Scientific Paper

Evaluation of the socioecological resilience in family agriculture scenarios in five Cuban provinces

Leidy Casimiro-Rodríguez[1] *https://orcid.org/0000-0002-0530-3786*, José Antonio Casimiro-González[2] *https://orcid.org/0000-0001-6551-7949*, Jesús Suárez-Hernández[3] *https://orcid.org/0000-0002-6232-1251*, Giraldo Jesús Martín-Martín[3] *https://orcid.org/0000-0002-8823-1641*, Marlen Navarro-Boulandier[3] *https://orcid.org/0000-0003-0351-5651* and Irán Rodríguez-Delgado[4] *https://orcid.org/0000-0002-6453-2108*

[1]*Universidad de Sancti Spíritus, Avenida de los Mártires, Esquina Carretera Central, Sancti Spíritus, Cuba.* [2]*Cooperativa de Créditos y Servicios Rolando Reina Ramos, Sancti Spíritus, Cuba.* [3]*Estación Experimental de Pastos y Forrajes Indio Hatuey, Universidad de Matanzas, Central España Republicana CP 44280, Matanzas, Cuba.* [4]*Universidad Técnica de Machala, Ecuador. E-mail:* leidy7580@gmail.com

Abstract

Objective: To evaluate the socioecological resilience in 15 family farms, located in five Cuban provinces, and to generate concrete proposals for promoting their agroecological transition.

Materials and Methods: The methodology for the evaluation of socioecological resilience (MESR) proposed by Casimiro-Rodríguez (2016), was applied. Surveys and field trips were carried out in several family farms that are part of the scenarios benefitted by the project BIOMAS-Cuba. The evaluated farms are located in the provinces Las Tunas (2), Holguín (1), Sancti Spíritus (4), Matanzas (8) and Mayabeque (1).

Results: From the analysis conducted in the 15 farms to define the principal components obtained from the corresponding correlation matrix, 85 % of the total variability was explained by the first four principal components. In the principal component 1 (PC1), the indicators external inputs used in production, energy efficiency, percentage of energy injected to the farm from outside, percentage of energy utilized from the farm, energy balance, energy cost of protein production and index of dependence on external inputs, stand out. In farm 13, the tridimensional indicators (technological-economic-energy) were more efficient in the estimation of resilience and those that characterized the PC1 stood out.

Conclusions: The results highlight a moderate resilience as average, because although the farms self-supply their food, mostly with good productivity per hectare per year and high technological change capacity, they still have an index of dependence on external inputs which influences the unfavorable results shown by several efficiency indicators.

Keywords: farmer families, sovereignty, efficiency, indicators

Introduction

The agricultural modernization process since the green revolution until the present has been characterized by processes that transform the production forms, productivism based on intensification, concentration and specialization of productions, industrialization with high demand of capital and external inputs and scientification, which subordinates traditional farmer knowledge to the dictates of science and scientific research.

These aspects, among others, have contributed to unsustainability, depletion of natural resources and ecosystemic crises, which has originated the dissociation between agriculture and its socioecological context, because industrial agriculture, alien to the reproduction cycles of farmer societies and to their function of maintaining and reproducing family agriculture, has generated socioeconomic inequalities, fundamental cause of the strong rural migratory processes that occur at present (Ikerd, 2016; Nicholls *et al*., 2017).

Nevertheless, unlike industrial agriculture, agroecology, as innovation process in knowledge and technologies, built in constant reciprocity with social movements and political processes (González-de-Molina and Caporal, 2013), contributes the scientific-practical fundamentals for the transition from animal husbandry production systems to diversified production systems. Such systems subsidize their own fertility and productivity, with soil conservation and amelioration practices, with the animal husbandry-agriculture integration and lower dependence on oil and its derivatives, for which they constitute more resilient systems, which play a fundamental role in the mitigation and adaptation to the climate change (Fernández *et al*., 2018).

Received: April 08, 2020
Accepted: November 18, 2020

How to cite this paper: Casimiro-Rodríguez, Leidy; Casimiro-González, J. A.; Suárez-Hernández, J.; Martín-Martín, G. J.; Navarro-Boulandier, Marlen & Rodríguez-Delgado, I. Evaluation of the socioecological resilience in family agriculture scenarios in five Cuban provinces. *Pastos y Forrajes*. 43 (4):286-296, 2020.

Among the challenges of climate change, at present the approach of socioecological resilience (SER) is applied to determine the sustainability of agroecosystems, incorporating the idea of adaptation, learning, innovation, novelty and self-organization in the face of stress or disturbance situations (Montalba *et al.,* 2013), so that socioecological systems can preserve the essential attributes in a socially desirable and ecologically possible regime, thus being sustainable in time (Salas-Zapata *et al.,* 2011).

