales. Editorial UNED. Madrid. España.

37. Hernández F. & Robaina, J. (2017). Guía para la utilización de la metodología Delphi en las etapas de comprobación de productos terminados tipo software educativo. Revista 16 de abril, 56(263):26-

38. Cárdenas, G., Gómez, H. & Vásquez, L. (2005). Desarrollo y Validación de Metodología para evaluar con Indicadores la Sustentabilidad de Sistemas Productivos Campesinos de la Asociación de Caficultores Orgánicos de Colombia – Acoc. Trabajo Presentado al Seminario Internacional sobre «Enfoques y Perspectivas de la Enseñanza del Desarrollo Rural», organizado por la Universidad Javeriana en Bogotá.

39. Khatwania, G. & Kumar, A.(2017). Improving the Cosine Consistency Index for the analytic hierarchy process for solving multi-criteria decision making problems. Applied Computing and Informatics Vol. 13, Issue 2, p. 118-129. CABALA, P. (2010). Using the analytic hierarchy process in evaluating decision alternatives using the analytic hierarchy process in evaluating decision alternatives. Operations Research and Decisions. 20(1):5-23.

40. Wu, Z. & Abdul, G. (2020). Comparison of Multi-Criteria Group Decision-Making Methods for Urban Sewer Network Plan Selection. Department of Industrial Engineering, Université du Québec à Trois-Rivières, Trois-Rivières, p 26-48.

41. Saaty, T. (2001). The Analytic Network Process. Decision Making with the Analytic Network Process. Pittsburg University Press. p. 1-26.38.

42. Saaty, T. (2009). Extending the Measurement of Tangibles to Intangibles. International Journal of Information Technology y Decision Making. 8(1):7-27.

43. Al Ammary, J. (2012). Educational Technology: A way to enhance student achievement at the University of Bahrain. Procedia - Social and Behavioral Sciences Vol. 55, p. 248 – 257.

44. Ospina, O., Duque, H. & Farfán, F. (2003). Análisis económico de la producción de fincas cafeteras convencionales y orgánicas en transición en el departamento de Caldas. Cenicafé. 54(3): 197-207

45. García-Valcárcel, A., Basilotta, V., & López, C. (2014). Las TIC en el aprendizaje colaborativo en el aula de Primaria y Secundaria. Comunicar, 42, 65-74

46. Riaño, N. (2016). Modelo agrícola para la selección de fincas productoras de café diferenciado (orgánico). Ing. Thesis, Universidad Militar Nueva Granada, Bogota D.C, Colombia.

47. Campistrous, L. & Rizo, C. (1998). Indicadores e investigación educativa. Instituto Central de Ciencias Pedagógicas. La Habana: Ministerio de Educación.

Este estudio fue financiado por los autores. Los autores declaran no tener ningún conflicto de interés.