In this context, the relation and interconnection between the farmer family and research centers is highly important, because technological innovation processes should consider the interaction between the technological component and the system of social, cultural and productive relations in which farmers develop, for the agroecological transition (AT) to be really effective.

The Pastures and Forages Research Station Indio Hatuey (EEPFIH) and several Cuban institutions through international collaboration projects and through agricultural extension and innovation processes contribute to knowledge management. From built capacities contextualized in several family farms of the country, they work to solve local problems, support AT and enhance socioecological systems, so that the effects of climate change can be faced and mitigated, by showing increasingly higher resilience levels.

The objective of this study was to evaluate the socioecological resilience in 15 family farms, located in five provinces of Cuba, and generate concrete proposals to promote their agroecological transition.

Materials and Methods

Surveys and field trips were carried out in several family farms that are part of the scenarios benefitted by the project BIOMAS-Cuba. The evaluated farms are located in Las Tunas (2), Holguín (1), Sancti Spíritus (4), Matanzas (8) and Mayabeque (1) provinces.

The selection criteria of the non-probabilistic sample (15 farms) were based on the representativeness of several provinces and municipalities involved in the AT process with the companionship of Cuban institutions and international collaboration projects.

As selection criterion, the high heterogeneity among the farms is given according to the different levels of diversity of crop, animal and forestry species. Each farm represents a special case, which is not comparable with the others for its production purposes, market relations, management characteristics, soil types, ownership types and others (table 1).

Table 1 shows the characterization of the selected farms, regarding area, social object and evolution of the agroecological transition.

The farms were characterized in detail to know their structure and functioning. The limits and surface (area) of the system, subsystems, their main interactions, as well as the inputs and outputs were thoroughly described in order to measure the socioecological resilience through the application of the methodology of evaluation of the socioecological resilience (MESR) in a family farm (Casimiro-Rodríguez, 2016).

The analysis of the different MESR indicators and indexes was carried out with the information corresponding to 2015 and comprised only the first cycle of the methodology (table 2).

For the integral analysis of the results from the surveys in the 15 farms (indicators related to the estimation of resilience), the statistical method proposed by Torres *et al*. (2008) was used, from which the following algorithm was developed:

- With the data obtained from the indicators in the 15 farms the data matrix to be processed was built
- Testing of the premises of application of the multivariate methods through the correlation matrix
- Identification and selection of the order of importance of the variables in the explanation of the variability of socioecological resilience
- Classification of the farms, according to the indicators related to socioecological resilience and based on the criteria efficiency index and group formation

The results obtained when developing this algorithm allowed to define three groups of farms, depending on the estimation of the socioecological resilience (low, moderate and acceptable performance), and to compare these performances with regards to the results obtained by Casimiro-Rodríguez and Casimiro-González (2018) in a study conducted in Finca del Medio.

The statistical processing of the data was carried out through the statistical package SPSS® Version 22 for Windows (IBM, 2015).

Results and Discussion

In the analysis conducted in the 15 farms to define the principal components obtained from the corresponding correlation matrix, 85 % of the total

Table 1. Characterization of the evaluated family farms.

Province	Municipality	Name of the farm	Area, ha	Social object	Evolution of the AT
Mayabeque	San José	El Mulato (1)	14,5	Staple crops	3
Matanzas	Jovellanos	La Coincidencia (2)	23	Staple crops	3
	Perico	La Palma (3)	13,42	Cattle	3
	Perico	Mercedita (4)	5,07	Fruit plants	3
	Calimete	La Arboleda (5)	7	Staple crops	3
	Calimete	Godínez (6)	3,49	Pigs	2
	Colón	Huerto Escolar (7)	13,42	Cattle	2
	Colón	La Quinta (8)	33	Cattle	3
	Colón	La Cantera (9)	3	Staple crops	4
Sancti Spíritus (SS)	Cabaiguán	Flor del Cayo (10)	9,64	Tobacco	3
	Cabaiguán	Las Dos Rosas (11)	12,42	Tobacco	3
	SS	San José (12)	9,2	Tobacco	4
	Taguasco	Del Medio (16)[1]	10	Milk	5
Holguín	Gibara	Santa Ana (13)	5	Staple crops	5
Las Tunas	Manatí	Los Pinos (14)	19,05	Staple crops	3
	Las Tunas	Recompensa (15)	9	Pigs	2

AT: agroecological transition, AT: 1 Totally conventional agriculture, 2: Development of some agroecological practices, 3: Development of agroecological practices combined with the use of external agrochemicals and concentrate feeds, 4: Predominance of the agroecological design and management, although they utilize some external agrochemicals and concentrate feeds and 5: Total agroecological management and design

Table 2. Description of the indicators used in MESR.

Index	Indicator	Relative bearing	Description
Food sovereignty (FS)	Pp	0,33	Quantity of people fed by protein of animal or plant origin/ha/year, and by both
	Pe	0,01	Quantity of people fed by energy of animal or plant origin/ha/year, and by both
	Af	0,66	Feeding percentage of the family that lives in the farm and is satisfied by its productions
Technological sovereignty (TS)	LUI	0,0054	Land utilization index
	EI	0,2013	Level of inputs not generated or utilized in the farm used in the productive system, %
	H	0,2814	Diversity of production with the application of Shannon index
	UIRES	0,4011	Utilization index of the potential of renewable energy sources, associated to appropriate technologies
	IIF	0,1108	Innovative intensity of the farm, %
Energy sovereignty (ES)	EE	0,4024	Energy efficiency
	EFE	0,1104	Energy percentage injected to the farm from outside
	EF	0,2824	Energy percentage utilized from the farm, %
	EB	0,2015	Energy balance
	ECP	0,0033	Energy cost of protein production
Economic efficiency (EE)	CBR	0,1	Cost/benefit ratio
	IDIE	0,9	Index of dependence on external resources

[1]Farm 16, as it had a longer period than 15 years of AT and showed very favorable values in most indicators, was used as reference for comparing the results with the other farms (Casimiro-Rodríguez and Casimiro-González, 2018).

variability was explained by the first four principal components (table 3). From this it is inferred that an accurate selection of the indicators that could be related to the socioecological resilience (SER) was carried out.

In PC1 the indicators: EI, EE, EFE, EF, EB, ECP and IDIE stand out similarly. In such component the technological, energy and economic dimensions are intertwined, and the indicators associated to food sovereignty are totally excluded.

In PC2, the most important indicators were AF, LUI, H and IIF. Except AF, the rest corresponds to technological sovereignty. While in PC3 Pp and Pe stood out, associated to the dimension food sovereignty. PC4 was denominated UIRES, for which it could be typified as potential of utilization of renewable energy sources (RES).

Because the above-mentioned indicators are the ones that vary the most, in numerical terms it can be stated that through their analysis resilience can be estimated.

Classification of the farms. Table 4 shows the efficiency of each one of the indicators for the estimation of resilience, when making the same study in the 15 farms. Navarro *et al*. (2012) stated that the efficiency index depends on the variables of higher preponderance. These authors defined that the highest values indicate the variables with the highest influence in each case.

According to the efficiency indexes, in farm 13 the tridimensional indicators (technological-economic-energy) were more efficient in the estimation of resilience. That is, it is in this farm where the indicators of PC1 were expressed in a more outstanding way.

This result coincides with the fact that farm 13 (Santa Ana) is the only one that in characterization (market relations, structure and functioning of subsystems and main interactions) shows a totally agroecological design and management, with the highest quantity of family members inserted in the food production system and high capacity of technological change.

Likewise, the high energy efficiency is given because, approximately, 50 % of the energy used for the family agricultural production and reproduction is supplied from the endogenous resources of the farm, and only 25 % of the necessary inputs come from outside. As consequence, this farm has a low index of dependence on external resources.

Table 3. Matrix of preponderance factors between the PCs and the indicators associated to socioecological resilience.

Indicator	PC 1	PC 2	PC 3	PC 4
People fed/ha-year, protein contributions	-0,473	-0,032	**0,811**	0,297
People fed/ha-year, energy contributions	-0,477	0,077	**0,804**	0,290
Food percentage for the family produced in the farm	0,608	**0,672**	0,063	-0,309
Land utilization index	-0,021	**0,829**	-0,120	0,128
Percentage of external inputs used for production	**-0,877**	0,073	-0,136	-0,073
Diversity of production through Shannon index	0,598	**0,736**	-0,130	-0,094
Utilization index of the potential of renewable energy sources, associated to appropriate technologies	0,295	-0,240	0,436	**-0,695**
Innovative intensity of the farm	0,390	**0,699**	0,241	0,290
Energy efficiency	**0,892**	-0,176	0,201	0,242
Percentage of energy injected to the farm from the outside	**-0,947**	0,148	-0,174	0,051
Percentage of energy utilized from the farm (human, animal, RES)	**0,947**	-0,148	0,174	-0,051
Energy balance of production	**0,892**	-0,179	0,172	0,268
Energy cost of protein production	**-0,653**	0,284	0,342	-0,013
Cost/benefit ratio	0,100	-0,179	-0,552	0,569
Index of dependence on external inputs	**-0,849**	0,174	-0,093	-0,153
Proper value	6,732	2,490	2,167	1,348
Explained variance, %	44,879	16,600	14,449	8,990
Accumulated variance, %	44,879	61,480	75,929	84,919

Table 4. Efficiency of the indicators related to SER.

Farm	Efficiency matrix			
	EfPC1	EfPC2	EfPC3	EfPC4
1	**-0,98**	**1,06**	-0,47	**-1,07**
2	-0,49	0,16	**-0,94**	-0,01
3	0,59	**-1,42**	0,01	**-1,86**
4	-0,36	-0,41	-0,56	**-1,80**
5	-0,85	0,93	0,54	-0,34
6	-0,45	-0,64	**3,15**	0,51
7	-0,71	0,12	-0,02	0,05
8	0,71	0,44	-0,80	0,55
9	0,18	**1,20**	0,72	-0,76
10	-0,59	0,24	-0,46	0,90
11	-0,54	0,14	-0,02	**1,02**
12	0,42	0,64	-0,22	**1,11**
13	**3,05**	0,31	0,34	-0,15
14	0,36	-0,08	-0,70	**1,14**
15	-0,34	**-2,68**	-0,57	0,70

The farms in which the indicators associated to technological sovereignty (PC2) were better expressed were 1 and 9. The latter stood out with the highest index. In the worst situation were 3 and 15, without excluding farm 6.

These results were influenced by production diversity and crop association. The farms El Mulato (1) and La Cantera (9) have high productive efficiency, which is reflected on the utilization of spaces and the correct assembly in the design of rotation programs and crop association with high diversity and animal husbandry-agriculture integration. The same does not occur in La Palma (3) and La Recompensa (15), which showed scarce variety of crops with regards to the farm area and, besides, low self-supply of food for the family; similar situation was shown by the farm Godínez (6).

It is interesting that precisely in farm 6 the indicators that typify PC3 (food sovereignty) showed the highest positive effect. That is, in spite of being the farm with higher indexes of productivity per area, which is an important component for obtaining economic profits, it was not obtained based on the energy efficiency, agroecological management and design, because it was the farm that showed the highest index of dependence on external resources, higher energy costs for production and low level of socioecological resilience.

This result corroborates the report by Silva-Santamaría and Ramírez-Hernández (2017) and FAO (2018), who reinforce the notion that efficiency depends on the diversification of agricultural systems and on the design of functional biodiversity, in terms of utilization of resources (nutrients, water and energy), which is not necessarily translated into higher productivity.

The high values of Pp and Pe in farm 6 are explained because its production is focused mainly on pig husbandry, which has high caloric and protein potential, and not on the diversity of production, where this farm showed the lowest values.

The farms, whose social object is pig production, showed high productivity with regards to the area, but exhibited the lowest levels of energy efficiency and the highest dependence indexes on external resources, because they base their productive model on a constant import of concentrate feeds and drugs. Nevertheless, part of the crop production (*Manihot esculenta* L., *Zea mayz* L., *Ipomoea batatas* L., among others) is also used for animal feeding, and not for the offer to the population. This influences the fact that local markets do not show availability of foodstuffs which, like cassava, have traditionally been part of typical Cuban food. These farms perceive most of their incomes by selling the pig production. Having an economy that is not supported on a variety of options, they can be more vulnerable to the hardship of any external shock, whether from climate or market.

Precisely, in the farms with higher diversification and better strategy in the agroecological design and management (farms 1, 5, 9, 12 and 13), the energy and protein contributions were not the most outstanding ones. This received the contribution, for example, of the case of fruit trees as part of the production, which are low in energy and protein contributions, and also affect the energy balance. However, the family self-supply obtained very favorable percentages, and the interrelation with the local food market is characterized by its variety, dynamics and constant flow.

In these farms, the use of chemical inputs for production was lower than in the other farms, due to the lower incidence of pests or diseases, and of both, and to the better soil conservation. According to Vázquez (2015) and Fernández *et al*. (2018), the importance of biodiversity for agricultural systems lies on the decrease of the homogenization and simplification of agroecosystems, which contributes higher resistance to disturbances, lower vulnerability to diseases and pests, and benefits in the prevention of soil erosion.

According to the efficiency index of PC3, farm 2 showed the most negative value, without underestimating its similar performance in farms 8 and 14. These farms are the ones with higher size in the selected samples and those that obtained lower yield per ha/year, fundamentally because of the little utilization of spaces, unproductive areas and low production intensity. These results coincide with the studies conducted by Contreras-León and Rodríguez-Lozano (2017), who state that lower-size farms are the ones that show better diversity, productivity and efficiency indexes.

The utilization of RES was more efficient in farms 11, 12 and 14, with the highest positive value for 14. The worst performance was recorded in farms 3 and 4.

The favorable performance of this indicator is due to the utilization of RES with appropriate technologies. The farms that obtained better results have biodigester and windmill, which allows to use biogas for cooking and refrigerating foodstuffs and the utilization of wind energy to supply water for the family and animals.

Yet, the potential for the utilization of the different RES is not found in its maximum capacity, because of the inexistence in the national market of appropriate technologies and resources for their installation, starting up and maintenance of this type of energy sources. This is in addition to the high costs of acquisition of the technologies that are commercialized in Cuba, which prevents the access to them by the farmer families.

In this sense, the farms that have biodigester and windmill have acquired these technologies through the link with the project BIOMAS-Cuba.

After identifying the farm or farms in which the indicators associated to resilience are expressed more efficiently or where they are worse manifested, it is important to emphasize that around the value of the highest positive efficiency index (Ef), which corresponds to a certain farm, the others should be, which can show a similar and acceptable resilience performance. To verify this consideration cluster analysis was carried out.

From the efficiency indexes the existence of farms with similar performances was analyzed, so that the responses were as efficacious and efficient as possible in the estimation of resilience. In the clustering process the cut was made for a certain value of the dissimilarity coefficient (table 5), which led to the classification of the farms and the formation of three groups.

For the election of the groups where resilience was more efficiently expressed, the one or ones in which there was better global performance in the variables with higher preponderance in PC1 were selected. Figure 1 shows the average values of each variable for each group.

In farm 13 (group III) the highest averages were recorded for the indicators EE, EF and EB. At the same time, in this group the lowest averages for EI, EFE, ECP and IDIE (figure 1) were found. These results are useful, because in the context of socioecological resilience at lower energy costs for agricultural production and better utilization of internal resources (family and animal labor, RES, production of organic fertilizers, utilization of residuals,

Table 5. Groups formed by the cluster analysis.

Formed groups	Dissimilarity coefficient	Farms
I	1,35	1, 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 14 y 15
II		6
III		13

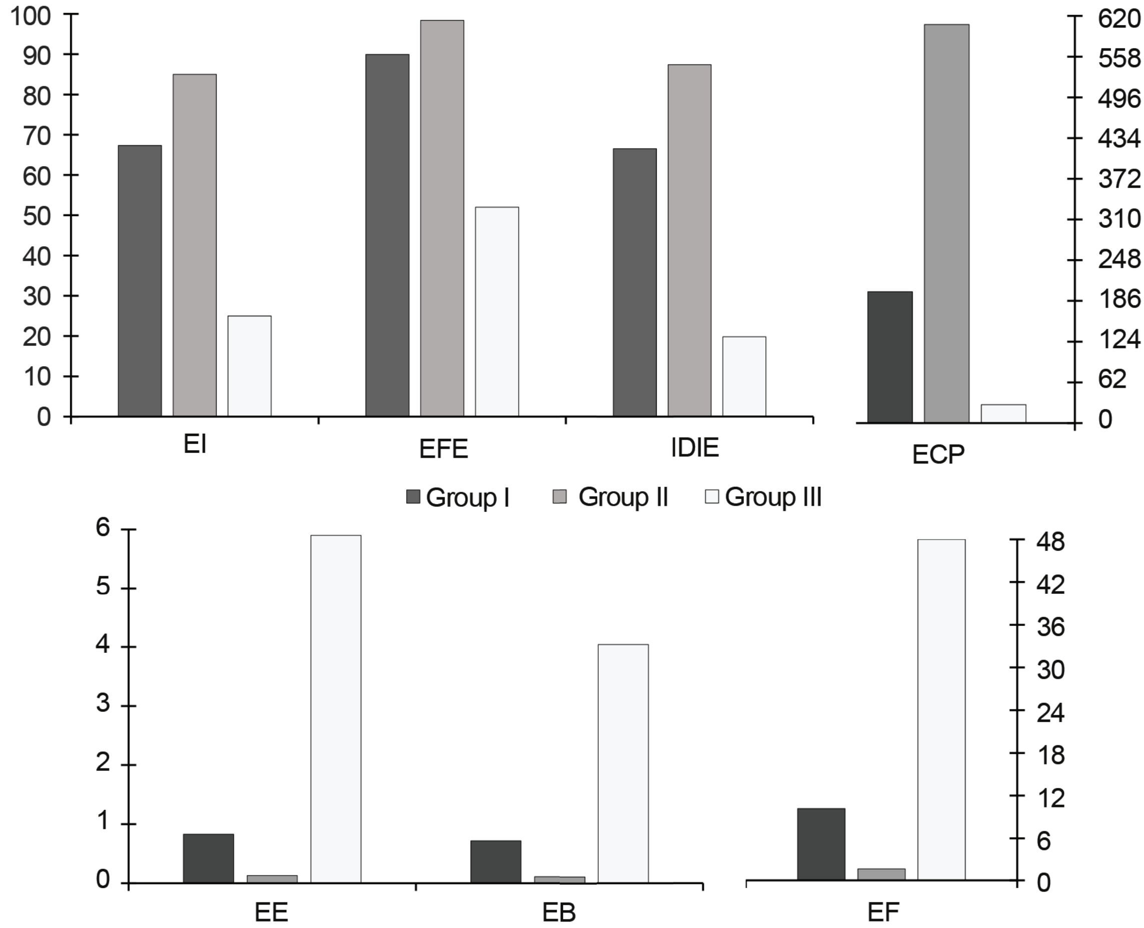

Figure 1. Average of the variables with higher preponderance in CP1 for each of the groups formed for socioecological resilience.

EI: external inputs used in production, EFE: percentage of energy injected to the farm from outside, IDIE: index of dependence on external resources, ECP: energy cost of protein production, EE: energy efficiency, EB: energy balance and EF: Percentage of energy utilized from the farm.

high biodiversity in time and space), the farm that obtains the highest indexes (in this case 13) will be less dependent and show the best resilience indexes. And this is possible because it can respond with higher capacity to climate disturbances, due to the high efficiency and to the diversity of productive options, and to the fact that it depends on resources it has continuously available.

The socioecological interactions generate constant readjustments and changes in the dynamics and structures of the farms. In turn, these interactions favor that the farms with better results are able to adapt due to their capacity of learning, innovation, novelty and self-organization (Salas-Zapata *et al.,* 2011; Montalba *et al.,* 2013).

In addition, according to the results shown in table 3, the highest positive value of the efficiency index was recorded just in farm 13. A totally contrary performance is reflected in farm 6 (group II), which allows to identify it as the one with the worst expression of resilience.

In group I moderate values were found for the indicators of higher preponderance in PC1. In all the cases, such values were closer to group II than to group III. Nevertheless, the average value of LUI was higher for the farms of group 1, and indicators Pp, Pe, AF and H (related to PC2 and PC3) were closer to farm 13 than to farm 6 (figure 2), without neglecting to mention that the value of IURES (PC4) was similar to the one recorded by farm 13.

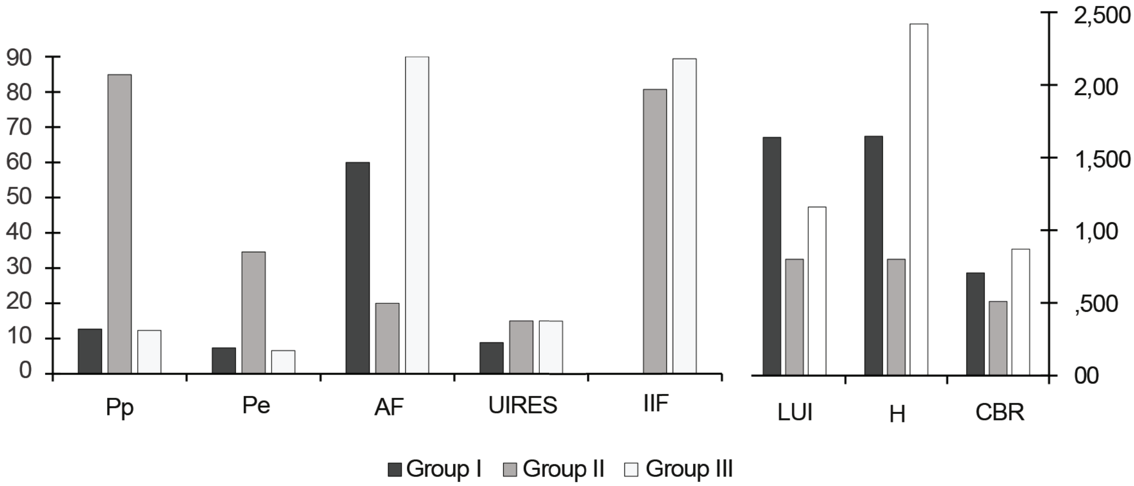

Figure 2. Average of the variables associated to technological sovereignty (PC2), food sovereignty (PC3) and utilization of RES (PC4) for each one of the groups formed for socioecological resilience.

Pp: production per hectare per year in protein, Pe: production per hectare per year in energy, AF: family self-supply, UIRES Index: utilization of renewable energy sources, IIF: innovative intensity index of the farm, LUI: land utilization index, H: Shannon index and CBR: cost benefit ratio.

This analysis allows to gather in group I those farms that reach moderate resilience. Among the 15 farms under study, resilience is expressed in better conditions in 13, lower in 6 and intermediate in those farms of group I. This interpretation is supported on the analysis of the farms included in the three groups and on the efficiency index.

From the application of the MESR, farm 13 is part of the scale that comprises the farms with high socioecological resilience. However, the economic profit and means of life are not favorable for the continuity of these results, something similar occurred in several of the studied farms. It is considered that this aspect must be influenced by new public policies and promotion activities to incentivize the permanence of farmer families and the sustained production of foodstuffs on agroecological bases, so that their efficiency, productivity and resilience indexes are increased.

For the other farms to increase their socioecological resilience (SER) indexes, endogenous resources should be utilized with higher efficiency and their systems should be redesigned from the principles of agroecology, as well as decrease considerably the input of external resources (concentrate feeds, fuels and chemical products). In addition, different appropriate technologies for the maximum utilization of RES should be contextualized.

In spite of the results in the estimation of RES of farm 13, its categorization as farm of high performance is not high, due to the differences between this farm and Finca del Medio for the same indicators identified in PC1 as the ones with higher preponderance (tridimensional). Table 7 show the magnitudes in which the farms of the three groups need to improve key indicators to increase the SRI.

The indicators EI, EFE, EF and IDIE are expressed in percentage, for which the analysis is based directly on the differences between the mathematical magnitudes. Thus, farm 13 (group III) should decrease 15,0, 36,9 and 18,00 % for EI, EFE and IDIE, respectively. At the same time, it should increase 36,85 % to match the performance of EF in Finca del Medio (Casimiro-Rodríguez and Casimiro-González, 2018).

The other indicators have different levels of appreciation. Thus, the lowest values of ECP are the desired ones, as it was argued above. For these indicators, farm 13 should decrease 27,5 units. Meanwhile, the increases are related to EE (11,4) and EB (6,9).

The interpretation of table 6 allows to make concrete recommendations to farm 6 (group II) for a transition process to start aimed at SER, as well as to those farms of group I so that the improvement of their technological, productive, energy and economic processes propitiates advancing towards a similar

Table 6. Performance of the tridimensional indicators in Finca del Medio and its relation with the formed groups for the estimation of the SER.

Finca del Medio	Category	EI	EE	EFE	EF	EB	ECP	IDIE
	Reference	10,00	17,30	15,10	84,85	10,90	0,60	1,80
Group III	Acceptable	25,00	5,90	52,00	48,00	4,04	28,10	19,80
Group I	Intermediate	67,31	0,83	89,81	10,19	0,72	199,98	66,52
Group II	Low	85,00	0,13	98,40	1,60	0,11	606,90	87,40

EI: external inputs used in production, EFE: percentage of energy injected to the farm from outside, IDIE: index of dependence on external resources, ECP: energy cost of protein production, EE: energy efficiency, EB: energy balance and EF: percentage of energy utilized from the farms.

performance to that of farm 13. The improvement of the indicators of table 7 will allow to outline sound strategies in the 15 studied farms, related to the performance of SER in Finca del Medio.

As AT and the achievement of resilient socio-ecological systems depend on a continuous process of change and adaptation, to advance to higher stages each group must define actions and designs that progressively improve the results.

Group III (farm 13) should increase the utilization of RES to decrease the entrance of external inputs, which lies mainly on conventional energy for crop irrigation. In addition, it should use appropriate technologies to increase the efficiency of family work, add values to their production for increasing its product portfolio, widen the production processes in the farm and thus, obtain higher economic profits.

The farms belonging to groups I and II should establish a redesign strategy on agroecological bases in order to increase the economic, productive and energy efficiency in food production, by constituting cycle closures and functional interrelations of each component and utilizing residuals for the elaboration of organic fertilizers and substitution of chemical fertilizers. They should focus on the maximum possible use of RES with appropriate technologies to decrease the need for fossil fuels and increase the productivity of labor.

The farms that have biodigester should make a more efficient use of biogas as energy and of the liquid and solid effluents for the fertilization of the different crops, which in many cases are wasted.

In general, the studied farmer families have high capacity of technological change, and those capacities for innovating, experimenting and exploring should constitute a facilitator to work jointly in new strategies of design and management of the agroecosystem and enhance the transition process (Ortega, 2018).

Through the processes facilitated by the members of the project BIOMAS-Cuba, the sampled farms are locally articulated in several processes of agricultural production and services. They lead community processes in an innovation system with permanent access to knowledge, which allows its adoption and generalization as important part of the agroecological design and management for the integrated food and energy production with gender approach.

To all the above-explained facts, BIOMAS-Cuba has contributed favorably, reinforcing the effective link with research centers, universities and coordination spaces through the municipal platforms. In this regard, Vázquez *et al.* (2015) consider that this link favors capacity building, adoption of new technologies, among other processes which, in turn, allow the agroecological reconversion. And this occurs because it is taken into consideration that the socioecological resilience of family farms has limits associated with social factors and implies ecological, social and economic adjustments by the farmer families and the institutions, in addition to a dialog between farmer and scientific knowledge (Casimiro-Rodríguez and Casimiro-González, 2018).

It is considered that for the resilience of family farms the link of the family to the socioecological system is important. Thus, its permanence in such environment, the joint construction of the knowledge of each space and enhancement of farmer culture, the experimentation and innovation processes and the dialog of knowledge, which favors the transition on agroecological bases from the traditional knowledge contributed by farmers combined with the elements of modern agricultural science, is fundamental.

Conclusions

The results show, as average, moderate resilience, because although the farms are self-supplied with food, mostly with good productivity per hectare per year and high capacity of technological change, they still show an index of dependence on external inputs that influences the unfavorable results shown by several efficiency indicators.

The studied farmer families have high capacity of technological change. And these capacities to innovate, experiment and explore can constitute a facilitator to work jointly on new strategies of design and management of the agroecosystem and enhance the transition process.

With this research, an evaluation of technological criteria and efficiency is offered, for which the farms have a contextualized analysis that favors family decision-making leading to increase resilience. This evaluation also serves local decision-makers in the elaboration of agrarian policies which correct the critical points that put at risk the socioecological resilience of the farms in scenarios of family agriculture.

Acknowledgements

The authors thank the project BIOMAS-Cuba, funded by the Swiss Development and Cooperation Agency (SDC), which contributed the budget for conducting the research.

Authors' contribution

- Leidy Casimiro-Rodríguez. Conceptualized the idea of the research and carried out the statistical analyses. In addition, adapted the manuscript according to the reviewers' suggestions.
- José Antonio Casimiro-González. Contributed to data analysis and interpretation, as well as to the writing and revision of the manuscript.
- Jesús Suárez-Hernández. Contributed to data analysis and interpretation, as well as to the writing and revision of the manuscript.
- Giraldo Jesús Martín-Martín Contributed to data analysis and interpretation, as well as to the writing and revision of the manuscript.
- Marlen Navarro-Boulandier. Contributed to data analysis and interpretation, as well as to the writing and revision of the manuscript.
- Irán Rodríguez-Delgado. Contributed to data analysis and interpretation, as well as to the writing and revision of the manuscript.

Conflict of interests

The authors declare that there is no conflict of interests among them.

Bibliographic references

Casimiro-Rodríguez, Leidy. *Bases metodológicas para la resiliencia socioecológica de fincas familiares en Cuba*. Tesis presentada como requisito para optar al título de Doctora en Agroecología. Medellín, Colombia: Universidad de Antioquia, 2016.

Casimiro-Rodríguez, Leidy & Casimiro-González, J. A. How to make prosperous and sustainable family farming in Cuba a reality. *Elem. Sci. Anth*. 6:77, 2018. DOI: https://doi.org/10.1525/elementa.324.

Contreras-León, Adriana L. & Rodríguez-Lozano, Gloria I. Medición de la eficiencia relativa de fincas ganaderas con servicio de asistencia técnica. *Rev. Fac. Cienc. Econ*. 25 (1):117-128, 2017. DOI: http://dx.doi.org/10.18359/rfce.1776.

FAO. *Agricultura sostenible y biodiversidad: un vínculo indisociable*. Roma: FAO, 2018.

Fernández, Margarita; Williams, Justine; Figueroa, Galia; Graddy-Lovelace, G.; Machado, M.; Vázquez, L. *et al.* New opportunities, new challenges: Harnessing Cuba's advances in agroecology and sustainable agriculture in the context of changing relations with the United States. *Elem. Sci. Anth*. 6:76, 2018. DOI: https://doi.org/10.1525/elementa.337.

González-de-Molina, M. & Caporal, F. R. Agroecología y política. ¿Cómo conseguir la sustentabilidad? Sobre la necesidad de una agroecología política. *Agroecología*. 8 (2):35-43. https://revistas.um.es/agroecologia/article/view/212171, 2013.

IBM. *SPSS Statistics. Versión 22 para Windows*. Valencia, España: Business Machines Corp, 2015.

Ikerd, J. Multifunctional small farms: essential for agricultural sustainability and global food sovereignty. *LRRD*. 28 (11). http://www.lrrd.org/lrrd28/11/iker28192.html, 2016.

Montalba, R.; García, M.; Altieri, M. A.; Fonseca, F. & Vieli, L. Utilización del Índice Holístico de Riesgo (IHR) como medida de resiliencia socioecológica a condiciones de escasez de recursos hídricos. Aplicación en comunidades campesinas e indígenas de la Araucanía, Chile. *Agroecología*. 8 (1):63-70. https://revistas.um.es/agroecologia/article/view/182991, 2013.

Navarro, Marlen; Febles, G. & Torres, Verena. Bases conceptuales para la estimación del vigor de las semillas a través de indicadores del crecimiento y el desarrollo inicial. *Pastos y Forrajes*. 35 (3):233-246. http://scielo.sld.cu/pdf/pyf/v35n3/pyf01312.pdf, 2012.

Nicholls, Clara I.; Altieri, M. A. & Vázquez, L. L. Agroecología. Principios para la conversión y el rediseño de sistemas agrícolas. *Agroecología*. 10 (1):61-72. https://revistas.um.es/agroecologia/article/view/300741, 2017.

Ortega, Delphine. *Agroecología: innovaciones para sistemas agrícolas y alimentarios sustentables*. Ámsterdam, Países Bajos: Amigos de la Tierra. http://www.biodiversidadla.org/Recomendamos/Agroecologia-innovaciones-para-sistemas-agricolas-y-alimentarios-sustentables, 2018.

Salas-Zapata, W. A.; Ríos-Osorio, L. A. & Álvarez-Del Castillo, J. Bases conceptuales para una